ATTACHMENT A

ANALYSIS OF FLOW MODIFICATIONS

Attachment A – Analysis of Flow Modifications

The District completed the following flow-related analyses of the USFWS recommendations for flow modifications in the Loup River bypass reach and the Tailrace Canal (and subsequently in the lower Platte River):

- Consumptive use
- Economic impact of bypass flows
- Minimum flow of 1,000 cfs in the Tailrace Return

Consumptive Use Analysis

USFWS has recommended minimum flow bypass amounts as well as a restriction on the maximum amount of flow that can be diverted by the Project. In USFWS's February 9, 2009, letter to FERC commenting on the District's Pre-Application Document, USFWS "identified 0.1 acre-foot/year as the de minimis threshold for considering the effects of depletions in flow in the nearest surface water tributary to the Platte River system. Projects whose depletions exceed the de minimis threshold would be considered to have a potentially significant effect on the Platte River target species, and would require consultation with the USFWS (http://www.fws.gov/platteriver/deminimis.htm)" (USFWS, February 9, 2009, Comment on Pre-Application Document). The results of the District's Study 5.0, Flow Depletion and Flow Diversion (Final License Application [FLA], Volume 3, Appendix D), show that consumptive use under current operations is less than the consumptive use that would occur under the no diversion condition.

The District evaluated the consumptive use for each of the minimum flow bypass amounts recommended by USFWS using the same methodology as detailed in Study 5.0, Flow Depletion and Flow Diversion (FLA, Volume 3, Appendix D, Section 4.2). The recommended minimum flow bypass amounts, the recommended maximum diversion amount, and combinations thereof, as follows, were evaluated:

- Minimum flow of 350 cfs from April 1 through September 30
- Minimum flow of 175 cfs from October 1 through March 31
- Minimum flow of 350 cfs from April 1 through September 30 AND minimum flow of 175 cfs from October 1 through March 31
- Maximum diversion amount of 2,000 cfs from March 1 through August 31
- Minimum flow of 350 cfs from April 1 through September 30 AND minimum flow of 175 cfs from October 1 through March 31 AND maximum diversion amount of 2,000 cfs from March 1 through August 31

To analyze the recommended minimum flow bypass amounts, synthetic hydrographs were developed in which the minimum flow bypass amount was maintained at the U.S. Geological Survey gage on the Loup River near Genoa. To analyze the maximum diversion amount, a synthetic hydrograph was developed in which no more than 2,000 cfs was allowed into the Loup Power Canal. The flows that were no longer being diverted into the canal were then bypassed and added to the flow in the Loup River downstream of the point of diversion. Each analysis was conducted for a wet, dry, and normal hydrologic year. The results of the analysis are shown in Table A-1 along with the results of the current operations analysis from Study 5.0 for comparison purposes. Each minimum flow bypass amount, regardless of hydrologic flow classification, results in an increase in consumptive use. For example, during a normal hydrologic year, the total consumptive use for current operations is 18,080 acre-feet. Requiring a minimum bypass of 350 cfs between April 1 and September 30 would increase that total consumptive use of 19,180 acre-feet, a difference of 1,100 acre-feet. Based on the results shown in Table A-1, the recommended minimum flow bypass amounts from USFWS violate the *de minimis* threshold when compared to current operations.

Table A-1. Summary of Consumptive Uses for Wet, Dry, and Normal Years

		Current Operations	Min. 350 cfs ONLY	Min. 175 cfs ONLY	Min. 350 cfs and 175 cfs	Max. 2,000 cfs	Min. 350cfs and 175 cfs and Max. 2,000 cfs
Normal Year – 2005							
Loup Power Canal	Total Mean Open Water Evaporation (acre-feet [AF])	6,030	6,030	6,030	6,030	6,030	6,030
	Total Mean Evapotranspiration (ET) (AF)	870	870	870	870	870	870
	Total Consumptive Use	6,900	6,900	6,900	6,900	6,900	6,900
Loup River Bypass Reach	Total Mean Open Water Evaporation (AF)	9,070	10,170	9,210	10,310	9,670	10,730
	Total Mean ET (AF)	2,110	2,110	2,110	2,110	2,110	2,110
	Total Consumptive Use	11,180	12,280	11,320	12,420	11,780	12,840
	Total Depletion	18,080	19,180	18,220	19,320	18,680	19,740
Dry Year – 2006							
Loup Power Canal	Total Mean Open Water Evaporation (AF)	6,010	6,010	6,010	6,010	6,010	6,010
	Total Mean ET (AF)	870	870	870	870	870	870
	Total Consumptive Use	6,880	6,880	6,880	6,880	6,880	6,880
Loup River Bypass Reach	Total Mean Open Water Evaporation (AF)	6,530	8,470	6,760	8,700	6,710	8,810
	Total Mean ET (AF)	2,100	2,100	2,100	2,100	2,100	2,100
	Total Consumptive Use	8,630	10,570	8,860	10,800	8,810	10,910
	Total Depletion	15,510	17,450	15,740	17,680	15,690	17,790
Wet Year – 2008							
Loup Power Canal	Total Mean Open Water Evaporation (AF)	5,670	5,670	5,670	5,670	5,670	5,670
	Total Mean ET (AF)	810	810	810	810	810	810
	Total Consumptive Use	6,480	6,480	6,480	6,480	6,480	6,480
Loup River Bypass Reach	Total Mean Open Water Evaporation (AF)	10,440	11,320	10,550	11,430	10,960	11,780
	Total Mean ET (AF)	1,960	1,960	1,960	1,960	1,960	1,960
	Total Consumptive Use	12,400	13,280	12,510	13,390	12,920	13,740
	Total Depletion	18,880	19,760	18,990	19,870	19,400	20,220

Economic Impact of Bypass Flows

In addition to consumptive use, the percentage of the diverted flow that would be required to meet the recommended minimum flow bypass amounts was also investigated for a wet, dry, and normal year. Using the synthetic hydrographs developed for the consumptive use analysis and the actual hydrograph for the U.S. Geological Survey gage on the Loup River near Genoa, the amount of water required each day to meet the recommended minimum flow bypass amount (that is, 350 cfs or 175 cfs) was calculated. For example, if the flow on July 3, 2005, at Genoa was 143 cfs, then an additional 207 cfs had to be bypassed to meet the recommended minimum flow bypass amount. The daily bypassed amounts were summed, and an annual bypassed water volume was calculated. Then, the makeup water (that is, the amount of diverted flow that would have to be bypassed to meet the recommended minimum flow bypass amounts) was calculated as a percent of the total diversion. For example, 5 percent of the diverted flow would have to be bypassed during a normal hydrologic year to make up the flow to meet the 350 cfs required between April 1 and September 30. Tables A-2 through A-4 show the bypass condition (the recommended minimum flow bypass amounts, the recommended maximum diversion amount, and combinations thereof), the number of days makeup water would be required, the amount of makeup water, and the percent of makeup water required as compared to the total diversion for a normal, dry, and wet hydrologic year classification, respectively.

The revenue lost as a result of a requirement to bypass a minimum flow amount was also calculated. As noted in the District's FLA (Volume 2, Exhibit E, Section E.7.2, pg. E-335), the value of water to the District is $5.60 per acre foot. Using this amount, the lost revenue for each year was calculated, as shown in Tables A-2 through A-4.

Table A-2. Normal Year Hydrologic Classification (2005)

Condition	Volume of Water Upstream of Diversion (acre-ft)	Original Volume of Water in Loup River at Genoa (acre-ft)	Volume of Water in Loup River at Genoa with Makeup Water (acre-ft)	Makeup Water Volume (acre-ft)	Makeup Water Volume as a Percent of Total Diverted	# of Days Makeup Water Required	Lost Revenue
Min. 350 cfs ONLY	1,689,700	598,700	650,300	51,600	5%	116	$289,200
Min. 175 cfs ONLY	1,689,700	598,700	607,300	8,600	1%	38	$48,200
Min. 350 cfs and 175 cfs	1,689,700	598,700	658,900	60,200	6%	154	$337,300
Max. 2,000 cfs	1,689,700	598,700	655,200	56,500	5%	67	$316,200
Min. 350 cfs and 175 cfs and Max. 2,000 cfs	1,689,700	598,700	707,300	108,600	10%	191	$608,300

Table A-3. Dry Year Hydrologic Classification (2006)

Condition	Volume of Water Upstream of Diversion (acre-ft)	Original Volume of Water in Loup River at Genoa (acre-ft)	Volume of Water in Loup River at Genoa with Makeup Water (acre-ft)	Makeup Water Volume (acre-ft)	Makeup Water Volume as a Percent of Total Diverted	# of Days Makeup Water Required	Lost Revenue
Min. 350 cfs ONLY	1,420,500	402,800	483,100	80,300	8%	161	$449,400
Min. 175 cfs ONLY	1,420,500	402,800	419,000	16,200	2%	59	$90,900
Min. 350 cfs and 175 cfs	1,420,500	402,800	499,300	96,500	9%	220	$540,400
Max. 2,000 cfs	1,420,500	402,800	424,300	21,500	2%	38	$120,600
Min. 350 cfs and 175 cfs and Max. 2,000 cfs	1,420,500	402,800	518,000	115,200	11%	240	$645,200

Table A-4. Wet Year Hydrologic Classification (2008)

Condition	Volume of Water Upstream of Diversion (acre-ft)	Original Volume of Water in Loup River at Genoa (acre-ft)	Volume of Water in Loup River at Genoa with Makeup Water (acre-ft)	Makeup Water Volume (acre-ft)	Makeup Water Volume as a Percent of Total Diverted	# of Days Makeup Water Required	Lost Revenue
Min. 350 cfs ONLY	2,186,300	891,800	937,300	45,500	4%	99	$255,000
Min. 175 cfs ONLY	2,186,300	891,800	895,800	4,000	0%	21	$22,300
Min. 350 cfs and 175 cfs	2,186,300	891,800	941,300	49,500	4%	120	$277,300
Max. 2,000 cfs	2,186,300	891,800	962,800	71,000	5%	81	$397,500
Min. 350 cfs and 175 cfs and Max. 2,000 cfs	2,186,300	891,800	1,007,600	115,800	9%	178	$648,800

Analysis of Minimum Flow of 1,000 cfs in Tailrace Return

USFWS requested a minimum flow from the Tailrace Return of 1,000 cfs from March 1 to August 31. The daily flow from the Nebraska Department of Natural Resources gage in the Tailrace Canal near the 8th Street bridge was compared with the daily flow needed to maintain a minimum of 1,000 cfs. The number of days on which there was insufficient daily flow in the Tailrace Canal to maintain a minimum flow of 1,000 cfs were tallied, as shown in Table A-5. This analysis was performed from 2003 through 2010.

Table A-5. Minimum Flow of 1,000 cfs

Year	Hydrologic Classification[1]	Number of Days without Sufficient Flow to Maintain Minimum Flow of 1,000 cfs
2003	Dry	44
2004	Dry	23
2005	Normal	32
2006	Dry	76
2007	Wet	13
2008	Wet	8
2009	Wet	8
2010	Wet	0
Total		**204**
Mean		**26**
Median		**18**

Note:
[1] *Hydrologic classification is for the Loup River at the point of diversion.*

ATTACHMENT B

FLOW BYPASS FOR SEDIMENTATION RESPONSE

Attachment B – Flow Bypass for Sedimentation Response

USFWS asserts that providing minimum flows in the Loup River bypass reach and limiting the amount of water diverted into the Loup Power Canal will offset a sediment deficit and degradation of the lower Platte River. This assertion and USFWS's rationale are flawed, incorrectly reference information from the District's relicensing studies, and in fact are in direct conflict with the results of the District's relicensing studies, existing literature, and physical evidence as documented in the following discussion:

- Tailrace return flows do contain sediment.
- There is no degradation at the Tailrace Return.
- There is no sediment deficit at the Tailrace Return.

Tailrace Return Flows DO Contain Sediment

First, the District would like to clarify that the study results do not show that sediment transport through the Tailrace Return is 0 tons/day, as has been misstated by USFWS. The modeling does not "show" a zero transport in the Tailrace Return. Instead, a boundary condition of 0 tons/day of sediment from the Tailrace Return flows was assumed, but only in order to evaluate a worst-case scenario (one of several runs) at Site 4. This highly conservative assumption is documented in several locations, including Study 2.0, Hydrocycling (FLA, Volume 3, Appendix B, Section 4.5.6), and Study 14.0, Alternative Project Operation and Sediment Management (FLA, Volume 3, Appendix J, Sections 4.1.2 and 4.1.5). As stated in those studies, it was assumed in the model for current operations that the Tailrace Return flows did not contain any sediment load. As noted in Study 2.0, Hydrocycling (FLA, Volume 3, Appendix B, Section 4.5.6), the District believes that the return flows do contain sediment based on observations, photos, and the Missouri River Basin Commission analysis (1975).

Subsequent to the current operations model, FERC requested that the District evaluate sediment augmentation alternatives (FERC, December 21, 2011). To do so, the current operations model was modified to include various sediment augmentation rates, treating the Tailrace Return as a modeled reach with a constant downstream boundary bed elevation, as documented in Study 14.0, Alternative Project Operation and Sediment Management, (FLA, Volume 3, Appendix J, Section 4.1.5). Allowing the model to determine the sediment load based on slope and canal dimensions provided greater model stability than adding a sediment load with the Tailrace Return flows. The Tailrace Return, or Tailrace Branch as it is referred to in Study 14.0, was entered into the model using the canal channel dimensions and bed elevations as shown on District design drawings. The slope of the Tailrace Canal was varied to achieve different target average sediment augmentation load rates. A slope of 0.00007 foot/foot, the actual slope of the Tailrace Return, results in an average daily sediment capacity of 550 tons/day (FLA, Volume 3, Appendix J, Table 4-2). Thus, the model results do not show sediment transport through the Tailrace Return as "0 tons/day," as this was an assumed boundary condition for only the run representing a worst-case scenario. When the Tailrace Return was modeled to evaluate augmentation alternatives, the model results showed sediment transport of 550 tons/day when using the actual canal dimensions and slope.

There is No Degradation at the Tailrace Return

USFWS also misstates that the model results show that channel bed degradation, "i.e. net large-scale evacuation of channel bed material," occurs near the Project Tailrace Return after the post warm-up period. As stated in Study 14.0, Alternative Project Operation and Sediment Management (FLA, Volume 3, Appendix J, Section 5.1.1), the trends for all simulated sediment augmentation amounts show a relatively horizontal line or a small amount of aggradation (not "evacuation") during the post warm-up period. This is followed by degradation occurring as a result of the high flow period of 1993, then a recovery period through mid-2003, and relatively stable trends for the final 2 years (FLA, Volume 3, Appendix J, Figure 5-15). The assumed 0 tons/day simulation follows a similar trend as the sediment augmentation simulations, with the exception of a slight degradational trend (approximately 0.2 foot over 3 years, or 0.8 inch/year) between the end of the warm-up period and 1993. After 1993, the assumed 0 tons/day simulation trends upward through a recovery period and then is generally stable at levels comparable to the augmentation runs from 1997 through the end of the simulation (approximately 9 years).

There is No Sediment Deficit at the Tailrace Return

Finally, USFWS misstates that results from Study 1.0, Sedimentation (FLA, Volume 3, Appendix A) show that the Project erodes 944,632 cubic yards of local sediment near the Project Tailrace Return on an average annual basis. USFWS based this number on the amount of material removed from the Loup River at the Settling Basin, approximately 35 miles upstream of the Platte River confluence, as the result of dredging (USFWS, February 16, 2012) and asserted that this amount of sediment must be eroded at the Tailrace Return as a result. First, the District notes that this allegation ignores the fact that intervening sediment supplies to each successive location in the river exceed the transport capacities. Abundant amounts of additional sediment supplies occur between the point of diversion and the Tailrace Return. Further, there is no result in Study 1.0, or any other study in the FLA, that suggests that erosion of 944,632 cubic yards of local sediment is occurring at the Tailrace Return on an average annual basis. In fact, the results of Study 1.0, based on a significant amount of analysis and literature, showed that all gaged and ungaged sites are in regime, are not supply limited, and are not aggrading or degrading. In addition, several pieces of physical evidence, as listed below, corroborate the study findings that there is no erosion occurring at the Tailrace Return:

- Cross sections at the ungaged sites upstream and downstream of the Tailrace Return showed aggradation between measurements (FLA, Volume 3, Appendix B, Study 2.0, Hydrocycling).
- USGS bed, bank, and sandbar sediment samples in 2010 just downstream of the Tailrace Return are finer than the samples near Duncan and are consistent with the gradations near North Bend, Ashland, and Louisville, suggesting that there is no

coarsening or degradation occurring (District letter dated November 23, 2011, in response to comments on the Updated Study Report).

- There is no sign of large-scale scour or erosion occurring downstream of the Tailrace Weir, as shown in Photos 1 and 2, taken during low flow in July and September 2012, respectively. In addition, the Tailrace Weir has not experienced any undermining since Project inception, nor has the District ever implemented any erosion countermeasures (for example, riprap).

Photo 1. Aerial Photo of Tailrace Weir, July 2012.

Photo 2. Ground-Level Photo of Tailrace Weir, September 2012.

In order to amass 944,632 cubic yards of sediment in a year, approximately 0.5 foot of erosion and scour would need to occur everywhere for 6 miles downstream of the Tailrace Return. After 35 years at that rate, approximately 20 feet of scour would have occurred over those 6 miles.

In summary, with regard to Paragraph 1 of USFWS Recommendation No. 1-3:

- The results in Study 14.0, Alternative Project Operation and Sediment Management (FLA, Volume 3, Appendix J), did not “show” that sediment transport through the Tailrace Return is “0 tons/day” under current operations. In contrast, moderate rates are indicated by the hydraulics and other literature.
- The results of Study 1.0, Sedimentation (FLA, Volume 3, Appendix A), do not show that the Project erodes 944,632 cubic yards of local sediment near the Tailrace Return on an average annual basis.
- Physical evidence at the Tailrace Return shows no signs of coarsening, erosion, or “large-scale evacuation” of bed material.

With regard to USFWS's reference to Schmidt and Wilcock (2008), this generalization about impacts of water and sediment storage impoundments on sandbars and riparian ecosystems is not relevant to fact-finding in this application. The District performed studies in the Platte and Loup rivers in the vicinity of the Project and referenced USGS and USACE literature on the Platte and Loup rivers pertinent to the study area.

ATTACHMENT C

MACROINVERTEBRATE AND FISHERIES LITERATURE REVIEW

Attachment C – Macroinvertebrate and Fisheries Literature Review

The District reviewed the literature citations provided by USFWS regarding the effects of hydrocycling on primary productivity in support of its recommendation to maintain a minimum base flow of 1,000 cfs in the Tailrace Canal. The District finds that the cited literature are either 1) not applicable to the Loup River Hydroelectric Project (Project), 2) inconclusive, 3) unsubstantiated, or 4) counter to the USFWS representation of the findings.

Haxton and Findlay

Haxton and Findlay performed a compilation, review, and statistical analysis of existing studies and experiments related to dewatering. They gathered existing research by searching for key terms, such as "water power management," "dams AND fish," "dams AND invertebrates," "dams AND macroinvertebrates," "water level fluctuation," "water drawdown," "water drawdown AND fish," "water drawdown AND (macro)invertebrates," "minimum flow," "natural flow regime," "flows AND fish," "flows AND invertebrates," "hydroelectric dams," "reservoir," "peaking facilities," "run-of-the-river facilities," and "dewatering AND macroinvertebrates."

Their research focused on three questions, only one of which applies to Project operations: evaluate the effects of dewatering on macroinvertebrate communities. For their meta-analysis on the "effects of dewatering on macroinvertebrates," Haxton and Findlay evaluated 10 studies and 13 experiments.

Although the information in Haxton and Findlay provides additional information regarding a general relationship between macroinvertebrates and dewatering, particularly associated with dam structures; the specifics of the studies and experiments used in the analysis are not available, and it is impossible to determine if they are similar or relevant to Project operations. The following unique features of the Project make comparisons with general macroinvertebrate analyses unreliable:

- The Project does not have a "dam" in the traditional sense and does not impound water for long durations.
- Project hydrocycling operations are very consistent over days, weeks, months, and years—water is discharged for a period of several hours (typically 14 hours) each day (FLA, Volume 1, Exhibit B, Section B.2.4, pg. B-21) as compared to peaking at dams, which may occur much less frequently.
- The Project discharges flow into a wide, braided river with a sandy substrate as compared to a more typical defined channel with cobble substrate.
- The Project does not discharge hypolimnetic flows as compared to flows from a traditional dam structure.

As noted by Gislason (1985), comparing river systems can be problematic due to the multitude of site-specific factors such as stream order, substrate type, channel morphology, thermal regime, water quality, and the existing biotic community that would influence the impact of diel flow fluctuation on a particular stream (FLA, Volume 2, Exhibit E, Appendix E-2, Section 6.1.6, pg. 79).

Barada

USFWS's summary of Barada's findings regarding Platte River catfish populations is a misrepresentation and misleading citation of what is actually stated in the 2009 thesis. The District does not dispute the USFWS statement regarding Barada's findings of slower growth rates for channel catfish collected in the Platte River compared to growth rates in published literature; however, the District clarifies that this is not unexpected of a Midwestern, braided, sandbed river that by its very nature has continually changing habitat quantity, quality, and availability (Barada, 2009). The following quotations contained within Barada's thesis support the notion that both central and lower Platte River channel catfish growth rates are a symptom of the broader fluvial environment and not District operations:

- Barada page 104 – "Growth of channel catfish in the Platte River is similar to other Nebraska rivers…. However, when compared to growth standards for the species (Hubert 1999), mean back-calculated lengths at age were consistently below the 50th percentile…. Similarly, von Bertalanffy growth functions for central Platte River and lower Platte River channel catfish exhibited slower growth when compared to the standard von Bertalanffy growth function for channel catfish (Jackson et al. 2008…)." (Note: table and figure references have been omitted.)
- Barada page 6 – "Channel catfish from the Platte River tend to have relatively slow growth with age-3 mean length of 202-mm (Holland and Peters 1992a). However, this slow growth is comparable to other channel catfish populations in Nebraska and the Great Plains...."
- Barada page 6 – "Growth patterns across the channel catfish's geographic range are not evident (Hubert 1999) and growth rates within the same river system have shown no river-wide latitudinal (Pegg and Pierce 2001) or longitudinal (Holland and Peters 1992a) trends."

Regarding the USFWS assignment of Barada's "conclusion" that Project hydrocycling reduces availability of channel catfish prey, which reduces consumption of prey items, the District clarifies that Barada made no such conclusion. Instead, Barada speculated on the effect of hydrocycling to channel catfish populations and openly provided the following qualifications of his speculation that cannot isolate Project-induced effects to channel catfish or lower Platte River productivity:

- Barada page 38 – "McBride (1995) and Peters and Parham (2008) documented a diversity of macroinvertebrates in the Platte River that suggest food availability is not limited for smaller catfish."
- Barada page 44 – "Specific investigations concerning prey availability, food habits, and recruitment would be beneficial in understanding factors influencing channel catfish relative abundance, size structure and condition in the Platte River." (Barada did not sample for macroinvertebrates/channel catfish forage.)

- Barada page 109 – "Determining direct factors affecting growth and mortality is difficult because environmental variability is often high. Specific investigations concerning prey availability, food habits, angler exploitation and their spatial variability throughout the Platte River would be beneficial to determine factors that are affecting channel catfish growth. Further, channel catfish are a mobile species (Bunnell 1988, Dames et al. 1989, Chapman 1995, Pellet et al. 1998) which may confound spatial comparisons."
- Barada page 108 – "Prey availability, flow modifications, habitat conditions and tributary inflows are probably not the only factors influencing growth rates of channel catfish in the Platte River. Intra- and inter-specific competition (Carlander 1969, Colombo 2007, Michaletz 2009), temperature (Kilambi et al. 1971, Andrews and Stickney 1972, Suja et al. 2009) and watershed characteristics (Shephard and Jackson 2006) have also been documented to influence channel catfish growth. It is likely that a myriad of these factors and their interactions are playing a role in influencing channel catfish growth throughout the Platte River."
- Barada page 34 – "These findings highlight the complexity of the Platte River system where numerous biotic and abiotic factors are likely influencing channel catfish population characteristics throughout the Platte River."

Beyond the above-provided qualifications of Barada's speculation regarding the effect of hydrocycling on channel catfish populations, Barada provided the following alternative (non-Project related) explanations for varying growth rates within Platte River channel catfish:

- Barada page 39 – "Spatial differences in channel catfish condition could also be influenced by a recent nutrient upsurge in the central Platte River creating more secondary production and available forage. Reservoirs experiencing low water levels where growth of terrestrial vegetation takes place in exposed areas, followed by flooding of vegetation, can simulate a nutrient upsurge and increase productivity (Summerfelt 1999). The central Platte River may be experiencing similar effects where higher water events during my study … have increased terrestrial plant inundation, possibly increasing production and available forage. The central Platte River also exhibits lower turbidity levels that may promote increased macrophyte growth. Invertebrate production and the production of insectivorous fishes have been directly correlated to attachment surface area (Pardue 1973) and macrophyte density (Wiley et al. 1984). This information suggests increased productivity, including plants, invertebrates and forage fish, is likely a positive influence on channel catfish condition in the central Platte River." (Note: a figure reference has been omitted.)
- Barada page 34 – "Lowest relative abundances were observed at the most upstream and downstream sites with the lower Platte River exhibiting higher relative abundances compared to the central Platte River. Consequently, channel catfish in the central Platte River displayed larger size structures and higher conditions compared to the lower Platte River."

In addition to the erroneous statements provided by USFWS regarding Barada's findings, the content of Barada's findings omitted by USFWS is equally misleading. Most notable are the multiple statements by Barada that the greatest abundance of channel catfish occurs in the Platte River sample locations nearest the Project's Tailrace Return. These statements suggest that Project operations are in no way limiting channel catfish habitat downstream of the Tailrace Return.

Anderson

The District notes that Anderson (2010) used virtually the same general and river-specific references as Barada (2009). Both Barada (2009) and Anderson (2010) were graduate theses prepared under Dr. Mark Pegg at the University of Nebraska-Lincoln.

USFWS's summary of Anderson's findings regarding mortality of shovelnose sturgeon in the Platte River is also a misrepresentation of what is actually stated in the 2010 thesis. Anderson posited several possible causes of increased shovelnose sturgeon mortality on the lower Platte River. The following quotation from Anderson's thesis provides clarification on her theories regarding shovelnose sturgeon mortality:

- Anderson page 15 – "The explanation for high mortality may be a number of different reasons including harsh environmental conditions, emigration or illegal harvest. Abiotic factors or extreme environmental conditions (e.g., hydropeaking) may be influencing the populations [*sic*] older fish in that either conditions are too harsh and survival becomes difficult or that conditions are not suitable and older fish are emigrating. Emigration of older fish may also be due to movements to suitable spawning habitats. Another possible explanation for high mortality is high rates of undocumented or illegal harvest of shovelnose sturgeon."

References

Anderson, T.L. 2010. Shovelnose Sturgeon Age and Growth Characteristics and Fish Community Characteristics of the Lower Platte River and Missouri River Near Nebraska. M.S. Thesis, University of Nebraska, Lincoln Nebraska.

Barada, T.J. 2009. Catfish Population Dynamics in the Platte River Nebraska. M.S. Thesis, University of Nebraska, Lincoln Nebraska.

Gislason, Jeffery C. 1985. Aquatic Insect Abundance in a Regulated Stream Under Fluctuating and Stable Diel Flow Patterns. *North American Journal of Fisheries Management* 5:39–16.

Haxton T.J., and C.S. Findlay. 2008. Meta-analysis of the Impacts of Water Management on Aquatic Communities. *Canadian Journal of Fisheries and Aquatic Sciences* 65:437–447.

ATTACHMENT D

TECHNICAL REVIEW OF
PARHAM (2007), PETERS AND PARHAM (2008), NGPC (2007), AND NGPC (2008)

SWCA
ENVIRONMENTAL CONSULTANTS
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Summary of Technical Reviews of Peters and Parham (2008), Parham (2007), Nebraska Game and Parks Commission Draft Biological Opinion (2007), and Nebraska Game and Parks Commission (2008) as they Relate to Pallid Sturgeon (*Scaphirhynchus albus*), Interior Least Tern (*Sterna antillarum*), and Piping Plover (*Charadrius melodus*) Habitat Requirements in the Lower Platte River, Nebraska

Prepared for

Fennemore Craig, P.C.

Prepared by

SWCA Environmental Consultants

June 17, 2009

Summary of Technical Reviews of Peters and Parham (2008), Parham (2007), Nebraska Game and Parks Commission Draft Biological Opinion (2007), and Nebraska Game and Parks Commission (2008) as they Relate to Pallid Sturgeon (*Scaphirhynchus albus*), Interior Least Tern (*Sterna antillarum*), and Piping Plover (*Charadrius melodus*) Habitat Requirements in the Lower Platte River, Nebraska

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June 17, 2009

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APPENDIX A: SOURCE DOCUMENTS *(on attached CD)*

Parham (2007)
Peters and Parham (2008)
Nebraska Game and Parks Commission Draft Biological Opinion (2007)
Nebraska Game and Parks Commission (2008)

APPENDIX B: INDEPENDENT REVIEWS OF PETERS AND PARHAM (2008), PARHAM (2007), AND THE NGPC BO (2007) *(on attached CD)*

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1.0 INTRODUCTION

1.1 BACKGROUND

Water management in the lower Platte River (defined by the Nebraska Game and Parks Commission [NGPC] as the Platte River below the mouth of the Loup River to the confluence of the Missouri River) has the potential to impact three species protected under the federal Endangered Species Act of 1973, as amended (16 U.S.C. §§ 1531 et seq.). The U.S. Fish and Wildlife Service listed the pallid sturgeon (*Scaphirhynchus albus*) as endangered in 1990, the piping plover (*Charadrius melodus*) outside of the great lakes watershed as threatened in 1985, and the interior population of the least tern (*Sterna antillarum*) as endangered in 1985. These species are also protected under the Nebraska Nongame and Endangered Species Conservation Act (Neb. Rev. Stat. §§ 37-901 et seq.).

In May 2000, NGPC initiated a five-year research study to evaluate the habitats and ecology of the pallid sturgeon and sturgeon chub (*Macrhybopsis gelida*) in the lower Platte. The purpose of this research was largely to evaluate possible relationships between the habitats available to the pallid sturgeon and sturgeon chub and river discharge. This research resulted in the completion of the following two technical reports:

- Peters, E.J., and J.E. Parham. 2008. Ecology and Management of Sturgeon in the Lower Platte River, Nebraska. Nebraska Technical Series No. 18, Nebraska Game and Parks Commission, Lincoln, Nebraska (Peters and Parham 2008).[1]
- Parham, J.E. 2007. Hydrologic Analysis of the Lower Platte River from 1954–2004, with Special Emphasis on Habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon (Parham 2007).

These reports are having a substantial bearing on the development of and decisions made by the Nebraska Department of Natural Resources (DNR) and NGPC. NGPC's Draft Biological Opinion dated October 19, 2007 (Draft BO or NGPC 2007) and "Assessment of the Pallid Sturgeon, Least Tern and Piping Plover in the Lower Platte River" (NGPC 2008) substantially relies on these reports to evaluate potential impacts relating to the continued issuance of surface water appropriations by DNR in the lower Platte. These four documents are provided in Appendix A of this document.

The Lower Platte Basin Coalition, the Proponents of Sound Science for the Lower Platte River Policy Coalition, and Fennemore Craig, P.C., have solicited the comments of various technical experts to assess the scientific merits of the results and conclusions of the above three documents. This document serves to summarize the major themes common among the reviews and to provide additional insight into the possible use of any of those documents for water and species management decisions in the lower Platte River. Because of the nature of this summary document and the commonality among the comments provided by the reviewers, the reviews will not be

[1] NGPC (2007), Parham (2007), and reviews by technical experts (Appendix B) cite the draft version report: Peters and Parham (2007)

cited each time they are referenced. Rather, reviews will only be directly cited when directly quoted in the text. All reviews are presented in their entirety in Appendix B of this document.

1.2 SUMMARY OF FINDINGS

The introduction of the Draft BO states that inadequate scientific data initially existed on the ecological requirements of the pallid sturgeon to determine the impacts of surface water appropriations on pallid sturgeon (NGPC 2007). As a result, Drs. Peters and Parham were contracted to complete a large hydrologic and ecological study of the three listed species in the lower Platte River (Peters and Parham 2008; Parham 2007).

While the studies had multiple goals and objectives, the overarching intent of the studies was to establish relationships between river discharge and habitat availability for pallid sturgeon, least tern, and piping plover. Numerous major scientific flaws have been identified in both reports which call into question most of the major conclusions contained in Peters and Parham (2008), Parham (2007), the related Draft BO (NGPC 2007), and NGPC (2008). Based largely on the flawed logic presented in Peters and Parham (2008) and Parham (2007) the Draft BO recommends to eliminate future additional degradation of the magnitude or structure of hydrograph and to not allow additional depletions that would reduce the magnitude, timing, and frequency of flows in the lower Platte.

The logic used to establish flow recommendations in these reports is fundamentally flawed. Assigning a singular flow recommendation fails to recognize the highly variable nature of the hydrology and morphology of a dynamic sandbed river and the vital importance of the antecedent conditions. The assumptions used and cited by Peters and Parham were largely developed for fixed-bed systems with gravel or cobble substrate rather than for a large plains river system. The authors should have recognized the inherent variability in the Platte River and taken an approach that evaluated the conditions where suitable habitat failed to exist in the system rather than trying to use a method to optimize habitat conditions at all times. As an example, on the Pecos River in New Mexico, a smaller but similar river system, a range of flow conditions provided suitable habitat conditions for the fish community throughout the year (Kehmeier et al. 2007). By recognizing this variability, water managers were able to provide water at times when the fish community most needed it.

For a variety of additional reasons described in the following pages the recommendation in the Draft BO and NGPC 2008 that the timing and duration of 8,100 cubic feet per second (cfs) in the lower Platte River below the confluence with the Elkhorn River should be protected from further degradation and depletion is not scientifically supportable. The Peters and Parham reports did not meet the objectives of establishing a linkage between discharge and habitat for the pallid sturgeon, least tern, or piping plover. The conclusions drawn by the authors and by NGPC are scientifically unfounded and misleading. Additionally, the flow recommendations identified in Peters and Parham (2008), Parham (2007), and the Draft BO for the pallid sturgeon are contradictory to the recommendations for the least tern and piping plover. Application of either recommendation would be highly arbitrary. Consequently, the results of these reports do not represent the best science and should not be used to make any recommendations for water management or species management in the lower Platte River basin.

2.0 REVIEW OF PETERS AND PARHAM (2008)

The Peters and Parham (2008) report is the result of two separate research efforts, one jointly funded by the Pallid Sturgeon/Sturgeon Chub Task Force to which the NGPC was partner and one funded from a grant from the Federal Aid to Sportfish Restoration program funded solely through the NGPC. The goals of the first effort were focused on life history information on pallid sturgeon and sturgeon chub. The goals of the second effort were to describe and quantify the habitat use of sturgeon and to describe their ecological relationships with the fish community in the lower Platte River. The authors collected fisheries, hydrology, water quality, and geomorphology data between 2000 and 2004 to attempt to relate the habitat requirements of pallid sturgeon, shovelnose sturgeon (*Scaphirhynchus platorynchus*), and sturgeon chub to river discharge.

Chapter 10 of the Peters and Parham (2008) report attempted to integrate all of the fisheries, physical habitat, hydrology, and geomorphology data into measures of habitat availability, quality, and connectivity. As such, this synthesis document will primarily focus on the merits of Chapter 10 and the integration of the physical and biological data collected.

There are major flaws in the analyses and interpretation presented in Chapter 10. Several of the issues identified limit or preclude the use of the information contained therein for water and wildlife/fisheries management purposes. Additionally, the power of the datasets is too limited to be used to develop reliable water and habitat management recommendations. The following sections present and describe the fundamental flaws that limit the utility of the Peters and Parham (2008) report for water and species management in the lower Platte River.

2.1 COMMENTS RELATED TO FISHERIES DATA

While not presented in Chapter 10 of Peters and Parham (2008), the fisheries data serve as the basis for the authors' characterization of the relationship between river discharge and habitat availability, quality, and connectivity. The authors captured pallid and shovelnose sturgeon in the lower Platte by using a variety of gear types that had been proven in the Missouri River and elsewhere. These data are useful for generally characterizing seasonal use (presence/absence), demographics, and condition of the fish that were subject to capture with these gear types. However, the use of these data to develop habitat/discharge relationships is problematic.

The gear types used are not appropriate for characterizing specific habitat use by pallid sturgeon for the following reasons:

- Drifting trammel and gill nets were effective in capturing sturgeon and other species. However, when pallid sturgeon were captured, the authors inappropriately used average depths and velocities over the entire 200- to 400-meter (m) sampled reach to characterize their habitat. Generalizing habitat conditions at this scale ignores the site-specific micro- or meso-habitat conditions that pallid sturgeon select. Averaging reach-wide habitat conditions assumes that the fish are using the most abundant habitat and fails to recognize that many species select habitat in a manner that is disproportionate to its availability.

- Trotlines were also effective in capturing sturgeon, but the use of trotlines for establishing habitat use is inappropriate. Trotlines are baited with items meant to lure fish from the habitats they are currently in to the habitat where the trotline is set. Use of habitat data collected from fish captured using trotlines is simply describing the conditions where the trotline was set, not the conditions of the habitat that the fish typically use. Additionally, the majority of trotlines were set in deep water habitats, which may have biased the habitat analysis against shallower water areas where sturgeon might also have been present. A more appropriate method would have been the random placement of trotlines throughout the river reach in both shallow and deep water habitats.
- Use of radio telemetry on tagged individuals is potentially more accurate than the other methods to identify specific locations of fish habitat use. However, in a relatively shallow river like the Platte, fish locations documented with telemetry methods could reflect their refuge or escape habitat rather than their preferred habitat. Radio tracking fish in the manner the authors used requires air boats or wading to identify the exact location of a tagged fish. Both of these methods are likely to alert the tagged fish, motivating them to move to areas where they may feel safest; given the broad and open morphology of the Platte River, it is likely the fish would move to deeper water. This escape response could be exaggerated in a short-term tracking study such as the one presented in Peters and Parham (2008). Tagged fish likely would attempt to escape any humans or equipment that they might associate with their recent capture and tagging event. The authors did not acknowledge that the tagging event could cause changes in behavior as the individuals recover from the incisions and stress sustained during the tagging process. Triangulation methods from the shoreline would have been a better method to use to determine specific habitat use because the fish would be less likely to be frightened out of its selected habitat.

  The largest problem with the Peters and Parham (2008) telemetry data is in the analysis of the observations of radio tagged pallid sturgeon. In total, 32 data points were collected from the six tagged fish. It appears that the authors used each of the 32 data points as unique, independent observations of habitat use even though individual fish accounted for multiple observations. The only way the telemetry data could be used without compromising the inferential strength of the analyses would be if sample sizes for all fish tagged were approximately the same. This clearly was not the case and the resulting statistical analyses using the telemetry data should be viewed as invalid. Of the 32 observations, 26 (81% of observations) came from just two fish (Fish 621 and Fish 542). Habitat use measured from the same fish on subsequent days or over a relatively short period of time should not be considered independent observations. Therefore, the authors are largely describing the habitat use of just two fish over a relatively short period of time. It would be difficult and inappropriate to extrapolate these habitat use patterns to the entire pallid sturgeon population in the lower Platte River. At the very least, the degrees of freedom that the authors could reliably use for statistical analysis would be 6 (number of fish) rather than 32 (number of observations). The reduction in the degrees of freedom that could be used in statistical testing could substantially change the results and interpretation of the study.

The authors documented seasonal use of the lower Platte River by pallid sturgeon. During this study, mature adults were only observed in the spring, and all radio implanted pallid sturgeon returned to the Missouri River shortly after being tagged. Additionally, the authors provided capture information for two pallid sturgeon of unknown size that were collected on 23 July 2004 and 25 September 2004 by the University of Nebraska statewide stream fisheries inventory project, which used different habitat measurement methodologies. The authors cited the capture data as plausible evidence that the pallid sturgeon were using the lower Platte for spawning activities. However, they did not provide evidence that pallid sturgeon spawn in the lower Platte River. In seven years of larval drift sampling, only 14 sturgeon larvae were collected. Species of larval sturgeon could not be determined by genetic testing because of the type of preservative used (i.e., formalin). Given the number of resident shovelnose sturgeon that were documented in the river, it is probable that these larvae were shovelnose sturgeon. Additionally, although individual data points are consistent with common migration patterns for adult sturgeons (Bemis and Kynard 1997), the authors did not document an organized migration of pallid sturgeon into or out of the lower Platte River during the spring or any other season. Pallid sturgeon movement into the lower Platte River could have been opportunistic, made more likely by slightly higher spring flows, warmer temperatures, or changes in prey availability. Seasonal documentation of pallid sturgeon habitat could have biased the resulting habitat analyses. The only habitat use that could be evaluated using the Peters and Parham (2008) datasets would be spring habitat use.

2.2 MODELS OF HABITAT AVAILABILITY, QUALITY, AND CONNECTIVITY

In Chapter 10 and throughout the Peters and Parham report, the authors recognized the importance of discharge in creating and maintaining habitat in a mobile bed river system such as the lower Platte River. However, the methods used in describing the relationship between river discharge and habitat availability are fundamentally flawed.

To assess the relationship between river discharge and habitat availability and connectivity, the authors used the following multi-step process:

1. Digitize from aerial photos the availability of open water, shallow sandbar complex, wooded island, and exposed sandbar habitats and characterize the relationship between their availability and river discharge by fitting an equation to the datasets.
2. Determine the quality of the habitat delineated by comparing 1980s vintage Instream Flow Incremental Methodology (IFIM) data to habitat availability data.
3. Assess habitat suitability by statistically integrating the availability of each habitat type and the observed use of each habitat type as determined by radio telemetry results from tagged pallid sturgeon and shovelnose sturgeon.
4. Describe habitat suitability as a function of river discharge by fitting an equation to the datasets.
5. Determine habitat connectivity by comparing river discharge to the linear extent of open water habitats that were more than 25 m from shallow sandbar complexes or exposed islands/sandbars and fitting an equation to the relationship between connectivity and discharge.

The following sections comment on the approach used to determine relationships between habitat and discharge by roughly following the approach presented in steps 1 through 5, above.

2.2.1 Characterizing Habitat Availability as a Function of River Discharge from Aerial Photo Interpretation

Analysis of aerial photos can be used to generally quantify habitat availability in fixed-bed stream systems, when implemented using standard and repeatable methods and coupled with habitat verification procedures (groundtruthing). Peters and Parham's (2007) habitat quantifications in the lower Platte River using aerial photos are not reliable because the resolution of the photos was inadequate, the dataset was not groundtruthed, turbid water conditions likely obscured diagnostic habitat features, and the method is generally inappropriate for shifting sand-bed river systems.

Habitat delineation and quantification for pallid sturgeon was conducted by one technician from relatively low resolution photos. No groundtruthing was conducted to check accuracy of the habitat classification assignments. Classifications assigned to the aerial photo data included exposed sandbars (sandbars that were not inundated and did not have woody vegetation), wooded islands (exposed sandbars with woody vegetation established), open water (areas where the technician could not see the river bottom and that were outside a 25-m buffer surrounding the exposed sandbars or wooded islands), and shallow sandbar complexes (areas that were covered with water but where the technician could see the bottom of the river or areas within the 25-m buffer placed around exposed sandbars).

Aerial photos taken from 20,000 feet do not have adequate resolution to allow for accurate or reliable habitat delineation. To cover the uncertainty associated with this method, the authors were very conservative in their habitat classifications. For example, a channel less than 50 m wide between two sandbars (25-m buffers placed around two adjacent islands) would be classified as a "sandbar complex," regardless of its depth. This same classification would be used to describe a large sand flat covered in 10 centimeters (cm) of water, even though the first example might provide high quality habitat to sturgeon while the inundated sand flat would likely be uninhabitable by large fish. This conservative quantification approach may have grossly underestimated the amount of high quality habitat available, particularly for pallid sturgeon at moderate flows. Additionally, the authors also cited in their literature review that pallid sturgeon preferred the areas just downstream of sandbars or along sandbar ledges. The placement of the arbitrary 25-m buffer around sandbars would likely eliminate many of these areas from consideration as suitable habitat.

Because of naturally high turbidity in the lower Platte River, delineation of open water habitats from aerial photos is inappropriate and unreliable. This issue could have been avoided had the authors performed standard groundtruthing procedures to verify that the open water classifications identified on the photos corresponded to actual open water habitats on or near the day the photos were taken. In the Draft BO, the NGPC indicated that pallid sturgeon in South Dakota use areas with turbidity measurements ranging from 31.3 Nephelometric turbidity units (NTU) to 137.6 NTU (Erickson 1992). Bramblett (1996) found the mean Secchi disc transparency was 7.8 inches (20 cm) at 115 pallid sturgeon locations in the upper Missouri and Yellowstone rivers. Similarly, Davies-Colley and Smith (2001) reviewed relationships between visible depth and turbidity. Data presented in that paper demonstrate that visible depth is approximately 6 cm at 100 NTU in New York and 10 cm at approximately 70 NTU for 97 rivers in New Zealand. Chapter 3 of the Peters and Parham report clearly demonstrates that high turbidity is expected for nearly all flows in the lower Platte River. Because of the high turbidity it is possible that the open water habitats delineated from photos taken during turbid river conditions are not open water as defined in the Peters and Parham (2008) report. Rather, much of the habitat is likely inundated, shallow sandbar complexes where water depths might be no greater than 6 to 10 inches (15 to 25 cm), depths the authors cite as unsuitable for pallid sturgeon. Similarly, habitat classifications at low flows could be flawed. At lower flows, turbidity should be much lower than during higher discharges. The same habitat conditions (water depth and structure) could be classified as open water when turbidity is high and as shallow sandbar complex when turbidity is relatively low. This biases flow recommendations toward higher flows for maintenance of open water habitat.

The discharge/habitat relationships described by the authors are flawed and cannot be used for management recommendations for several reasons. The authors took the data points generated from the aerial photo interpretation and created curves that predicted habitat availability at discharge using the Curve 2-D 5.01 program (Systat 2002). Due to the relative scarcity of data points, the authors grouped the data for the entire length of the lower Platte River. For each taxon (birds and fish), the authors created one habitat quantity to discharge curve per habitat type (for birds there was only one habitat type). The implicit assumption of this method is that the discharge to habitat type availability relationship is the same throughout the lower Platte River, which contradicts their physical description of the river.

While the curve fit appears to be acceptable for fish (r^2 ranging from 0.86 to 0.89, Figures 10.8 through 10.10 in Peters and Parham 2008), and poor for birds ($r^2 = 0.45$, Figure 2.10 in Parham 2007), the methods used to derive these models are suspect. The authors used a non-standard curve-fitting approach to develop these relationships. The resulting models were complex, non-linear equations that had no physical or scientific basis. Rather, the authors were fitting an arbitrary equation to a dataset. It should be noted that all datasets can be fit with some model that best describes the variability in that dataset if enough model parameters are used. While the adjusted r-squared statistic used by the authors helped to protect against over-parameterization of a model, alternative statistics such as Akaike's information criterion (AIC) are generally viewed as a superior method of weighting a model’s fit versus the number of parameters in the model. The high number of parameters and the complex, non-linear nature of the equations that were fit to the data indicate that the relationship identified by the authors is not real. Instead, the curve was set to fit their dataset.

Developing a relationship between discharge and habitat availability in a sandbed river using the flawed approaches described above is also inappropriate because of the complex relationships between discharge, channel morphology, and habitat. The following paragraphs describe fundamental flaws in the reasoning used by the authors to describe this relationship. These paragraphs are taken directly from the review completed by Dr. Gary Lewis and are consistent with other reviews that were received for the Peters and Parham (2008) report:

The study design and draft reports place total reliance on the assumption that the relationship between in-stream habitat, as defined by hydraulic parameters, and discharge rate is "singular." A singular relationship in nature is one that can have only one outcome (habitat) for each discharge. This is not consistent with the body of knowledge of morphologic channel-forming processes of braided rivers. The error made is that the authors assume that the channel geometry and braided morphology of the study area on any given day can be described by, and more importantly, predicted by a single parameter, the daily discharge rate that happens to be flowing through the area that day.

Nothing in the body of knowledge on geomorphology suggests that river morphology for a braided river at any point in time is a function of just the daily discharge that happens to be flowing through any segment on any given day. By stating that future flows must be regulated to match flow rates on particular days when habitat existed, the authors reveal the deficiency in understanding this point. Instead of being singular, stream geometry is the time-dependent result of many other factors, particularly antecedent conditions leading up to the day when an observed flow is passing through the reach. The morphology (and habitat) at any cross-section or within any reach is categorically not the result of the discharge that day as implied throughout the subject reports, including the Opinion. A channel shaped by fluvial processes can experience the same morphology for a wide range of discharge rates, and any single flow rate can pass through a variety of geometries.

The report also places emphasis on an implied, singular relationship between discharge and channel geometry, and similarly assumes that the cross-sectional geometry can be described by, and predicted by, one parameter, daily discharge. While rigid-bed hydraulics supports this, the science of fluvial hydraulics does not. It should also be noted, as described in more detail below, that universally-accepted relationships between discharge and channel geometry parameters (depth, width, area) for either fixed or mobile bed channels were not applied in developing the relationships, yet the literature is amply supplied with models and methods of studying river mechanics using these broadly accepted, and widely applied techniques. The investigators' lack of training in these fields probably kept them from adopting standard technologies.

Instead of being governed by a single discharge passing on any given day, standard literature on rivers in general, and on the Platte and lower Platte in particular, is unanimous in proving that the channel morphology is formed and maintained by the "dominant" or "effective" discharge. These are similar terms describing that flow rate, or range of flow rates, which transport the greatest amount of sediment, and logically shape it. For braided rivers, these are not the bankfull flow or 1.5-yr flood rates.

Marlette and Walker (1968) studied the channel-shaping processes at the Missouri River confluence with the lower Platte (the fact that their publication was peer-reviewed is extremely relevant), and the USGS and others (USGS 1981 &1983; HDR 1983; Parsons 2003) have supported the principles of effective discharge as being fully applicable in defining channel geometry throughout the Platte and lower Platte River. Yet the Ecology Report fails to cite these investigations or apply the standard methods and principles adopted by other scientists in relating channel shape with the discharge hydrograph. Instead, the assumption is made that both habitat and channel geometry are formed by, can be described by, and can be predicted by, a single measure (the serendipitous daily discharge passing by on any given day). It is further assumed by the report authors that this relationship is singular, and that the singular relationships can be best and adequately described on the basis of statistical curve-fitting (Systat 2002) versus physical-process analysis and analogs.

2.2.2 Characterizing Habitat Quality as a Function of River Discharge

Habitat quality was described by comparing the habitat availability data from aerial photo interpretation to IFIM data collected by the NGPC in the 1980s. The specific methods used to link the IFIM data to the fisheries and photo interpretation datasets is not clearly described in the report. It appears that the authors used the IFIM data from the 1980s and integrated it with the availability of habitats identified from the 1993, 1999, and 2002 aerial photos to provide an approximate proportion of "quality" habitat over the range of photos captured in the aerial photos. IFIM data generally consist of point measurements of depth, velocity, substrate, and cover across a series of transects spaced at relatively even intervals through a reach of river. Generally, transects are linked together to form a grid of cells that are assessed for habitat quality based on the physical measurements taken across the various transects. It does not appear that the authors used the data in this standard manner.

2.2.3 Characterizing Habitat Suitability

Chi-square selectivity analyses were used by the authors to evaluate the suitability of habitat. The chi-square test compared the availability of the depth and velocity habitat indicators from the IFIM transects to the observed use of depth and velocity as recorded from the radio telemetry data for pallid and shovelnose sturgeon.

Use of this IFIM data is questionable in a mobile sandbed river. Kehmeier et al. (2007) discussed that cross-sectional, two-dimensional analyses such as IFIM assume a stable bedform and cross-sectional profiles for prediction of changes in habitat conditions in response to changes in river discharge. This assumption is violated in mobile sandbed rivers such as the Platte where bed scouring and sandbar migration result in variable cross-sectional profiles even at the same discharge. Additionally, IFIM data were only collected at flows up to 6,767 cfs. Even if use of IFIM were valid in the Platte River, any discharge greater than this could not be linked to any sturgeon habitat data collected at flows greater than 6,767 cfs.

The models selected by Peters and Parham to describe the relationship between habitat suitability and river discharge are subject to the same criticisms as the models selected to describe the relationships between habitat availability and discharge. The complex, non-linear models might be the "best fit" models for the data, but without any scientific or physical basis they are not scientifically reliable. Additionally, the models for both pallid sturgeon and shovelnose sturgeon show habitat increasing with an asymptote near 9,000 cfs, nearly 2,300 cfs above the limits of the IFIM data. Extrapolation beyond the limits of the measured IFIM data is not valid. Furthermore, the model equations that the authors selected for pallid sturgeon and shovelnose sturgeon are drastically different. We recognize that these are different species but would expect that the models for suitable habitat would be somewhat similar for the two species.

2.2.4 Characterizing Habitat Connectivity

The authors generally conclude that 8,100 cfs is necessary to maintain 100% connectivity in the lower Platte River. However, the data presented by the authors contradicts this statement and suggests that connectivity is provided at much lower flows. Table 10.3 and Figure 10.17 clearly illustrate that connectivity is provided at flows as low as 5,610 cfs. It is likely that river connectivity is provided at much lower flows than this as the authors' relationship is only based on a few photos at a few reaches in the lower Platte. The models used to describe connectivity should not be used for numerous reasons, some of which are summarized below.

For the same reasons as described for the previously discussed habitat models, the habitat connectivity model is fundamentally flawed (i.e., described by complex non-linear equation, results tied to unrelated IFIM datasets, error-prone aerial photo interpretation used, etc.). However, the largest, and most arbitrary assumption made in the development of this model was the placement of a 25-m buffer around all shallow sandbar complexes. Peters and Parham assumed that adult pallid sturgeon would be averse to swimming through narrow channels or water less than 1.5 m deep when searching for suitable habitat upstream (even though they documented adult sturgeon in water only 0.6 m deep). This means that a channel could be 50 m in width (25 m around two adjacent bars) and greater than 1.5 m in depth but still be considered unconnected and unusable for pallid sturgeon. The assumption of applying a 25-m buffer dramatically overestimates the discharge necessary to provide functional connectivity.

There are numerous geomorphic and hydrologic rationales that the authors did not consider when developing their connectivity model. As with the other habitat models, the authors viewed habitat connectivity as a singular function of discharge and did not consider the temporal changes in connectivity as being important, especially at lower flows. The following paragraphs are taken directly from the review completed by Dr. Gary Lewis and describe the flawed approach that was used in developing this model:

> The report defines connectivity as a condition where each cross-section was classified with five percent or more (25m) of the width as open water, but with the uncertainty of all remotely-sensed classifications, and based on the altitude of the imagery used, it would be easy to miss an otherwise-connected system. Close examination of Fig. 10.6 shows that the low percent connectivity values for low flows was almost entirely the result of two unconnected reaches, classified as connected, being separated by segments classified as shallow complexes. With the scant data and high-altitude problem, misinterpretation of the imagery might have significantly biased the results.
>
> To illustrate, the photo for 1,400 cfs in Figure 10.6 has the connectivity terminating at the right bank near the center of the photo, but the braid along

which open water was classified from the left continues across the floodway toward another open-water-classified braid, yet the observer did not consider the crossing to be open water. Another crossing just west of where the open water class terminated is considerably wider, so it is reasonable that it would not be particularly deep. But the braid that crosses between the two open-water segments is as narrow as the braids that were classified as open water in the same photo. If the two segments classified as open water in this photo are actually connected, the percent connectivity in this figure alone would increase from around 60 percent to nearly 100 percent.

Snapshots in time (the aerial photos) do not address the time-variability of a braided stream. Nor do transects taken at considerable distances apart capture the transient physical processes of transport of sediments and macro forms moving past and between the transects. With further regard to Fig. 10.6, this “snapshot in time” problem raises another potentially serious misconception evident with the report. Even if the segment of the braid between the two unconnected open water segments in fact did not meet the requirements for migration at the point in time that the photo was taken, the shape and depth of the connecting channel is not fixed, and could easily change to match the braid at both ends within hours of the photograph. In fact, this would be more probable than concluding that a braid would maintain different hydraulic geometries along the same braid for any appreciable length of time.

2.3 CONCLUSIONS REGARDING THE PETERS AND PARHAM (2008) REPORT

Because of the numerous flaws and errors identified in Chapter 10 of Peters and Parham (2008), the report should not be used to make management decisions in the lower Platte River. The flow recommendations for pallid sturgeon habitat are not supported by the data collected during the study. The authors used a limited dataset to make recommendations that exceeded the limits of what the data can support. The use of nonstandard habitat assessment and quantification methods is not supported by related literature in biological, statistical, and hydrological sciences and calls into question all recommendations made in the report. In sum, these recommendations are not based on reliable, let alone the best, science.

3.0 REVIEW OF PARHAM (2007)

The Parham (2007) report is intended to provide an analysis of the hydrologic conditions of the lower Platte River; describe the flow regime without providing a normative flow recommendation; and assess which flows would support the ecological requirements for the interior least tern, piping plover, and pallid sturgeon.

Analyses and results presented in the Parham (2007) report primarily were completed in the Indicators of Hydrologic Alteration (IHA) software package. The intent of IHA is to characterize the hydrological conditions and the Environmental Flow Components (EFCs) in a river system (The Nature Conservancy [TNC] 2007) to provide an ecologically relevant assessment of a flow regime. EFCs are defined in Parham (2007) as extreme low flows, low flows, high flow pulses, small floods, and large floods. In addition, flow exceedance tables, coefficients of dispersion, low to median flow ratio, base flow indices, flow duration curves, and a number of other analytical methods were used to describe the hydrology of the lower Platte River.

The report identifies that the lower Platte River retains the natural hydrograph characteristics when compared to the central Platter River system. Because of this, Parham focuses much of the discussion on the changes in hydrology in the central Platte and how those changes might impact the interior least tern and piping plover. Parham (2007) generally only discusses the pallid sturgeon results from Peters and Parham (2007) (the draft of Peters and Parham 2008) with little new information. Because of the numerous flaws discussed previously for Peters and Parham (2008), the information related to sturgeon in Parham (2007) is subject to the same criticisms. As such, the focus of the Parham (2007) review will be to evaluate the merits of the hydrologic analyses and any related recommendations for interior least tern or piping plover habitat requirements.

3.1 REVIEW OF HYDROLOGIC ANALYSIS

The analyses used by Parham to characterize hydrologic conditions is a non-standard approach. The IHA software is intended to characterize ecologically important aspects of a hydrologic dataset and compare the pre-development flow regime to the flow regime after it has been altered (TNC 2007). The tool is meant to be used with other ecologically important information to assess progress towards meeting conservation goals in river systems (Richter et al. 1996). While the software might be a useful tool for evaluating hydrologic changes and assessing progress made towards various goals, it is not a tool for establishing minimum flow requirements or specific hydrological management requirements. More robust analysis of hydrologic datasets is required to establish these requirements.

IHA predetermines ecologically important indicators rather than considering unique conditions required by each species. In the Platte River and other similar dynamic sandbed rivers, the habitat conditions necessary for each species are as much a function of the antecedent flow conditions as they are of the current conditions. Parham recognizes this in Chapter 2, page 46, when describing the relationship of bar height to previous river discharges. However, he fails to expand this issue and does not recognize that there is not a singular relationship between the availability of habitat and an observed discharge. Since the IHA software does not allow for an assessment of the variability and complexity of antecedent discharge conditions, the recommendations made using information from the IHA model are unreliable and should not be used for management decisions in the lower Platte River.

Additionally, the IHA software is a “black box” program with the actual algorithms used to process the dataset hidden from the user. The program requires calibration to ensure the data are processed correctly. Parham (2007) did not provide information on calibration, if completed. Small errors in the calibration process or data entry process could create unintended consequences and call the results of the model into question.

In addition to the above issues related to the use of the IHA model, numerous flaws related to the analysis and interpretation of the hydrologic data limit the utility of the Parham (2007) report for use by water and species managers. Because of the numerous technical issues related to the interpretation of the hydrologic data presented in Parham (2007), only those directly related to the determinations in the Draft BO (NGPC 2007) and/or the flow recommendations made for the pallid sturgeon, least tern, or piping plover are discussed.

Parham (2007) uses a flawed approach to characterize the channel-forming (bankfull) flows and/or effective discharge in the lower Platte River. Dr. Gary Lewis identified that Parham's use of the Rosgen approach (1996) and Dunne and Leopold's (1978) definition of bankfull and effective discharges are inaccurate as neither approach applies to braided, mobile sandbed rivers. In a braided sandbed system such as the lower Platte River, bankfull or channel-forming flows are difficult to quantify because it is difficult to determine the actual banks based on natural channel migration between high flow events, locations of natural levees, as well as other physical features in the river channel (HDR 1983; Marlette and Walker 1968; Smith 1971; USGS 1981, 1983a, 1983b). Dr. Lewis goes on to discuss that a flood flow that fills the entire braided channel far exceeds the discharge necessary to maintain the channel. In addition to using non-standard methods to characterize the effective discharge, Parham (2007) failed to recognize that effective discharge had been quantified using methods more defensible than the IHA model. To support this, Dr. Lewis states:

> …the effective discharges in the lower Platte were documented by Marlette and Walker (1968). As proof that equating the bankfull flow or even the 1.5-yr flood in a braided river with the effective discharge seriously overstates the effective discharge, Marlette and Walker found that the effective discharge at North Bend is 8,000 cfs, yet Table 1.17 shows that the authors contend that a flow of 21,280 cfs is required to maintain the channel morphology.

The Parham (2007) report also deviates from traditional hydrologic sciences when assessing flood frequencies. Parham used the IHA model to identify the 1.5-year return interval as a surrogate for bankfull or channel-forming flow and crudely supported this choice using data contained in Rosgen (1996) which has previously been discussed as not applying to braided sandbed rivers. Rather than using the IHA model to determine the 1.5-year return event as effective discharge, Dr. Gary Lewis suggests that the Parham report should have used the:

> …U.S. Water Resources Council Bulletin 17B Log-Pearson Type III flood frequency method. To evaluate the accuracy of the IHA values, all peak flows at the USGS Louisville gauge were downloaded and applied to the 17B method yielding results that show that the values in Table 8 are significantly over-stated. For example, Bulletin 17B shows that the 1.5-yr flow rate is 34,580 cfs, not 39,800 cfs. Bulletin 17B places 95 percent confidence intervals on the estimates. The upper limit of the interval is 39,600 cfs. Unless different data sets or different methods were used, this suggests that the values in Table 8 may have been selected at the upper limit of the statistical confidence interval, and if so, reasons for this apparent bias for high-end flows should have been provided in the narrative.

The non-standard approaches used to characterize the hydrology of the lower Platte River preclude the use of the recommendations made in Parham (2007) for making any scientifically sound management decisions related to water management. As an example, at the Duncan gage, Parham overstated the effective discharge by 266% when compared to the effective discharge calculations made by Marlette and Walker (1968) using widely accepted methodologies. Thus, the estimate of effective discharge requiring 39,800 cfs at Louisville is likely an extremely large overestimate of what is actually necessary to maintain the channel. Using the Parham data for the 1.5-year return flow and the recommendations that resulted from those data would greatly overstate the amount of water necessary to provide the channel processes necessary to maintain habitat for the pallid sturgeon, least tern, or piping plover.

3.2 REVIEW OF TERN AND PLOVER HABITAT QUALITY, QUANTITY, AND SUITABILITY

Parham used a three-step approach to determine the suitability of plover and tern nesting habitat in the lower Platte River. First, Parham (2007) assumed that quality habitat existed if tern and plover nests avoided inundation. To determine the probability of inundation, Parham (2007) assessed whether flows during the May 1 though August 31 breeding and nesting period would rise to within 1.5 feet of the highest water level predicted for the 1.5 years prior to the breeding and nesting period. If water levels remained more than 1.5 feet lower than the prior 1.5-year high water elevation, it was defined as quality habitat. If at any time water levels during the breeding and nesting period came within 1.5 feet of the high water elevation for the prior 1.5 years, it was defined as non-quality habitat.

Second, habitat quantity was determined by digitizing the surface area of all sandbars that were greater than 3.58 acres in size, mostly free of vegetation, and disconnected from shore. The digitization process was identical to that described for determining pallid sturgeon habitat availability in the Peters and Parham (2008) report. The combined surface areas of these types of bars were divided by the total area of the channel to provide an estimate of the percentage of habitat available. Habitat availability was then compared to discharge using the Curve 2-D program (Systat 2002).

Habitat suitability in each reach was then described as an index calculated by multiplying the habitat quality values (0 if water levels rose to within 1.5 feet of the top of the bar and 1 if water levels did not rise to within 1.5 feet of the top of the bar) by the habitat quantity values (percentage of channel containing sandbars greater than 3.58 acres and disconnected from shore) for each nesting period. Flow conditions providing the top one-third of the habitat suitability index scores were defined as being favorable for piping plover and least tern nesting.

Parham (2007) relied on models of data from aerial photo analyses, similar to those described for pallid sturgeon in the Peters and Parham (2008) report, to evaluate the quality, quantity, and suitability of tern and plover habitat in the lower Platte River. As such, there are several methodological factors that do not allow for the accurate determination of suitable nesting habitat availability for interior least tern and piping plover in the lower Platte River. These factors have been largely discussed previously as part of the review of the Peters and Parham (2008) report.

One factor that limits the use of the Parham (2007) data for determining suitable nesting habitat is that the analysis of piping plover and least tern nest success assumes that the birds would abandon the nest if sandbar height above the water surface was less than 1.5 feet. However, the 1.5-foot cutoff is arbitrary. It was based on one literature reference (Ziewitz et al. 1992), which indicated that this was the lowest elevation that nests were observed. Parham (2007) does not provide any information about the Ziewitz et al. (1992) survey methods, when in the nesting period the observations were made (e.g., initiation of nesting), the number of observations made, or the antecedent flow conditions.

The elevation cutoff would be more objective if based on the soil's water conductance capabilities, multiple literature citations, or even additional unpublished observations of terns or plovers abandoning nests when water elevations rose to within 1.5 feet of the nest. Additionally, the birds likely would not abandon the nest if brief dampness occurred near the end of the 60-day nesting period. While it is true that the birds could not keep a young chick or egg warm in a damp nest, a larger chick is more capable of thermoregulation and has greater mobility. For these reasons, the habitat quality analysis in Parham (2007) is overestimating the necessary height of the sandbars and could be underestimating the amount of quality habitat.

A second factor is the use of the 3.58-acre size cutoff for islands suitable to nesting, based on a recommendation in Ziewitz et al. (1992). This cutoff is inconsistent with an observation by Wycoff (1960), which is quoted in the Draft BO: between 1949 and 1954, 20–35 terns consistently nested on "a low, sandy island not over 75 feet wide, about 200 feet long, and lying nearly a quarter-mile west of the Platte River bridge which is straight south of Lexington Nebraska." This island would have been approximately 0.34 acre in size, one tenth the size Parham (2007) defined as being suitable for nesting. Overestimation of suitable island size may have led to gross underestimation of nesting habitat availability at discharge.

A third factor that limits the use of the Parham (2007) data for determining suitable nesting habitat is the approach used to delineate habitat polygons. The delineation of suitable bars for nesting using aerial photos is flawed for many of the same reasons previously discussed for the Peters and Parham (2008) report, especially the lack of groundtruthing. The flaws associated with the delineation process alone make the tern and plover habitat assessment presented in Parham (2007). Additionally, and for the same reasons discussed for Peters and Parham (2008), the use of Curve 2D 5.01 (Systat 2002) to determine the relationship between tern and plover habitat quantity and river discharge does not provide an accurate model because the curve fitting process produced complex models without a scientific basis for this complexity.

3.3 CONCLUSIONS REGARDING THE PARHAM (2007) REPORT

For many of the same reasons cited for the Peters and Parham (2008) report, the findings and recommendations presented in the Parham (2007) report are not reliable for making management decisions in the lower Platte River. The nonstandard hydrologic analyses presented in the report, including the improper use of the IHA software, highlight the author's lack of understanding of the fundamentals of fluvial geomorphology and the hydrology of a dynamic sandbed river system. Additionally, the analyses of habitat quality, quantity, and suitability presented in Parham (2007) suffered from many of the same fundamental flaws described for Peters and Parham (2008). These flaws preclude the use of the information contained in the Parham (2007) report for making species and water management decisions and/or recommendations.

4.0 REVIEW OF DRAFT BIOLOGICAL OPINION AND NGPC 2008

The following pages contain a review of the Draft BO (NGPC 2007) and NGPC (2008). Because of the considerable overlap between the Peters and Parham (2008) and Parham (2007) reports and the Draft BO, only those comments specific to the Draft BO and the NGPC (2008) report are addressed in this section. Because many of the recommendations made in the Draft BO and NGPC (2008) report are based on the findings presented in the Peters and Parham (2008) (or its draft: Peters and Parham 2007) and Parham (2007) reports, the major technical flaws and errors that have been discussed previously in this document invalidate any of the decisions or recommendations made in the Draft BO that used the results of the reports. A more detailed review of the Draft BO is provided in Appendix B of this document. The review contains numerous technical and editorial issues that would need to be resolved before finalizing the Draft BO.

4.1 THE DRAFT BO IS INCONSISTENT WITH BEST SCIENCE FOR LISTED SPECIES

In the Introduction, the Draft BO presents a very informative and comprehensive literature review and summary of the scientific information available for the pallid sturgeon, interior least tern, and piping plover. The life-history of each species is described in detail using appropriate and relevant literature. It is recognized that the Peters and Parham (2008) and Parham (2007) reports were largely completed to support the recommendations made in the Draft BO because of a perceived lack of information related to the habitat requirements and water needs of the three listed species. However, NGPC should have recognized the flaws in the Peters and Parham (2008) and Parham (2007) reports and used the data presented in those reports in an appropriate manner. Instead, when formulating water and species management recommendations, the Draft BO abandons much of the quality information contained in its introduction and instead uses the flawed arguments of the Peters and Parham (2008) and Parham (2007) reports as the basis of the opinion.

As an example, in the Introduction, the Draft BO describes the fundamental elements of pallid sturgeon habitat as being the bottom of swift waters of large, turbid, free-flowing rivers with braided channels, dynamic flow patterns, flooding of terrestrial habitats, and extensive microhabitat diversity. Peters and Parham (2008) relied heavily on habitat data collected at the approximate locations of a few tagged pallid sturgeon to characterize suitable habitat in the lower Platte River rather than looking for the fundamental elements of pallid sturgeon habitat documented in other rivers (e.g., Missouri, Kansas, and Yellowstone rivers). In fact, the preferred habitats defined by Peters and Parham (2008) sometimes contradict those defined by studies in other rivers. Peters and Parham (2008) rated open water habitat as being much higher quality habitat for pallid sturgeon than sandbar complexes. Yet, sandbar complexes are a dominant characteristic of the braided channels and diverse microhabitats that are fundamental elements of pallid sturgeon habitat in other rivers (Forbes and Richardson 1905; Kallemeyn 1983; Gilbraith et al. 1988; Mayden and Kuhajada 1997 per the Draft BO).

A second example of the Draft BO abandoning the information contained in its Introduction in favor of the flawed Peters and Parham (2008) information is related to pallid sturgeon microhabitat use. According to the Draft BO, Snook et al. (2002) found pallid sturgeon in water as shallow as 0.15 m in the lower Platte River. Peters and Parham (2008) identified a much greater depth for connectivity with an emphasis on open water habitats. This biases the recommendations in the Draft BO towards high flows without necessarily protecting the microhabitat diversity that supports pallid sturgeon. Ultimately, the timing and variation in flow, as well as the channel morphology, may be much more important to the conservation of pallid sturgeon than minimum flows. The Draft BO should have identified these factors as important rather than focusing on a singular flow recommendation from the flawed analytical approaches presented in Peters and Parham (2008).

The Draft BO also does not provide conclusive evidence of wild or stocked pallid sturgeon spawning in, migrating seasonally into, or residing year round in the lower Platte. The document describes one apparently gravid female pallid sturgeon that was tagged by Peters and Parham (2008) that stayed around the Louisville area for several days and then moved rapidly downstream to the Missouri River. The Draft BO presumes that this fish spawned, but this fish was not recaptured and it is unknown whether this fish spawned in the lower Platte River or not. Similar behavior was exhibited by tagged pallid sturgeon after a back flushing operation by the MUD water treatment plant (NGPC 2007:32). The Draft BO describes how Peters and Parham (2008) captured larval sturgeon on May 23, 2001, just prior to the female sturgeon moving downstream and uses this as circumstantial evidence of pallid sturgeon reproduction. In actuality, only one sturgeon larva was captured in the year 2001 and the species is unknown. This is not reliable evidence that pallid sturgeon are spawning in the lower Platte River or that providing 8,100 cfs to ensure connectivity for spawning sturgeon is necessary.

Flaws in the analyses used to support the Draft BO are serious enough to call into question all recommendations made in the Draft BO. For example, the frequency of pallid sturgeon habitat use and results of the analysis of sturgeon habitat preferences in Figure 32 (on page 73 of the Draft BO) are contradictory. Oddly, Figure 32 is presented twice in the Draft BO, each containing different data. This comment refers to the second Figure 32 in the Draft BO. The second highest frequency of pallid sturgeon is found in a habitat type (0.6 m deep) that the same figure indicates the species allegedly avoids. Similarly, the figure indicates that pallid sturgeon select deep habitat types when the frequency of capture becomes increasingly rare as the water depth increases. This analysis is based on very sparse data for pallid sturgeon (Peters and Parham 2008) and its interpretation appears to be biased toward deep water habitats.

The largest single issue identified in the Draft BO is related to the determination that 8,100 cfs is necessary to provide sufficient habitat connectivity for pallid sturgeon use. It is interesting to note that the Peters and Parham (2008) and Parham (2007) reports stated that the intent of the studies was to provide necessary information for inclusion in the Draft BO but "not to provide a recommendation of an appropriate normative flow, but to characterize different aspects of the flow regime." Clearly, the authors of the Draft BO did not take this into account as the data, analyses, and interpretations related to pallid sturgeon flow requirements presented in the Peters and Parham (2008) and Parham (2007) reports were directly cited as the supporting information used to establish the normative flows presented in the Draft BO.

Figure 35, presented below, was taken directly from the Draft BO and illustrates the data used to establish the 8,100 cfs recommendation. The following paragraphs describe the reasons that the analysis presented in Figure 35 should not be used to establish flow recommendations for the lower Platte River.

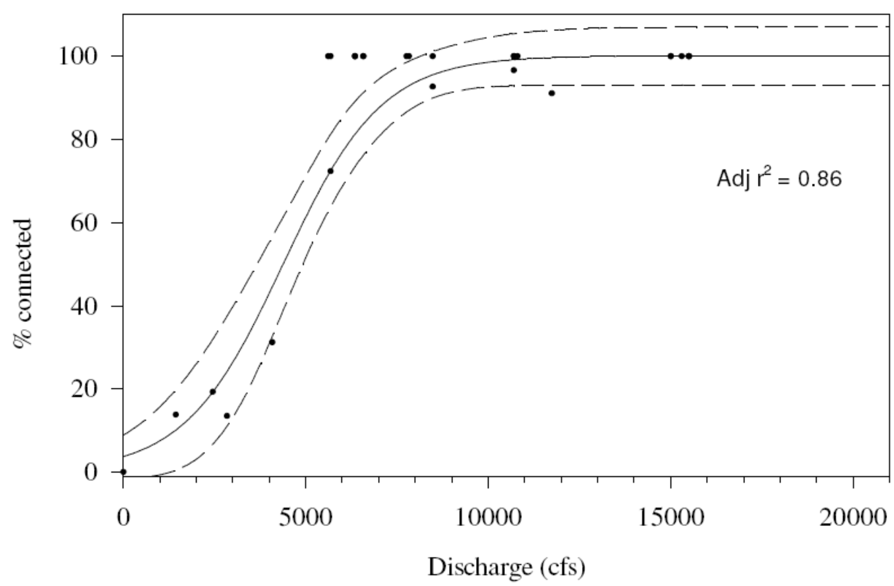

Figure 35: Curve of the best fit for river connectivity vs. discharge for the lower Platte River. The solid line represents the fitted line, the dashed lines are the 95% confidence intervals about the line, and the dots are the observations.

First, in Figure 35, 8 of the 20 data points fall outside the 95% confidence intervals. The confidence in this analysis is clearly overstated. No more than one data point should fall outside the 95% confidence interval. As presented, the confidence intervals are not better than 40% confidence intervals and require correction before finalizing the Draft BO. It appears that the eight data points were either ignored in the calculation of the best fit line or that the confidence intervals were incorrectly calculated and/or displayed.

Second, the interpretation presented in the Draft BO for Figure 35 is that 8,100 cfs are required for 100% connectivity. However, the data points in the figure clearly show that 100% connectivity is achieved between approximately 5,000 and 8,000 cfs at all but one of the sites. While the exceedance rate for 8,100 cfs is between 40% and 45% between April and June, the exceedance rate for 5,000 cfs during the same period is much better, between 70% and 85%. Additionally, 5,000 cfs would be much closer to the 5,480 cfs identified in Parham (2007) as having the highest habitat availability for tern and plover breeding and nesting. While the analysis of available bird habitat in Parham (2007) is flawed, lowering the pallid sturgeon flow recommendations to a level closer to that identified for the tern and plover would reduce the conflicts between the flow recommendations for the three species as it currently exists in the Draft BO.

The Draft BO prescribes minimum flow recommendations of 8,100 cfs from April 1through June, 7,000/6,000 cfs during successive halves of July, and 4,950 cfs throughout the rest of the year to "maintain habitat for pallid sturgeon." Because the Draft BO relies on the fundamentally flawed findings and recommendations presented in Peters and Parham (2007, 2008) and Parham (2007) and because of the flaws in the unique analyses presented in the Draft BO, the water management and species management recommendations contained in the Draft BO are not scientifically sound.

4.2 THE DRAFT BO DOES NOT PROPERLY APPLY THE JEOPARDY STANDARD

The Draft BO states that the continued issuance of surface water appropriations in the lower Platte River basin would jeopardize the continued existence of the least tern, piping plover, and pallid sturgeon in Nebraska. There are no data contained in the Draft BO, Peters and Parham (2008), or Parham (2007) that suggest that additional appropriations reasonably would be expected to reduce appreciably the likelihood of both the survival and recovery of the listed species. In fact, none of the data demonstrates how additional appropriations would reduce the reproduction, numbers, or distribution of those species. The jeopardy opinion is unfounded and contradicted by analyses presented in Draft BO.

Both piping plover and least tern occur in the Platte River above its confluence with the Elkhorn River and additional appropriations downstream from the confluence would not impact the birds above the confluence. Additionally, the habitat model in Parham (2007) and presented as Figure 25 in the Draft BO found that the highest amount of shallow sandbar complexes, the habitat type most suitable for tern and plover nesting, would occur at flows between 1,000 and 5,000 cfs. While it has been pointed out earlier that the analyses used to create this model were flawed, the 1,000 to 5,000 cfs flow range presented in Figure 25 demonstrates that further surface water appropriations in the lower Platte River will not jeopardize the continued existence of the tern or plover. Rather, Figure 25 suggests that further surface water appropriations would create higher amounts of tern and plover habitat.

Analyses presented in Peters and Parham (2008), Parham (2007), and the Draft BO also demonstrate that suitable pallid sturgeon habitat is available at lower flows. According to Figure 34 in the Draft BO, approximately 50% of the lower Platte is suitable habitat at 5,000 cfs and approximately 25% is suitable habitat at flows between 2,000 and 3,000 cfs. Figure 35 of the Draft BO further illustrates that quality habitat is available at flows lower than the 8,100 cfs flow requirement imposed by the Draft BO. According to these models, suitable habitat conditions similar to those measured as part of the Peters and Parham (2008) and Parham (2007) efforts would occur even if the 8,100 cfs flow recommendation was reduced by 35–50%. There are no data in the Draft BO to support the notion that jeopardy will occur with less than 100% of suitable habitat available.

It is possible that the Draft BO confuses harm to individuals or a reduction in the optimal levels of habitat with the definition of jeopardy in Nebraska's Nongame and Endangered Species Conservation Act. A jeopardy action is typically defined as one that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species. The Draft BO, Peters and Parham (2008), and Parham (2007) all illustrate that habitat suitable for continued use and occupation by pallid sturgeon, tern, and plover populations would occur at flows less than 8,100 cfs. Since suitable habitat conditions occur at lower flows and these species continue to occupy those habitats, even if at reduced densities, the best science does not support the jeopardy call proposed in the Draft BO.

4.3 COMPARISON OF RECOMMENDATIONS IN NGPC (2008) AND THE DRAFT BIOLOGICAL OPINION

The NGPC (2008) report is very similar in structure to and shares most of its language with the Draft BO (NGPC 2007). As with the Draft BO, the NGPC (2008) report includes a good literature review for pallid sturgeon, least tern, and piping plover, but then heavily relies on the Peters and Parham (2008) and Parham (2007) reports for habitat and flow thresholds for the species of concern. The NGPC (2008) report cites Peters and Parham (2008), rather than Peters and Parham (2007) as the Draft BO had done.

There are some differences in the determinations of the Draft BO and conclusions of the NGPC (2008) assessment. The determination of the Draft BO is protective of current bankfull flows in the lower Platte River, defined as the 1.5-year return flow for the 1954–2005 period of record. These are 39,800 cfs from the confluence of the Elkhorn River to the confluence with the Missouri River and 21,300 cfs from the confluence of the Loup River to the confluence of the Elkhorn River. Rather than focus on the maintenance of current bankfull flows, the NGPC (2008) assessment instead recommends protecting or augmenting the frequency of the threshold peak flow, the peak flow necessary to maintain 3.0-foot sandbar height. Based on the research by Parham (2007), this requires flows of at least 38,170 cfs at regular intervals through the entire lower Platte River.

The NGPC (2008) report states that maintenance of the existing hydrograph will not address recovery of the least tern and piping plover, and its recommendations strive to protect or create optimal habitat conditions for least tern and piping plover. The sandbar height objective (i.e., 3.0 feet) used by the NGPC (2008) is higher than that used by Parham (2007) of 1.5 feet, and higher than the minimum defined by the Draft BO of 1.0 foot. This higher sandbar height is meant to provide maximum flooding protection for sandbar-nesting birds. According to the NGPC (2008) report,

> Ziewitz et al. (1992) measured characteristics of nesting habitat of least terns and piping plovers in the central and lower reaches of the Platte River. At the time of this study, most nesting birds were in the lower Platte River. They found that birds nested in areas where the channel was wider with a greater area of sandbars. They recommended that sandbars be at least 3.58 acres in size and that they be 2.99 feet above river level for maximum flooding protection, but should be at least greater than 1.48 feet in height.

Refer to Sections 3.1 and 3.2 for discussion of sandbar height standards and hydrologic analysis in Parham (2007).

The Draft BO and NGPC (2008) reports both identify flow thresholds for June, July, and August that should not be decreased in frequency, duration, or timing, but the thresholds differ slightly between the two sources (Table 4.1). The flows recommended by NGPC (2008) come directly from Table 2.10 in Parham (2007); they are the average monthly discharge during the breeding season for years with a predicted favorable nesting outcome. The flows recommended in the Draft BO are "based on the habitat suitability index analysis [for least tern and piping plover] and maximum shallow water values," but the exact source of the numbers is unclear.

Table 4.1. Comparison of Summer Flow Targets during Nesting Season Between the Draft BO (NGPC 2007) and NGPC 2008.

Reach	Month	Flow (cfs)	
		Draft BO	NGPC 2008
Loup R. to Elkhorn River	June	5,100	4,686
	July	3,350	3,921
	August	2,350	2,350
Elkhorn River to Missouri River	June	7,670	5,575
	July	4,840	5,191
	August	3,650	3,811

The Draft BO and NGPC (2008) agree that the current frequency, timing, and duration of 8,100 cfs flows must be protected between the Elkhorn River and the Missouri River from April through June to provide river connectivity for pallid sturgeon movement. Likewise, the sources agree that the frequency, timing, and duration of 7,000 cfs flows should be maintained from July 1–15 and 6,000 cfs flows should be maintained July 16–31 (to permit sturgeon migration downstream and larval drift), and 4,950 the rest of the year (for year-round sturgeon habitat). Generally, the numbers and figures in the NGPC (2008) assessment are more consistent with Parham (2007) than those in the Draft BO were (see Kehmeier and Widmer review in Appendix B for inconsistencies), suggesting that the two NGPC documents may have been prepared using different drafts of the Parham (2007) report.

The habitat standards for least tern and piping plover used by NGPC (2008) are higher than those used by NGPC (2007). But, both NGPC documents are based on the scientifically flawed Peters and Parham (2008) and Parham (2007) studies, so neither set of recommendations are reliable for species management.

5.0 CONCLUSION

The Introduction of the Draft BO states that inadequate scientific data existed on the ecological requirements of the pallid sturgeon to determine the impacts of surface water appropriations on pallid sturgeon, least tern, and piping plover prior to the completion of the Peters and Parham (2008) and Parham (2007) studies. Due to several fundamental flaws in these two studies, we conclude that existing scientific data are still inadequate to make this determination.

The primary objective of the Peters and Parham (2008) and Parham (2007) studies was to establish relationships between river discharge and habitat availability for pallid sturgeon, least tern, and piping plover in the lower Platte River with very limited information on historical river conditions. These studies were limited by sparse data (e.g., pallid sturgeon captures) and poor data quality (e.g., low-resolution photographs for habitat delineation). The analyses of these data relied on unsubstantiated assumptions, employed nonstandard habitat quantification and hydrologic methods, and exceeded the limits of what the data could support. The recommendations based on the findings of these studies are unreliable and unsuitable for use in resource management decisions.

The Draft BO uses the Peters and Parham (2007) and Parham (2007) reports as support for a normative flow recommendation, while ignoring the comprehensive literature summarized in its introduction. In addition to being based on flawed information, this singular flow recommendation fails to recognize the highly variable nature of the hydrology and morphology of a dynamic sandbed river and the vital importance of antecedent conditions.

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APPENDIX A

Source Documents: Parham (2007), Peters and Parham (2008), NGPC Draft Biological Opinion (2007), NGPC (2008)

Refer to attached CD

Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon

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Chapter 1 – Hydrological Analysis of the lower Platte River from 1954 – 2002.

Introduction:

The lower Platte River is the section of the Platte River downstream from the confluence of the Loup River near Columbus, Nebraska. The lower Platte River is a unique and in high demand resource. The lower Platte River still retains its characteristic combination of braided channels and shifting sandbars once common in much of the Missouri River and its tributaries (NRC 2005). These habitats support the continued presence of at least three endangered species; Interior Least Tern, Piping Plover, and Pallid Sturgeon, yet the demand for water from the river remains high.

Much of the western portions of the Platte River have been extensively modified for the storage and distribution of irrigation waters (Bentall 1982, NRC 2005) and modifications to the natural flow regime have resulted in large changes to the characteristic habitats of the river. The flow of the central Platte River is influenced by the water releases from the 2.4 billion m^3 Lake McConaughy Reservoir and except at times when it is full and spilling water, the Central Nebraska Public Power and Irrigation District control the water release schedule (Anderson and Rodney 2006). As a result of this and other large reservoirs upstream of both the North and South Platte Rivers and the reduction in flow volume from water use for irrigation, drinking water, and power production, the channel morphology of central Platte River has changed due to the encroachment of trees in the channel (Williams 1978, Eschner et al., 1983, Simons and Associated, Inc., 2000). In comparisons of mean annual flows pre and post development, Simons and Associates (2000) estimated pre-development flows in the central Platte River to be at least 2.8 million acre feet, while Stroup et al.(2001) reported the mean annual flow near Grand Island between 1940 and 1998 to be near 1.15 million acre feet. This results in a loss of almost 60% of pre-development flows in the central Platte River.

In contrast to the central Platte River, major shifts in habitat and river channel morphology have yet to occur in the lower Platte River making this stretch of river unique in the region (Rodekor and Engelbrecht 1988, Eschner 1983, NRC 2005). There has been some narrowing of the river channel and stream bed degradation in the lower Platter River, although a small amount compared to sites in the central Platte River (Eschner et al. 1983, Chen et al. 1999). Although changes to the lower Platte River have not been as extensive as the central Platte River, analyses are necessary to understand the current hydrology and to predict the effects that future changes in flow may have on the endangered species that depend on it.

This report resulted from a request from the Nebraska Game and Parks Commission (NGPC) for an analysis of the daily flow gage records on select gages in and around the lower Platte River, NE. The lower Platte River in this analysis is defined as the stretch from the confluence with the Loup River to the confluence with the Missouri River. The hydrologic analysis is descriptive in nature. The main product requested was an analysis of magnitude, timing, frequency, duration, and rate of change of river discharge characteristics of the major gages associated with the lower Platte River and its tributaries over a comparable time period. This included the production of flow exceedance tables for each gage.

The role of natural flow variability and its important role in the ecological health of a river system has been well documented (Arthington et al. 1992, Poff et al 1997, Annear et al. 2004, Mathews and Richter 2007). Natural flow variability is also an important concern in Nebraska (NGPC 2005, NRC 2005). In the National Research Council review of the Platte River, it was recommended that the Department of Interior agencies begin moving toward a “normative” flow approach (NRC 2005). This analysis intended to provide a description of the flow characteristics of the lower Platte River and it main tributaries over the past 52 years. The goal is not to provide a recommendation of an appropriate normative flow, but to characterize different aspects of the flow regime. A description of the normative flow regime for the lower Platte will also require an description of pre-development flows as changes to the Platte River’s flow characteristics were extensive prior to 1954 (NRC 2005). Currently, no comparative flow records exist for pre-development flows on the lower Platte River, so this analysis will focus on flows over the past 52 years.

In addition to the analysis of the flow records for the lower Platte River over the last 52 years, NGPC was interested in understanding how the flows found in the lower Platte River may, or may not, support the habitats and needs of Least Terns, Piping Plovers, and Pallid Sturgeon. Models of habitat suitability were created for Least Terns and Piping Plovers based on past flow data (Chapter 2) and available information on Pallid Sturgeon was expanded in table format to better describe critical flow standards (Chapter 3).

Methods:

The gages chosen for analysis in this report were: Platte River near Duncan, NE (USGS gage 06774000); Loup River near Genoa, NE (USGS gage 06793000); Loup River Power Canal near Genoa, NE (USGS gage 06792500); Platte River near North Bend, NE (USGS gage 06796000); Elkhorn River near Waterloo, NE (USGS gage 06800500); Salt Creek near Greenwood, NE (USGS gage 06803555); and Platte River near Louisville, NE (USGS gage 06805500).

The mean daily flow data was downloaded from the USGS website at:

http://nwis.waterdata.usgs.gov/ne/nwis/dv/

To provide a consistent time period for analyzing the flow data, the time period from January 1, 1954 to December 31, 2005 was selected. This time period was available for each of the gages. Additionally, the status of the flow data was checked and approved for publication. No flow data was in the provisional status. The water year in these analyses runs from January to December at the request of NGPC. The flow data described in this chapter were used in the entire report.

All data was imported and stored in a Microsoft Access database to allow quick retrieval of data sets required for each analysis. Most basic statistics were calculated in a Microsoft Excel spreadsheet. Additionally, these results were double checked by the output from the software package Indicators of Hydrologic Alteration (IHA). Some of the more advanced statistics were derived only in IHA as noted in the individual sections below.

The main IHA web page was located at:

http://www.nature.org/initiatives/freshwater/conservationtools/art17004.html

The IHA software calculates 32 parameters thought to characterize the five main biologically relevant flow characteristics: magnitude, timing, duration, frequency, and rate of change (Richter et al. 1996). In addition to traditional hydrologic statistics, IHA uses a series of rules based on the flow percentiles compute statistics for a suite of “environmental flow components” (EFCs): extreme low flows, low flows, high flow pulses, small floods, and large floods (see IHA software for full description of the methodology). This approach differs from the traditional exceedance or monthly flow statistics in that it provides the statistics only associated with the river when it is in a particular state. For example, the large flood events are not averaged in with the low flow events obscuring the characteristics of each flow type.

IHA is considered a good tool for establishing baselines for describing hydrological regimes (Annear et al. 2004). IHA can compare pre- and post- impact conditions if an available pre-impact daily flow record exists. For this analysis, no pre-impact analysis was attempted as comparable daily flow records do not exist prior to 1954 for each site.

Changes to the Platte River's discharge were extensive prior to 1954 (NRC 2005). This analysis characterizes the discharge characteristics for the past 52 years.

Several metrics were derived from the raw flow data that were thought to be relevant in characterizing the lower Platte River's hydrology and capacity to provide habitat for endangered species. These metrics were calculated for each gage and are described below.

Exceedance Tables

Annual flow exceedance tables focus on the aspects of magnitude and frequency of the discharge record, while monthly exceedance tables also consider the timing of the discharge. Flow exceedance tables are a standard way of viewing the frequency at which a given discharge was equaled or exceeded. In an exceedance table, low flows are most often exceeded so they have high exceedance probabilities. The exceedance table can be used to determine the frequency at which different flow amounts occur in the river. Exceedance tables are useful in assessing flow availability. Caution should be used in interpreting the results of exceedance tables as reflecting naturally available flows as the tables reflect the conditions during the time period analyzed (Annear et al. 2004). In this report, exceedance tables are provided for annual and monthly flow conditions. Exceedance tables were created in an Excel spreadsheets using the percentile function on the full daily flow record from 1954 – 2004 for each gage site.

*Note an exceedance table is the inverse of a percentile table. For example a flow that is exceeded 80% of the time is considered to occur in the 20th percentile of all flows. An exceedance flow can be interpreted as the flow that is available as that percent of time. For example, an 80% exceedance flow is available (or is equaled or exceeded) 80% of the time. High exceedance percentages are generally low flows, while high percentiles are high flows. In this report, exceedance values are generally used, although for some statistics percentiles are given. For sake of clarity, percentages referring to exceedance flow values are termed exceedance percentages, while all other percentages are refer to as percentile flow values.

Coefficient of Dispersion

The coefficient of dispersion (CD) characterizes the consistency, timing, and rate of change of the flow regime, especially focusing on moderate flows. The CD is a measure of the distribution of the data about the median value in non-parametric statistics that is analogous to the coefficient of variation about the mean in parametric statistics. The CD is calculated as ((25th exceedance percentile - 75th exceedance percentile) / 50th exceedance percentile). A single value of the CD is not highly significant to understanding the discharge characteristics of the lower Platte River. CD measures are useful when comparing values among different datasets, such as, comparing the CD for recorded discharge rates in June vs. July, or comparing CD values for different gage sites. If the values for CD are different in the comparison, then it reflects some change in the dispersion of the discharge data. Possibly, there are more extreme flow events in June than July, and if so, the CD value for June would be higher than for July. Table 1.1 shows an example of how changes in the range influence observed CD values. While the standard has a value of 1 in this example, it is only for comparative purposes. When the range increased, the CD increased and similarly, when the range decreased the CD decreased.

Table 1.1. Examples of the measure of the coefficient of dispersion (CD).

% Exceeded	Standard	Range increasing		Range decreasing	
75%	500 cfs	250 cfs	500 cfs	750 cfs	500 cfs
Median	1,000 cfs	1,000 cfs	1,000 cfs	1,000 cfs	1,000 cfs
25%	1,500 cfs	1,500 cfs	2,000 cfs	1,500 cfs	1,250 cfs
CD	1	1.25	1.5	0.75	0.75
		Increase in CD		Decrease in CD	

Low Flow to Median Flow Ratio

The low to median flow ratio (LMR) also characterizes flow consistency and timing, but unlike the CD, the LMR focuses on low flows. While the CD is derived from the main body of the dataset (between the 25th and 75th exceedance percentiles), in some instances changes in more extreme values are of interest. For example, low flow events are of particular interest on the lower Platte River. Are low flows becoming more frequent? Are they more common during certain times of the year? These are common and important questions when trying to understand the discharge patterns observed in the river. In this case, a specifically designed ratio can be used to compare among datasets. For the lower Platte River analysis, a LMR was developed. This is simply defined as the ratio of the 95th exceedance percentile (low flow) to the 50th exceedance percentile (median). The 95th exceedance percentile is not intended to be a measure of baseflow in the river, yet it is an extreme value that will be highly influenced by changes in baseflow.

Here is a *hypothetical* example of how changes in LMR values may reflect changes observed on a river. Prior to construction of an upstream diversion, a river had a median discharge of 1000 cfs with a 95th exceedance percentile flow of 100 cfs resulting in a LMR of 0.1. After the diversion opened, 90 cfs was removed each day. Both the median and 95th exceedance percentile flows decreased by 90 cfs resulting in a decrease of the LMR statistic to 0.01. Alternatively, it is possible that a cessation of groundwater pumping may have increased the lowest flows in the river from the normal 100 cfs to 250 cfs at the 95th exceedance percentile. In this case an increase from 0.1 to 0.25 LMR would be observed. Table 1.2 shows the values and changes described in the examples. Just as in the CD value description, a single value of LMR is relatively uninformative. It is the comparison of different datasets that provides the utility of the LMR. Additionally, the LMR of 95th exceedance percentile to the 50th exceedance percentile is only one possibility. A ratio could be developed to look at changes in high flow events just as easily. However, the choice for the ratio percentiles used in the LMR calculations was based on the biological questions at issue.

Table 1.2. Examples of the measure of the Low Flow to Median Flow Ratio (LMR).

	Standard	Decreasing low flows	Increasing low flows
Low Flow	100 cfs	10 cfs	250 cfs
Median	1,000 cfs	900 cfs	1,000 cfs
LMR	0.1	0.01	0.25
		Decrease in LMR	Increase in LMR

Base flow Index

The base flow index characterizes low flow consistency. In this analysis, estimates of base flows were derived using the IHA software. The base flow index is an annual statistic which compared the 7-day minimum flow with the mean annual flow. The average of all years was provided as an estimate of the baseflow contribution to the river system. Given the annual nature of the statistic, it was not possible to examine changes in base flows during the year. The LMR statistic was used to examine changes in low flows (changes in the 95th exceedance percentage are expected to be reflective of changes in baseflow) throughout the year.

Flow Duration Curves

Flow duration curves characterize the magnitude and frequency of the discharge record. Flow duration curves are widespread in their use as they convey a wealth of hydrological information in a simple graphic display. (Voegel and Fennessey 1995). Flow duration curves have been used in “rule-of –thumb” to computerized incremental instream flow methods that translate the flow duration curve to a produce a habitat-duration curve (Gordon et al. 1992). A flow duration curve is a plot of discharge vs. percent of time that a particular discharge was equaled or exceeded, and is typically plotted on a log normal (discharge) to probability (exceedance value) scale. This changes typical sigmoid shape of the linear scaled plot to nearly a straight line. The flow-duration curve shape, especially in its upper and lower regions, is useful in evaluating of the characteristics of a river and its watershed. In the upper region, the shape of the curve denotes the flood regime characteristics (Moriwasa 1968). A steep curve is indicative of flashy floods usually resulting from rain events, while a flatter upper region could be the result of a steadier snowmelt runoff or upstream flood regulation by reservoir storage. In the lower region, the shape of the curve indicates low flow patterns. A steady falling line suggests the discharge in the river is mostly controlled by runoff as the longer time since last rainfall will result in lower flows. If the line flattens out then the low flows are sustained throughout the year due to groundwater adding to baseflow or to artificial flow regulation. A line that drops off quickly suggests water is being lost from the river channel possibly as a result of the surface water returning to groundwater or water being removed artificially for use outside of the river channel.

Minimum and Maximum Discharge, and Zero Flow Day Characteristics:

These statistics characterize the magnitude and frequency of extreme events. Minimum and maximum discharge characteristics were provided for the 1-day, 7-day, 30-day, and 90-day averages for the gage sites. In addition to the median values, ranges of exceedance percentages were calculated along with the coefficient of dispersion for the statistics. Statistics for 1-day flow represent the annual extreme condition, as compared to the week long (7-day), month long (30-day), or season long (90-day) extremes.

Bankfull flows:

Bankfull flows consider the magnitude and frequency of higher flows. Bankfull flows are high flow events that occur relatively frequently. The bankfull flows are considered to be flows that reach the top of the rivers banks. Larger flood occur and overtop the banks, but the bankfull flows have a large influence on the observed geomorphology of the river channel (Rosgen 1996). A generally accepted geomorphological definition of bankfull flow is:

> "The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing the work that results in average morphological characteristics of channels" (Dunne and Leopold 1978).

Bankfull discharge can also be named the effective discharge as it is the discharge that moves the most sediment over time. Large floods move substantial amounts of sediment, but they occur infrequently. In contrast, smaller floods move less sediment per flood, but occur much more frequently resulting in more overall sediment moved. To estimate bankfull discharge for the Platte River gages, a 1.5 year return period for small floods was chosen within the IHA software. Rosgen (1996) suggests that the 1.5 year flood event is typically close to the bankfull discharge. This can vary in different river types, but is the average of numerous rivers studies (Annable 1994).

Environmental Flow Characteristics:

Environment Flow Components (EFCs) and associated statistics characterize the magnitude, duration, frequency, timing, and rate of change of the discharge record. The Indicators of Hydrologic Alteration (IHA) software calculates a series of flow conditions that are intended to represent a spectrum of flow conditions that need to be maintained in order to support riverine ecological integrity. The five different types of Environment Flow Components are: low flows, extreme low flows, high flow pulses, small floods, and large floods.

The following description of the flow types is from the IHA software text "Analyzing Hydrologic Data Using the IHA - *Indicators of Hydrologic Alteration Version 7 help.*"

Low flows – This is the dominant flow condition in most rivers. In natural rivers, after a rainfall event or snowmelt period has passed and associated surface runoff from the catchment has subsided, the river returns to its base- or low-flow level. These low-flow levels are sustained by groundwater discharge into the river. The seasonally-varying low-flow levels in a river impose a fundamental constraint on a river's aquatic communities because it determines the amount of aquatic habitat available for most of the year. This has a strong influence on the diversity and number of organisms that can live in the river.

Extreme low flows – During drought periods, rivers drop to very low levels that can be stressful for many organisms, but may provide necessary conditions for other species. Water chemistry, temperature, and dissolved oxygen availability can become highly stressful to many organisms during extreme low flows, to the point that these conditions can cause considerable mortality. On the other hand, extreme low flows may concentrate aquatic prey for some species, or may be necessary to dry out low-lying floodplain areas and enable certain species of plants such as bald cypress to regenerate.

High-flow pulses – During rainstorms or brief periods of snowmelt, a river will rise above its low-flow level. As defined here, high-flow pulses include any water rises that do not overtop the channel banks. These pulses provide important and necessary disruptions in low flows. Even a small or brief flush of fresh water can provide much-needed relief from higher water temperatures or low oxygen conditions that typify low-flow periods, and deliver a nourishing subsidy of organic material or other food to support the aquatic food web. High-flow pulses also provide fish and other mobile creatures with increased access to up- and downstream areas.

Small floods – During floods, fish and other mobile organisms are able to move upstream, downstream, and out into floodplains or flooded wetlands to access additional habitats such as secondary channels, backwaters, sloughs, and shallow flooded areas. These usually inaccessible areas can provide substantial food resources. Shallow flooded areas are typically warmer than the main channel and full of nutrients and insects that fuel rapid growth in aquatic organisms. As used here, a "small flood" includes all river rises that overtop the main channel but does not include more extreme, and less frequent, floods.

Large floods – Extreme floods will typically re-arrange both the biological and physical structure of a river and its floodplain. These large floods can literally flush away many organisms, thereby depleting some populations but in many cases also creating new competitive advantages for some species. Extreme floods may also be important in forming key habitats such as oxbow lakes and floodplain wetlands.

Results:

The Louisville and North Bend sites are within the lower Platte River. The Duncan site was the most downstream on the central Platte River and describes conditions upstream of the lower Platte River and the central Platte River contribution to the lower Platte River. The North Bend site describes a combination of central Platte River discharge and Loup River discharge. The Louisville site describes the combination of discharge from the central Platte River, Loup River, Elkhorn River, and Salt Creek as well as other smaller tributaries.

*Note – The table and figures for the results section follow the written descriptions of each site. The tables and figures are not grouped by site, but grouped by analysis type and then ordered by site. This allows all sites to be compared for each type of result. The order of tables and figures is as follows:

- Average monthly median discharges comparing each site (Figure 1.1),
- Annual and monthly exceedance flows tables for each site (Tables 1.3 to 1.9),
- Flow duration curves for each site (Figures 1.2 to 1.8),
- Exceedance rates for minimum flow, maximum flow, and number of zero flow days for each site (Tables 1.10 to 1.16),
- Bankfull flow characteristics for each site (Table 1.17), and
- Proportion of flows from tributaries of the lower Platte River during moderately, high flows, low flows, and flood flows (Table 1.18).

In addition to these tables and figures, an additional group of figures showing results for numerous environmental flow characteristics are provide in Appendix 1. Information includes:

- Annual Peak Flow Exceedance Curves comparing sites,
- Monthly Median Discharge for each gage site,
- 1, 7, 30, and 90-day Annual Minimum Discharge for each gage site,
- 1, 7, 30, and 90-day Annual Maximum Discharge for each gage site,
- Annual Number of Zero Flow Days for each gage site,
- Annual Date, Number, and Duration of Low Flows for each gage site, and
- Annual Date, Number, and Duration of High Flows for each gage site.

<u>General Site comparisons:</u>

In terms of average median discharge, the Platte River sites for Louisville and North Bend had the highest annual and monthly discharge rates. The Loup River in combination with the Loup River Power Canal had the next largest flows, followed by the central Platte River and the Elkhorn River with comparable annual amounts, and Salt Creek being the lowest for annual and monthly median discharge. The Platte River sites displayed a spring rise and summer fall, while the Loup and Elkhorn Rivers, and Salt Creek had more stable flows throughout the year. Overall flows were the highest from February to June and lowest from July to October. Flood flows could happen throughout the year, but were most frequent in March and June, while the lowest flows of the years were generally in late July or August. The Platte River and its tributaries were not flashy rivers and they generally rose at twice the speed at which they fell and resulted in the length of time for flood waters to pass usually being measured in weeks to months. Not surprisingly, the smallest tributary, Salt Creek, displayed the flashiest flood characteristics. The magnitude of flood flows generally followed the overall median flow patterns with Louisville and North Bend having the largest flows followed by the Loup and Elkhorn Rivers. As a result of extensive flow modification, the central Platte River flood flows are now smaller than Salt Creek.

Platte River near Duncan, NE

On an annual basis, the mean discharge for the Platte River near Duncan, NE for the period of record from January 1, 1954 to Dec 31, 2005 was 1,867 cfs with a median flow of 1,250 cfs. The difference between the mean and median flows reflected the presence of high flow pulses recorded at the gage. Based on all daily flow recordings for the time period, the flow was greater than 417 cfs 80% of the time. Around 3% of the time the river was at zero flow. The river's discharge was greater than 1,000 cfs for 58% of the days, greater than 5,000 cfs for 6% of the days, and greater than 10,000 cfs for 1% of the days. The maximum flow recorded for the Platte River near Duncan was 23,800 cfs on 7/1/1983. For annual peak flows, the Platte River near Duncan exceeded 4,280 cfs in 8 out of 10 years, 7,000 cfs in 5 out of 10 years, and 13,800 cfs in 2 out of 10 years. The bankfull flows that occur every 1.5 years on average peaked at 7,130.

In terms of monthly median flow rates, the Platte River near Duncan, NE peaked in March (2,365 cfs) and was lowest in August (232 cfs). The river exceeded 1,000 cfs during February, March, and April more than 80% of the time. Zero flow days were possible from July until December, but were most frequent in August and September. The coefficient of dispersion (CD) reflected a change in flow characteristics between the winter and spring time period and late summer and fall. The low flow to median flow ratio (LMR) also reflected this pattern suggesting that base flow was missing from the river during the late summer and fall.

A description based on the median Environmental Flow Characteristics (EFC) for the middle Platte River near Duncan, NE resulted in the river as having the highest stable flows in March (1,618 cfs) dropping to lows in August (259 cfs) and with little change in discharge between October and January (1,000 cfs to 1,100 cfs). On an annual basis, the base flow was estimated to be 3% of the mean flow. The extreme low flows (less than 10% of annual mean) approached zero flow (1.9 cfs) during an 11 day event around August 25. Approximately 3 in 10 years would experience zero flow. There were 7 high flow pulses lasting 6 days per event. These pulses peaked at 2,650 cfs and occurred most commonly around the end of May. These high flow pulses rose nearly twice as fast as they fell (400 cfs and -233 cfs, respectively). Every other year there was a small flood event that approached a peak of 9,800 cfs lasting 63 days and was centered in mid May. Once every ten years a large flood would peak in late April near 22,500 cfs and last nearly 2 months (54 days) from beginning rise to return to low stable flow conditions. The flood waters would rise at 1,282 cfs per day and fall more slowly at -560 cfs per day.

Loup River near Genoa, NE

The Loup River near Genoa, NE had highly modified flow characteristics as it is downstream of the intake for the Loup Power Canal. The flow in the river at this site was influenced by seasonal flow as well as the amount of water needed for hydropower production. The median flow for the Loup River near Genoa was 120 cfs for the period of record between 1954 and 2005. Based on all daily flow recordings for the time period, the flow was greater than 28 cfs 80% of the time. Around 1% of the time the river was at zero flow. The river's discharge was greater than 1,000 cfs for 23% of the days, greater than 5,000 cfs for 1% of the days, and greater than 10,000 cfs for less than 1% of the days. The maximum flow recorded for the Loup River near Genoa was 70,800 cfs on 8/13/1966. Annual peak flows for the Loup River near Genoa exceeded 6,060 cfs in 8 out of 10 years, 8,880 cfs in 5 out of 10 years, and 16,200 cfs in 2 out of 10 years.

For median monthly flow, the Loup River near Genoa, NE was highest in December (1,000 cfs) and relatively high in January through March (840 to 957 cfs). The median monthly flows for the rest of the year were much lower with the only flow over 100 cfs occurring in April (271 cfs). The lowest median monthly flow occurred in August when median flow average 31 cfs. Zero flow days were possible from July until October, but were most frequent in July and August occurring on average 5% of the time.

The median Environmental Flow Characteristics (EFC) for the lower Loup River near Genoa, NE described the river as having the highest stable flows in January through March (289 to 204 cfs) with discharge less than 100 cfs the rest of the year with August having the lowest flows (28 cfs). The extreme low flows (less than 10% of annual mean) approached 3 cfs during a 4 days event around August 16. Approximately 1 in 10 years the Loup River near Genoa, NE would experience zero flow. There would be 16.5 high flow pulses lasting 4 days per event. These pulses would peak at 1,064 cfs around mid July. These high flow pulses would rise and fall at a similar rate (264 cfs and -200 cfs, respectively). Every other year there would be a small flood event that would approach 12,500 cfs lasting 23 days and centered in early May. Once every ten years a large flood would peak in mid June near 38,600 cfs and last 3 weeks from beginning rise to return to low stable flow conditions. The flood waters would rise at 3,637 cfs per day and fall more slowly at -2,903 cfs per day.

Loup River Power Canal near Genoa, NE

The Loup Public Power District (LPPD) has a hydropower station near Columbus, Nebraska that utilizes water diverted from the Loup River at Genoa, Nebraska. LPPD has been generating hydropower since March 5, 1937 and holds one of the most senior water rights in the basin. The power generating process is generally a pass through system and under their appropriation; the diversion facilities cannot pass more than 3,500 cubic feet per second. According to an agreement between LPPD and the Commission, LPPD always passes a minimum of 50-100 cfs of Loup River flow past their point of diversion.

The Loup River Power Canal withdrew an annual median flow of 1,800 cfs. This varied from a high of 2,190 cfs in April to a low of 761 cfs in December. It appeared from the monthly median flow rates that the Loup River Power Canal withdraws approximately 2000 cfs in most months with the other months around 1,000 cfs. Flows observed in the canal were greater than 3,020 cfs only 1% of the time on an annual basis. When flows were greater than 3,500 cfs in the Loup River above the Canal intake, the excess water flowed past the intake down the Loup River. In addition the flows captured by the Loup River Power Canal from the Loup River were returned to the Platte River several miles downstream of the confluence of the Loup and Platte Rivers. The intake flows are not directly correlated to the outfall flows into the Platte River, although as water is released through the power plant, water is added to the reservoir so that a similar flow pattern exists. On a daily basis the flows do not necessarily correspond, but the combination of the Loup River and Loup River Power Canal is an approximation of the water entering the Platte River from the Loup River system. Not included in this analysis were the hourly power peaking flows generated by power production. The daily mean flow was used in all calculations. The power peaking flows are an important issue, but beyond the scope of this analysis.

The median Environmental Flow Characteristics (EFC) for the lower Loup River Power Canal near Genoa, NE are inappropriate to describe flow conditions in the canal as it is controlled by the demand for energy not rainfall or groundwater flow. The Loup River Power Canal on average drew the most water in April (2,230 cfs) with December having the lowest flows (767 cfs). Most months the median canal flow was between 1,200 and 1,900 cfs. The 3-day minimum canal flow was 26 cfs and the 3-day maximum canal flow was 2,918 cfs. Overall, the Loup River Power Canal contained a large portion of the Loup River flow below Genoa for a good portion of the year.

Platte River near North Bend, NE

The gage site on the Platte River near North Bend, NE was the first gage on the lower Platte River. The annual median flow for the Platte River near North Bend was 3,630 cfs and was highest in March, April, and May with the peak in April at 5,880 cfs. The lowest monthly median flows were in August at 1,670 cfs. The coefficient of dispersion was generally stable with a value under 1 and the LMR was 0.27 annually. These metrics both suggest a large portion of base flow in this section of the river. Monthly flows approaching or exceeding 1,000 cfs were observed in all months greater than 80% of the time, with flows greater than 1,000 cfs 99% of the time in February to June and again in October. On an annual basis, flow of 5,000 cfs occurred more than 30 % of the time and more than 10,000 cfs 5% of the time. The maximum flow recorded for the Platte River near North Bend was 82,300 cfs on March 10, 1993. In terms of peak flows, flows greater than 21,000 cfs were observed in 1 out of 2 years and flows greater than 38,000 cfs were seen 1 out of every 5 years on average. The bankfull flows that occur every 1.5 years on average peaked at 21,280.

The median Environmental Flow Characteristics (EFC) for the lower Platte River near North Bend, NE described the river as having the highest stable flows in March and April (near 4,300 cfs) dropping to lows in August (1,815 cfs) and with another peak in November (3,545 cfs). On an annual basis, the base flow was estimated to be 19% of the mean flow. The extreme low flows (less than 10% of annual mean) typically occurred 5 times annually for 2 days per event. The lowest of these would be near 858 cfs around August 14. Only once in ten years would the extreme low flows reach 623 cfs. There would be 10 high flow pulses lasting 4 days per event. These pulses would peak at 6,085 cfs around June 20. These high flow pulses would rise nearly twice as fast as they would fall (1,044 cfs and -590 cfs, respectively). The bankfull flows that occur every 1.5 years on average peaked at 7,130 (Table 1.17). Every other year there would be a small flood event that would approach 26,950 cfs lasting 32 days and centered in early June. Once every ten years a large flood would peak in late April near 64,900 cfs and last nearly 1.5 months (46 days) from beginning rise to return to low stable flow conditions. The flood waters would rise at 6,244 cfs per day and fall more slowly at -1,686 cfs per day.

Elkhorn River near Waterloo, NE

The gage on the Elkhorn River near Waterloo, NE represented the contribution of the second largest tributary of the lower Platte River. The Elkhorn drained into the Platte River from the north and supplies a considerable amount of water to the Platte River. On an annual basis, the median flow of the Elkhorn River near Waterloo was 861 cfs. This made the contribution of the Elkhorn River approximately 45% of that of the Loup River system (Loup River and Loup River Power Canal combined). Median monthly flows in the Elkhorn River were highest from March to June with the peak in June at 1,620 cfs. In contrast to these values, the rest of the year's median monthly flow did not exceed 1,000 cfs and were more commonly around 600 cfs. The lowest median monthly flow was 524 cfs observed during September. The coefficient of dispersion and LMR (annual value of 0.33) suggested a stable base flow in the Elkhorn River near Waterloo. In terms of peak flows, the maximum discharge recorded during the time period of 1954 to 2005 was 44,500 cfs on March 29, 1962. On average the peak flow that occurred every other year was 14,200 cfs and once out of every five years the peak flow exceeded 23,100 cfs.

The median Environmental Flow Characteristics (EFC) for the lower Elkhorn River near Waterloo, NE described the river as having the highest stable flows in April (1,040 cfs) dropping to lows in September (503 cfs) and not rising substantially until the following March. On an annual basis, the base flow was estimated to be 26% of the mean flow. The extreme low flows (less than 10% of annual mean) typically occur once per year for 5 days. The low flow would be 251 cfs around November 17. Only once in ten years would the extreme low flows reach 128 cfs. There would be 7 high flow pulses lasting 5 days per event. These pulses would peak at 2,370 cfs around June 21. These high flow pulses would rise nearly twice as fast as they would fall (585 cfs and -282 cfs, respectively). Every other year there would be a small flood event that would approach 18,950 cfs lasting 35 days and centered in early June. Once every ten years a large flood would peak in early April near 41,000 cfs and last nearly 50 days from beginning rise to return to low stable flow conditions. The flood waters would rise at 4,354 cfs per day and fall more slowly at -1,098 cfs per day.

Salt Creek near Greenwood, NE

Salt Creek near Greenwood, NE was the largest tributary of the lower Platte River that drained into the river from the south. It was much smaller than the Loup or Elkhorn Rivers with an annual median flow of 146 cfs. Salt Creek near Greenwood had relatively stable flows throughout the year which peaked in March at 208 cfs and fell to a low of 116 cfs in October. The stable flow and large base flow are reflected in the coefficient of dispersion and LMR values during the months. June displayed the widest coefficient of dispersion as June flows were likely to be lower or higher than average. In terms of annual peak flows, Salt Creek near Greenwood reached 8,090 cfs in 1 out of 2 years and 20,300 cfs in 1 out of 5 years. The maximum flow recorded during the period between 1954 and 2005 was 37,100 cfs on June 13, 1984.

The median Environmental Flow Characteristics (EFC) for Salt Creek near Greenwood, NE described the river as having relatively stable flows all year ranging from a high of 168 cfs in March to a low of 99 in October. On an annual basis, the base flow was estimated to be 27% of the mean flow. The extreme low flows (less than 10% of annual mean) of 61 cfs occurred for 2 days in early October. Only once in ten years would the 1-day minimum flow reach 28 cfs. There would be 12 high flow pulses lasting 3.5 days per event. These pulses would peak at 357 cfs around July 12. These high flow pulses would rise nearly twice as fast as they would fall (140 cfs and -70 cfs, respectively). Every other year there would be a small flood event that would approach 13,230 cfs lasting 22 days and centered in late June. Once every ten years a large flood would peak in early July near 33,750 cfs and last nearly 78 days from beginning rise to return to low stable flow conditions. The flood waters would rise at 1,381 cfs per day and fall more slowly at -822 cfs per day.

Platte River near Louisville, NE

The gage near Louisville, NE on the Platte River was located downstream of all of the other gages previously discussed and was a combination of the waters received from these tributaries, direct runoff, as well as direct groundwater contributions. The median annual discharge at the gage was 5,230 cfs. Monthly median flows peaked in March at 8,355 cfs and reached their lowest during August at 2,720 cfs. Median monthly flows were greater than 5,912 cfs in March and greater than 1,470 cfs in August 80% of the time. A spring rise and late summer low was clearly observed in the monthly flow data. The annual coefficient of dispersion (0.93) and LMR (0.28) values reflected a large baseflow component to discharge. In terms of annual peak flows, the maximum flow recorded was 138,000 cfs on July 25, 1993. The median annual peak flow was 40,800 cfs and in 20% of the years a peak of 54,500 cfs was recorded. The bankfull flows that occur every 1.5 years on average peaked at 39,800.

The median Environmental Flow Characteristics (EFC) for the lower Platte River near Louisville, NE described the river as having the highest stable flows in March (6,360 cfs) dropping to lows in August (2,980 cfs) and rising again to peak in the next March. On an annual basis, the base flow was estimated to be 24% of the mean flow. The extreme low flows (less than 10% of annual mean) typically occur 3 or 4 times for 3.5 days per event. The lowest of these would near 1,320 cfs around August 19. Only once in ten years would the extreme low flows reach 1,122 cfs. There would be 9 high flow pulses lasting 5 days per event. These pulses would peak at 9,778 cfs around June 25. These high flow pulses would rise nearly twice as fast as they would fall (1,838 cfs and -954 cfs, respectively). Every other year there would be a small flood event that would approach 50,500 cfs lasting 25 days and centered in mid June. Once every ten years a large flood would peak in mid May near 114,000 cfs and last nearly 3 months (83 days) from beginning rise to return to low stable flow conditions. The flood waters would rise quickly at 7,926 cfs per day and fall more slowly at -3,506 cfs per day.

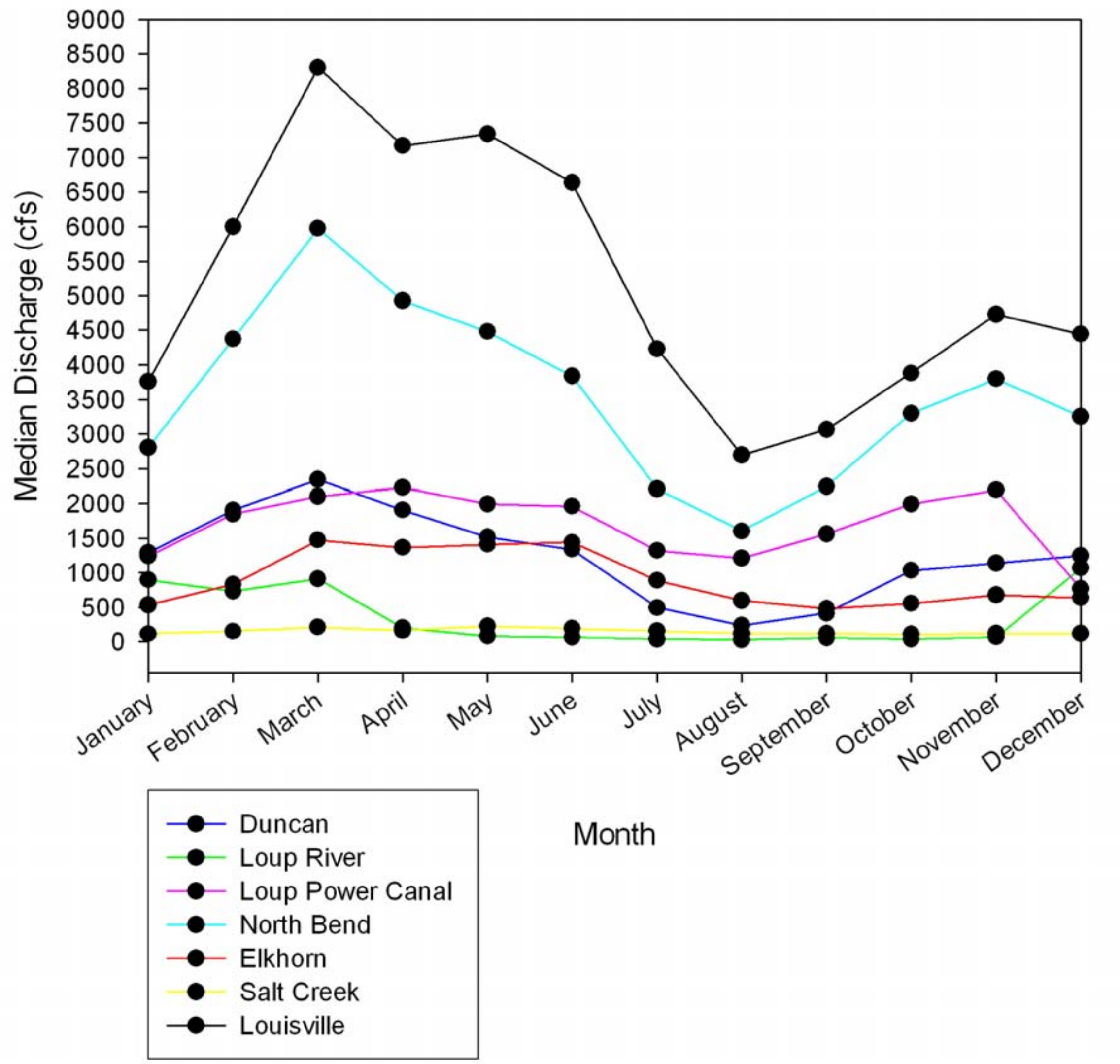

Figure 1.1. Average monthly median discharges (cfs) for the seven gage sites for 1954 – 2005.

Table 1.3. Annual and monthly exceedance flows (cfs) for the Platte River near Duncan, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	0	58	425	576	335	11	1	0	0	0	0	0	0
98%	0	268	540	643	405	106	7	0	0	0	0	0	135
97%	0	351	590	693	515	168	11	0	0	0	0	0	210
96%	1	400	620	747	566	207	27	0	0	0	0	0	270
95%	3	450	656	799	609	272	55	0	0	0	0	120	342
90%	85	558	799	1,051	785	423	149	5	0	0	8	414	480
85%	247	660	940	1,277	937	551	276	17	1	2	242	580	607
80%	417	740	1,060	1,400	1,060	692	383	38	6	8	328	712	725
75%	565	850	1,200	1,578	1,210	820	472	80	16	13	459	782	830
70%	704	939	1,364	1,730	1,410	951	617	129	43	77	565	838	900
65%	832	1,020	1,500	1,890	1,560	1,100	773	206	92	145	671	914	1,000
60%	973	1,100	1,600	2,000	1,690	1,250	934	288	139	204	767	982	1,060
55%	1,100	1,200	1,792	2,200	1,820	1,450	1,116	408	180	281	843	1,076	1,120
50%	1,250	1,300	1,900	2,365	1,950	1,620	1,265	533	232	388	959	1,165	1,210
45%	1,420	1,400	2,050	2,501	2,180	1,771	1,470	686	315	492	1,060	1,280	1,301
40%	1,610	1,546	2,200	2,710	2,350	2,020	1,710	824	397	594	1,170	1,474	1,500
35%	1,830	1,700	2,420	2,920	2,500	2,300	2,020	1,030	492	777	1,340	1,610	1,602
30%	2,100	1,897	2,650	3,094	2,650	2,597	2,455	1,247	608	1,030	1,570	1,780	1,800
25%	2,400	2,093	2,900	3,323	2,900	3,060	3,220	1,463	772	1,290	1,963	2,050	2,000
20%	2,740	2,300	3,100	3,588	3,220	3,558	4,302	1,868	1,068	1,720	2,348	2,322	2,300
15%	3,200	2,794	3,500	4,021	3,700	4,364	6,000	2,484	1,444	2,202	2,684	2,720	2,684
10%	4,000	3,200	4,182	5,314	4,611	5,864	8,758	3,804	2,149	3,001	3,310	3,071	3,098
5%	5,690	3,700	5,642	7,120	6,367	8,721	11,200	5,925	3,069	4,311	4,840	4,341	3,970
4%	6,300	3,900	6,000	7,860	7,186	9,899	12,264	6,557	3,506	4,838	5,162	4,550	4,100
3%	7,220	4,337	7,000	8,900	7,755	11,434	13,723	7,781	4,300	5,397	5,467	4,892	4,400
2%	8,766	4,700	8,200	9,898	9,978	13,678	15,464	9,996	5,546	5,876	5,859	5,303	4,700
1%	11,300	5,578	8,600	11,589	13,600	15,989	21,741	12,445	6,001	6,724	7,051	5,656	5,198
CD	1.47	0.96	0.89	0.74	0.87	1.38	2.17	2.60	3.26	3.30	1.57	1.09	0.97
LMR	0.00	0.35	0.35	0.34	0.31	0.17	0.04	0.00	0.00	0.00	0.00	0.10	0.28

Table 1.4. Annual and monthly exceedance flows (cfs) for the Loup River near Genoa, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	0	20	38	29	7	4	1	0	0	0	0	4	12
98%	1	35	44	37	10	6	2	0	0	0	1	6	16
97%	2	42	50	48	14	7	4	0	0	0	2	7	20
96%	4	47	60	51	17	9	6	0	0	2	3	9	25
95%	5	50	70	57	18	10	7	0	0	2	4	10	28
90%	12	72	120	78	34	14	15	2	2	7	6	18	51
85%	19	109	180	120	56	19	21	5	3	12	9	23	83
80%	28	170	250	188	68	25	28	9	4	16	12	28	140
75%	38	270	330	292	82	36	35	13	7	23	15	34	236
70%	48	350	410	391	94	45	44	17	9	30	19	40	350
65%	59	452	500	500	120	53	52	22	12	34	23	49	500
60%	73	580	600	653	153	62	57	28	16	42	26	56	700
55%	91	700	680	795	194	72	63	33	21	51	30	66	877
50%	120	840	840	957	271	81	71	38	31	59	36	80	1,000
45%	182	1,000	1,000	1,150	356	96	82	43	39	66	41	108	1,200
40%	300	1,100	1,150	1,300	477	122	100	49	50	75	48	165	1,400
35%	459	1,250	1,350	1,500	606	168	135	56	58	86	54	285	1,600
30%	653	1,414	1,500	1,727	721	260	211	67	71	103	67	447	1,760
25%	920	1,653	1,780	1,940	906	446	366	76	90	119	80	605	1,900
20%	1,240	1,876	2,100	2,248	1,150	727	656	101	108	152	115	835	2,080
15%	1,620	2,000	2,500	2,750	1,460	1,180	1,182	158	137	286	219	1,152	2,200
10%	2,100	2,327	3,000	3,427	2,151	1,830	2,002	358	367	681	394	1,630	2,500
5%	2,900	2,880	4,060	5,000	2,950	3,041	3,546	1,430	987	1,571	877	2,201	2,958
4%	3,080	3,000	4,500	5,924	3,143	3,511	4,176	1,886	1,252	2,003	1,050	2,350	3,000
3%	3,480	3,100	5,010	7,602	3,612	4,147	4,887	2,177	1,627	2,547	1,337	2,502	3,085
2%	4,160	3,300	6,902	9,985	4,185	5,036	6,367	2,808	1,988	2,978	1,856	2,700	3,206
1%	6,000	3,762	8,295	13,000	4,792	6,905	10,282	4,272	2,730	3,590	2,286	3,068	3,500
CD	7.35	1.65	1.73	1.72	3.05	5.06	4.66	1.66	2.69	1.63	1.81	7.13	1.66
LMR	0.04	0.06	0.08	0.06	0.07	0.12	0.10	0.00	0.00	0.04	0.10	0.13	0.03

Table 1.5. Annual and monthly exceedance flows (cfs) for the Loup River Power Canal near Genoa, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	23	15	53	64	1,060	142	532	226	123	46	245	16	10
98%	45	20	94	143	1,170	908	693	268	312	109	1,062	21	14
97%	64	24	121	193	1,258	1,110	798	315	345	540	1,140	42	17
96%	96	33	153	268	1,354	1,160	865	362	386	630	1,184	53	19
95%	139	38	230	370	1,440	1,220	948	377	435	687	1,230	65	22
90%	481	80	545	808	1,670	1,410	1,180	504	548	850	1,380	215	42
85%	747	143	836	1,120	1,780	1,490	1,310	587	668	948	1,490	750	58
80%	957	247	1,086	1,500	1,840	1,570	1,400	687	726	1,040	1,580	1,456	83
75%	1,150	406	1,280	1,690	1,900	1,660	1,500	795	800	1,160	1,670	1,760	126
70%	1,310	571	1,440	1,790	1,970	1,730	1,610	882	856	1,240	1,760	1,940	201
65%	1,450	764	1,548	1,840	2,020	1,820	1,720	979	922	1,317	1,830	2,020	308
60%	1,570	966	1,640	1,910	2,070	1,890	1,796	1,080	994	1,390	1,904	2,080	436
55%	1,690	1,100	1,726	2,000	2,130	1,960	1,870	1,180	1,090	1,476	1,970	2,130	595
50%	1,800	1,220	1,790	2,050	2,190	2,030	1,960	1,285	1,170	1,550	2,030	2,180	761
45%	1,890	1,350	1,840	2,100	2,250	2,091	2,040	1,390	1,240	1,630	2,110	2,210	928
40%	1,970	1,460	1,900	2,176	2,300	2,160	2,140	1,480	1,340	1,700	2,170	2,280	1,120
35%	2,050	1,552	1,932	2,260	2,360	2,250	2,230	1,560	1,440	1,780	2,240	2,330	1,300
30%	2,130	1,670	1,980	2,340	2,430	2,330	2,330	1,690	1,557	1,870	2,290	2,400	1,530
25%	2,220	1,800	2,020	2,440	2,490	2,440	2,470	1,860	1,670	1,970	2,360	2,470	1,763
20%	2,330	1,920	2,060	2,560	2,570	2,520	2,582	2,000	1,810	2,100	2,450	2,550	1,970
15%	2,460	2,010	2,120	2,650	2,662	2,630	2,720	2,194	1,970	2,200	2,540	2,610	2,130
10%	2,610	2,070	2,210	2,750	2,790	2,759	2,800	2,390	2,130	2,380	2,650	2,680	2,299
5%	2,790	2,190	2,460	2,880	2,890	2,905	2,920	2,710	2,405	2,720	2,780	2,790	2,570
4%	2,830	2,226	2,520	2,910	2,920	2,950	2,950	2,811	2,490	2,780	2,810	2,820	2,626
3%	2,870	2,260	2,610	2,930	2,970	3,003	3,000	2,870	2,580	2,840	2,840	2,850	2,697
2%	2,920	2,380	2,696	2,978	3,036	3,108	3,030	2,968	2,708	2,870	2,870	2,890	2,768
1%	3,020	2,549	2,790	3,010	3,100	3,179	3,080	3,088	2,870	2,918	2,939	2,940	2,880
CD	0.59	1.14	0.41	0.37	0.27	0.38	0.49	0.83	0.74	0.52	0.34	0.33	2.15
LMR	0.08	0.03	0.13	0.18	0.66	0.60	0.48	0.29	0.37	0.44	0.61	0.03	0.03

Table 1.6. Annual and monthly exceedance flows (cfs) for the Platte River near North Bend, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	470	575	1,090	2,156	2,232	1,423	1,016	219	231	501	1,301	864	611
98%	638	765	1,400	2,727	2,454	1,667	1,240	347	309	598	1,372	1,234	728
97%	775	925	1,671	2,903	2,625	1,810	1,400	394	361	733	1,463	1,600	823
96%	895	1,050	1,834	3,000	2,720	1,919	1,534	445	396	788	1,550	1,800	974
95%	984	1,126	2,000	3,161	2,780	2,036	1,620	500	441	842	1,630	1,960	1,067
90%	1,380	1,451	2,480	3,571	3,139	2,381	1,950	673	686	1,080	1,890	2,390	1,401
85%	1,740	1,700	2,754	3,877	3,389	2,630	2,210	821	864	1,230	2,030	2,690	1,700
80%	2,060	2,000	3,000	4,140	3,630	2,890	2,430	979	973	1,370	2,200	2,848	2,000
75%	2,340	2,150	3,200	4,488	3,840	3,090	2,688	1,170	1,060	1,490	2,368	2,980	2,200
70%	2,600	2,300	3,500	4,730	4,077	3,383	2,897	1,380	1,160	1,650	2,510	3,130	2,500
65%	2,840	2,500	3,664	5,000	4,297	3,607	3,150	1,590	1,260	1,807	2,650	3,330	2,700
60%	3,100	2,600	3,900	5,300	4,526	3,860	3,400	1,780	1,380	1,970	2,830	3,486	2,900
55%	3,380	2,700	4,200	5,560	4,740	4,160	3,730	2,030	1,510	2,140	3,010	3,620	3,100
50%	3,630	2,900	4,470	5,880	5,000	4,435	4,080	2,270	1,670	2,280	3,220	3,745	3,300
45%	3,920	3,100	4,700	6,191	5,295	4,800	4,510	2,570	1,850	2,455	3,441	3,905	3,510
40%	4,250	3,400	5,000	6,526	5,568	5,180	5,080	2,816	2,076	2,650	3,686	4,070	3,800
35%	4,620	3,600	5,400	6,872	5,950	5,652	5,700	3,212	2,310	2,910	4,000	4,280	4,062
30%	5,010	3,941	5,792	7,347	6,396	6,197	6,550	3,597	2,577	3,190	4,297	4,540	4,344
25%	5,520	4,378	6,160	8,030	6,860	6,890	7,980	4,113	3,003	3,613	4,710	4,850	4,653
20%	6,080	4,800	6,600	8,700	7,632	7,880	9,566	4,868	3,538	4,200	5,040	5,310	5,000
15%	6,900	5,200	7,396	9,607	8,543	9,214	11,700	5,774	4,214	4,917	5,520	5,840	5,500
10%	8,230	6,000	8,706	11,200	9,961	11,300	14,400	7,590	5,109	6,023	6,149	6,450	6,178
5%	10,800	7,041	11,000	15,045	12,000	14,000	18,400	10,915	6,612	8,151	8,009	7,442	7,000
4%	11,900	7,522	11,828	16,956	12,800	15,224	20,528	12,556	7,200	8,748	8,516	7,853	7,326
3%	13,200	7,800	12,700	19,067	13,946	17,000	24,492	14,734	7,800	9,266	9,107	8,232	7,867
2%	15,400	8,156	14,448	23,178	16,464	20,300	26,982	17,580	8,583	10,100	10,054	8,809	8,200
1%	20,200	8,400	17,000	30,545	20,969	25,089	33,928	21,879	10,189	11,841	11,000	9,840	8,629
CD	0.88	0.77	0.66	0.60	0.60	0.86	1.30	1.30	1.16	0.93	0.73	0.50	0.74
LMR	0.27	0.39	0.45	0.54	0.56	0.46	0.40	0.22	0.26	0.37	0.51	0.52	0.32

Table 1.7. Annual and monthly exceedance flows (cfs) for the Elkhorn River near Waterloo, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	170	173	230	416	485	366	331	152	110	121	194	212	197
98%	212	196	240	447	553	406	366	199	134	131	212	250	216
97%	236	212	260	460	603	439	402	229	156	148	221	288	230
96%	260	235	273	480	630	481	436	249	173	168	252	299	247
95%	280	250	290	520	642	522	465	267	196	198	266	309	260
90%	350	300	359	700	712	614	599	363	249	244	299	356	310
85%	414	340	400	781	788	686	694	438	305	294	351	425	350
80%	469	366	460	851	872	778	770	497	358	334	392	480	400
75%	518	398	520	922	944	895	882	566	408	380	436	511	447
70%	571	430	580	998	1,020	974	1,020	643	458	410	461	548	470
65%	632	460	630	1,090	1,110	1,090	1,150	718	489	438	480	576	519
60%	696	490	700	1,180	1,190	1,180	1,296	801	520	464	510	610	560
55%	770	520	760	1,300	1,270	1,330	1,460	878	557	495	535	651	603
50%	861	560	880	1,400	1,390	1,520	1,620	964	596	524	563	673	640
45%	955	625	1,000	1,530	1,550	1,720	1,850	1,070	657	558	597	706	680
40%	1,060	700	1,100	1,720	1,750	2,000	2,120	1,190	715	620	640	757	730
35%	1,180	800	1,210	1,892	1,930	2,220	2,500	1,350	780	691	725	875	800
30%	1,330	860	1,350	2,140	2,193	2,540	2,930	1,530	849	802	843	972	880
25%	1,540	920	1,500	2,453	2,773	2,870	3,460	1,740	970	895	967	1,050	980
20%	1,830	1,000	1,700	2,858	3,370	3,360	4,132	2,038	1,140	975	1,120	1,120	1,118
15%	2,260	1,100	2,000	3,494	3,972	3,990	5,092	2,434	1,370	1,130	1,260	1,250	1,250
10%	3,040	1,249	2,500	4,589	4,901	4,848	6,841	3,039	1,800	1,430	1,540	1,541	1,480
5%	4,690	1,540	3,500	7,000	7,089	7,173	10,100	4,555	2,540	2,181	2,039	2,061	1,750
4%	5,420	1,700	4,028	7,505	7,996	7,800	11,400	5,507	2,974	2,526	2,182	2,146	1,810
3%	6,410	1,847	5,396	9,168	8,807	8,477	13,600	6,447	3,360	2,935	2,447	2,312	1,930
2%	8,000	2,039	7,000	12,512	11,128	9,656	15,846	8,526	3,966	3,448	2,938	2,673	2,076
1%	11,500	2,400	8,898	21,212	12,864	12,445	20,582	12,267	7,996	4,703	3,751	3,344	2,209
CD	1.19	0.93	1.11	1.09	1.32	1.30	1.59	1.22	0.94	0.98	0.94	0.80	0.83
LMR	0.33	0.45	0.33	0.37	0.46	0.34	0.29	0.28	0.33	0.38	0.47	0.46	0.41

Table 1.8. Annual and monthly exceedance flows (cfs) for Salt Creek near Greenwood, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	34	25	40	44	49	50	44	40	35	30	34	36	29
98%	40	28	44	62	54	54	54	45	40	34	36	39	36
97%	48	32	50	66	64	60	62	51	48	40	38	44	41
96%	54	34	54	72	68	64	66	54	55	45	42	52	45
95%	60	40	58	75	72	68	69	58	59	50	51	58	52
90%	75	60	75	91	93	87	86	72	74	73	71	78	68
85%	85	72	93	103	105	103	100	85	82	78	76	85	77
80%	93	80	102	113	112	114	114	95	88	84	81	93	87
75%	101	90	109	129	120	125	127	103	94	90	86	101	92
70%	108	94	117	140	129	137	139	112	99	95	92	106	98
65%	116	100	125	157	142	151	154	125	106	101	97	110	104
60%	124	105	132	171	152	168	171	140	117	107	101	114	109
55%	134	111	147	187	168	192	185	156	126	114	108	118	115
50%	146	120	160	208	186	233	213	175	133	123	116	123	120
45%	160	127	173	230	206	272	251	190	141	132	125	131	124
40%	178	138	190	255	230	317	296	210	150	141	138	140	130
35%	200	150	205	280	272	370	343	238	166	151	152	155	140
30%	226	163	233	308	310	430	407	271	185	170	166	169	150
25%	264	190	260	351	356	527	510	320	213	192	182	191	170
20%	317	205	295	422	439	655	634	395	249	232	211	214	185
15%	398	222	357	563	569	925	829	494	315	292	246	253	210
10%	569	260	448	922	776	1,328	1,212	782	414	407	333	325	249
5%	1,090	346	653	1,729	1,261	2,235	2,585	1,629	812	780	562	407	325
4%	1,330	354	763	2,186	1,470	2,557	3,053	1,948	1,066	919	710	469	349
3%	1,760	438	964	2,683	1,818	3,427	3,858	2,513	1,440	1,112	938	503	380
2%	2,402	564	1,386	3,510	2,631	4,330	5,958	3,349	2,286	1,478	1,198	592	430
1%	3,892	893	2,050	4,770	3,632	5,259	9,383	6,158	3,780	2,472	2,160	902	533
CD	1.12	0.83	0.94	1.07	1.27	1.73	1.80	1.24	0.89	0.83	0.83	0.74	0.65
LMR	0.41	0.33	0.36	0.36	0.39	0.29	0.32	0.33	0.44	0.41	0.44	0.47	0.43

Table 1.9. Annual and monthly exceedance flows (cfs) for the Platte River near Louisville, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	744	1,004	1,750	3,027	3,210	2,072	1,606	513	366	366	1,543	1,416	718
98%	1,010	1,270	1,932	3,513	3,554	2,370	1,877	604	493	672	1,700	1,921	1,009
97%	1,220	1,433	2,442	3,793	3,728	2,483	2,088	710	573	932	1,820	2,300	1,210
96%	1,360	1,604	2,647	4,244	3,864	2,669	2,317	819	700	1,010	1,890	2,460	1,344
95%	1,490	1,750	2,800	4,411	3,979	2,816	2,490	900	763	1,050	1,980	2,550	1,496
90%	2,020	2,102	3,146	5,030	4,499	3,580	3,030	1,291	1,090	1,310	2,290	3,120	2,020
85%	2,510	2,400	3,500	5,450	5,000	4,007	3,489	1,600	1,330	1,550	2,527	3,420	2,400
80%	2,930	2,700	3,900	5,912	5,370	4,530	3,898	1,910	1,470	1,768	2,730	3,638	2,800
75%	3,300	2,990	4,200	6,310	5,695	5,000	4,418	2,200	1,600	1,970	2,880	3,830	3,100
70%	3,630	3,100	4,600	6,653	6,000	5,450	4,920	2,500	1,720	2,150	3,060	4,000	3,400
65%	4,000	3,300	5,032	7,000	6,220	5,930	5,357	2,880	1,900	2,420	3,259	4,187	3,700
60%	4,390	3,500	5,400	7,488	6,520	6,410	5,886	3,264	2,170	2,650	3,454	4,356	4,000
55%	4,780	3,749	5,800	7,870	6,980	6,889	6,550	3,660	2,450	2,920	3,650	4,530	4,300
50%	5,230	4,000	6,000	8,355	7,420	7,415	7,180	4,075	2,720	3,180	3,920	4,740	4,500
45%	5,790	4,221	6,400	8,881	7,920	7,941	7,912	4,551	3,030	3,405	4,270	4,990	4,750
40%	6,260	4,600	7,000	9,426	8,500	8,616	8,904	5,086	3,332	3,700	4,662	5,300	5,056
35%	6,800	5,000	7,600	10,200	9,268	9,320	9,944	5,842	3,700	4,044	5,092	5,820	5,400
30%	7,420	5,465	8,200	10,900	10,100	10,500	11,400	6,437	4,120	4,470	5,820	6,300	5,880
25%	8,160	6,153	8,940	11,700	11,100	11,600	13,300	7,203	4,818	5,193	6,515	6,773	6,400
20%	9,150	6,608	9,704	13,000	12,700	13,300	15,800	8,088	5,778	6,152	7,060	7,236	6,928
15%	10,500	7,400	10,800	15,000	14,700	15,600	19,645	9,514	7,000	7,013	7,670	7,770	7,440
10%	12,700	8,510	12,420	17,700	17,600	19,090	24,000	12,490	8,480	8,331	9,098	8,811	8,229
5%	18,000	10,000	16,860	24,945	22,905	25,900	31,700	17,745	10,400	11,000	11,000	10,300	9,625
4%	20,132	10,400	18,000	28,112	25,264	27,868	34,692	19,312	10,900	11,764	11,756	10,900	9,939
3%	23,000	11,000	19,296	33,400	28,922	32,000	40,492	22,501	12,867	13,346	12,700	11,200	10,100
2%	27,316	11,178	21,976	39,546	33,082	35,890	46,728	27,578	16,556	15,064	14,078	11,700	10,656
1%	36,008	12,000	30,096	52,746	39,300	40,589	58,000	38,090	25,156	19,641	16,789	12,900	11,178
CD	0.93	0.79	0.79	0.65	0.73	0.89	1.24	1.23	1.18	1.01	0.93	0.62	0.73
LMR	0.28	0.44	0.47	0.53	0.54	0.38	0.35	0.22	0.28	0.33	0.51	0.54	0.33

J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

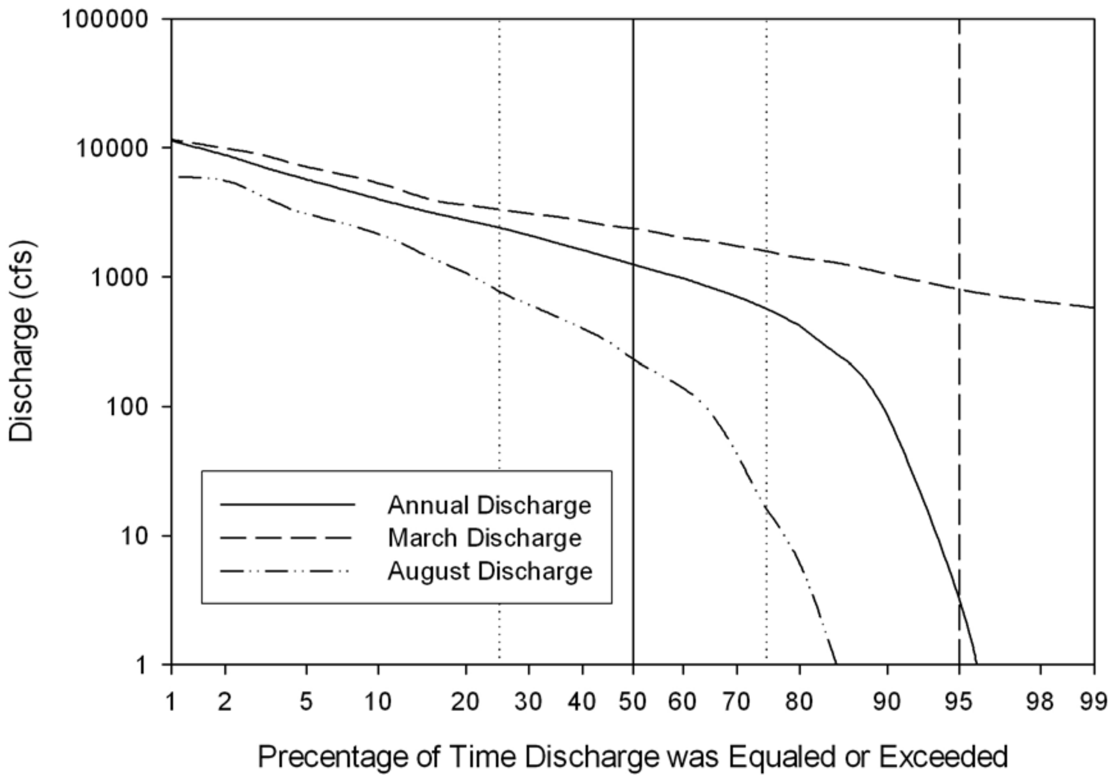

Figure 1.2. Flow duration curve for the Platte River near Duncan, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

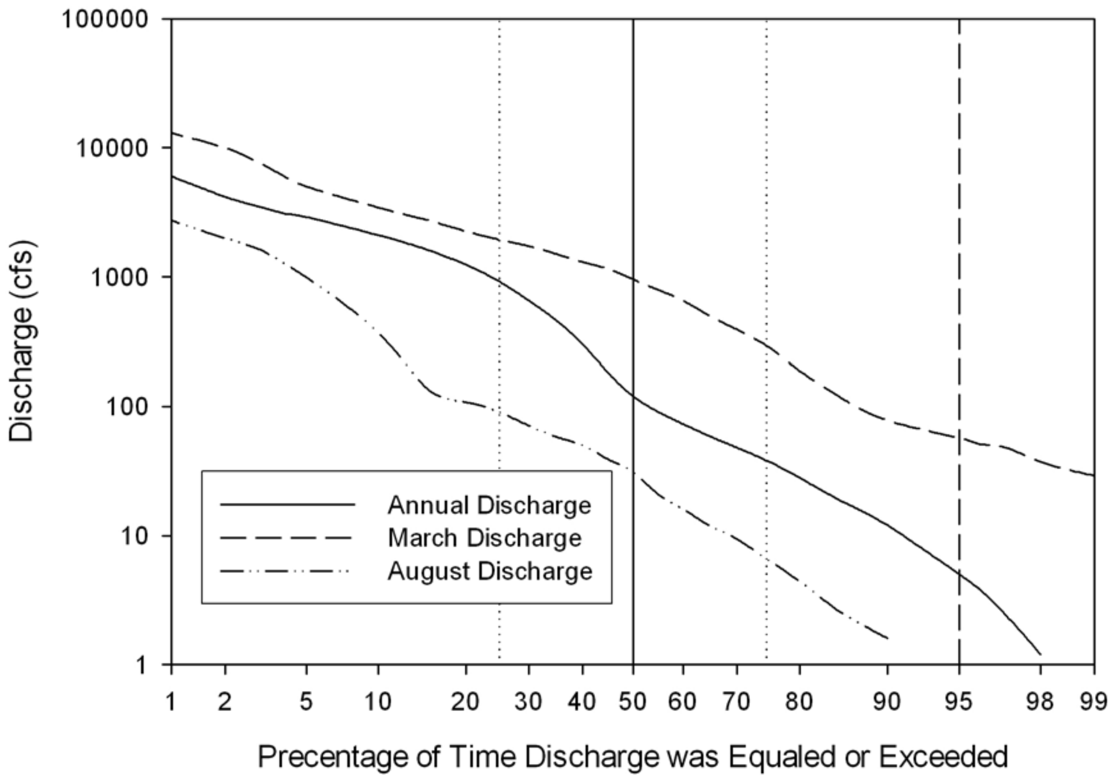

Figure 1.3. Flow duration curve for the Loup River near Genoa, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

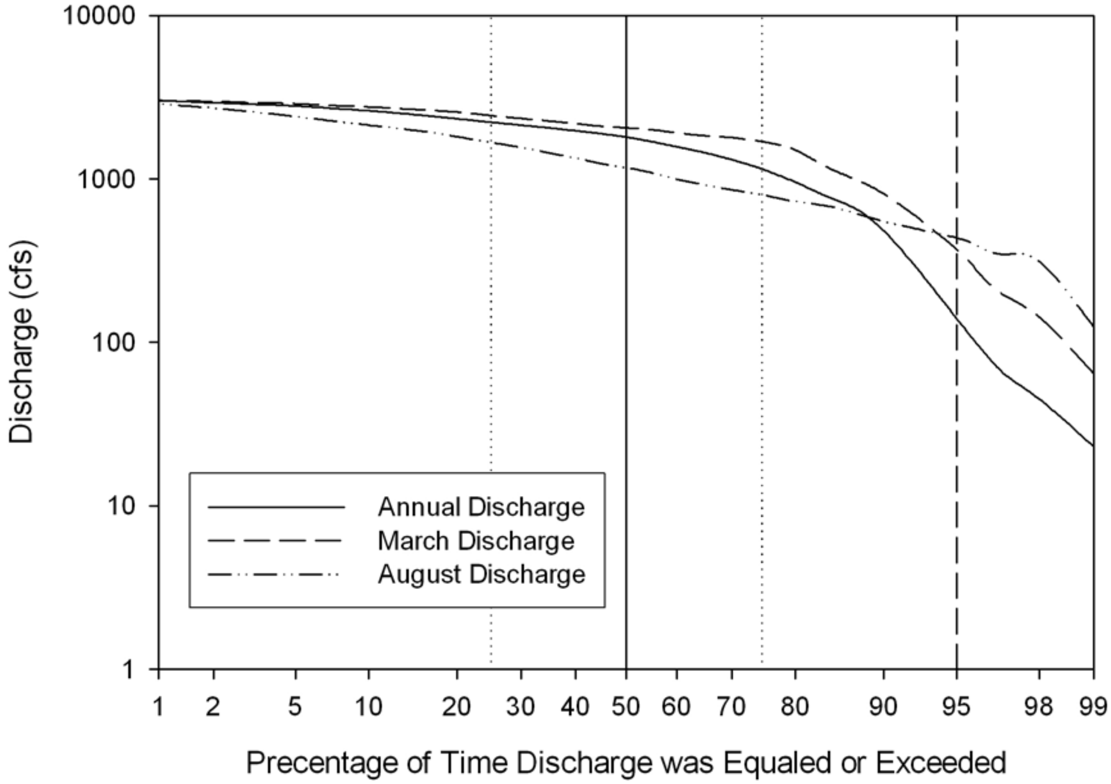

Figure 1.4. Flow duration curve for the Loup River Power Canal near Genoa, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

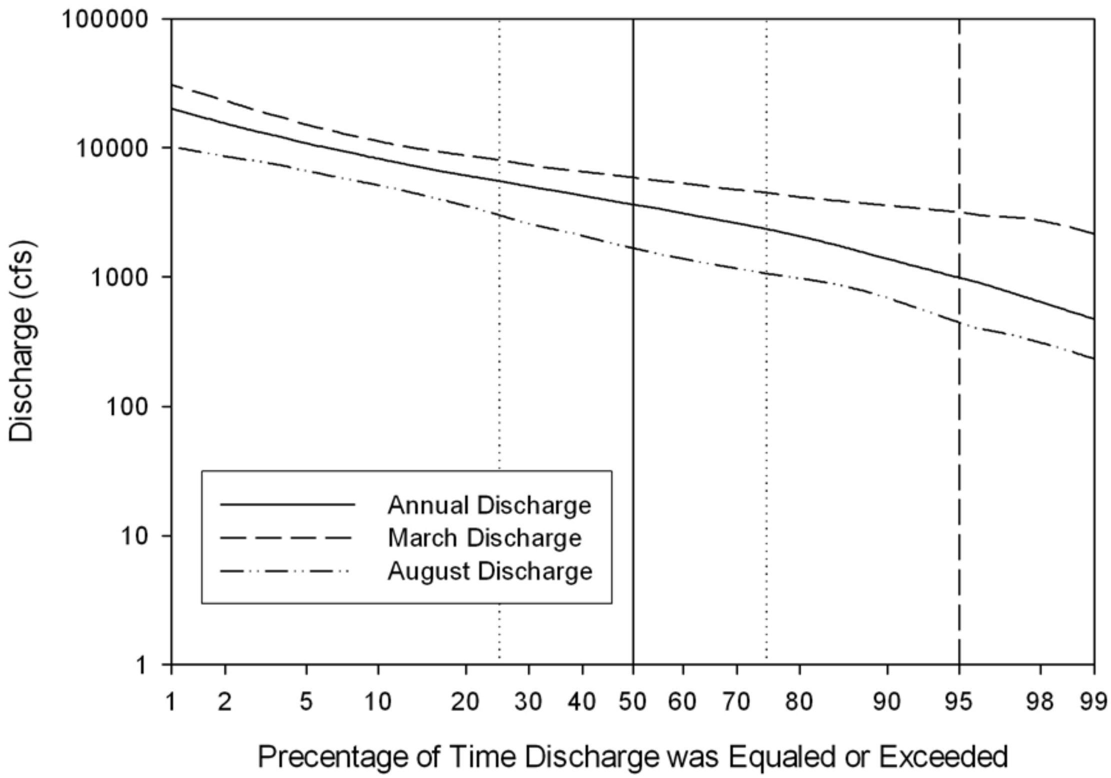

Figure 1.5. Flow duration curve for the Platte River near North Bend, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

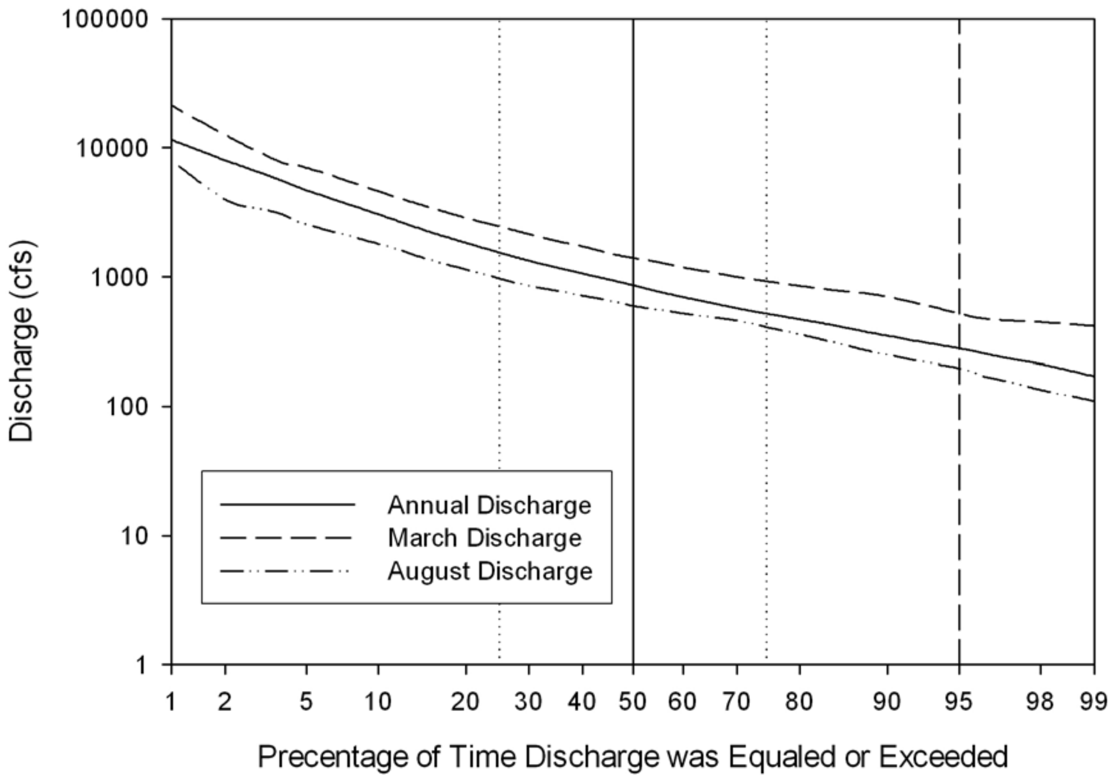

Figure 1.6. Flow duration curve for the Elkhorn River near Waterloo, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

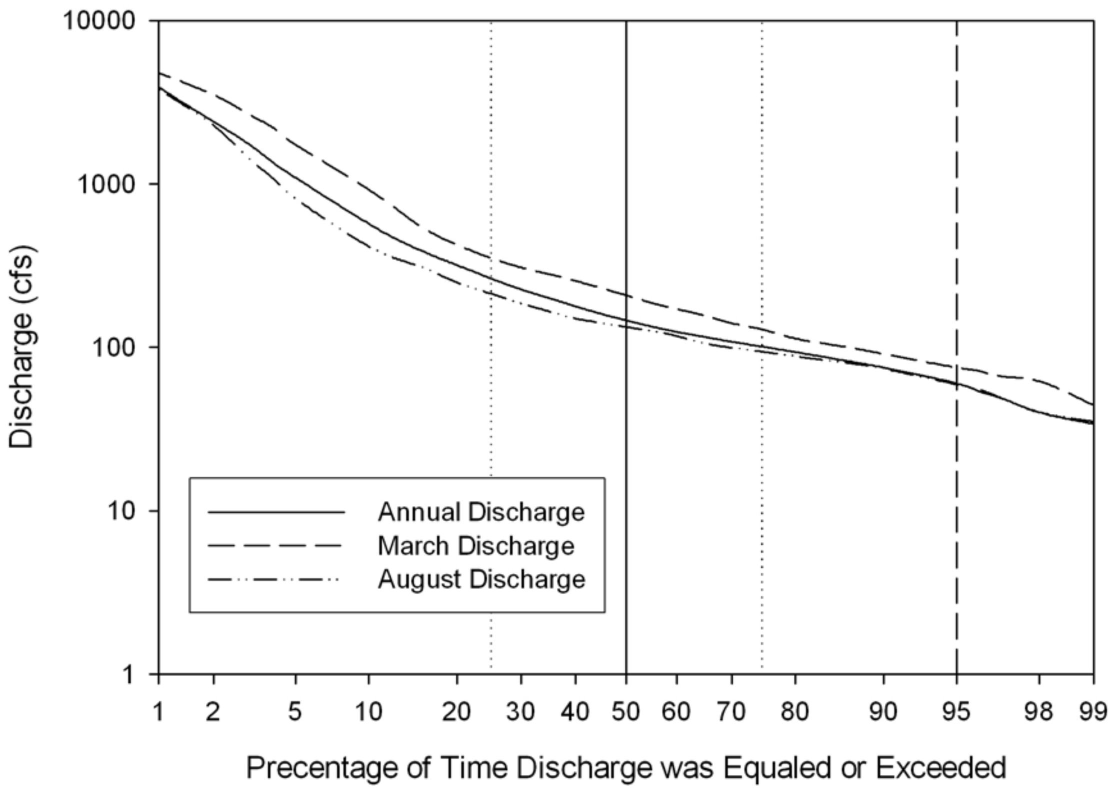

Figure 1.7. Flow duration curve for Salt Creek near Greenwood, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

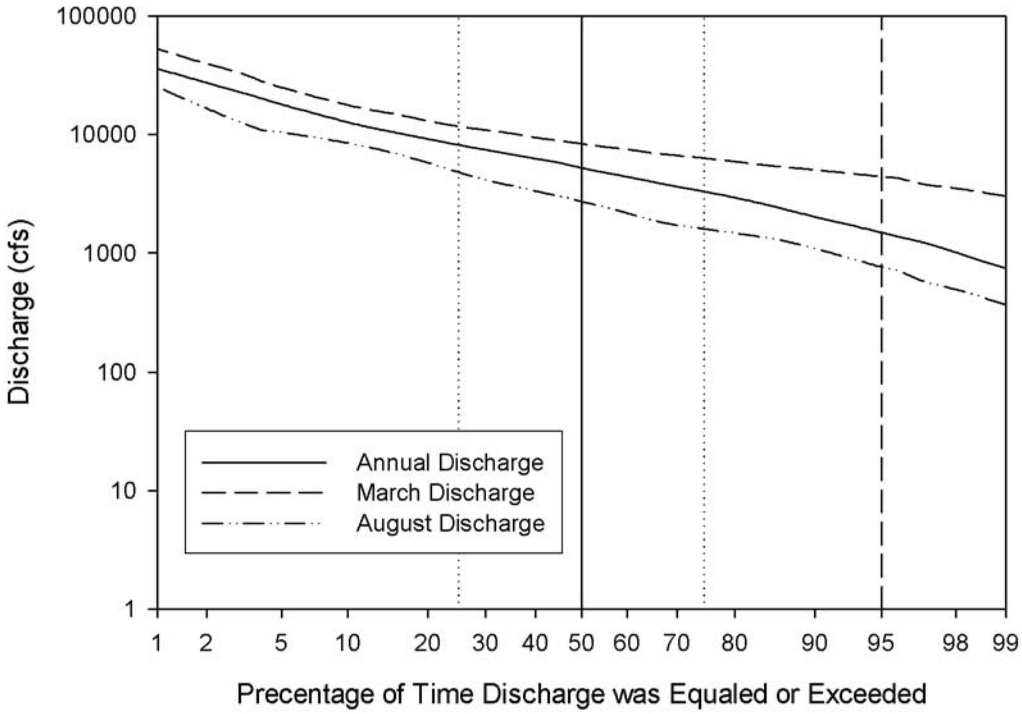

Figure 1.8. Flow duration curve for the Platte River near Louisville, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

Table 1.10. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Platte River near Duncan, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	0	0	24	227	450	9.46
3-day minimum	0	0	27	237	478	8.87
7-day minimum	0	1	43	281	674	6.47
30-day minimum	0	9	132	489	1,141	3.64
90-day minimum	4	88	457	1,010	2,068	2.02
1-day maximum	3,432	4,305	7,015	11,830	17,900	1.07
3-day maximum	3,264	3,950	6,373	10,770	17,390	1.07
7-day maximum	2,728	3,428	5,439	10,100	14,040	1.23
30-day maximum	1,863	2,481	3,455	6,229	10,530	1.09
90-day maximum	1,419	1,924	2,595	4,078	6,845	0.83
Number of zero days	0	0	0	2	69	0.00

Table 1.11. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Loup River near Genoa, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	0	1	5	12	22	2.19
3-day minimum	0	1	7	14	27	1.97
7-day minimum	0	2	8	21	30	2.25
30-day minimum	1	5	14	40	81	2.47
90-day minimum	9	24	59	97	214	1.22
1-day maximum	4,179	6,365	8,995	14,980	30,000	0.96
3-day maximum	2,987	4,179	6,443	11,090	23,330	1.07
7-day maximum	2,327	3,008	4,279	7,294	13,520	1.00
30-day maximum	1,161	1,626	2,366	3,907	4,549	0.96
90-day maximum	644	899	1,469	2,073	2,585	0.80
Number of zero days	0	0	0	0	29	0.00

Table 1.12. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Loup River Power Canal near Genoa, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	4	9	17	32	62	1.38
3-day minimum	7	14	26	44	102	1.13
7-day minimum	20	32	55	111	308	1.45
30-day minimum	199	370	527	788	951	0.79
90-day minimum	765	986	1,204	1,397	1,574	0.34
1-day maximum	2,800	2,893	2,980	3,120	3,285	0.08
3-day maximum	2,728	2,810	2,918	3,053	3,181	0.08
7-day maximum	2,615	2,717	2,829	2,974	3,062	0.09
30-day maximum	2,275	2,465	2,579	2,736	2,818	0.11
90-day maximum	1,972	2,152	2,276	2,419	2,503	0.12
Number of zero days	0	0	0	0	0	0.00

Table 1.13. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Platte River near North Bend, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	249	354	532	714	1,292	0.68
3-day minimum	290	427	684	904	1,464	0.70
7-day minimum	333	519	781	1,065	1,633	0.70
30-day minimum	612	938	1,294	1,909	2,918	0.75
90-day minimum	1,095	1,366	2,034	3,283	4,109	0.94
1-day maximum	10,480	13,280	21,150	32,280	59,630	0.90
3-day maximum	8,522	11,390	16,970	28,300	48,690	1.00
7-day maximum	7,452	9,493	14,940	19,710	36,840	0.68
30-day maximum	5,447	6,249	9,145	12,000	18,740	0.63
90-day maximum	4,084	5,391	6,570	8,929	11,930	0.54
Number of zero days	0	0	0	0	0	0.00

Table 1.14. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Elkhorn River near Waterloo, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	128	186	261	441	668	0.98
3-day minimum	134	198	278	455	714	0.93
7-day minimum	141	217	319	501	753	0.89
30-day minimum	187	277	415	636	879	0.86
90-day minimum	304	409	546	998	1,371	1.08
1-day maximum	4,314	7,878	14,550	21,600	37,180	0.94
3-day maximum	3,440	6,424	10,960	16,620	32,700	0.93
7-day maximum	2,596	4,559	8,099	10,720	20,770	0.76
30-day maximum	1,517	2,327	4,103	6,319	10,290	0.97
90-day maximum	1,189	1,757	2,482	4,044	5,855	0.92
Number of zero days	0	0	0	0	0	0.00

Table 1.15. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Salt Creek near Greenwood, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	28	51	70	97	129	0.66
3-day minimum	31	55	72	98	134	0.60
7-day minimum	34	61	75	100	136	0.51
30-day minimum	54	74	92	113	183	0.43
90-day minimum	76	92	123	153	244	0.49
1-day maximum	2,300	3,800	8,145	15,780	23,900	1.47
3-day maximum	1,309	2,288	4,337	9,638	13,620	1.70
7-day maximum	697	1,285	2,477	4,769	7,075	1.41
30-day maximum	316	529	1,139	2,022	3,042	1.31
90-day maximum	235	354	590	1,162	1,520	1.37
Number of zero days	0	0	0	0	0	0.00

Table 1.16. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Platte River near Louisville, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	411	690	1,110	1,633	3,008	0.85
3-day minimum	475	802	1,212	1,913	3,336	0.92
7-day minimum	589	904	1,355	2,290	3,543	1.02
30-day minimum	945	1,343	1,919	3,363	4,928	1.05
90-day minimum	1,493	2,256	2,999	5,119	6,627	0.95
1-day maximum	17,480	24,350	40,950	52,750	94,850	0.69
3-day maximum	15,350	20,330	33,450	42,810	82,640	0.67
7-day maximum	11,970	15,660	24,230	32,850	61,650	0.71
30-day maximum	7,880	9,986	14,380	21,370	34,330	0.79
90-day maximum	6,757	7,554	10,190	14,630	21,060	0.69
Number of zero days	0	0	0	0	0	0.00

Table 1.17. Bankfull flow characteristics for the Platte River gage sites.

Site	Peak (cfs)	Duration (days)	timing	rise rate (cfs)	fall rate (cfs)
Duncan	7,130	32	5/26	555	-463
Loup River	10,930	21	5/7	1,514	-1,094
North Bend	21,280	35	5/15	1,387	-1,465
Elkhorn River	16,700	35	6/9	2,672	-940.5
Salt Creek	9,520	20.5	6/22	2,041	-570.3
Louisville	39,800	22.5	6/4	4,177	-2,331

* approximately 3,000 cfs could be added to the peak flow statistics for Loup River as an approximation of the water diverted through the Loup River Power Canal.

Table 1.18. Proportion of flows from tributaries of the lower Platte River during moderately high flows, low flows, and flood flows (cfs).

Site	Period Higher flows May 80% exceed	% of Louisville flow Period Higher flows May 80% exceed
Central Platte River (Duncan)	692	15.3%
Loup River (Loup River +Loup Power canal)	1,595	35.2%
Elkhorn River	778	17.2%
Salt Creek	114	2.5%
Lower Platte River (Louisville)	4,530	100.0%

Site	Period of lower flows July 80% exceed	% of Louisville flow Period of lower flows July 80% exceed
Central Platte River (Duncan)	38	2.0%
Loup River (Loup River +Loup Power canal)	696	36.4%
Elkhorn River	497	26.0%
Salt Creek	95	5.0%
Lower Platte River (Louisville)	1,910	100.0%

Site	Bankfull flows 1.5 year return flood	% of Louisville flow Bankfull flows 1.5 year return flood
Central Platte River (Duncan)	7,130	17.9%
Loup River (Loup River +Loup Power canal)	13,955	35.1%
Elkhorn River	16,700	42.0%
Salt Creek	9,520	23.9%
Lower Platte River (Louisville)	39,800	100.0%

Conclusions:

The hydrologic analysis of the lower Platte River showed a river that retains its most natural characteristics as one travels further downstream. The central Platte River is highly modified and its hydrograph bears little resemblance to historical estimates (Figure 1.9). The central Platte River contributes approximately 15 % of the water volume of the lower Platte River at Louisville during non-irrigating seasons, but only 2% in the summer (Table 1.16). Flood flows have also been decreased as the central Platte River now provides less water than Salt Creek in terms of bankfull flood flows (17.9% to 23.9% of Louisville bankfull flows.) Additionally, the Platte River is a sandbed river with interaction between surface and subsurface flows. There are areas of gaining and losing flows on the Platte River (NRC 2005). When observing seasonal changes in LMR values for the central Platte River at Duncan, modification of the river's low flow regime becomes apparent. While it is beyond the scope of this analysis to estimate the gaining or losing nature of different sections of river, it is unlikely that this geologically controlled aspect of the river bed changes substantially with in the seasons in a natural setting. While some variation is expected and probably natural as a result in seasonal changes in evapotranspiration, broad shifts from a river with baseflows (LMR near 0.35 for January to May) to a river without baseflows during irrigating seasons (LMR near 0 for June to November) likely reflects the withdrawal of water for irrigation.

The addition of the Loup River water and that of the Loup River Power Canal are important in providing substantial amounts of water to the lower Platte River. The Loup River contributes approximately 35% of the water to the lower Platte River (Table 1.16) The Loup River is not without modification, yet its contribution to the lower Platte River is substantial and important. The effect of the hydropower return on the lower Platte River was obvious. From the daily variation in flow volume (Figure 1.10) to the overall steady contribution of baseflow to the lower Platte River (nearly a median of 2,000 cfs daily in most months) the power return has a large effect on the downstream sections of the Platte River. While the hydropeaking may cause some environmental damage due to the rapid wetting and drying of shallow river areas, it may also serve to mobilize sediment at higher rates during the pulses keeping sandbars free from vegetation (Ed Peters, personal communication). It is beyond the scope of this analysis to assess the role of hydropower peaking on the lower Platte River, but it may be an important factor in the observed habitats on the lower Platte River.

With the addition of the Elkhorn River and then Salt Creek, the lower Platte River in the vicinity of Louisville, NE seems to retain much of the important flow characteristics of its natural hydrograph. The spring rise and summer low flows exist at Louisville, yet the peak observed in mid June during the 1895- to 1905 time period near Duncan is not as pronounced. (Figures 1.1 and 1.9) The variable timing of water inputs from the upstream sources provide baseflow throughout much of the year with no large shift in CD or LMR values during the seasons. Additionally, peak flows exist at frequent and relatively large magnitudes (bankfull flows near 40,000 cfs occurring at a 1.5 year return period and ten year floods averaging nearly 114,000 cfs). As a result, the channel of the lower Platte River still contains a wide range of habitats from large sandbars and woody islands to shallow sandbars and swift channels. The combination consistent low flows and frequent high flows support the development of the different habitats (Figure 1.11).

It is important to remember that the range of flows in this analysis were all modified flows. The analysis only covers the years 1954 – 2005, and the major upstream dams were in place prior to this period. The last of large upstream reservoir, Lake McConaughy began filling in 1941, and Calamus Reservoir on a tributary of the Loup River was completed in 1985. As a result, the conditions observed today may not resemble historical natural conditions, but at least in the Louisville area, many of the important riverine habitats still exist in the river.

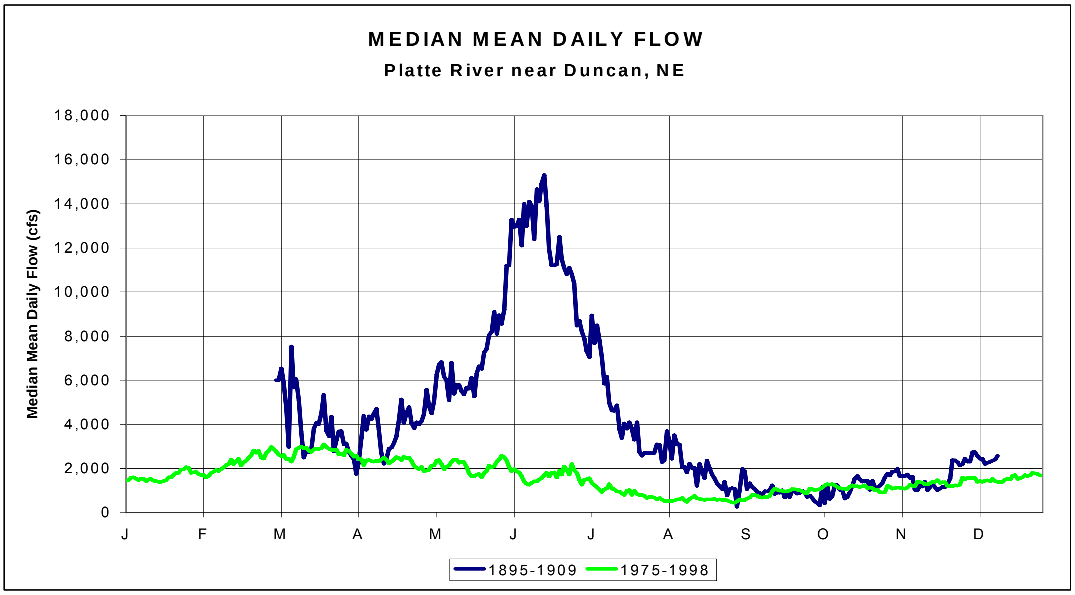

Figure 1.9. Median mean daily flow in the Platte River at Duncan, Nebraska, in 1895-1909 vs. 1975-98. (USGS gage data, as presented in Platte River FEIS, USDOI (2006)).

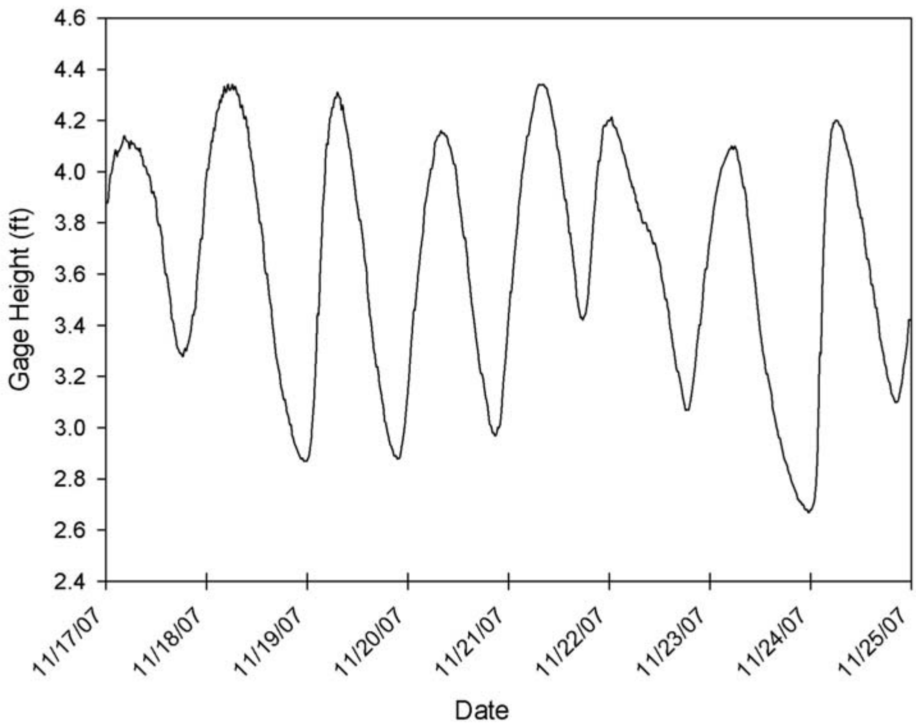

Figure 1.10. Water depth (ft) fluctuations in the Platte River near North Bend, NE (USGS Gage No 0679600) during November 17 – 25, 2007. Data is in provisional status.

Figure 1. 11. The lower Platte River downstream of the Louisville gage site during low flow conditions. Note the presence of exposed sandbars, shallow sandbar complexes, as well as deeper channels near the shorelines.

Chapter 2 - Estimation of Least Tern and Piping Plover nesting habitat in relation to river discharge

Introduction:

Least Terns and Piping Plovers are endangered birds that nest on the sandbars of the lower Platte River. These birds typically select nest sites on dry, unvegetated sandbars and unvegetated portions of sandbars. Exposed sandbars are created during periods of higher flows where the river waters erode, move, and deposit the sandy bed materials into the mosaic of scalloped sandbars and braided channels. As the discharge falls after a flood period, the water depth decreases and much of the channel is exposed in the form of newly created sandbars. Sandbars vary in size, shape, and height, and in depositional areas of the river (wider and lower slope than average) large sandbars are common. Over time, the sandbars erode naturally from the effects of wind, water, and ice although some may be stabilized by vegetation. The natural process of sandbar formation, erosion, and stabilization with vegetation are illustrated in Figures 2.1, 2.2, and 2.3.

Figure 2.1. Moderately high water on the lower Platte River near North Bend on June 14, 2007. Note the ripples in the center of the photograph. These reflect the presence of shallow sandbars not far beneath the surface. Compare this to the smooth water seen on left side of the photograph, where water was deeper. Higher flows scour channels, move sand downstream, deposit it in lower velocity areas, and clear overtopped sandbars of vegetation. (Photo by Joel Jorgensen, NGPC).

Figure 2.2. A large sandbar near Valley, NE on July 13, 2007 exposed during a period of lower water discharge. Note the lack of vegetation on the sandbar and the relative height of the sandbar above the waterline. This sandbar would provide nesting habitat for Least Terns or Piping Plovers if future water discharge did not rise to a level that would flood nests. (Photo by Joel Jorgensen, NGPC).

Figure 2.3. Vegetated sandbars in the Platte River near Columbus, NE on September 9, 2007. If higher water discharge does not occur, the exposed sandbars will become

covered by vegetation. Note the swath of dark green woody sapling vegetation, only a few years old, established mid-channel. Vegetated sandbars are not suitable nesting habitat for Least Terns or Piping Plovers. (Photo by Joel Jorgensen, NGPC).

This chapter provides an analysis of the timing, duration, and magnitude of river discharge that creates and sustains nesting habitat for Least Terns and Piping Plovers. To accomplish this, several aspects of discharge and nesting requirements were considered. These include:

1. Define Least Tern and Piping Plover nesting requirements with respect to river discharge

2. Estimate of the height of sandbars created by river discharge

3. Determine the relationship between past high water flows and current sandbar height

4. Estimate the potential for nest inundation under historical discharge conditions

5. Estimate the surface area of large sandbar habitat, that is disconnected from the shoreline, in relation to river discharge

6. Estimate overall historical nesting habitat suitability from discharge records.

7. Describe the discharge characteristics of years with high habitat suitability.

Methods:

The data used to describe the timing, duration, and nesting habitats of Least Terns and Piping Plovers was based on a review of the literature (Haig 1992, Kirsch 1992, Sidle et al. 1992, Ziewitz et al. 1992, Kirsch 1996, Thompson et al. 1997, Aron 2005, and NRC 2005) and in consultation with NGPC biologists. The models presented here associate descriptions of the habitats used by breeding birds to past discharge records of the lower Platte River.

The characteristics of sandbars used to describe nesting habitat with respect to river discharge were assumed to be similar for Least Terns and Piping Plovers. Consequently, only one set of calculations is used to estimate the amount of nesting habitat for these two species on the lower Platte River. Two metrics were created to describe different aspects of river sandbars, the first termed habitat quality and the second termed habitat quantity. These two metrics were combined to characterize nesting habitat suitability.

Several of the analytical methods used to create the habitat quality and quantity metrics, and to estimate suitability were similar. The analyses all used the mean daily flow record available for the time period 1954 – 2005 from the USGS website: (http://nwis.waterdata.usgs.gov/ne/nwis/sw). The analyses follow identical methodology for each of the river gage sites, near Louisville (Site Number 6805500), North Bend (Site Number 6796000), and Duncan (Site Number 6774000). The Louisville and North Bend sites are within the lower Platte River. The Duncan site was the most downstream on the central Platte River and describes conditions upstream of the lower Platte River. The Duncan site describes the central Platte River contribution to the lower Platter River. The North Bend site describes a combination of central Platte River discharge and Loup River discharge. The Louisville site describes the combination of discharge from the central Platte River, Loup River, Elkhorn River, and Salt Creek.

The *breeding season* is defined as the period from May 1 to August 31 in each year (a total of 123 days). The breeding season covered the period of time when the majority of nesting occurs for Least Tern and Piping Plover on the river. Additionally, a 60-day nesting period was established to cover nest initiation, nesting, hatching, and fledging. A *nesting period* is defined as 60 consecutive days during the breeding season. The first nesting period was May 1 to June 30, the second was May 2 to July 1, and so on until the final nesting period from July 2 to August 31. The nesting periods are a 60-day moving window with the breeding season. There were a total of 63 nesting periods in each breeding season.

The nesting period reflects a period of time that terns or plovers have an opportunity to successfully fledging young. Breeding season arrival, nest initiation, incubation periods, and hatch-to-fledgling periods vary between the two species and between individuals. Piping Plovers arrive in late April and early May, earlier than Least Terns which arrive in late May. Piping Plover incubation averages 28 days (Haig 1992) and chicks fledge 21–35 days post-hatching (Aron 2005). Least Tern incubation is shorter, generally 18–21 days, but can also be as long as 28 days (Thompson et al. 1997, Aron 2005). Juvenile terns are capable of flight approximately 21 days post-hatching (Thompson et al. 1997). The average incubation to fledging time for Least Terns is estimated to be 42 days and 56 days for Piping Plovers. Additional time is required prior to incubation for pairs to form pair bonds, engage in courtship, make nest scrapes, select a nest site, and lay eggs. It generally takes 6 days for the typical 4 egg Piping Plover clutch to be completed (Haig 1992). Least Terns typically have 3 egg clutches, laying one egg every one or two days (Thompson et al. 1997). Overall, the average arrival to fledging time for Least Terns was estimated around 55 days to 65 days for Piping Plovers. The nesting period is assumed to be 60 days for both species given the variation in length of time needed for each step in the breeding season.

Habitat Quality

Habitat quality measured the possibility of nest inundation. More specifically, the *habitat quality* metric is a combination of the height of the sandbars created by the highest flows in the preceding 1.5 years with the height of the water surface during a 60-day nesting period. This metric estimates the likelihood that acceptable flow conditions were present during a given 60-day nesting period.

Five assumptions were developed after consultation with NGPC biologists and the relevant literature.

1. The highest discharge in the preceding 1.5 years was considered the current "habitat forming flow." This is roughly analogous to the bankfull discharge which is considered the 1.5 return flood flow (Rosgen 1996). The bankfull discharge corresponds to the discharge which generally does the work that results in average morphological characteristics of channels (Dunne and Leopold 1978). Additionally, the maximum height of the sandbars available to the birds was controlled by the past flood events. The 1.5 year window also accounts for the natural revegetation processes. It is assumed sandbars that are not flooded will become unsuitable nesting habitat as vegetation grows up on the sandbar after 1.5 years. Least Terns generally select sites that lack vegetative cover (Dirks 1990, Ziewitz et al. 1992), but may nest on sites with up to 30 percent vegetative cover (Schulenberg and Placek 1984, Dryer and Dryer 1985, Rumancik 1985). The optimum range for vegetative cover on Piping Plover nesting habitat has been estimated at 0–10 percent (Armbruster 1986). The estimate that sandbars remain unvegetated for 1.5 years is likely longer than actually occurs. Sandbars are colonized quickly by grasses and fast growing species such as cottonwood trees and willows in the absence of higher flow. Cottonwood trees are a fast growing species and can grow 10 meters in four years (Putnam et al. 1960). Estimating the rate of growth and amount of vegetative cover on a sandbar was outside the scope of this analysis; therefore sandbar habitat was considered unvegetated for the whole 1.5 year period.

2. The maximum water surface elevation during the 60-day nesting period was at least 1.5 foot lower than the height of the sandbars created by the habitat forming flow. The 1.5 foot height is based on reported minimum sandbar elevations at nesting sites (Ziewitz et al., 1992). This height is a conservative estimate for several reasons. First, natural erosion (Bauer and Schmidt, 1993) and erosion associated with hydropower peaking (Dexter and Cluer, 1999) would decrease the overall height of sandbars created by peak flows (up to 1.5 years without erosion is assumed in this analysis). Second, the analysis uses mean daily discharge values and does not account for the daily flow fluctuations resulting from the hydropower peaking discharges from the Loup Power Plant Canal (Figure 2.4). Least Terns and Piping Plovers nest on dry sandbars and do not place nests on moist substrates (Thompson et al. 1997, Haig 1992), therefore the sandbar elevation must be high enough to avoid inundation during flow fluctuations.

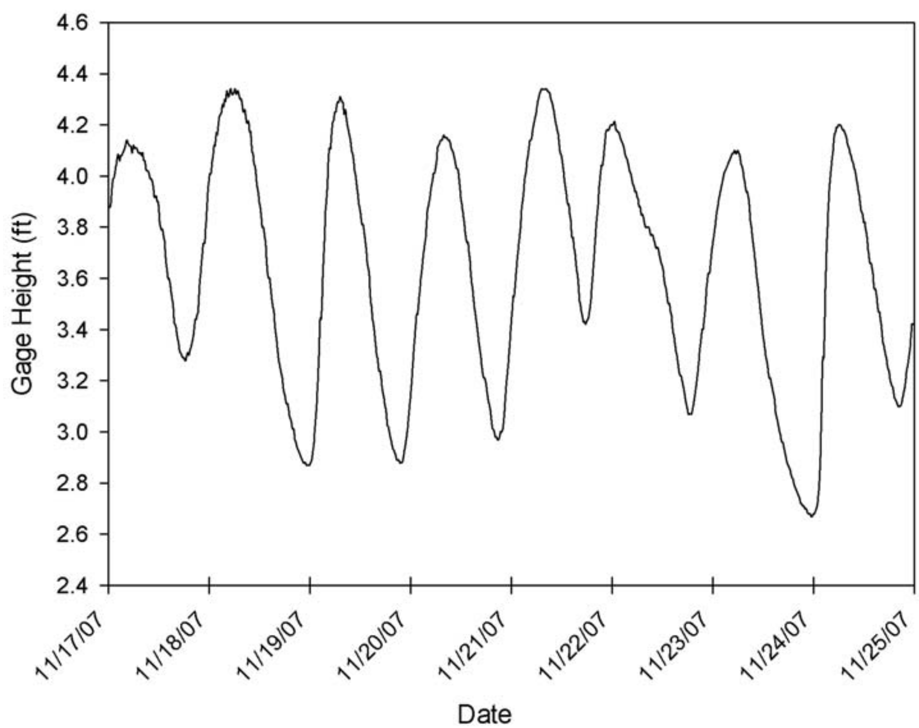

Figure 2.4. Water depth (ft) fluctuations in the Platte River near North Bend, NE (USGS Gage No 0679600) during November 17 – 25, 2007. Data is in provisional status.

3. If all days in a nesting period had a maximum sandbar elevation greater than or equal to1.5 ft above the water surface elevation, then the nesting period is considered acceptable for nesting. Conversely, if a nesting period had any day with maximum sandbar elevations less than 1.5 ft above water surface elevation, then the entire period is considered unacceptable for nesting.

4. It is also assumed that birds would renest if conditions were appropriate after a nest inundating flood. Any nesting period could be used by the birds even if preceded by unsuitable conditions. While the model assumes unlimited renesting, in reality the number of times a pair of birds can renest is limited. For example, upon the loss of eggs or newly hatched chicks, a pair of Piping Plovers may renest up to four times, but renesting efforts usually result in fewer eggs being produced (Lingle 1988, USFWS 1990). The likelihood of renesting decreases with progression of the breeding season. New nests are rarely initiated after the first week of July (NGPC database).

5. The overall habitat quality for a single breeding season is the sum of the nesting periods considered acceptable for nesting. A single 60-day nesting period would allow the birds to have a successful breeding season. This presupposes that the birds "know" on which date they should begin nesting for acceptable flow conditions during the future 59 days. As the number of acceptable nesting periods increase, the chance of nesting with acceptable conditions increases. For example, if 10 nesting periods were acceptable, the birds would have a 10 out of 63 (maximum number of nesting periods in a breeding season) chance of selecting an acceptable nest initiation date.

To estimate the height of sandbars created by the 1.5 year peak flow, the USGS discharge data was converted to estimate the channel characteristics created by the flows. Mussetter Engineering, Inc. (2002) calculated the channel characteristics and sediment transport capabilities of the lower Platte River in the vicinity of the mouth of the Elkhorn River. Nine transects crossing the width of the river were located up and downstream of the mouth of the Elkhorn River. The discharge to channel depth data for each of the nine transects was averaged to provide a general description of discharge to channel depth to be used to represent the conditions for the lower Platte River as a whole. A line was fit to the data to create an equation to estimate channel depth from the discharge using Table Curve 2D 5.01 (Systat, 2002). Selection of the most appropriate curve followed methods outlined in the curve-fitting software. This process generally followed the criteria simultaneously increasing adjusted r^2 values, reducing parameterization, eliminating unstable or undefined regions, and examining the curve with the goal of choosing the simplest equation that describes the curve. The equation for the channel depth to discharge relationship was used to determine channel depth for each daily discharge record.

The height of the sandbars created by the discharge is considered the inverse of channel depth. For example, if a discharge of 10,000 cfs creates a channel depth of 2.4 ft, then areas outside of the main channel will deposit sand to nearly the surface of the water. It was assumed that the currently active channel (the area underwater) will have a range of depths from nearly 0 inches to 2.4 ft in the channel. If the discharge fell to 5,000 cfs, the new channel depth of 1.7 ft would result in exposed sandbars of 0.7 ft. This is likely a maximum estimate of sandbar height as some smoothing of the exposed sandbars is expected to occur by natural erosion and some infilling of the bottom of channel. It is also expected that sandbars are not evenly distributed throughout the river channel, being more common in depositional areas, but that average conditions were similar in each river reach.

To determine the daily values for the habitat quality metric during the 4-month breeding season, the mean daily flow for each day and the maximum daily flow for the preceding 1.5 year period were recorded. These discharge values were converted to sandbar heights using the depth to discharge equation provided above. The difference between the maximum sandbar height during the preceding 1.5 year period and the daily value was calculated. If this difference was greater or equal to 1.5 ft, then the daily value was set to 1; if the difference was less than 1.5 ft then the daily value was set to 0. The minimum value for the 60-day nesting period was determined. If the minimum value for habitat quality was 0 during the 60-day nesting period, the nesting period was considered to be unacceptable. If the minimum value for habitat quality was 1 during the 60-day nesting period, then habitat conditions were considered to be acceptable for successful nesting. For each year, the number of all acceptable nesting periods was tallied and the percent of the total number of nesting periods during each breeding season was calculated.

<u>Habitat Quantity</u>

While *habitat quality* measures the height of sandbars and the possibility of nest inundation, *habitat quantity* is a measure of the amount of exposed sandbars at different discharge rates. This metric does not determine if the flow conditions are acceptable, but rather gives an estimate of the amount of available habitat over the 60-day nesting period.

To estimate the area of exposed sandbars available to Least Terns and Piping Plovers in relation to discharge, aerial photographs of different reaches of the lower Platte River were analyzed. Digital orthoquadrangle (DOQ) images were collected for the area covering the lower Platte River for 1993, 1994, and 1999. These DOQs were provided by the National Aerial Photography Program (NAPP). The 1:40,000 scale aerial photographs were taken at 20,000 ft above the land surface with a 6-inch focal length camera. The scanned images were rectified to orthographic projections of 1 m resolution based on the National Mapping Standards and cast on the Universal Transverse Mercator Projection (UTM) on the North American Datum of 1983 (NAD83). The images for the NAPP within each year were acquired over a number of different days as the flight lines for the images covered the segment of the state in a north-south direction. A portion of the images for the 1993 state coverage were reacquired in 1994, presumably as a result of unsatisfactory image quality. A total of 7 different dates were used to develop the 1993 (1994) images and 5 dates for the 1999 images. Since the images were acquired on different days, discharge values were not consistent across the combined image of the 103 RM river segments; therefore, contiguous image groups were developed for individual dates. An additional flight on was made on August 15, 2003 to acquire images during drought conditions. The images were acquired from approximately 6,000 ft above the land surface with a Nikon F4 digital camera with images taken from a port in the bottom of a small aircraft. Each contiguous image group was digitized, classified, and post-processed individually. Each image group was projected into NAD83 UTM zone 14 prior to digitizing.

The aerial images were classified at the 1:5000 scale using on-screen digitizing methods in ArcGIS 9.2 (ESRI 2007) following the procedure in Peters and Parham (*in press*). The habitat in the images was classified using the following criteria.

1. Sandbars were at least 3.58 acres in surface area. This size was recommended by Ziewitz et al. (1992).

2. Sandbars were mostly free of seasonal or woody vegetation. The determination of whether the sandbar had too much vegetation was based on the size of the unvegetated area. If the area was greater than 3.58 acres, then the sandbar was considered acceptable. For example, if a sandbar was 6 acres with 4 acres unvegetated, than the sandbar was considered suitable.

3. Sandbars were disconnected from the shoreline. Isolated sandbars provide protection from mammalian predators and increased distance from perch locations of avian predators. Lingle (1993b) reported that about 53 percent of Least Tern and Piping Plover deaths along the central Platte River were due to predation, and Ivan and Murphy (2005) found that mammals were more important predators of piping plover eggs than avian predators.

After classification, the total area of acceptable sandbar habitat was determined and then converted to a percentage of the total channel area. Mean daily discharge was recorded from the USGS gage sites chosen with respect to distance from and the locations of major tributaries. In locations where tributaries entered downstream of an upstream main river gage, discharge readings from more than one gage were combined. The aerial images covered a range of river discharges from 0 to 21,000 cfs and covered sections of the river from near Columbus to the mouth near Plattsmouth.

To provide a generalized pattern for the area of sandbars meeting the necessary criteria vs. discharge, the data were arranged from lowest to highest discharge and a line was fit to the data using Table Curve 2D 5.01 (Systat, 2002). Selection of the most appropriate curve followed methods described above for the discharge to channel depth estimate in the habitat quality analysis. For each day, the percent habitat available was calculated from the daily mean flow discharge using the modeled relationship. The average available habitat for the 60-day nesting period, rounded to the nearest whole value, is used as an estimate of overall percent habitat available during the nesting period.

Suitable Habitat

Suitable habitat is calculated as a combination of *habitat quality* and *habitat quantity*. To calculate the occurrence of suitable habitat, the value for habitat quality (0 or 1 acceptable nesting period) was multiplied by the value for habitat quantity (0 to 6% total river area) for the nesting period in the breeding season. This resulted in a range of 0 to 6 for suitable habitat. The units for suitable habitat are percent area by percent time for a given nesting period. This reflects a range of conditions from no suitable habitat to the maximum available suitable habitat for nesting Least Terns and Piping Plovers. The average of the values was calculated for each breeding season.

Determining Favorable Flow Characteristics

To estimate the discharge characteristics that resulted in “favorable” years for Least Terns and Piping Plovers, the discharge statistics for the best scoring years at each site are described. The favorable year groups were separated by selecting the top one third of the non-zero suitable habitat data distribution, including ties. The average 1.5 year maximum discharge and average monthly flow statistics were calculated using this data to estimate suitable flow characteristics that resulted in Least Terns and Piping Plovers nesting habitat with the greatest likelihood of successful nesting. To determine which months contributed to the overall favorable score for the year, a criterion was established that the monthly average habitat suitability scores would be equal or greater than the minimum habitat suitability score for any year in the favorable year group at that site. This was to avoid averaging in characteristics for a poor month from an overall good year.

Results:

The relationship between discharge and channel depth (and it's inverse, sandbar height) was based on the river transect data in Mussetter Engineering, Inc. (2002). The average discharge and channel depths for the reported nine Platte River transects are shown in Table 2.1.

Table 2.1. Averaged data from Mussetter Engineering, Inc. (2002) for the lower Platte River transects.

Discharge (cfs)	Depth (ft)
5,000	1.7
10,000	2.4
20,000	3.3
50,000	5.7

An additional point located at zero discharge and zero depth was added prior to solving the equation. A line was fit to the data to create an equation to estimate channel depth from the discharge data (Figure 2.5). The line fit the data closely with $r^2 = 99.6$ (Equation 1).

Equation 2.1. The relationship for the curve of discharge (x in cfs) vs. channel depth (y in ft) (where: $a = 0$ and $b = 0.024723028$).

$$y = a + bx^{0.5}$$

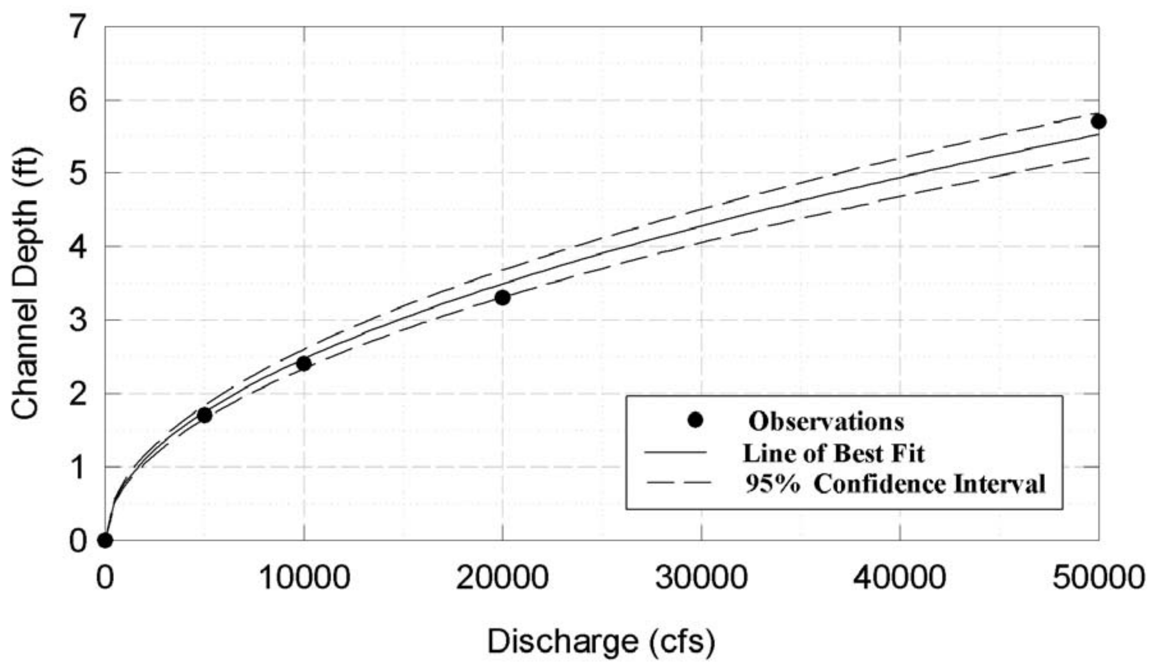

Figure 2.5. The modeled relationship between channel depth (ft) and river discharge (cfs) (Equation 2.1).

The average habitat conditions found in the Platte River changed as a function of the increase in discharge from near Duncan, to North Bend, and to Louisville. Habitat forming flows (estimated by the 1.5 year return flood flow) increased from approximate 7,000 cfs near Duncan to nearly 40,000 cfs near Louisville. These higher flows carry larger amounts of sediment which results in the development of higher sandbars. Channel depths (and their inverse, sandbar height) range from 2.1 ft at Duncan to nearly 5 ft at Louisville. The median discharge in June at the three sites was approximately 1/5 of the habitat forming flows. The depths and the sandbar heights that would be flooded by the median June discharge range from 0.9 to 2.1 ft at Duncan and Louisville, respectively (Table 2.2). Average height of sandbars at these three gage sites would range from about 1.2 ft above the median June discharge for Duncan to nearly 2.8 ft for Louisville (Table 2.3). Sandbar height increased in a downstream direction. Sandbars with the requirements of at least 1.5 ft of sandbar height (Ziewitz et al. 1992) were only available from North Bend downstream and with higher sandbars available downstream from Louisville.

Table 2.2. Flow profiles for habitat forming discharge (estimated as 1.5 year return flood flow), median June discharge from (1954 – 2005) and estimate channel depths at the corresponding discharges near the three Platte River gages.

Site	Discharge at 1.5 year return (cfs)	Channel Depth (ft) at 1.5 year return	Median June Discharge (cfs)	Channel Depth (ft) at June Median Discharge
Duncan	7,130	2.1	1,265	0.9
North Bend	21,280	3.6	4,080	1.6
Louisville	39,800	4.9	7,180	2.1

Table 2.3. Estimated sand bar height in river near the three Platte River gage locations based on the difference between habitat forming discharge and median June discharge.

	Sandbar Height (ft)
Duncan	1.2
North Bend	2.0
Louisville	2.8

Habitat Quality:

While the general characteristics of the different river reaches are interesting, they reveal little about the actual conditions that the nesting birds encounter in a given breeding season. Although on average, sandbars of 1.5 ft above median June flow rate may be available, for a successful nesting to occur the nest location must stay dry during the 60-day nesting period. The habitat quality estimate compares the height of the sandbars created by the last 1.5 year high flow event with the maximum depth of water during the preceding 60-day period. In this analysis, the year begins in 1956, not 1954, as 1.5 year of flow record was required before an estimate could be created.

Several patterns for habitat quality were apparent. First, the percent of acceptable nesting periods was higher in the downstream sections of the Platte River (Figures 2.6, 2.7, and 2.8). This was consistent with the trend of increased sandbar height in downstream reaches. Second, downstream reaches were not always the best in every year. For example, in 1960 the habitat quality indices for Duncan and North Bend (63) each were much higher than for Louisville (8) (Table 2.4). Flood waters from the Elkhorn River probably inundated nests downstream from it's confluence with the Platte River. Differing flow conditions from the Platte, Loup, and Elkhorn River, and Salt Creek all contribute to shifting availability of sufficiently high sandbars on the lower Platte River in different years. In some years, all reaches had acceptable habitat quality and in other years, all reaches had poor habitat for nesting birds. In 1978, all reaches had good conditions, while in 1977, all sites had poor conditions. The high flows of 1977 would have inundated most nests during the summer, but resulted in favorable conditions the following year. The timing, duration, and magnitude of the flows are key to the habitat quality in any given year.

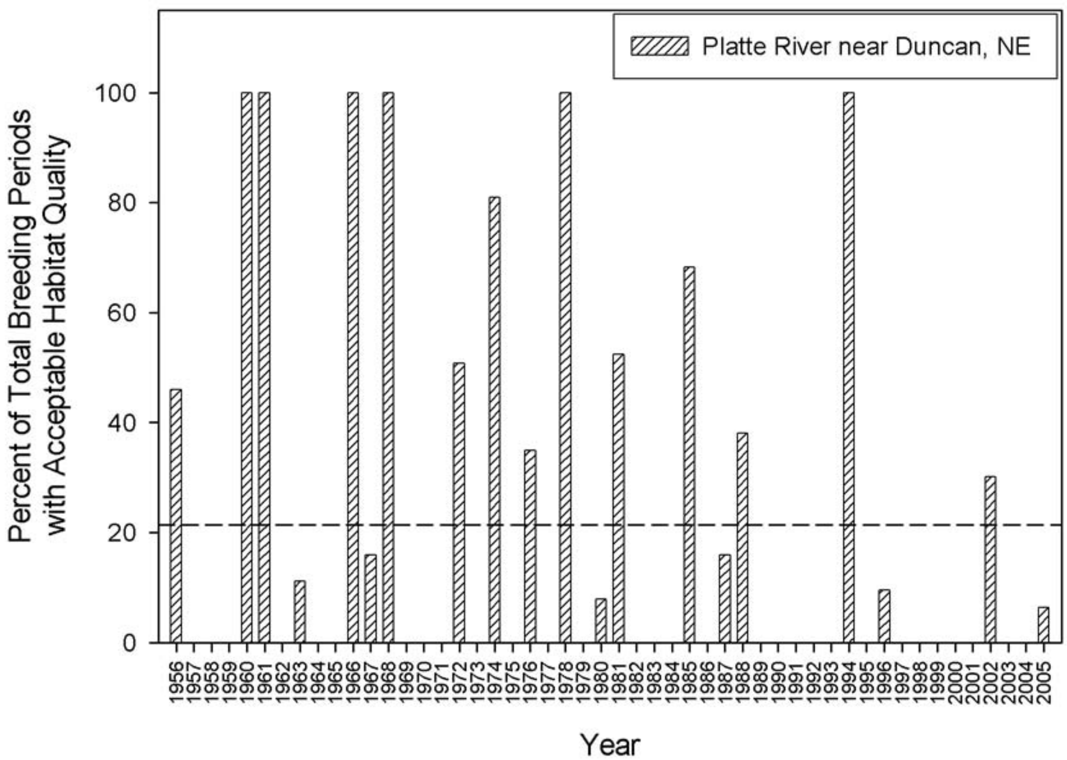

Figure 2.6. Habitat quality estimates for the Platte River near Duncan, NE. The bars represent the percent of the total acceptable nesting periods within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

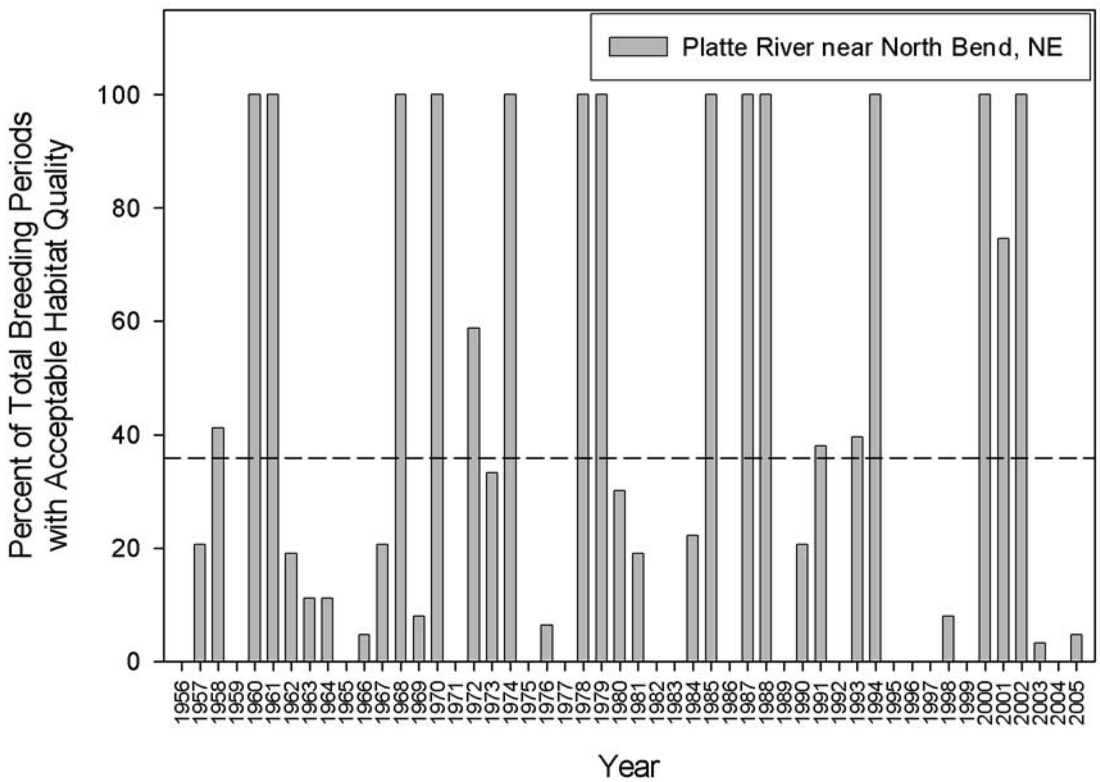

Figure 2.7. Habitat quality estimates for the Platte River near North Bend, NE. The bars represent the percent of the total acceptable nesting periods within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

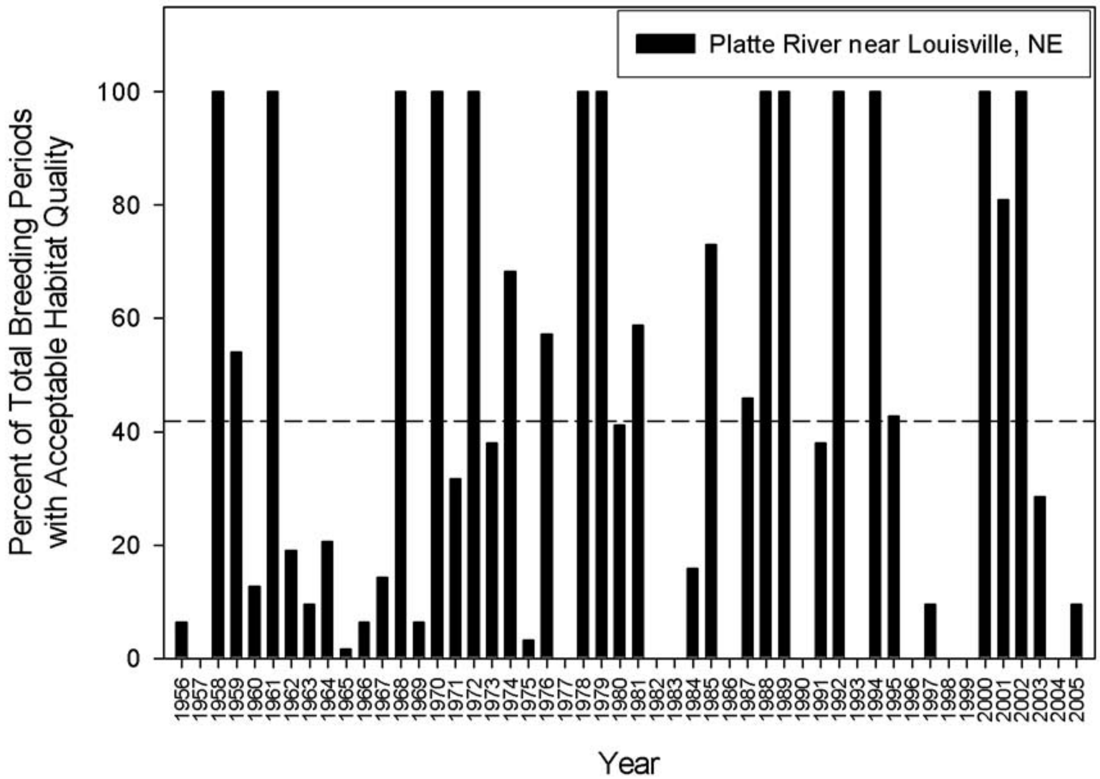

Figure 2.8. Habitat quality estimates for the Platte River near Louisville, NE. The bars represent the percent of the total acceptable nesting periods within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

Table 2.4. Habitat quality estimate comparisons for the Platte River reaches near the three gage sites for the time period from 1956 to 2005. The units are the number of acceptable nesting period in a given breeding season with the maximum number of possible nesting periods equal to 63.

Year	Habitat Quality for Platte River near Duncan, NE	Habitat Quality for Platte River near North Bend, NE	Habitat Quality for Platte River near Louisville, NE
1956	29	0	4
1957	0	13	0
1958	0	26	63
1959	0	0	34
1960	63	63	8
1961	63	63	63
1962	0	12	12
1963	7	7	6

1964	0	7	13
1965	0	0	1
1966	63	3	4
1967	10	13	9
1968	63	63	63
1969	0	5	4
1970	0	63	63
1971	0	0	20
1972	32	37	63
1973	0	21	24
1974	51	63	43
1975	0	0	2
1976	22	4	36
1977	0	0	0
1978	63	63	63
1979	0	63	63
1980	5	19	26
1981	33	12	37
1982	0	0	0
1983	0	0	0
1984	0	14	10
1985	43	63	46
1986	0	0	0
1987	10	63	29
1988	24	63	63
1989	0	0	63
1990	0	13	0
1991	0	24	24
1992	0	0	63
1993	0	25	0
1994	63	63	63
1995	0	0	27
1996	6	0	0
1997	0	0	6
1998	0	5	0
1999	0	0	0
2000	0	63	63
2001	0	47	51
2002	19	63	63
2003	0	2	18
2004	0	0	0
2005	4	3	6
Average	**13.5**	**22.6**	**26.4**

Habitat Quantity:

A total of 26 different image groups were classified. They ranged in length from 2.8 to 38.3 km and appropriate habitat quantity ranged 0 to 9.3% of the total river area (Table 2.5). The relationship between the amount of large, unvegetated, disconnected sandbars and discharge shows a pattern where large sandbars are more common at moderate discharge rates than at low or high rates and is illustrated in Figure 2.9. The equation describing the relationship between large disconnected sandbars and discharge had a moderately good fit with an $r^2 = 0.45$ (Equation 2). The distribution of large sandbars was associated with wider areas of the river channel (typical deposition areas) and discharge and channel morphology influenced the amount of observed sandbar habitat. Local channel morphology accounts for some of the scatter in the data. The maximum amount of large disconnect sandbar habitat was observed around 5,480 cfs (Figure 2.10).

The relationship between large sandbars and river discharge displayed several additional patterns. Large, unvegetated, and disconnected from the shoreline sandbars were not common at any discharge rate. At high discharge rates, a large amount of the channel was underwater in either shallow sandbar complexes or open water. While at low discharge levels, small exposed sandbars were common and the larger sandbars were generally connected to the shore. Overall, it appears that the large sandbars selected by nesting Least Terns and Piping Plovers made up a maximum of only 6% to 7% of the overall habitat in the lower Platte River. Large, disconnected sandbars are available at a wide range of discharge rates. The maximum of 6.7% available habitat occurred at 5,480 cfs with 50% of the maximum available habitat available between 3,910 and 11,900 cfs. This general picture of the availability of large sandbars for nesting birds was developed for the lower Platte River from discharge rates between 0 and 21,000 cfs, but the actual amount available to nesting birds also depends on the recent discharge history at the site, as well as local channel morphology.

The general pattern of habitat availability as related to discharge is important, yet does not control the actual conditions encountered by birds during a given nesting period. Habitat was available for nesting birds in each reach during most years (Figures 2.11, 2.12, and 2.13). Percent available habitat ranged from 0 to 5 % in any given nesting period in a breeding season.

The pattern for habitat quantity was similar to that for habitat quality. Habitat quantity increased in a downstream direction. Rarely were there more large sandbars near Duncan than near Louisville under the discharge patterns over the last 50 years. The exception was in 1983 which had high flows most of the summer, and where the relatively lower flows at Duncan resulted in more available habitat than at downstream sites (Table 2.6). In most years, there appeared to be areas with large sandbars in the lower Platte River. In low flow years of 1956 and 1976, sandbar habitat was limited or unavailable.

Table 2.5. Descriptive information for the aerial images used for habitat classification from the lower Platte River, NE. The gage site represents the nearest USGS gage for classified image. In some cases, discharge was determined from a combination of USGS gages. Gage sites are as follows: LSV = Platte River at Louisville, NE; ASH = Platte River at Ashland, NE; LES = Platte River at Leshara; ELK = Elkhorn River at Waterloo, NBD = Platte River at North Bend, NE; LPC = Loup Power Canal at Genoa, NE; LPR = Loup River at Genoa, NE; DCN = Platte River at Duncan, NE. GPS coordinates are in decimal degrees and are located approximately mid-channel at the upstream and downstream ends of the river section. UPGPSW = upstream GPS west, UPGPSN = upstream GPS north, DGPSW = downstream GPS west, DGPSN = downstream GPS north.

Date	Gage Site	Discharge (cfs)	Length (km)	UPGPSW	UPGPSN	DGPSW	DGPSN	Bird Habitat (m2)	Bird Habitat (%)
15-Aug-02	DCN	0	5.7	-97.3801	41.3962	-97.3218	41.397	0	0.0
15-Aug-02	LES	953	4.5	-96.3578	41.2468	-96.3605	41.2191	0	0.0
15-Aug-02	LSV	1413	4.7	-96.2254	40.9979	-96.1718	41.0079	96,342	3.0
1-Apr-99	DCN	2437	5.1	-97.3801	41.3962	-97.3218	41.397	0	0.0
22-Apr-93	DCN	2825	11	-97.4431	41.3748	-97.3211	41.3965	74,128	1.2
1-Apr-99	DCN+LPR	4097	3.3	-97.3218	41.397	-97.2836	41.3965	25,089	1.7
21-Mar-94	DCN+LPR+LPC	4697	2.8	-97.3175	41.3985	-97.2833	41.3996	118,442	9.3
18-Apr-94	NBD	5615	5	-96.8182	41.4497	-96.7599	41.4526	87,959	3.2
4-Apr-99	LES	5686	16.4	-96.3534	41.2537	-96.313	41.1209	89,078	1.0
4-Apr-99	LES	5686	13.9	-96.5665	41.4357	-96.4318	41.3664	437,824	5.4
1-Apr-99	DCN+LPR+LPC	5827	3.5	-97.2836	41.3965	-97.2459	41.3845	196,651	8.7
16-Apr-93	NBD	6357	38.3	-97.2419	41.3833	-96.8235	41.4487	1,302,921	6.7
6-Apr-99	NBD	6569	15.8	-97.1304	41.3859	-96.9672	41.4408	655,448	6.7
21-Mar-94	DCN+LPR	6569	3.7	-97.2833	41.3996	-97.2462	41.3838	127,495	5.8
4-Apr-99	ASH	7769	11.8	-96.3182	41.1281	-96.3072	41.0368	69,875	1.0
14-Apr-93	ASH-ELK	7840	12.1	-96.3532	41.2536	-96.3203	41.1581	357,002	4.9
4-Apr-99	LSV	8476	31.3	-96.2557	41.0172	-95.9338	41.0586	1,151,315	6.1
6-Apr-99	LES	8793	8.3	-96.4417	41.3713	-96.3985	41.3089	10,316	0.2
22-Apr-93	NBD	10383	24.4	-96.7555	41.4525	-96.4903	41.3992	694,013	4.8
2-Apr-93	ASH-ELK	10736	6.5	-96.3794	41.2995	-96.3562	41.2469	223,550	5.2
6-Apr-99	LSV	10806	4.5	-96.2343	41.0041	-96.185	41.003	161,168	5.4
14-Apr-99	ASH	14408	7.2	-96.3172	41.0463	-96.2488	41.0157	16,029	0.3
16-Apr-93	ASH	15009	21	-96.3187	41.1279	-96.1837	41.0048	266,331	2.0
26-Mar-93	LSV	15503	29.4	-96.194	41.001	-95.881	41.0532	1,245,981	6.9
22-Apr-93	ASH-ELK	18929	12.7	-96.4547	41.3782	-96.3698	41.2911	172,940	2.2
19-Apr-99	LSV	21012	5.6	-95.9438	41.0579	-95.8808	41.0531	0	0.0

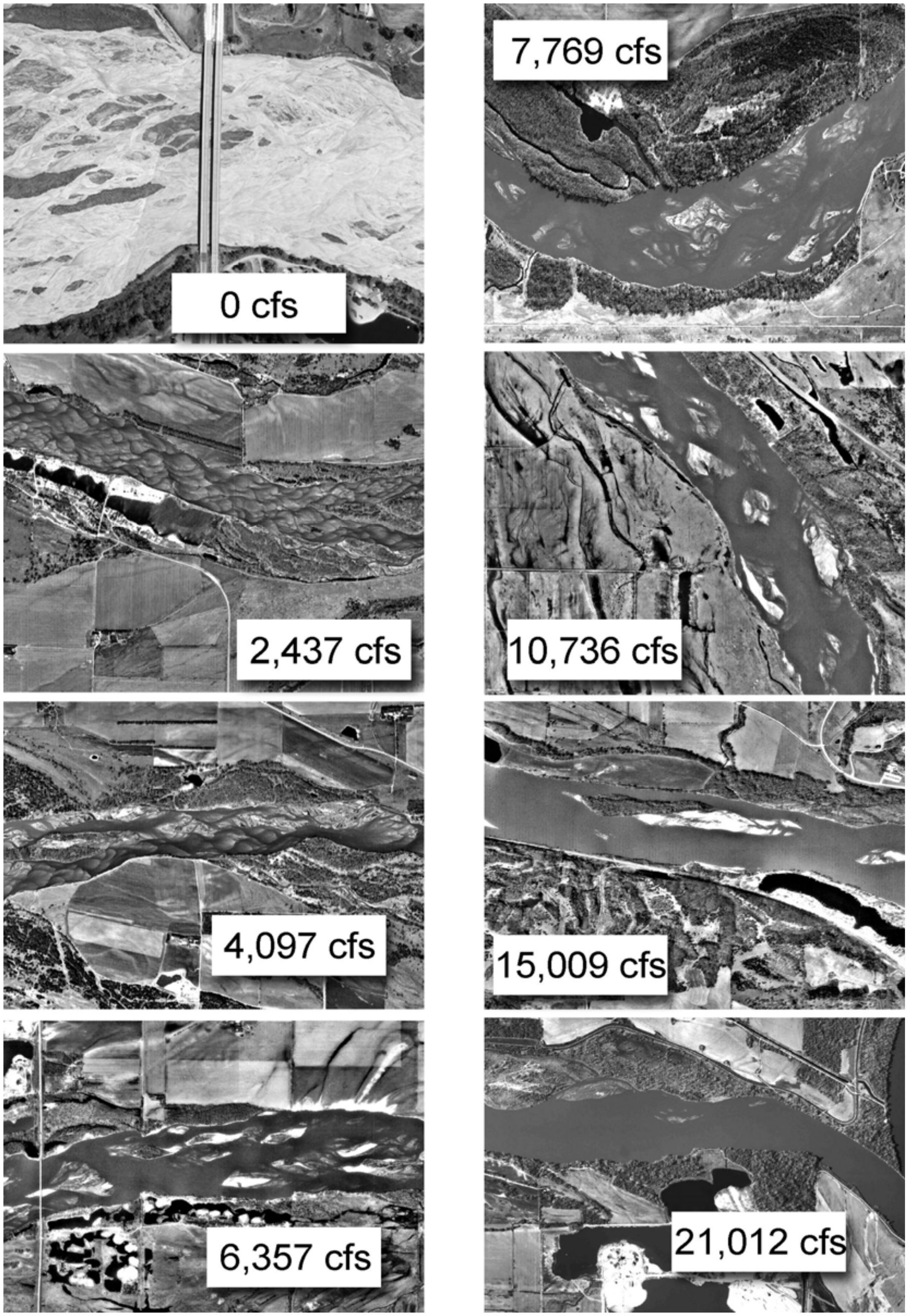

Figure 2.9. A series of aerial images from the lower Platte River showing changes in habitat in relation to discharge. The images were from a range of locations and a range of dates and are not all to the same scale. Note the change in the amount of large disconnected sandbars in the series of images.

Equation 2.2. The relationship for the curve of discharge (x in cfs) vs. percent available habitat (y) in the lower Platte River (where: a = 0.40534102, b = -0.000452565512, c = -9.4516773E-5, d = 7.3450789E-8, e = 7.9143834E-9, f = -4.9137201E-12, g = 3.2904805E-12, and h = 2.027508E-16).

$$y = \frac{a + cx + ex^2 + gx^3}{1 + bx + dx^2 + fx^3 + hx^4}$$

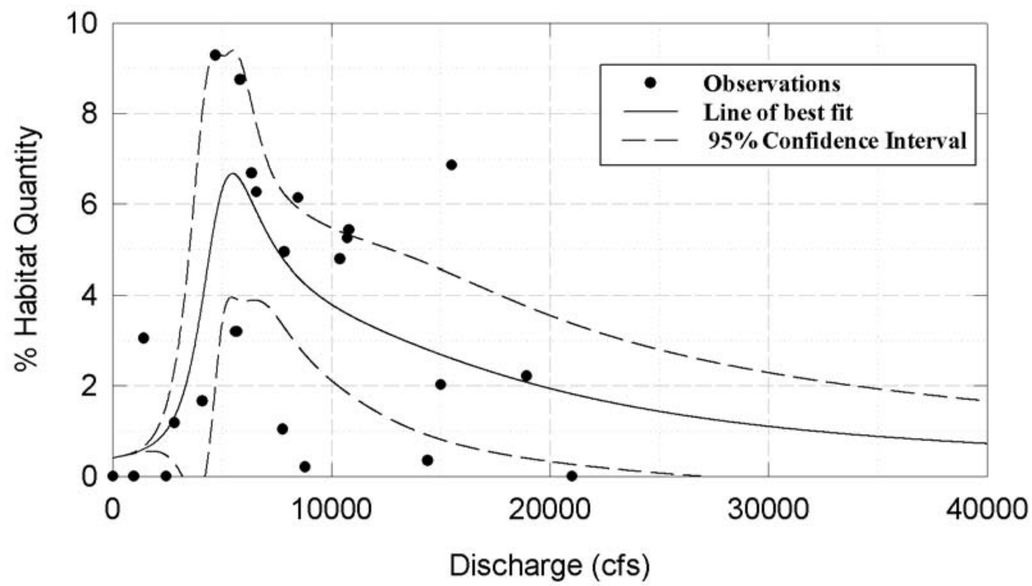

Figure 2.10. Modeled relationship between discharge (cfs) and percent habitat quantity for the lower Platte River (Equation 2.2). Habitat for Least Terns and Piping Plovers is defined as large, exposed sandbars that were disconnected from the shoreline.

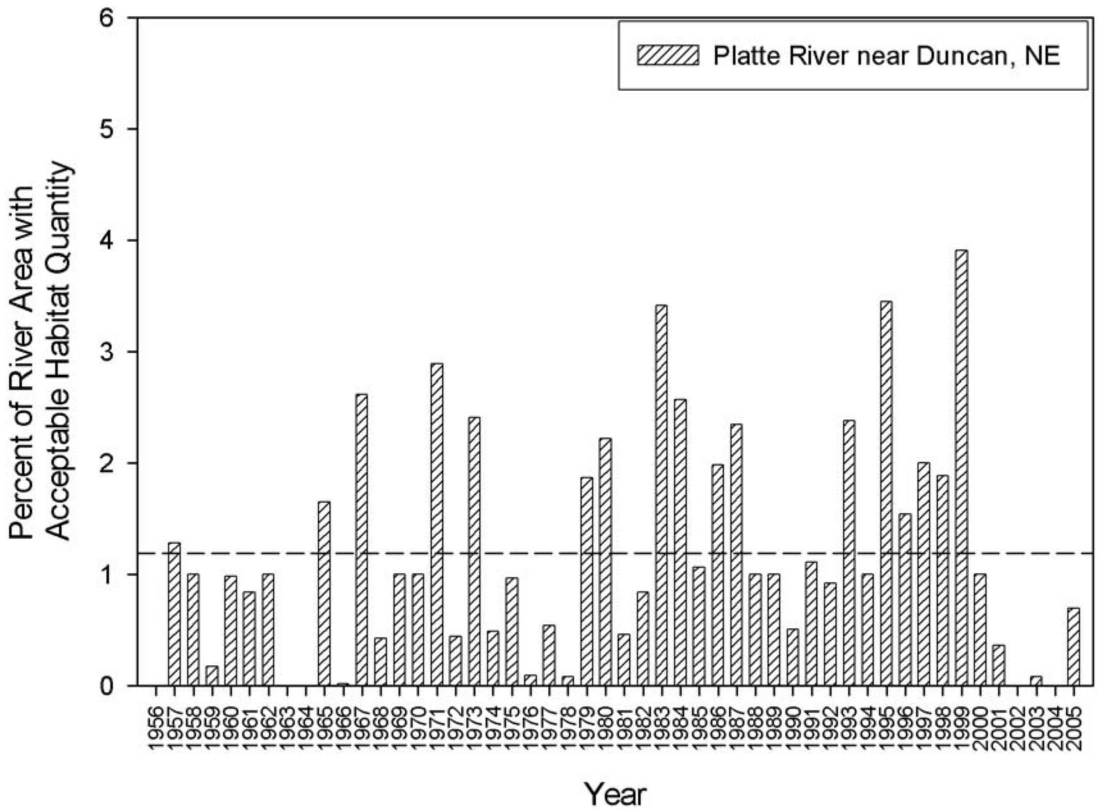

Figure 2.11. Habitat quality estimates for the Platte River near Duncan, NE. The bars represent the average percent of river area available to nesting birds within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

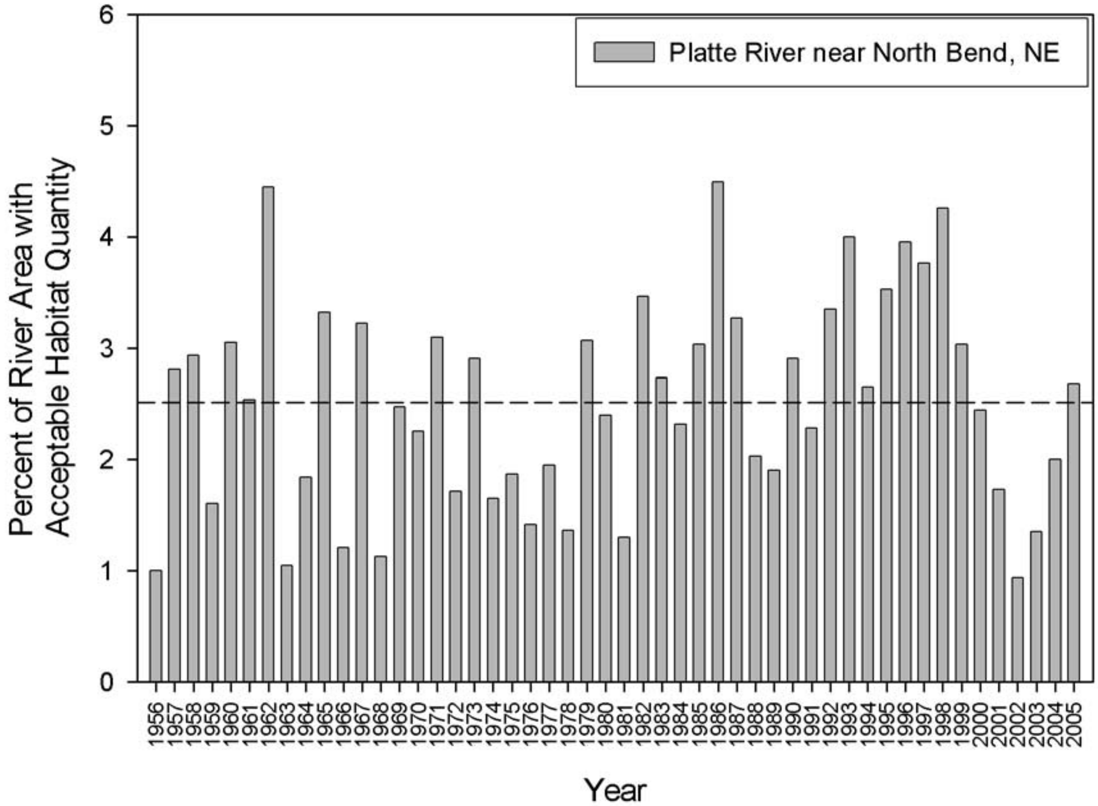

Figure 2.12. Habitat quality estimates for the Platte River near North Bend, NE. The bars represent the average percent of river area available to nesting birds within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

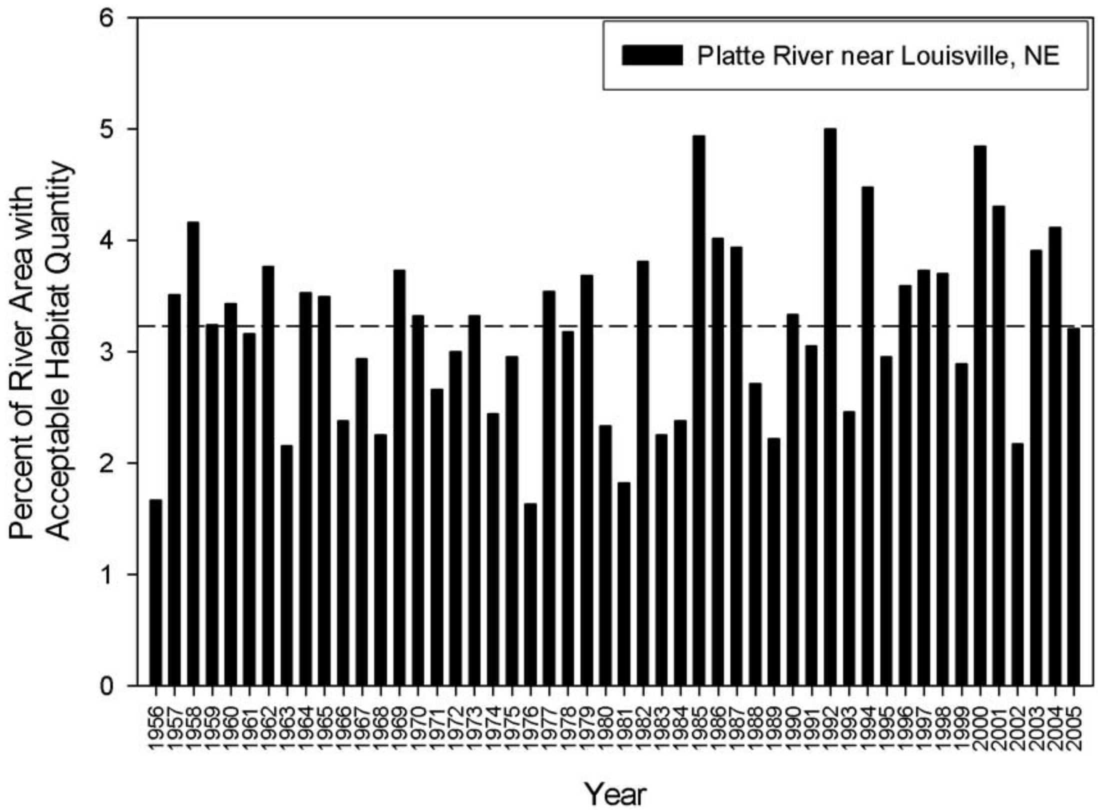

Figure 2.13. Habitat quantity estimates for the Platte River near Louisville, NE. The bars represent the average percent of river area available to nesting birds within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

Table 2.6. Habitat quantity estimate comparisons for the Platte River reaches near the three gage sites for the time period from 1956 to 2005. The units are the average percent of habitat available for each nesting period in a given breeding season.

Year	Percent Habitat Quantity for Platte River near Duncan, NE	Percent Habitat Quantity for Platte River near North Bend, NE	Percent Habitat Quantity for Platte River near Louisville, NE
1956	0.00	1.00	1.67
1957	1.29	2.81	3.51
1958	1.00	2.94	4.16
1959	0.17	1.60	3.24
1960	0.98	3.05	3.43
1961	0.84	2.54	3.16
1962	1.00	4.44	3.76
1963	0.00	1.05	2.16

1964	0.00	1.84	3.52
1965	1.65	3.32	3.49
1966	0.02	1.21	2.38
1967	2.62	3.22	2.94
1968	0.43	1.13	2.25
1969	1.00	2.48	3.73
1970	1.00	2.25	3.32
1971	2.89	3.10	2.67
1972	0.44	1.71	3.00
1973	2.41	2.90	3.32
1974	0.49	1.65	2.44
1975	0.97	1.87	2.95
1976	0.10	1.41	1.63
1977	0.54	1.95	3.54
1978	0.08	1.37	3.17
1979	1.87	3.06	3.68
1980	2.22	2.40	2.33
1981	0.46	1.30	1.83
1982	0.84	3.46	3.81
1983	3.41	2.73	2.25
1984	2.57	2.32	2.38
1985	1.06	3.03	4.94
1986	1.98	4.49	4.02
1987	2.35	3.27	3.94
1988	1.00	2.03	2.71
1989	1.00	1.90	2.22
1990	0.51	2.90	3.33
1991	1.11	2.29	3.05
1992	0.92	3.35	5.00
1993	2.38	4.00	2.46
1994	1.00	2.65	4.48
1995	3.44	3.52	2.95
1996	1.54	3.95	3.59
1997	2.00	3.76	3.73
1998	1.89	4.25	3.70
1999	3.90	3.03	2.89
2000	1.00	2.44	4.84
2001	0.37	1.73	4.30
2002	0.00	0.94	2.17
2003	0.08	1.35	3.90
2004	0.00	2.00	4.11
2005	0.70	2.68	3.21
Average	**1.19**	**2.51**	**3.23**

Suitable Habitat:

The combination of habitat quality and habitat quantity provides an index of the amount of suitable habitat available to nesting Least Terns and Piping Plovers during the late spring and summer breeding season on the lower Platte River. The suitable habitat metric reflects the history of preceding high flow events, the flow patterns during the breeding season, as well as the average amount of appropriate habitat. The suitable habitat metric has units that are a combination of time and area. Time is a function of the percentage of time quality habitat exists during the breeding season, while area is a function of the habitat quantity estimates.

Once again, suitable habitat appeared to occur more frequently in downstream reaches, with the most suitable habitat in the Louisville area and below (Figures 2.14). North Bend (Figure 2.15) had suitable habitat in many years but suitable habitat was not common near Duncan (Figure 2.16). There were years that more suitable habitat was found near Duncan and North Bend., than near Louisville, depending on flow from the tributaries (Table 2.7). For example, in 1960, river reaches near Duncan and North Bend had more suitable habitat than the reach near Louisville as a result of a flood from the Elkhorn River. Some variability is typical for breeding habitat on the Platte River under current flow conditions. In several years, suitable habitat was not predicted to occur in any reach of the river (1977, 1982, 1983, 1986, 1996, 1999, and 2004). Overall, out of 50 years, Duncan had 38, North Bend 15, and Louisville 11 years with no suitable habitat predicted.

To assess more general trends concerning suitable habitat for breeding Least Terns and Piping Plovers, the decadal average of the relative amount of suitable habitat was calculated. Several trends appear in the averaged data. First, there has been consistently more suitable habitat progressing downstream (Table 2.8 and Figure 2.17). Second, the period from 1986 – 1995 was the best period for the lower Platte River, while the decade from 1976 – 1985 was the best period near Duncan on the central Platte River. Third, suitable habitat has been decreasing near Duncan on the central Platte River and in the most recent decade little suitable habitat was predicted to have been present. Fourth, the most recent decade (1996 – 2005) had the least suitable habitat overall on the lower Platte River.

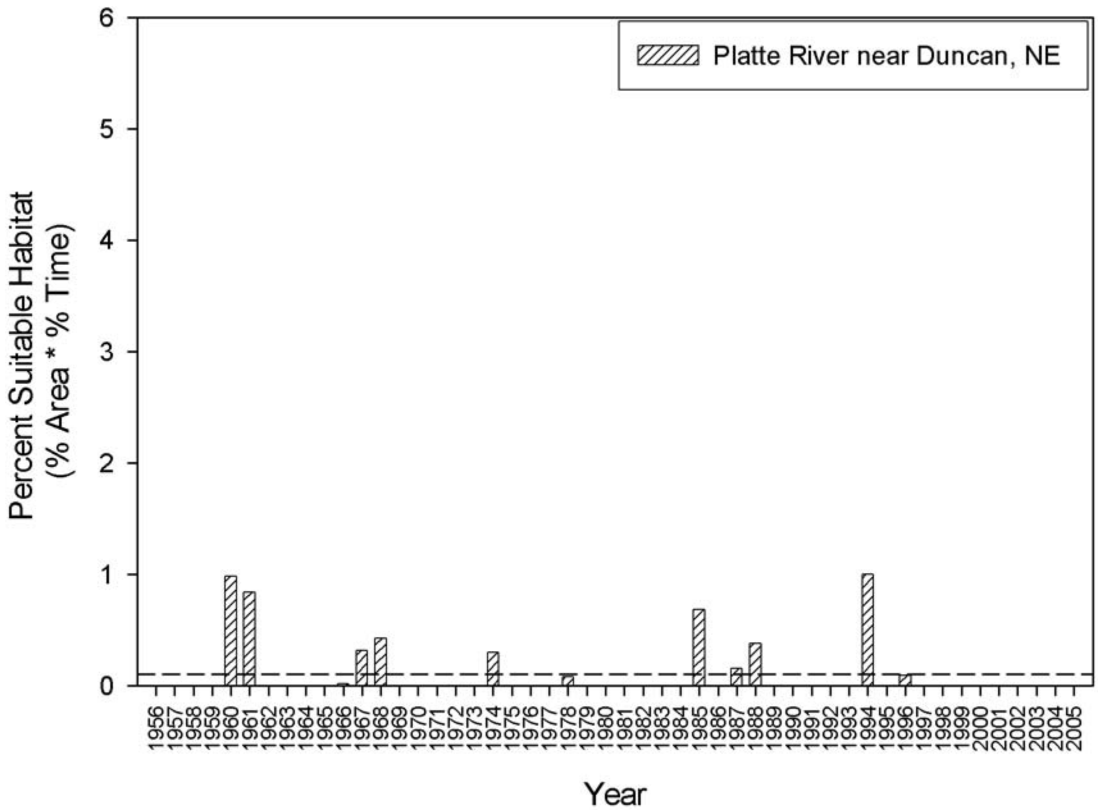

Figure 2.14. Suitable habitat estimates for the Platte River near Duncan, NE. The bars represent the average amount of suitable habitat within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005

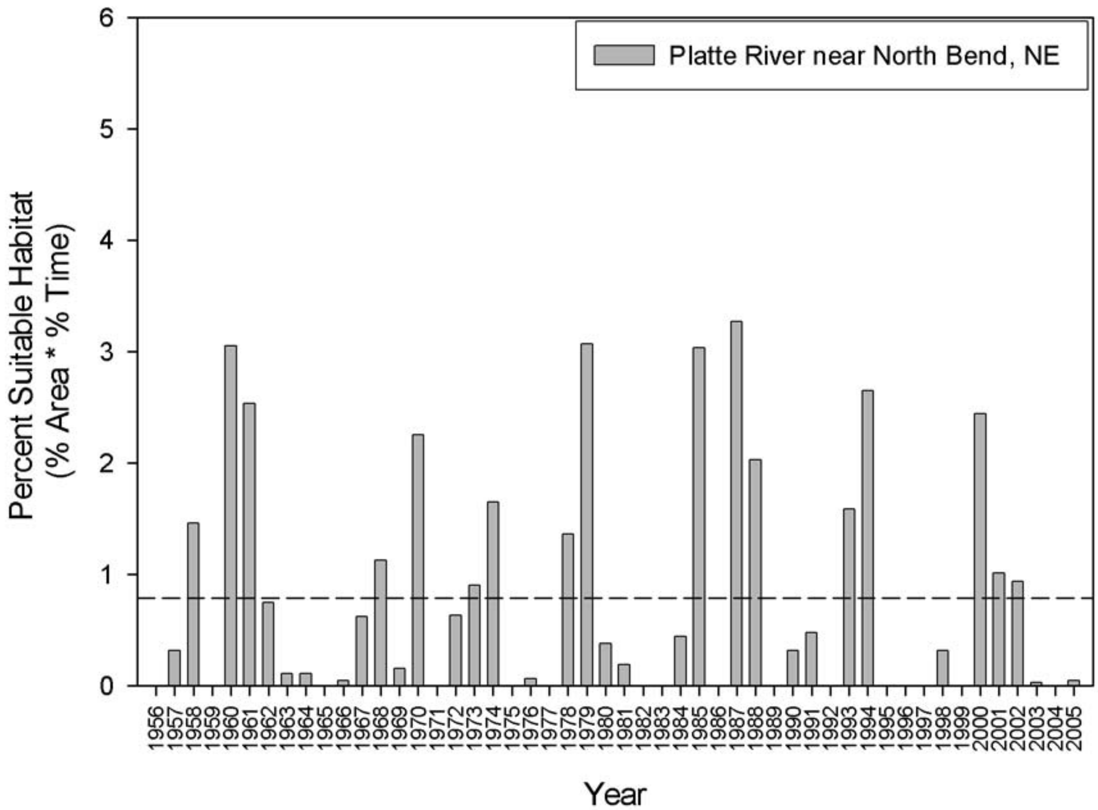

Figure 2.15. Suitable habitat estimates for the Platte River near North Bend, NE. The bars represent the average amount of suitable habitat within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

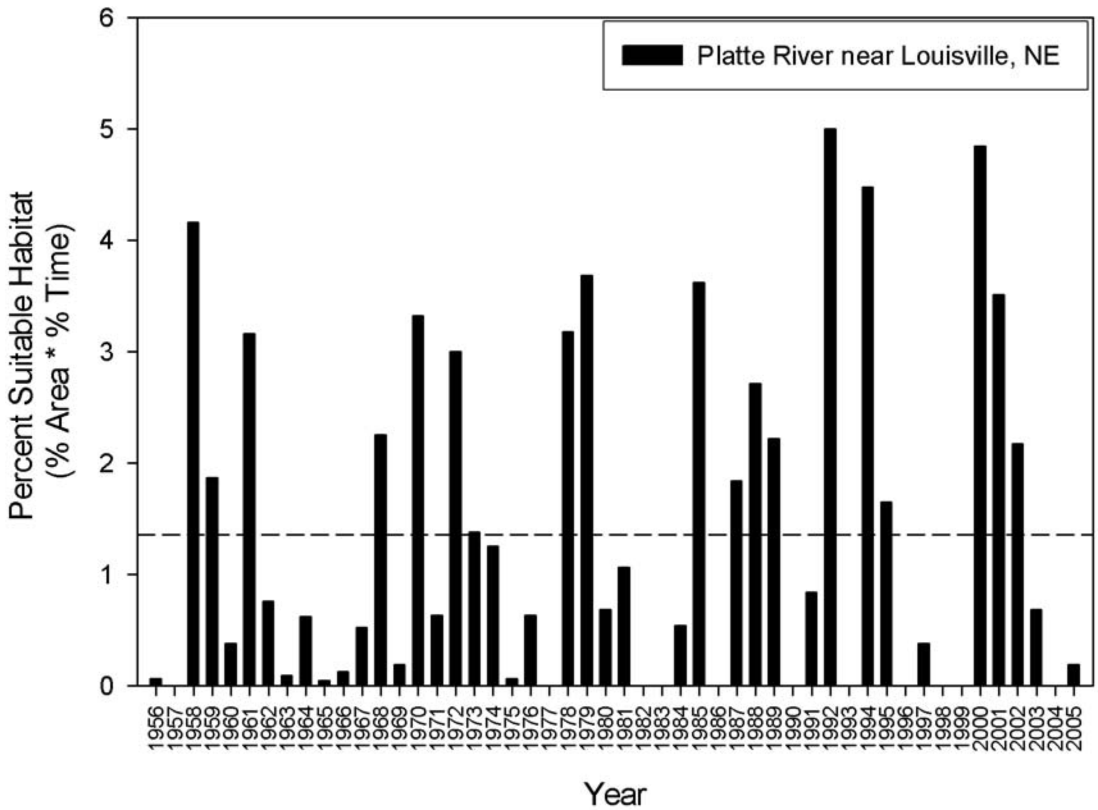

Figure 2.16. Suitable habitat estimates for the Platte River near Louisville, NE. The bars represent the average amount of suitable habitat within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

Table 2.7. Suitable habitat estimate comparisons for the Platte River reaches near the three gage sites for the time period from 1956 to 2005. The units are the average percent of suitable habitat for each nesting period in a given breeding season.

Year	Suitable Habitat for Platte River near Duncan, NE	Suitable Habitat for Platte River near North Bend, NE	Suitable Habitat for Platte River near Louisville, NE
1956	0.00	0.00	0.06
1957	0.00	0.32	0.00
1958	0.00	1.46	4.16
1959	0.00	0.00	1.87
1960	0.98	3.05	0.38
1961	0.84	2.54	3.16
1962	0.00	0.75	0.76
1963	0.00	0.11	0.10
1964	0.00	0.11	0.62

1965	0.00	0.00	0.05
1966	0.02	0.05	0.13
1967	0.32	0.62	0.52
1968	0.43	1.13	2.25
1969	0.00	0.16	0.19
1970	0.00	2.25	3.32
1971	0.00	0.00	0.63
1972	0.00	0.63	3.00
1973	0.00	0.90	1.38
1974	0.30	1.65	1.25
1975	0.00	0.00	0.06
1976	0.00	0.06	0.63
1977	0.00	0.00	0.00
1978	0.08	1.37	3.17
1979	0.00	3.06	3.68
1980	0.00	0.38	0.68
1981	0.00	0.19	1.06
1982	0.00	0.00	0.00
1983	0.00	0.00	0.00
1984	0.00	0.44	0.54
1985	0.68	3.03	3.62
1986	0.00	0.00	0.00
1987	0.16	3.27	1.84
1988	0.38	2.03	2.71
1989	0.00	0.00	2.22
1990	0.00	0.32	0.00
1991	0.00	0.48	0.84
1992	0.00	0.00	5.00
1993	0.00	1.59	0.00
1994	1.00	2.65	4.48
1995	0.00	0.00	1.65
1996	0.10	0.00	0.00
1997	0.00	0.00	0.38
1998	0.00	0.32	0.00
1999	0.00	0.00	0.00
2000	0.00	2.44	4.84
2001	0.00	1.02	3.51
2002	0.00	0.94	2.17
2003	0.00	0.03	0.68
2004	0.00	0.00	0.00
2005	0.00	0.05	0.19
Average	**0.11**	**0.79**	**1.36**

Table 2.8. Ten year average suitable habitat for the three Platte River gage sites.

Decade	Suitable Habitat for Platte River near Duncan, NE	Suitable Habitat for Platte River near North Bend, NE	Suitable Habitat for Platte River near Louisville, NE
1956-1965	0.18	0.83	1.12
1966-1975	0.11	0.74	1.27
1976-1985	0.08	0.85	1.34
1986-1995	0.15	1.03	1.87
1996-2005	0.01	0.48	1.18

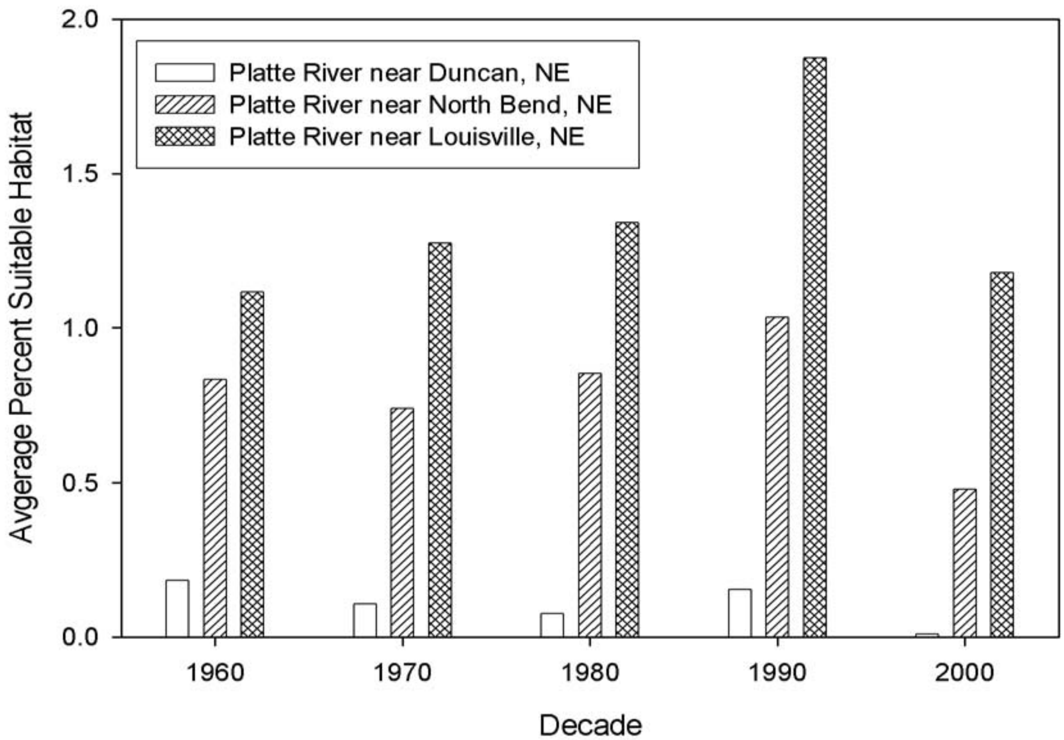

Figure 2.17. Comparison of ten year average suitable habitat for the three Platte River gage sites. The decades are 1956-1965, 1966-1975, 1976-1985, 1986-1995, and 1996-2005.

Comparisons of modeling results with actual field data

Historical accounts suggest that Least Terns and Piping Plovers were “a regular summer resident and breeder on the sandbars of the Platte River and its forks” (Tout 1947). At the Platte River south of Lexington, Wycoff (1960) reported finding Least Terns and Piping Plovers nesting during the 1950’s. Since that time, there has been a large decrease in the use of the central Platte River for nesting by these birds. Recent surveys find most birds associated with sand pits (Haig and Plissner 1992, Haig and Plissner 1996, Ferland and Haig 2002, NGPC database). The estimates of the amount of suitable habitat in the central Platte River near Duncan follow this pattern. Relative amounts of suitable habitat at Duncan average about 1/13 of the habitat near Louisville and 1/8 of the habitat near North Bend. Currently, little habitat exists in the central Platte River.

Biologists have been surveying the numbers of Least Terns and Piping Plovers nesting on the Platte River regularly since 1986 (Figures 2.18 and 2.19). Direct testing of the observations against the estimates of the amount of suitable habitat is not possible as the field observations do not measure nesting success (the successful fledging of chicks at the end of the season) but measure nest presence. The maximum number of nests observed during visits is presented because the fate of individual nests in unknown in many cases. The measurement of nest presence is important and is an effective gage of the relative population size and whether the habitat is actually being used by terns and plovers. Nest inundation may occur after the surveys, resulting in a season with a lot of nesting activity but little that is ultimately successful.

Against these caveats, the comparison of the field data to the modeling results is more subjective. Figures 2.18 and 2.19 approximately cover the final two decades shown in Figure 2.17. The general trends correspond with suitable habitat available in the Lower Platte River at both North Bend and Louisville from the mid 1980's to mid 1990's, and then a reduction of habitat at North Bend in more recent years. The amount of suitable habitat decreased near Louisville but was still present in most recent years. The years 1998 and 1999 were predicted to be poor years and that was reflected in the nest presence surveys.

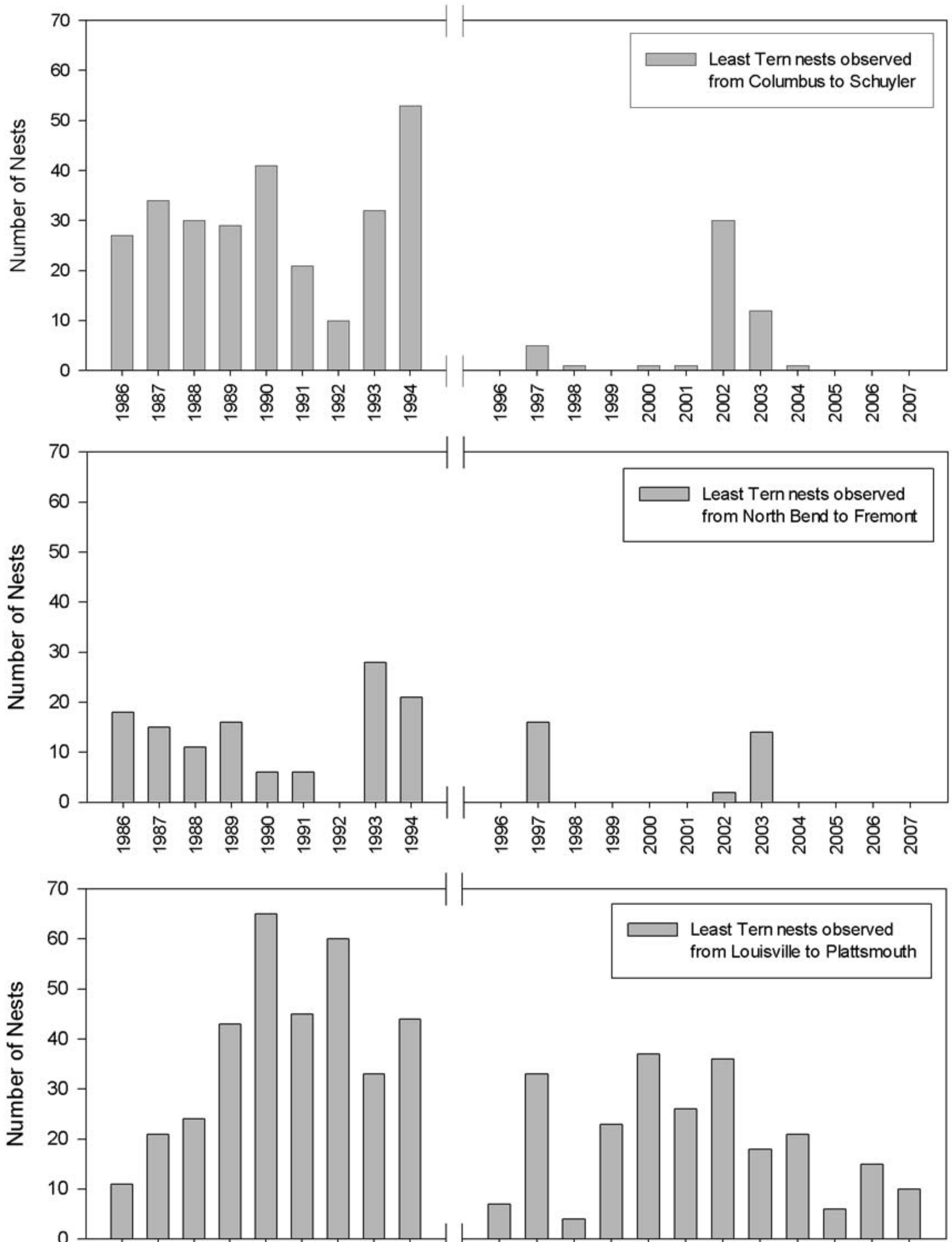

Figure 2.18. Number of least tern nests from river segments recorded during Nebraska Game and Parks Commission annual surveys. No surveys were completed in 1995.

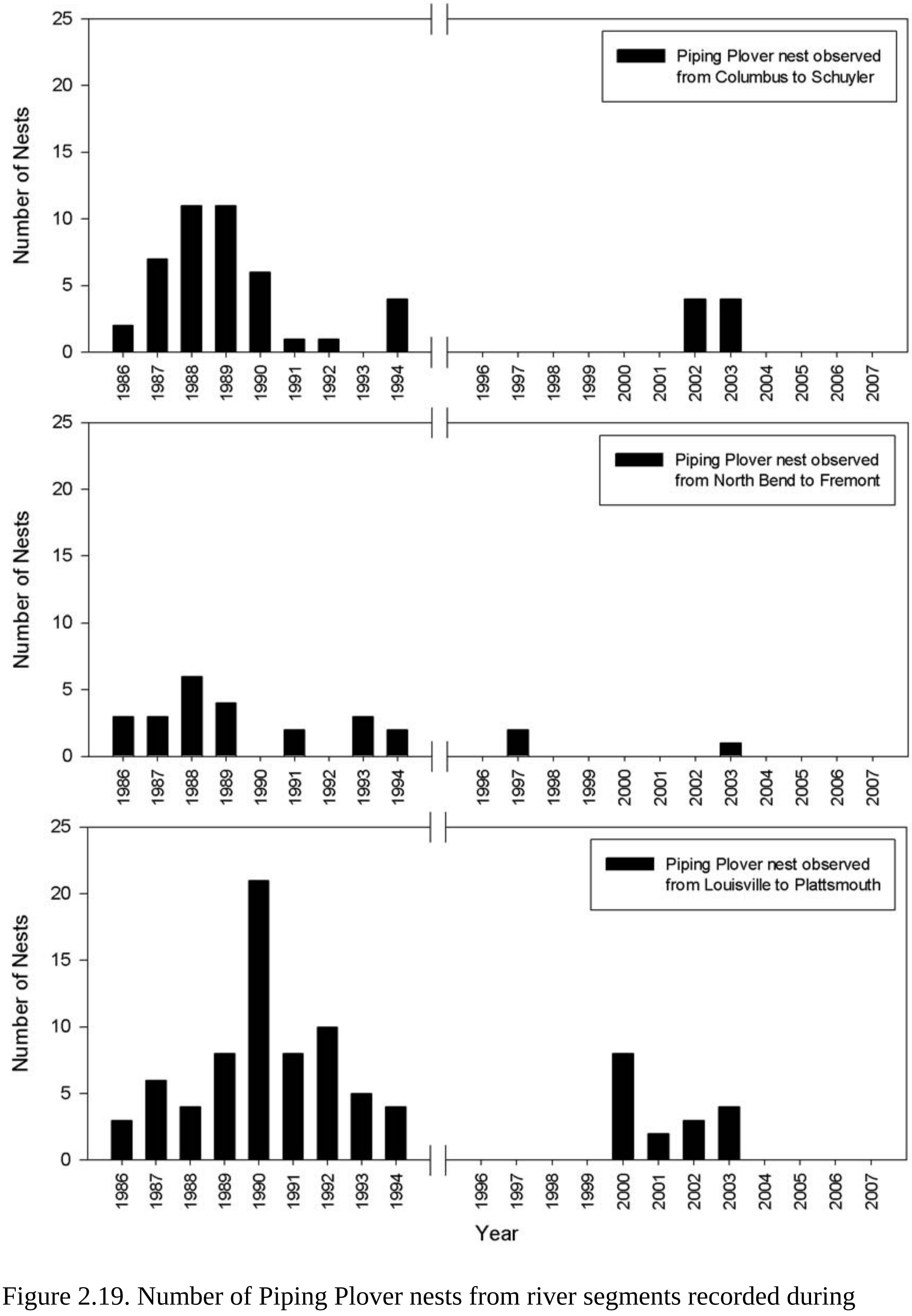

Figure 2.19. Number of Piping Plover nests from river segments recorded during Nebraska Game and Parks Commission annual surveys. No surveys were completed in 1995.

Determining Favorable Discharge Characteristics

The results of the habitat suitability index indicate which years (1956 – 2005) were *favorable years*, in that they had the appropriate sequence of flow conditions to produce sandbars where successful reproduction of least terns and piping plovers was most probable. Identifying favorable years allows characterization of the flow conditions that occurred during, and previous to, the years with the most suitable potential sandbar habitat. Each gage location was considered separately when identifying favorable years. Separation by gage location is necessary when describing flow conditions as locations used in this analysis have different flow regimes due to tributary influences. The average 1.5 year maximum discharge and average monthly flow statistics were calculated from this data set, providing an estimate of flow characteristics for favorable years.

In favorable years (top 1/3 of years with suitable habitat) higher peak flows usually resulted in higher amounts of suitable habitat (Table 2.9). Given the difference in suitable habitat among sites, the minimum suitable habitat score to be considered a favorable year was different for each site. The average suitable habitat score at Duncan was 0.88, at North Bend the average score was 2.51, and at Louisville the average score was 3.61. It is important to understand that the discharge conditions reflected by these favorable years at each of these sites are not directly comparable. The most favorable years at Duncan would be not be considered favorable years at Louisville. The results reflect the modified discharge conditions in the Platte River over the past 50 years and do not suggest that this is the natural or best possible condition (NRC 2005). The results only characterize the discharge conditions in the best years at each site.

The results reflect the need for high flows during the preceding 1.5 years to scour vegetation from sandbars and deposit new sandbars. Average peak flows were large in the Louisville (79,805 cfs) and at North Bend (54,182 cfs) reaches and much smaller in the Duncan reach (19,804 cfs). The large flow volumes at North Bend and Louisville provide substantial sediment transport capabilities. Minimum peak flows near Louisville and North Bend were larger than the maximum peak flows near Duncan. This suggests that peak flows from the central Platte River are not high enough to create suitable sandbar habitats for terns and plovers. Indeed, and not withstanding atypical occurrences or birds nesting on managed sites, these two species are now extirpated as breeding species from the central Platte River (Haig and Plissner 1992, Haig and Plissner 1996, Ferland and Haig 2002, NGPC database).

Discharge characteristics for favorable months showed that June and July were included in the favorable years more often then May and August (Table 2.10). North Bend and Louisville were the only reaches that had suitability scores over 4%. The average flow at Duncan decreased from a high of 1,710 cfs in June to a low of 572 cfs in August. The average flows for North Bend decreased each month from 5,129 cfs in May to 2,042 in August. Near the Louisville gage, the discharge decreased from 6,943 cfs in May to a low of 3,811 in August. The best overall month was May near Louisville with 6,943 cfs average discharge and an average habitat suitability score of 5.03%.

Visual inspection of the relationship between peak flows, summer flows, and suitable habitat resulted in the observation of two patterns (Figures 2.20, 2.21, and 2.22). First, in summers with mean flows substantially higher than average, little suitable habitat was observed (see year 1983 at all sites). This pattern is especially evident at Louisville, suggesting that high summer flows at Louisville were high enough to eliminate most suitable habitat, while some of the higher flows at North Bend did not preclude habitat. Summer mean flows near or slightly below 5,480 cfs resulted in the maximum amount of suitable habitat. This was a result of the maximum available habitat reaching a peak at 5,480 cfs (Figure 2.10). Second, the majority of higher suitable habitat years occurred in years with high peak flows.

The models in this chapter were based on sandbars of 1.5 feet in height above discharge levels. However, sandbars that were 2.99 ft above the water surface elevation were reported to be selected most often by terns and plovers on the lower Platte River (Ziewitz et al., 1992). Based on the maximum available habitat discharge, the peak flows necessary to create sandbars 2.99 feet in height can be calculated (threshold peak flows). At 5,480 cfs (discharge with maximum available habitat termed threshold summer flows), the water surface elevation was estimated at 1.83 ft. Adding the reported selected sandbar height of 2.99 ft to this elevation resulted in a sandbar height of 4.82 ft from the channel floor. The peak flow needed to create sandbars of 2.99 ft (4.82 ft from channel floor) was 38,170 cfs. When plotting a line at the threshold peak flow, a pattern became apparent. When comparing the threshold peak flow to years with suitable habitat greater than 2%, a peak flow of at least 38,170 cfs was observed in 7 of 9 years at North Bend and in 14 of 15 years at Louisville. Overall, 21 out of 24 (88%) of those years had a peak flow of at least 38,170 cfs. Peak flows near Duncan never reached the 38,170 cfs threshold and no years of suitable habitat greater than 2% were observed. When comparing the threshold peak flow to years with suitable habitat between 1% and 2% similar pattern exists. At all sites combined, 9 of 13 (69%) years had a peak flow greater than 38,170 cfs. Conversely, when comparing the threshold peak flow to years with 0% habitat suitability, 18 of 65 (28%) had flows greater than 38,170 cfs.

To have a successful breeding year, it is important to have high flood flows preceding falling flows during the breeding season. High flood flows or falling summer flows only, do not assure a successful breeding season.

Table 2.9. Results for 1.5 year flood discharge characteristics for top 1/3 of non-zero suitable habitat years near the three Platte River gages.

	Platte River near Duncan, NE	Platte River near North Bend, NE	Platte River near Louisville, NE
Number of non-zero years	12	34	39
Number of years in top 1/3	4	11	13
Maximum yearly suitable score	1.00	3.27	5.00
Average yearly suitable score	0.88	2.51	3.61
Minimum yearly suitable score	0.68	1.59	2.25
Maximum 1.5 year flood discharge (cfs)	22,900	82,300	138,000
Average 1.5 year flood discharge (cfs)	19,804	54,182	79,805
Minimum 1.5 year flood discharge (cfs)	15,317	30,267	39,700

Table 2.10. Monthly average discharge characteristics during breeding season for the top 1/3 of non-zero suitable habitat years near the three Platte River gages. Minimum suitable habitat score criteria for a month was from Table 2.9.

Site Name & Suitable Habitat Minimum	Month	Maximum Monthly Discharge (cfs)	Average Monthly Discharge (cfs)	Minimum Monthly Discharge (cfs)	Average Percent Suitable Habitat	Number of Months ≥ Min Score
Platte River near Duncan, NE Suitable Habitat (≥ 0.68)	May	3,990	1,535	763	0.85	2
	June	3,377	1,710	523	1.09	3
	July	1,582	662	215	1.06	3
	August	1,388	572	182	0.91	3
Platte River near North Bend, NE Suitable Habitat (≥ 1.59)	May	10,114	5,129	3,001	4.45	9
	June	10,319	4,686	2,095	4.21	11
	July	9,465	3,921	1,248	3.15	11
	August	4,559	2,042	870	2.33	7
Platte River near Louisville, NE Suitable Habitat (≥ 2.25)	May	10,174	6,943	4,879	5.03	8
	June	12,779	5,575	3,041	4.90	10
	July	13,129	5,191	2,217	3.83	12
	August	8,841	3,811	1,911	3.67	8

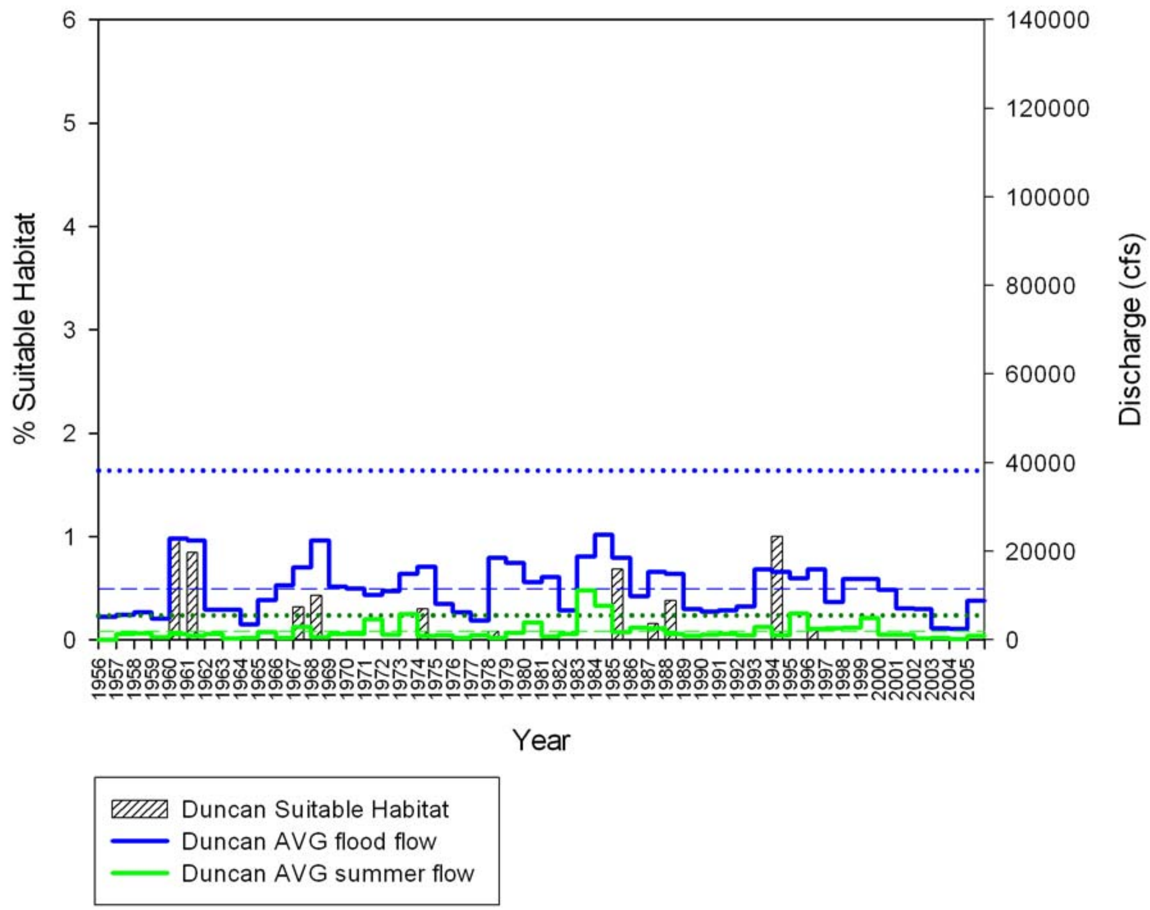

Figure 2.20. A comparison of average peak flows, average summer flows (May to August), and suitable habitat for the Platte River near Duncan, NE. The dashed lines represent the average flow for the period of record (blue for peak flows and green for summer flows). The green dotted line represents the threshold summer flow of 5,480 cfs and the blue dotted line represents the threshold peak flow of 38,170 cfs.

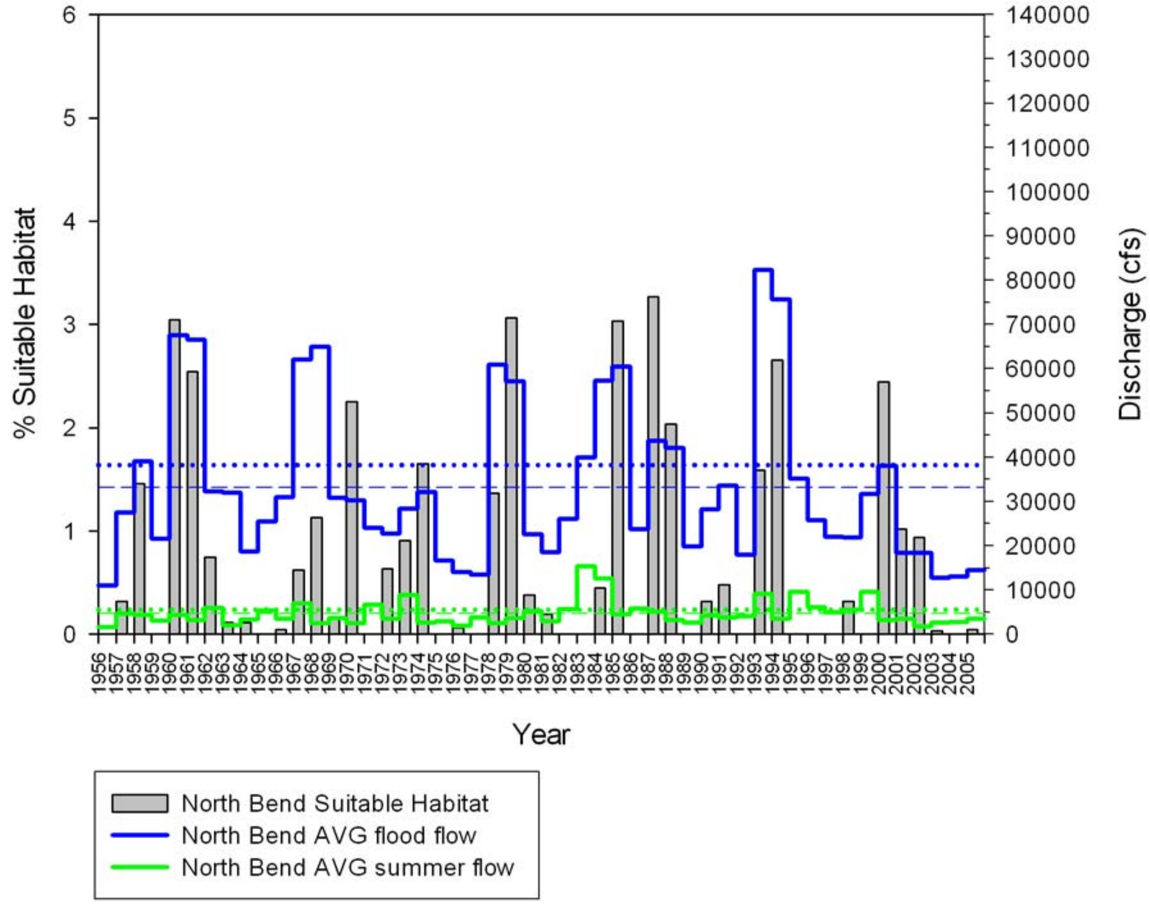

Figure 2.21. A comparison of average peak flows, average summer flows (May to August), and suitable habitat for the Platte River near North Bend, NE. The dashed lines represent the average flow for the period of record (blue for peak flows and green for summer flows). The green dotted line represents the threshold summer flow of 5,480 cfs and the blue dotted line represents the threshold peak flow of 38,170 cfs.

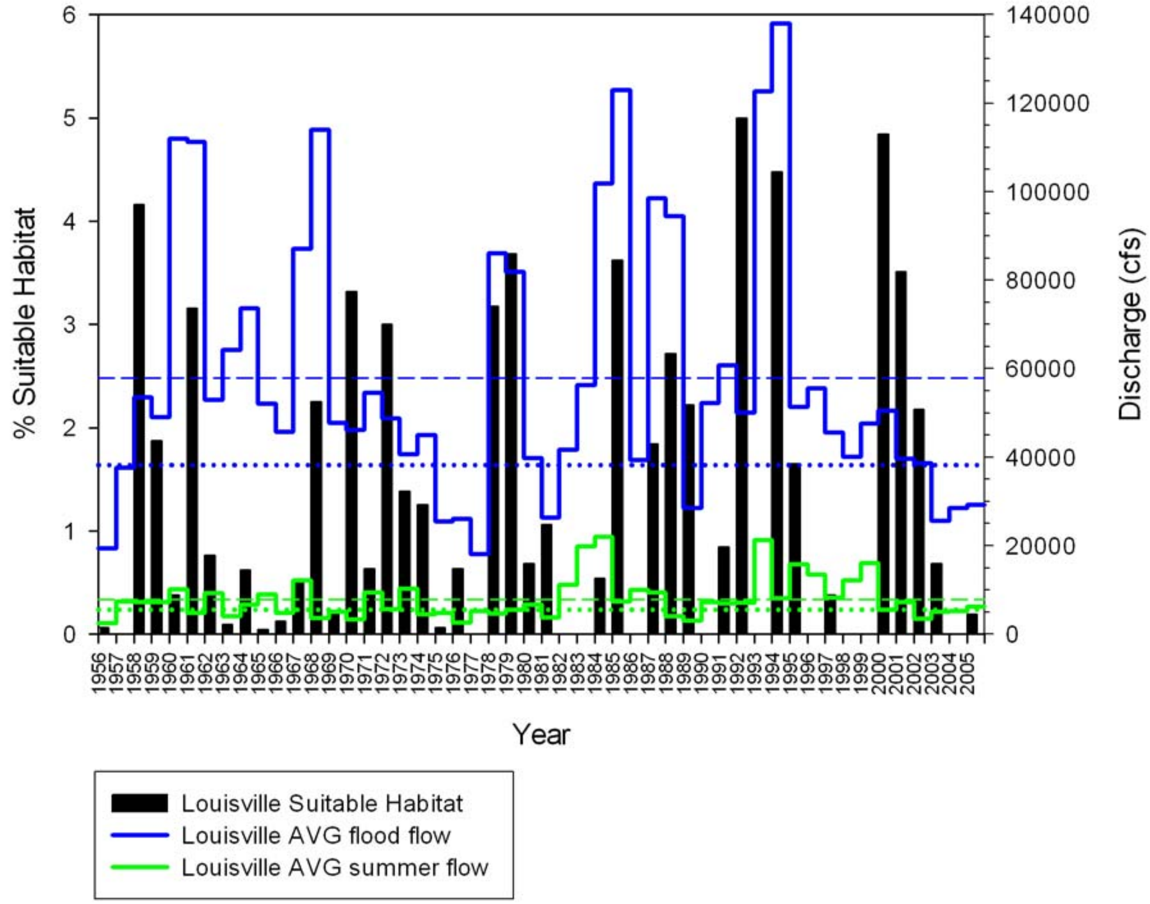

Figure 2. 22. A comparison of average peak flows, average summer flows (May to August), and suitable habitat for the Platte River near Louisville, NE. The dashed lines represent the average flow for the period of record (blue for peak flows and green for summer flows). The green dotted line represents the threshold summer flow of 5,480 cfs and the blue dotted line represents the threshold peak flow of 38,170 cfs.

Conclusions:

The model assumptions are simplifications of complex erosional and depositional processes that create and destroy sandbars on the lower Platte River. The modeling results take into account the timing, magnitude, and duration of flows observed on the lower Platte River over a 51 year period. The results are useful in understanding discharge characteristics potentially important to the creation and maintenance of suitable breeding habitat for Least Tern and Piping Plovers. It should be noted, however, that measures of suitable habitat produced here does not directly measure whether birds successfully fledged young in those years examined. There are other variables (predation rates, hail storms, human disturbance) that affect reproductive success that are not considered here. However, these other variables do not occur without nesting habitat and the presence of nesting birds.

The results illustrate the importance of high flow events in creating the large, disconnected, and unvegetated sandbars used by the Least Terns and Piping Plovers for nesting habitat. The size of the floods is not the only important characteristic, but also the frequency of the high flow events. Near Louisville, favorable years with relatively large amounts of suitable habitat were predicted in years following flows approximately 40,000 to nearly 140,000 cfs and near North Bend, these years were predicted in years following flows of approximately 30,000 cfs and 82,000 cfs. Flood flows are useful in transporting sediment during the year. Floods of these magnitudes during the breeding season most likely result in nest inundation and would be more beneficial for terns and plovers to create unvegetated sandbars if they occurred prior to nesting.

An important consideration, based on the role of the flood flows in creating suitable breeding habitat, is the protection of these larger flows from diversion. Water management actions that decrease the frequency or magnitude of flood flows will diminish the ability of the flows to create suitable sandbar habitats. Additionally, the source of sand sediment in the river and channel morphology needs to be protected, so the creation of large sandbars remains a relatively common occurrence. The interaction between the flood waters, sediment, and channel shape results in the observed sandbars on the lower Platte River. Protecting the peak discharges of a least 38,170 cfs from North Bend downstream would aid in maintaining the current levels of habitat in the lower Platte River. This minimum discharge for the 1.5 year peak flows only considers tern and plover nesting habitats and the importance of the larger less frequent flood events is not addressed.

In addition to the role of high flow in creating the suitable nesting sandbars for Least Terns and Piping Plovers, summer flows that do not rise high enough to flood nests, yet are high enough to maintain tern foraging and sandbar isolation are most favorable for increasing the likelihood that birds will successfully reproduce. Given the presence of large sandbars created by a recent flood event, the most desirable summer flows would range between 11,900 and 3,910 cfs to maximize the available amount of large sandbar habitat. The flows could be stable or falling, but rising flow would likely result in unsuitable habitat conditions. Favorable summer flow conditions ranged from approximately 5,100 cfs to 2,000 cfs at North Bend and flows from 6,900 cfs to 3,800 cfs at Louisville. Summer flows that meet the threshold of 5,480 cfs would maximize the amount of large, disconnected sandbars.

Identifying specific flow quantities the for lower Platte River that provide acceptable levels of nesting habitat for the Least Terns and Piping Plover is a difficult task. The natural, on-going process of sandbar creation, erosion, and stabilization is a function of time, discharge, sediment supply, vegetation growth, and channel morphology, not discharge alone. Estimates provided in this report only consider discharge characteristics over the past 50 years and the flows in the Platte River were highly modified prior to this time. While these habitat estimates attempt to provide targets for maximizing current habitats, historic quantities of habitat may have been substantially different from that reported here.

Improved estimates of sandbar height and nest inundation will improve the resolution of specific flow targets for maximization of habitat. The data used in creating the sandbar height estimates was from transects just up and downstream of the mouth of the Elkhorn River on the Platte River. The results were generalized and extended to characterize the lower Platte River, but local channel morphology has a large influence on the erosional and depositional processes at each site. Additionally, while the models accounted for the potential of nest inundation caused by daily fluctuations from hydropower generation, the modeling effort did not assess the role of hydropower peaking flows on the creation or maintenance of the sandbar habitats. The actual effect of hydro-peaking on Least Tern and Piping Plover habitat in the lower Platte River is currently unknown.

Nesting habitat is not the only important habitat component for terns and plovers and other wildlife on the lower Platte River. The mosaic of deep channels, shallow sandbar complexes, exposed sandbars, and woody islands provides habitat and food for a wide range of river species. Flows ranging from 4,000 to 7,000 cfs maximize the diversity of habitats in the lower Platte River (Figure 2.23). Flows in this range provide suitable habitat, as well as protect the birds from mammalian predators, by isolating the sandbars with swift, deep channels and support shallow water foraging areas. The estimate of suitable breeding conditions for Least Terns and Piping Plovers requires a balance between high flow events and the lower flows observed during nesting periods.

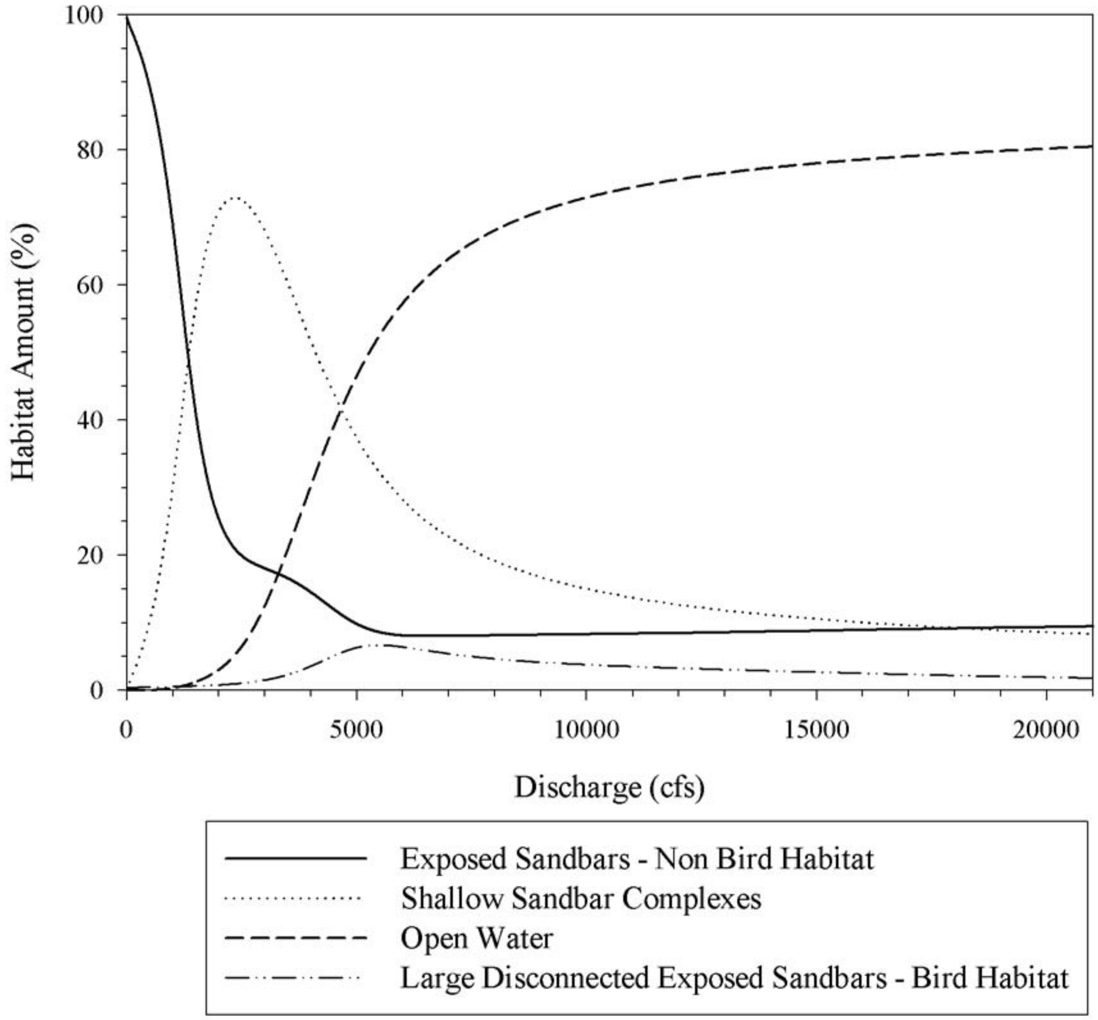

Figure 2.23. Major in channel habitat types (%) in relation to discharge (cfs) for the lower Platte River, NE. The curves for exposed sandbars, shallow sandbar complexes, and open water were reported in Peters and Parham (*in press*). The exposed sandbar category was separated into two categories, on with large disconnected exposed sandbars (bird habitat) and the other all other exposed sandbars (non bird habitat).

Chapter 3 - Estimation of Pallid Sturgeon suitable habitat and connectivity in relation to river discharge

Introduction:

Pallid sturgeon are an endangered fish that utilizes the lower Platte River. Pallid sturgeon are a large fish that is currently found in the reaches of the Platte River below the confluence with the Elkhorn River and in the lower reach of the Elkhorn River (NRC 2005). Historically, pallid sturgeon were more abundant in the main stem and major tributaries of the Missouri and Mississippi Rivers than they are currently capture data indicates (Forbes and Richardson 1905, Keenelyne 1989) In 1990, the pallid sturgeon was listed as an endangered species by the US Fish and Wildlife Service (Federal Register 55 [September 6, 1990]: 36641-36647). The decline of pallid sturgeon has been hypothesized as a result of overfishing and modification of rivers for navigation, power production, and agricultural water use (Kallemeyn 1983, USFWS 1993).

Pallid sturgeon live in the deep, swift water channels of the lower Platte River (Peters and Parham, *in press*). They have been tracked in deep channels near large sandbar complexes and in has been hypothesized that they choose current refugia on the bottoms of swift channels and feed on small fishes that are common on the nearby shallow sandbar areas (Snook et al. 2002).

In addition to using the river as habitat, pallid sturgeon have been observed moving up and back down the river in the spring months and this spring migration period has been hypothesized to be a spawning event (Peters and Parham, *in press*). The role of river connectivity to the movement of pallid sturgeon is important. The term river connectivity does not imply uninterrupted access (analogous to electricity and a wire, or a door being opened). It is better described as more like a large maze (Figure 3.1), with no "solutions"(fully connected paths) at low discharges. As discharge increases more paths are provided at the beginning of the maze starting at the confluence of the Platte River with the Missouri River and increase access upriver longitudinally. The paths through the maze increase as additional areas become connected at higher discharge until a path is "optimized" from the mouth of the Platte River to the mouth of the Elkhorn River.

Peters and Parham (*in press*) provided estimates of suitable habitat and river connectivity in relation to a range of discharges from 0 to 21,000 cfs for the lower Platte River. The goal of this chapter is to provide tables of discharge vs. suitable habitat and river connectivity based on the curves presented in Peters and Parham (*in press*). In addition, highlight values of the curves in terms of areas of maximum rate of change or changes in inflection of the curves to aid in choosing appropriate flow characteristics for maintaining habitat and river connectivity for pallid sturgeon.

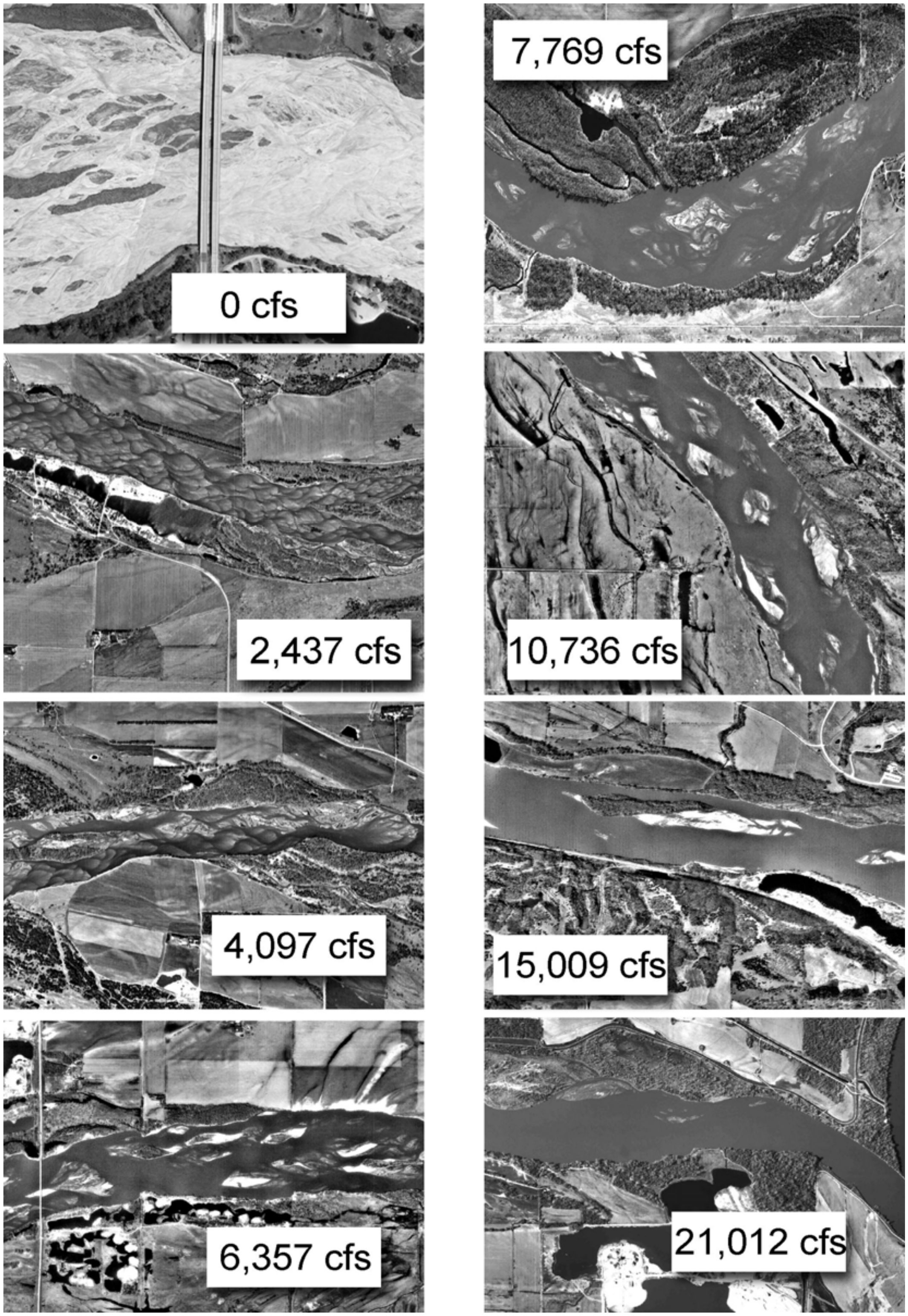

Figure 3.1. A series of aerial images from the lower Platte River showing changes in river connectivity in relation to discharge. The images were from a range of locations and a range of dates and are not all to the same scale. Note the changes in the deep channels that serve as pathways for pallid sturgeon in the series of images.

Methods:

The curves for suitable habitat for pallid sturgeon and river connectivity in Peters and Parham (*in press*) were recreated in table form providing a listing of standardized (to 100%) suitable habitat and river connectivity values from 0 to 21,000 cfs in 50 cfs steps. The relationship between suitable habitat and discharge and river connectivity and discharge are nonlinear relationships with rapid increases in habitat and connectivity before the rate of change slows as it reaches an asymptote.

Given this relationship, it is important to identify the values where small changes in discharge cause large changes in available habitat or connectivity. To determine the maximum rate of change of the curves, the first derivative was plotted and the peak of the curve was determined. Additionally, the second derivative was plotted to determine the location of the maximum rate of change for the first derivative in the upper half of the values. This was used to provide an upper critical value that would occur where the habitat or connectivity curve was beginning the almost linear drop over the middle ranges of each curve. An additional critical value was determined for each curve. For the habitat suitability curve, the point of discharge where 50% of the maximum available habitat was available was recorded. For the river connectivity curve, the point where the upper 95% confidence interval reached 100% connected was recorded.

Results:

<u>Suitable Habitat:</u>

Pallid sturgeon were found to select deep, swift waters of the Platte River (Peters and Parham, *in press*). These habitats are not common at low discharges on the lower Platte River and increase as river discharge increases (Figure 3.2 and Table 3.1). The location of maximum rate of change for the habitat suitability curve was located at 3,800 cfs and the upper critical point (maximum rate of change of the first derivative) was at 4,950 cfs (Figure 3.2). This suggests that discharge rates lower than 3,800 cfs are likely unsuitable for pallid sturgeon as habitats can disappear quickly below this level. The maximum amount of suitable habitat was set to equal 100% at 21,000 cfs in this analysis to determine the 50% value, but in Peter and Parham (*in press*) the total amount of suitable habitat rarely rises above 30% of total channel habitat. For pallid sturgeon 50% of the maximum available suitable habitat was observed at 4,450 cfs. When considering suitable habitat only, discharge rates near or above 5,000 cfs should provide adequate habitat for pallid sturgeon in the lower Platte River.

<u>River Connectivity:</u>

Pallid sturgeon are highly mobile fishes. To reach areas of suitable habitat (deep and swift habitats) they must traverse areas less suitable (shallow and/or slow habitats). In addition to general movement from area to area, pallid sturgeon potentially use the lower Platte River as spawning habitat during the spring migratory period (Peters and Parham, *in press*). For the observed upstream movements in April and May and the subsequent downstream movements during June and early July, there needs to be adequate water in the river to allow for passage for the fish to traverse the river. The river is generally unconnected at discharge rates below 4,400 cfs and rapidly becomes connected as discharges reaches 6,300 cfs (Figure 3.3 and Table 3.1). The river can be considered fully connected at a discharge of 8,100 cfs (Figure 3.4).

*Note – Table 3.1 is located at the end of the chapter due to its length.

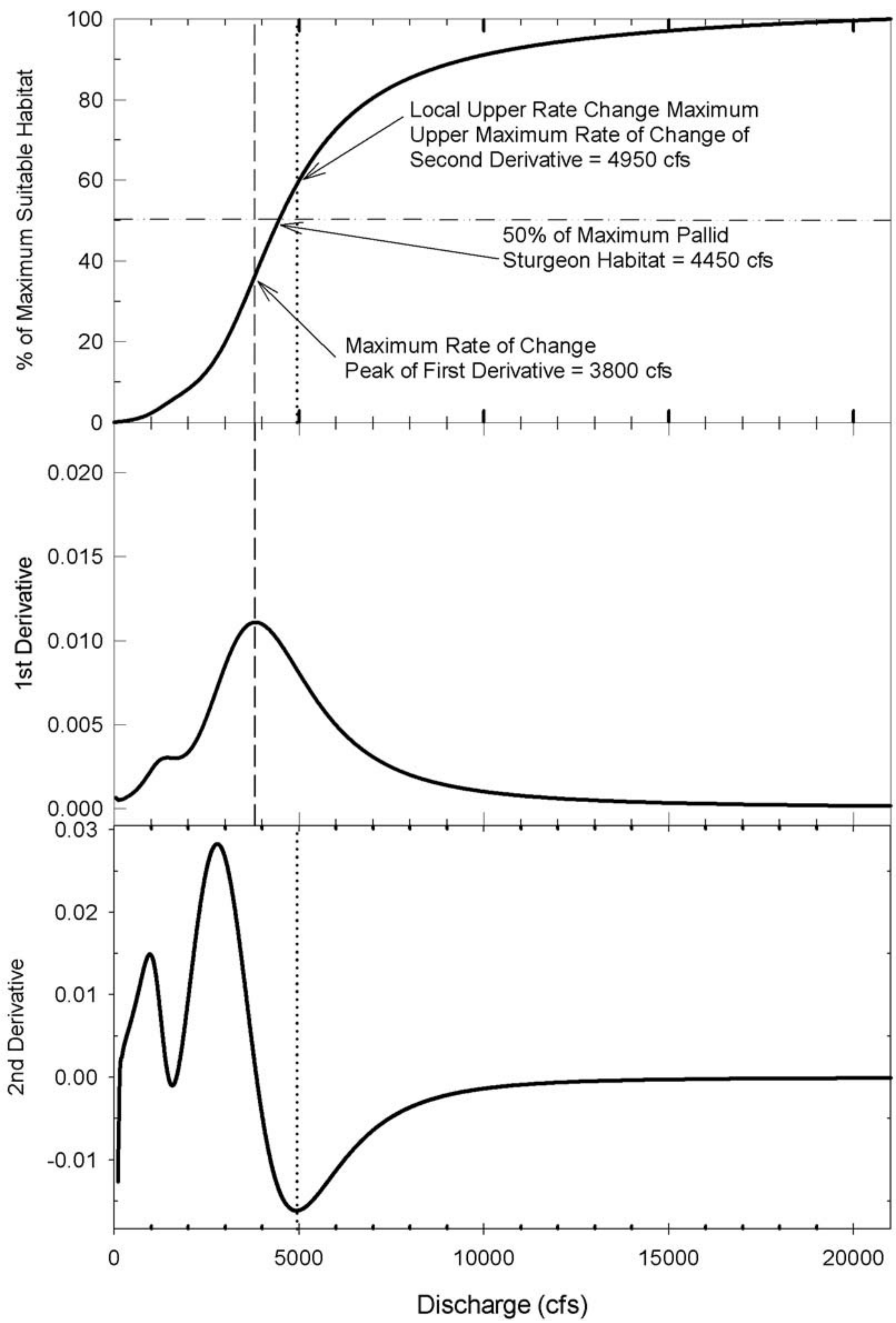

Figure 3.2. Maximum available suitable habitat, first derivative, and second derivative for pallid sturgeon in the lower Platte River, NE. Vertical dashed line is the maximum rate of change for the curve and the dotted line is the upper critical point defined as the maximum rate of change for the first derivative. The horizontal dashed line is the 50% maximum available habitat line.

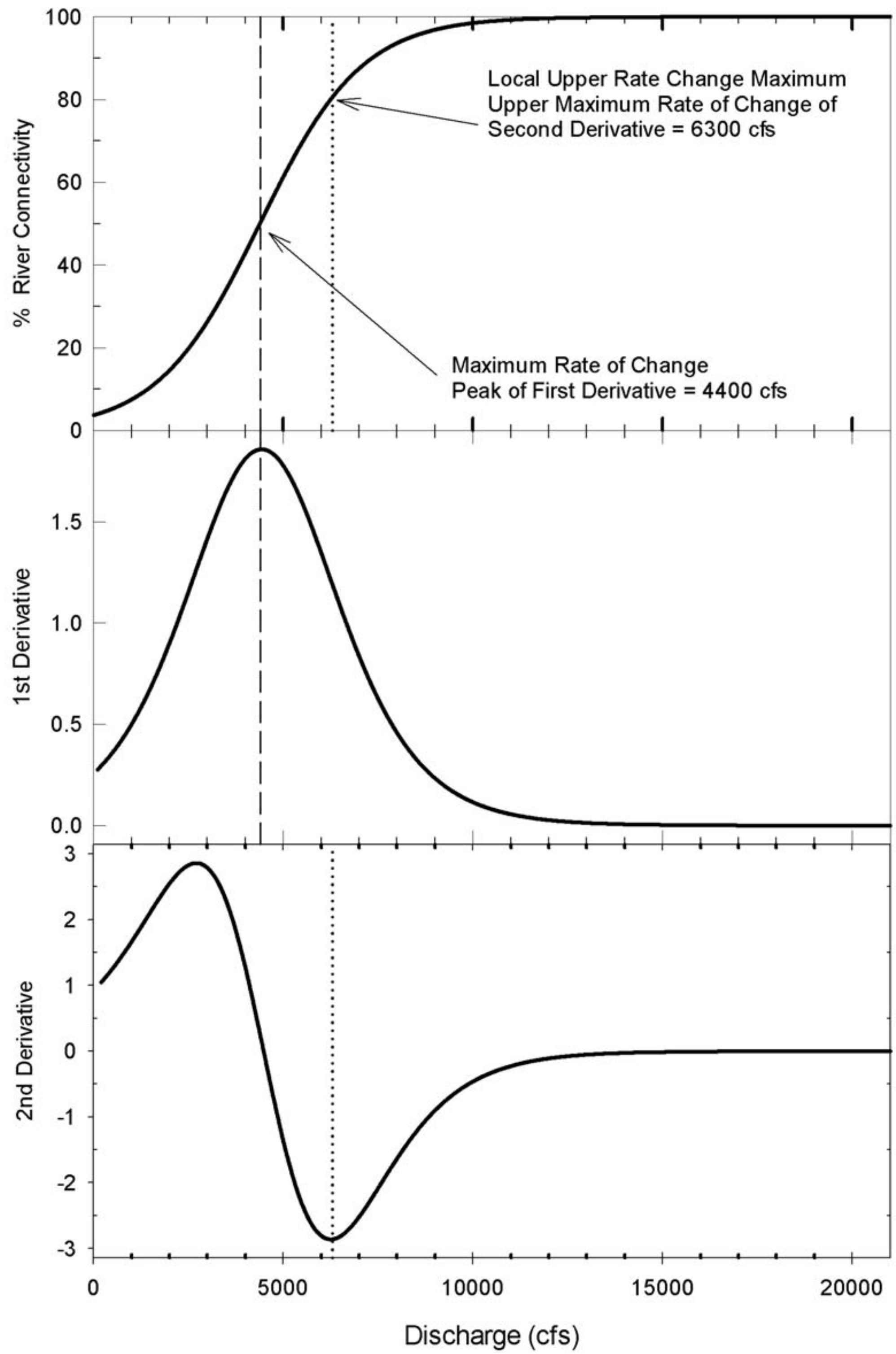

Figure 3.3. River connectivity, first derivative, and second derivative for the lower Platte River, NE. Vertical dashed line is the maximum rate of change for the curve and the dotted line is the upper critical point defined as the maximum rate of change for the first derivative.

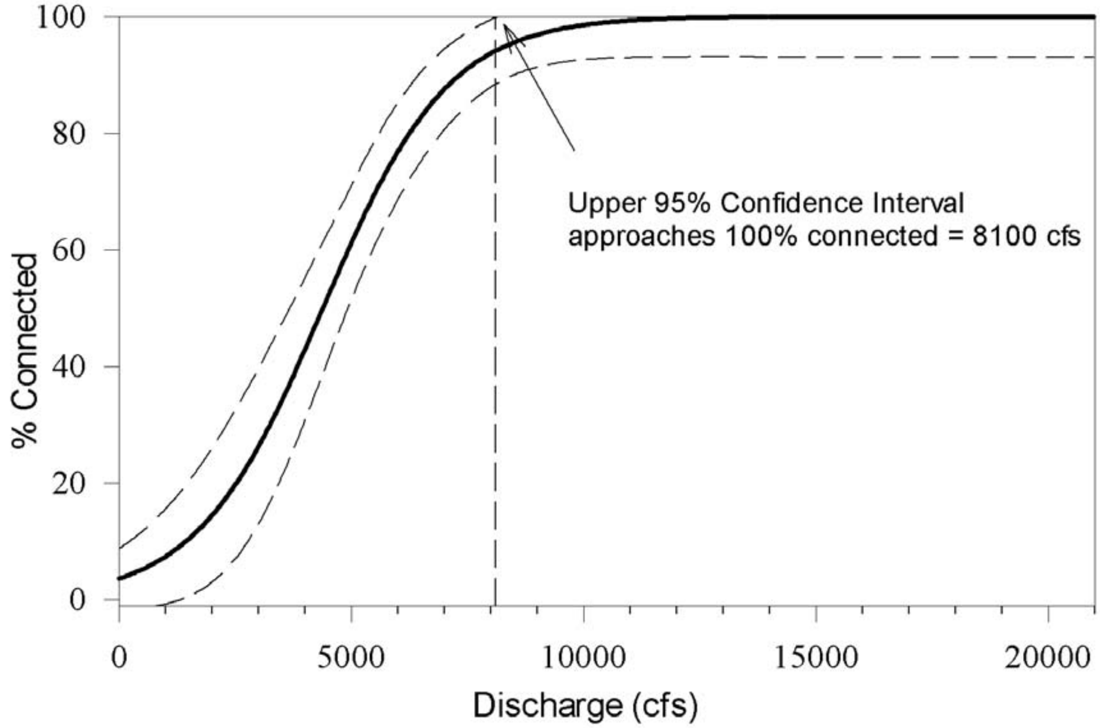

Figure 3.4. The curve for river connectivity with the upper and lower 95% confidence intervals. The vertical dashed line is the location where the upper 95% confidence interval reaches 100% connected.

Conclusions:

Pallid sturgeon select the deepest and swiftest waters in the lower Platte River and, therefore, it is highly dependent on the quantity of water in the river (Peters and Parham *in press*). During the spring migration period discharge level of 8,100 cfs would allow the sturgeon adequate movement throughout the lower Platte River, while outside of the migratory period a discharge of 4,950 cfs would maximize habitat while minimizing discharge.

When comparing these values with the exceedance values for the lower Platte River gages, more habitat was available in the downstream sections of the Platte River and the river was more highly connected in the spring than in other times of the year. Near Louisville, annual median discharge is 5,230 cfs and values greater than this are common in the spring months. More than 70% of the time during March, April and May, 5,000 cfs is available. In general, one could expect there to be suitable habitat for pallid sturgeon in the spring of the year in 7 out of 10 years on the lower Platte River from Louisville downstream. In contrast to this, at North Bend suitable habitat appears to be more limited in most years, with 5,000 cfs being exceeded 30% of the time and nearly 45% of the time during spring months. In the central Platte River near Duncan suitable habitat at 5,000 cfs occurs less than 5% of the time likely resulting in low amounts of suitable habitat west of North Bend at any time of the year. Interestingly, recreations of historical discharge for Duncan suggest that suitable habitat may have occurred in the central Platte in June of most years (Figure 3.5)

In terms of river connectivity, discharge values above 8,100 cfs would allow pallid sturgeon to move as needed among habitats and migrate up and back down the river for spring migratory purposes (e.g. spawning). Near Louisville, 8,100 cfs is equaled or exceeded nearly 45% of the time from March to June suggesting the river is connected in approximately 1 out of 2 years in this area. For North Bend, 8,000 cfs is exceed only 20 to 25% of the time in the spring months suggesting that pallid sturgeon may be able to move into this area in 1 out of 4 years on average during the spring. Near Duncan, the river is mostly unconnected for pallid sturgeon, with 8,000 cfs being exceeded in 2 to 5% of the spring months. Again, looking at the historical discharge estimates for Duncan, 8000 cfs was likely a common occurrence in this area prior to flow modifications (Figure 3.5).

Just like the least terns and piping plovers, pallid sturgeon use the mosaic of habitats in the lower Platte River and just providing deep swift channels is not likely to sustain the species. Pallid sturgeon eat small fishes that are commonly found in the shallow water of the river. Protecting the flows that scour deep channels, and create large disconnected sandbars likely will help each of these endangered species. Pallid sturgeon seem to have habitat use and movement patterns that follow the natural flow patterns of the Platte river. Most of their movement occurs from late March to early July when the river is usually high, and then they remain in deeper channels in the lower Platte River or return to the Missouri River when flows receded in the summer. Protecting or enhancing the spring rise in the lower Platte River is likely favorable to the continued use of the river by pallid sturgeon. In addition to protecting flows for river connectivity and suitable habitat, protecting high flows, sediment supply, and channel morphology will aid in protecting the natural shifting sandbars and deeper channels characteristic of the lower Platte River.

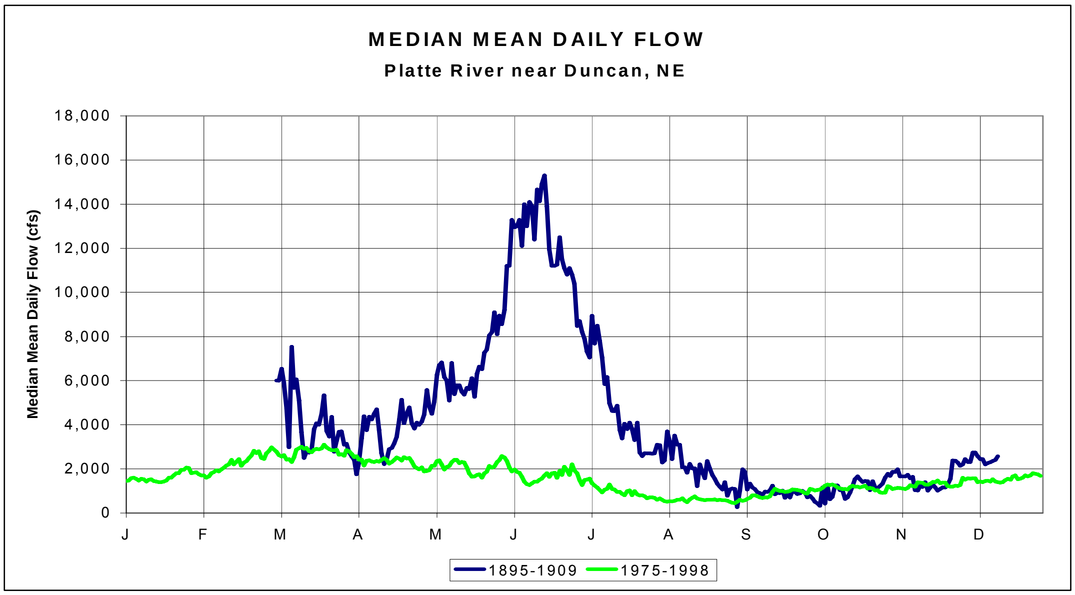

Figure 3.5. Median mean daily flow in the Platte River at Duncan, Nebraska, in 1895-1909 vs. 1975-98. (USGS gage data, as presented in Platte River FEIS, USDOI (2006)).

Table 3.1. Percent suitable habitat and river connectivity for pallid sturgeon in the lower Platte River at different discharge rates.

CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity
0	0.0%	3.7%	1,700	6.4%	12.0%	3,400	27.5%	32.5%
50	0.1%	3.8%	1,750	6.7%	12.4%	3,450	28.6%	33.3%
100	0.1%	4.0%	1,800	7.0%	12.8%	3,500	29.6%	34.2%
150	0.2%	4.1%	1,850	7.3%	13.2%	3,550	30.7%	35.0%
200	0.2%	4.3%	1,900	7.6%	13.6%	3,600	31.8%	35.9%
250	0.3%	4.4%	1,950	7.9%	14.1%	3,650	32.9%	36.7%
300	0.4%	4.6%	2,000	8.3%	14.5%	3,700	34.0%	37.6%
350	0.4%	4.8%	2,050	8.6%	15.0%	3,750	35.1%	38.5%
400	0.5%	4.9%	2,100	9.0%	15.5%	3,800	36.2%	39.3%
450	0.6%	5.1%	2,150	9.4%	16.0%	3,850	37.3%	40.2%
500	0.7%	5.3%	2,200	9.8%	16.5%	3,900	38.4%	41.1%
550	0.8%	5.5%	2,250	10.2%	17.0%	3,950	39.5%	42.0%
600	0.9%	5.7%	2,300	10.6%	17.5%	4,000	40.6%	42.9%
650	1.0%	5.9%	2,350	11.1%	18.1%	4,050	41.7%	43.9%
700	1.2%	6.1%	2,400	11.6%	18.6%	4,100	42.8%	44.8%
750	1.3%	6.3%	2,450	12.1%	19.2%	4,150	43.9%	45.7%
800	1.5%	6.5%	2,500	12.6%	19.8%	4,200	45.0%	46.6%
850	1.6%	6.8%	2,550	13.2%	20.4%	4,250	46.0%	47.5%
900	1.8%	7.0%	2,600	13.8%	21.0%	4,300	47.1%	48.5%
950	2.1%	7.2%	2,650	14.5%	21.6%	4,350	48.1%	49.4%
1,000	2.3%	7.5%	2,700	15.1%	22.3%	4,400	49.1%	50.3%
1,050	2.5%	7.7%	2,750	15.8%	22.9%	4,450	50.1%	51.3%
1,100	2.8%	8.0%	2,800	16.6%	23.6%	4,500	51.1%	52.2%
1,150	3.1%	8.3%	2,850	17.3%	24.3%	4,550	52.0%	53.1%
1,200	3.4%	8.6%	2,900	18.1%	24.9%	4,600	53.0%	54.0%
1,250	3.6%	8.9%	2,950	18.9%	25.6%	4,650	53.9%	55.0%
1,300	3.9%	9.2%	3,000	19.8%	26.4%	4,700	54.8%	55.9%
1,350	4.2%	9.5%	3,050	20.7%	27.1%	4,750	55.7%	56.8%
1,400	4.6%	9.8%	3,100	21.6%	27.8%	4,800	56.6%	57.7%
1,450	4.9%	10.2%	3,150	22.5%	28.6%	4,850	57.5%	58.6%
1,500	5.2%	10.5%	3,200	23.5%	29.3%	4,900	58.3%	59.5%
1,550	5.5%	10.9%	3,250	24.4%	30.1%	4,950	59.1%	60.4%
1,600	5.8%	11.2%	3,300	25.4%	30.9%	5,000	59.9%	61.3%
1,650	6.1%	11.6%	3,350	26.5%	31.7%	5,050	60.7%	62.2%

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CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity
5,100	61.5%	63.0%	6,800	79.2%	85.8%	8,500	87.2%	95.5%
5,150	62.3%	63.9%	6,850	79.5%	86.2%	8,550	87.4%	95.7%
5,200	63.0%	64.7%	6,900	79.8%	86.7%	8,600	87.6%	95.8%
5,250	63.7%	65.6%	6,950	80.1%	87.1%	8,650	87.7%	96.0%
5,300	64.4%	66.4%	7,000	80.5%	87.5%	8,700	87.9%	96.1%
5,350	65.1%	67.2%	7,050	80.8%	87.9%	8,750	88.0%	96.3%
5,400	65.8%	68.1%	7,100	81.1%	88.3%	8,800	88.2%	96.4%
5,450	66.4%	68.9%	7,150	81.3%	88.7%	8,850	88.3%	96.5%
5,500	67.1%	69.7%	7,200	81.6%	89.0%	8,900	88.5%	96.6%
5,550	67.7%	70.4%	7,250	81.9%	89.4%	8,950	88.6%	96.8%
5,600	68.3%	71.2%	7,300	82.2%	89.7%	9,000	88.7%	96.9%
5,650	68.9%	72.0%	7,350	82.4%	90.1%	9,050	88.9%	97.0%
5,700	69.5%	72.7%	7,400	82.7%	90.4%	9,100	89.0%	97.1%
5,750	70.0%	73.4%	7,450	82.9%	90.7%	9,150	89.2%	97.2%
5,800	70.6%	74.2%	7,500	83.2%	91.0%	9,200	89.3%	97.3%
5,850	71.1%	74.9%	7,550	83.4%	91.3%	9,250	89.4%	97.4%
5,900	71.6%	75.5%	7,600	83.7%	91.6%	9,300	89.5%	97.5%
5,950	72.2%	76.2%	7,650	83.9%	91.9%	9,350	89.7%	97.6%
6,000	72.7%	76.9%	7,700	84.1%	92.2%	9,400	89.8%	97.7%
6,050	73.1%	77.6%	7,750	84.4%	92.4%	9,450	89.9%	97.7%
6,100	73.6%	78.2%	7,800	84.6%	92.7%	9,500	90.0%	97.8%
6,150	74.1%	78.8%	7,850	84.8%	92.9%	9,550	90.1%	97.9%
6,200	74.5%	79.4%	7,900	85.0%	93.2%	9,600	90.3%	98.0%
6,250	75.0%	80.0%	7,950	85.2%	93.4%	9,650	90.4%	98.0%
6,300	75.4%	80.6%	8,000	85.4%	93.6%	9,700	90.5%	98.1%
6,350	75.8%	81.2%	8,050	85.6%	93.9%	9,750	90.6%	98.2%
6,400	76.2%	81.8%	8,100	85.8%	94.1%	9,800	90.7%	98.2%
6,450	76.6%	82.3%	8,150	86.0%	94.3%	9,850	90.8%	98.3%
6,500	77.0%	82.8%	8,200	86.2%	94.5%	9,900	90.9%	98.4%
6,550	77.4%	83.4%	8,250	86.4%	94.7%	9,950	91.0%	98.4%
6,600	77.8%	83.9%	8,300	86.5%	94.8%	10,000	91.1%	98.5%
6,650	78.1%	84.4%	8,350	86.7%	95.0%	10,050	91.2%	98.5%
6,700	78.5%	84.8%	8,400	86.9%	95.2%	10,100	91.3%	98.6%
6,750	78.8%	85.3%	8,450	87.1%	95.4%	10,150	91.4%	98.6%

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CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity
10,200	91.5%	98.7%	12,000	94.3%	99.7%	13,800	96.2%	99.9%
10,250	91.6%	98.7%	12,050	94.4%	99.7%	13,850	96.2%	99.9%
10,300	91.7%	98.8%	12,100	94.4%	99.7%	13,900	96.2%	99.9%
10,350	91.8%	98.8%	12,150	94.5%	99.7%	13,950	96.3%	99.9%
10,400	91.9%	98.9%	12,200	94.5%	99.7%	14,000	96.3%	99.9%
10,450	92.0%	98.9%	12,250	94.6%	99.7%	14,050	96.4%	99.9%
10,500	92.1%	99.0%	12,300	94.7%	99.7%	14,100	96.4%	99.9%
10,550	92.2%	99.0%	12,350	94.7%	99.7%	14,150	96.5%	99.9%
10,600	92.3%	99.0%	12,400	94.8%	99.7%	14,200	96.5%	99.9%
10,650	92.3%	99.1%	12,450	94.8%	99.8%	14,250	96.5%	99.9%
10,700	92.4%	99.1%	12,500	94.9%	99.8%	14,300	96.6%	99.9%
10,750	92.5%	99.1%	12,550	94.9%	99.8%	14,350	96.6%	99.9%
10,800	92.6%	99.2%	12,600	95.0%	99.8%	14,400	96.7%	99.9%
10,850	92.7%	99.2%	12,650	95.1%	99.8%	14,450	96.7%	99.9%
10,900	92.8%	99.2%	12,700	95.1%	99.8%	14,500	96.7%	99.9%
10,950	92.8%	99.2%	12,750	95.2%	99.8%	14,550	96.8%	99.9%
11,000	92.9%	99.3%	12,800	95.2%	99.8%	14,600	96.8%	100.0%
11,050	93.0%	99.3%	12,850	95.3%	99.8%	14,650	96.8%	100.0%
11,100	93.1%	99.3%	12,900	95.3%	99.8%	14,700	96.9%	100.0%
11,150	93.1%	99.4%	12,950	95.4%	99.8%	14,750	96.9%	100.0%
11,200	93.2%	99.4%	13,000	95.4%	99.8%	14,800	97.0%	100.0%
11,250	93.3%	99.4%	13,050	95.5%	99.8%	14,850	97.0%	100.0%
11,300	93.4%	99.4%	13,100	95.5%	99.8%	14,900	97.0%	100.0%
11,350	93.4%	99.4%	13,150	95.6%	99.9%	14,950	97.1%	100.0%
11,400	93.5%	99.5%	13,200	95.6%	99.9%	15,000	97.1%	100.0%
11,450	93.6%	99.5%	13,250	95.7%	99.9%	15,050	97.1%	100.0%
11,500	93.7%	99.5%	13,300	95.7%	99.9%	15,100	97.2%	100.0%
11,550	93.7%	99.5%	13,350	95.8%	99.9%	15,150	97.2%	100.0%
11,600	93.8%	99.5%	13,400	95.8%	99.9%	15,200	97.2%	100.0%
11,650	93.9%	99.6%	13,450	95.9%	99.9%	15,250	97.3%	100.0%
11,700	93.9%	99.6%	13,500	95.9%	99.9%	15,300	97.3%	100.0%
11,750	94.0%	99.6%	13,550	95.9%	99.9%	15,350	97.3%	100.0%
11,800	94.1%	99.6%	13,600	96.0%	99.9%	15,400	97.4%	100.0%
11,850	94.1%	99.6%	13,650	96.0%	99.9%	15,450	97.4%	100.0%
11,900	94.2%	99.6%	13,700	96.1%	99.9%	15,500	97.4%	100.0%
11,950	94.2%	99.6%	13,750	96.1%	99.9%	15,550	97.5%	100.0%

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CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity
15,600	97.5%	100.0%	17,400	98.5%	100.0%	19,200	99.3%	100.0%
15,650	97.5%	100.0%	17,450	98.6%	100.0%	19,250	99.4%	100.0%
15,700	97.6%	100.0%	17,500	98.6%	100.0%	19,300	99.4%	100.0%
15,750	97.6%	100.0%	17,550	98.6%	100.0%	19,350	99.4%	100.0%
15,800	97.6%	100.0%	17,600	98.6%	100.0%	19,400	99.4%	100.0%
15,850	97.7%	100.0%	17,650	98.7%	100.0%	19,450	99.4%	100.0%
15,900	97.7%	100.0%	17,700	98.7%	100.0%	19,500	99.5%	100.0%
15,950	97.7%	100.0%	17,750	98.7%	100.0%	19,550	99.5%	100.0%
16,000	97.8%	100.0%	17,800	98.7%	100.0%	19,600	99.5%	100.0%
16,050	97.8%	100.0%	17,850	98.8%	100.0%	19,650	99.5%	100.0%
16,100	97.8%	100.0%	17,900	98.8%	100.0%	19,700	99.5%	100.0%
16,150	97.8%	100.0%	17,950	98.8%	100.0%	19,750	99.6%	100.0%
16,200	97.9%	100.0%	18,000	98.8%	100.0%	19,800	99.6%	100.0%
16,250	97.9%	100.0%	18,050	98.8%	100.0%	19,850	99.6%	100.0%
16,300	97.9%	100.0%	18,100	98.9%	100.0%	19,900	99.6%	100.0%
16,350	98.0%	100.0%	18,150	98.9%	100.0%	19,950	99.6%	100.0%
16,400	98.0%	100.0%	18,200	98.9%	100.0%	20,000	99.6%	100.0%
16,450	98.0%	100.0%	18,250	98.9%	100.0%	20,050	99.7%	100.0%
16,500	98.1%	100.0%	18,300	99.0%	100.0%	20,100	99.7%	100.0%
16,550	98.1%	100.0%	18,350	99.0%	100.0%	20,150	99.7%	100.0%
16,600	98.1%	100.0%	18,400	99.0%	100.0%	20,200	99.7%	100.0%
16,650	98.1%	100.0%	18,450	99.0%	100.0%	20,250	99.7%	100.0%
16,700	98.2%	100.0%	18,500	99.0%	100.0%	20,300	99.8%	100.0%
16,750	98.2%	100.0%	18,550	99.1%	100.0%	20,350	99.8%	100.0%
16,800	98.2%	100.0%	18,600	99.1%	100.0%	20,400	99.8%	100.0%
16,850	98.2%	100.0%	18,650	99.1%	100.0%	20,450	99.8%	100.0%
16,900	98.3%	100.0%	18,700	99.1%	100.0%	20,500	99.8%	100.0%
16,950	98.3%	100.0%	18,750	99.2%	100.0%	20,550	99.8%	100.0%
17,000	98.3%	100.0%	18,800	99.2%	100.0%	20,600	99.9%	100.0%
17,050	98.4%	100.0%	18,850	99.2%	100.0%	20,650	99.9%	100.0%
17,100	98.4%	100.0%	18,900	99.2%	100.0%	20,700	99.9%	100.0%
17,150	98.4%	100.0%	18,950	99.2%	100.0%	20,750	99.9%	100.0%
17,200	98.4%	100.0%	19,000	99.3%	100.0%	20,800	99.9%	100.0%
17,250	98.5%	100.0%	19,050	99.3%	100.0%	20,850	99.9%	100.0%
17,300	98.5%	100.0%	19,100	99.3%	100.0%	20,900	100.0%	100.0%
17,350	98.5%	100.0%	19,150	99.3%	100.0%	21,000	100.0%	100.0%

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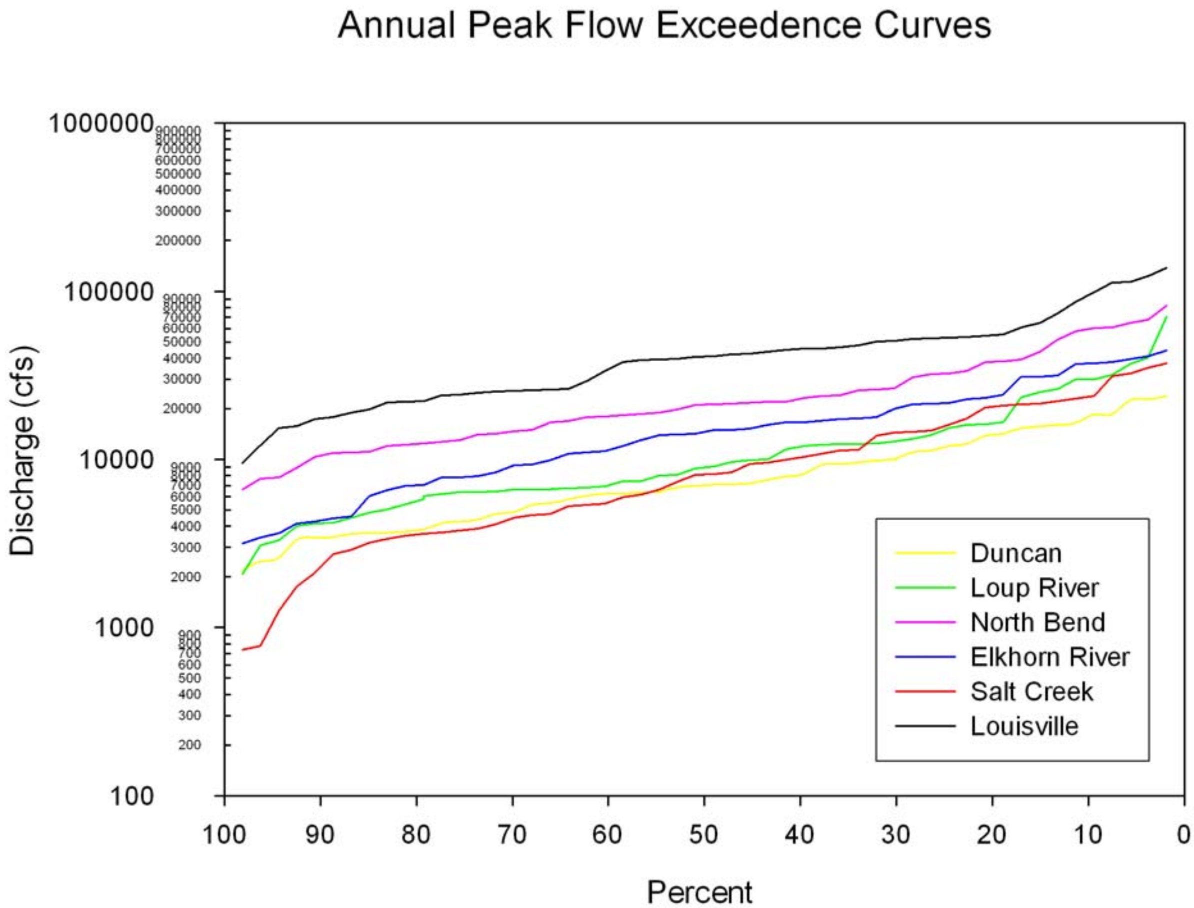
Appendix 1 – Graphs of the annual and monthly discharge characteristics for the Duncan, Loup River, Loup Power Canal, North Bend, Elkhorn River, Salt Creek, and Louisville gage sites for the period 1954 - 2005.

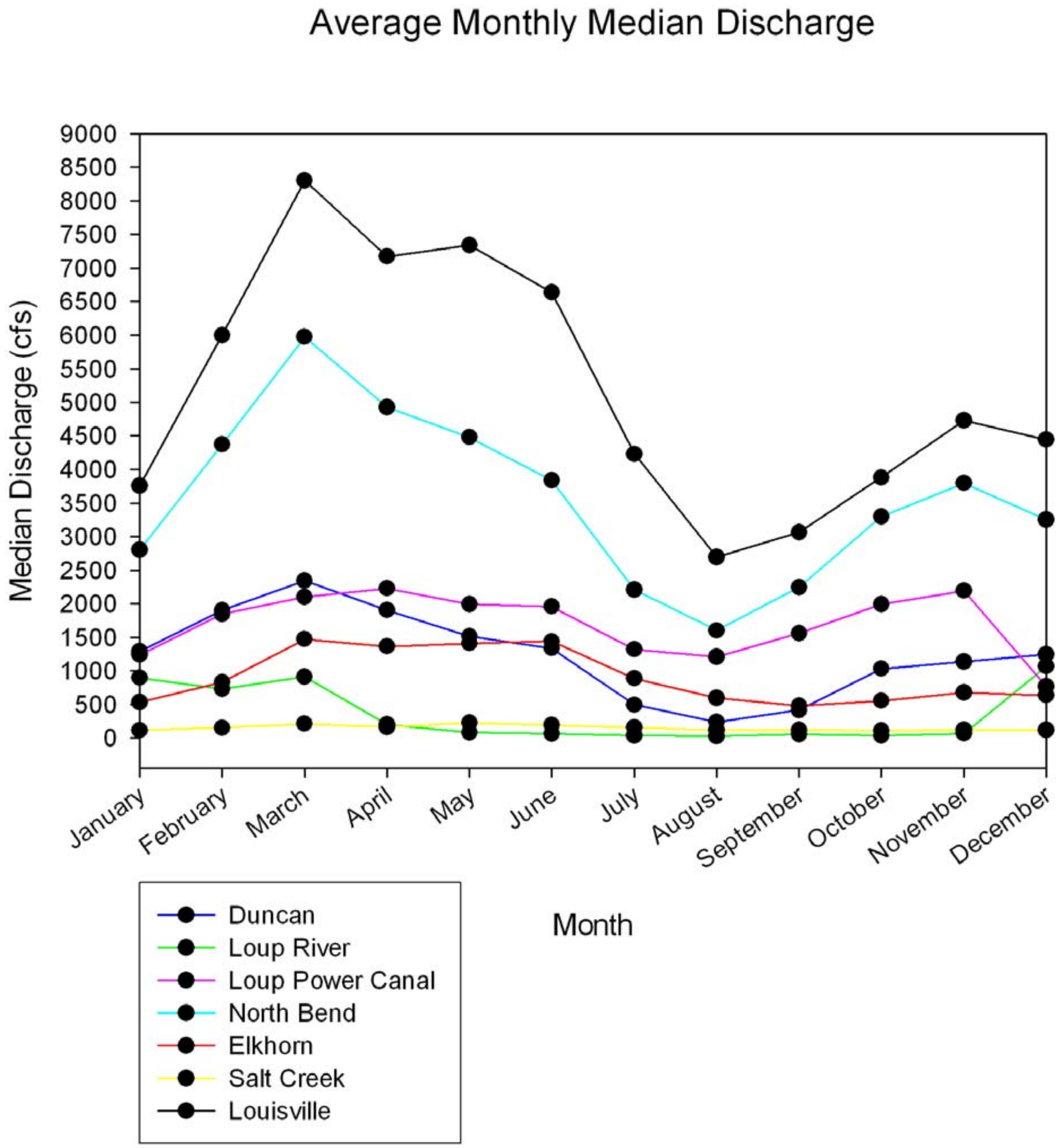
Information included for comparing sites:

- Annual Peak Flow Exceedance Curves
- Average Annual Monthly Median Discharge

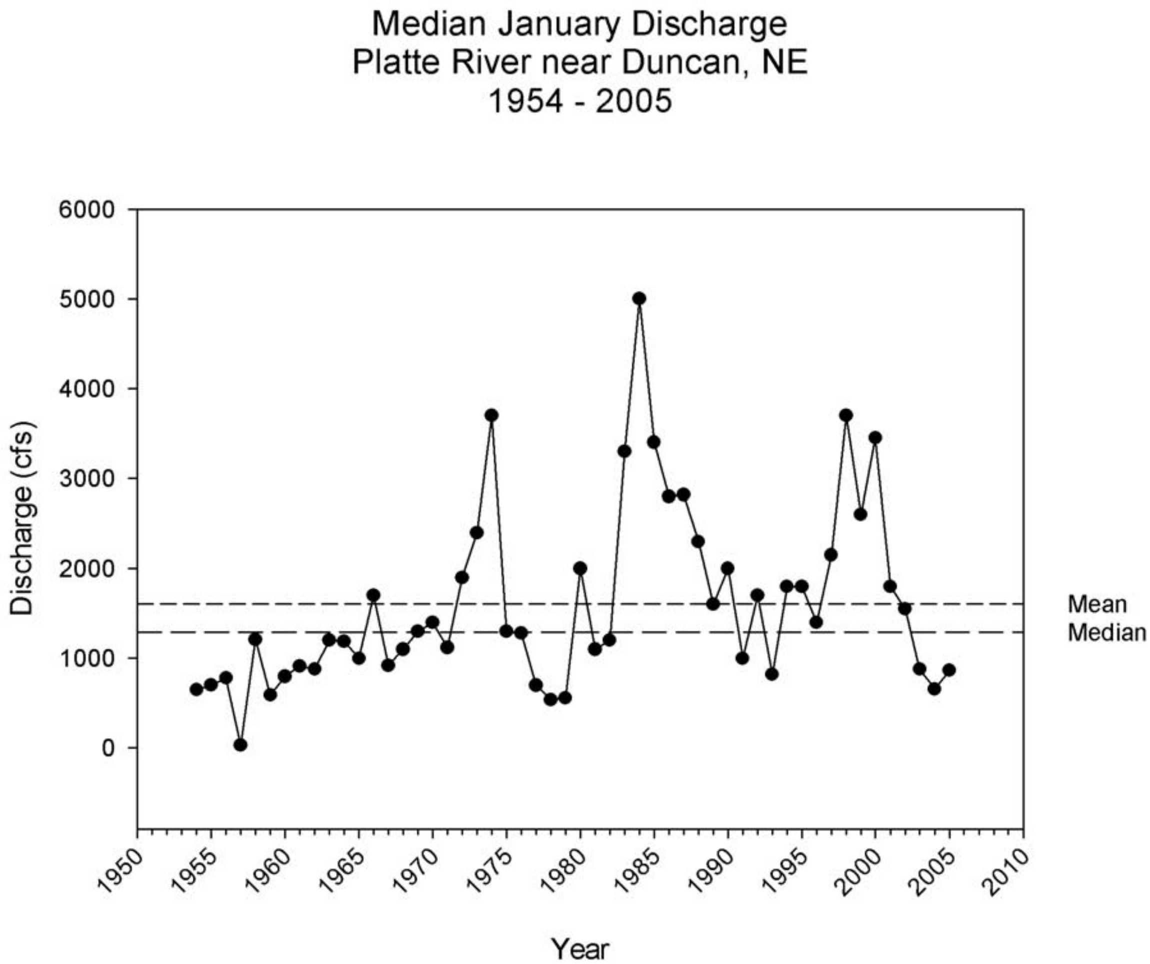
Information included for each gage site:

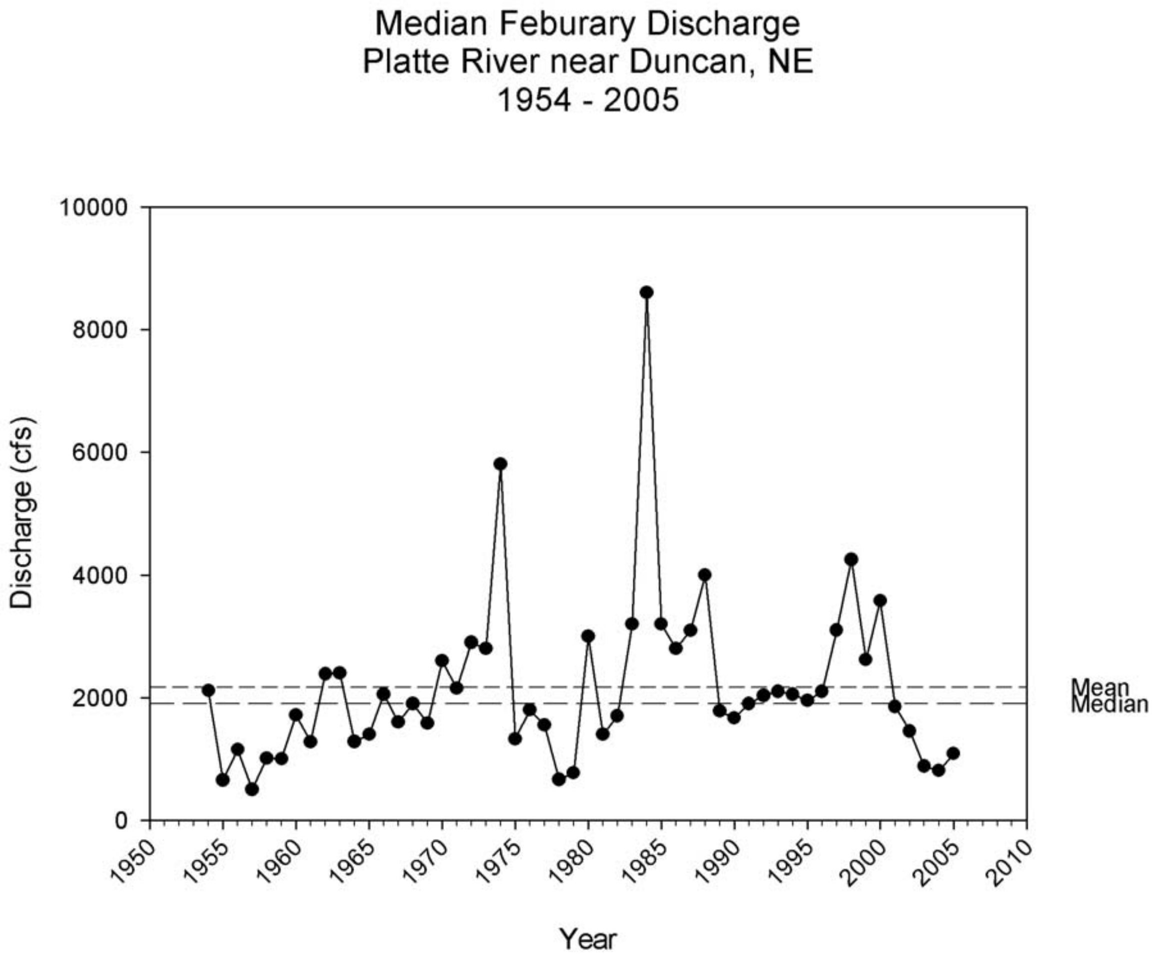
- Monthly Median Discharge
- 1, 7, 30, and 90-day Annual Minimum Discharge
- 1, 7, 30, and 90-day Annual Maximum Discharge
- Annual Number of Zero Flow Days
- Annual Date, Number, and Duration of Low Flows
- Annual Date, Number, and Duration of High Flows

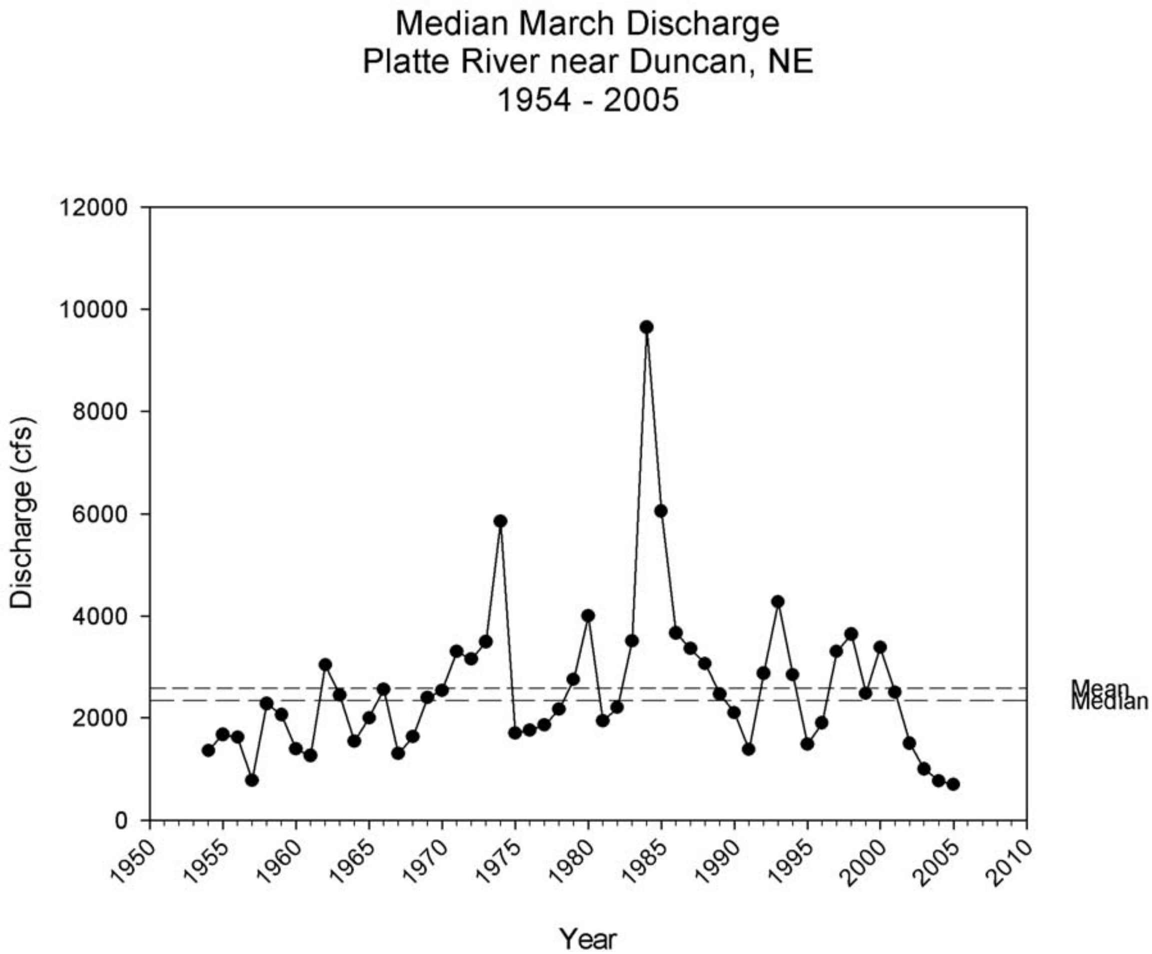

Annual Peak Flow Exceedence Curves
Discharge (cfs)
Percent
1000000
100000
10000
1000
100
100
90
80
70
60
50
40
30
20
10
0
Duncan
Loup River
North Bend
Elkhorn River
Salt Creek
Louisville

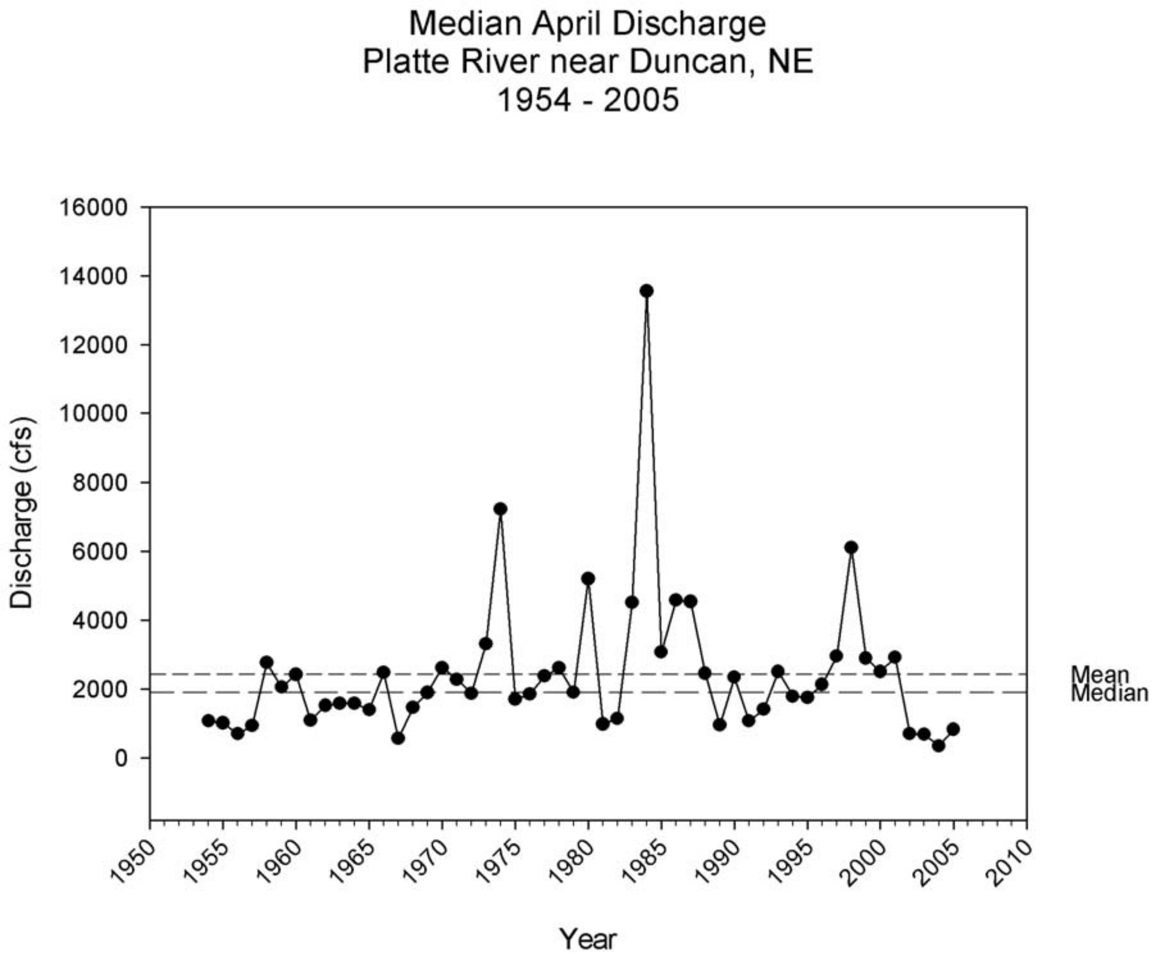


Average Monthly Median Discharge
Median Discharge (cfs)
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
January
February
March
April
May
June
July
August
September
October
November
December
Month
Duncan
Loup River
Loup Power Canal
North Bend
Elkhorn
Salt Creek
Louisville

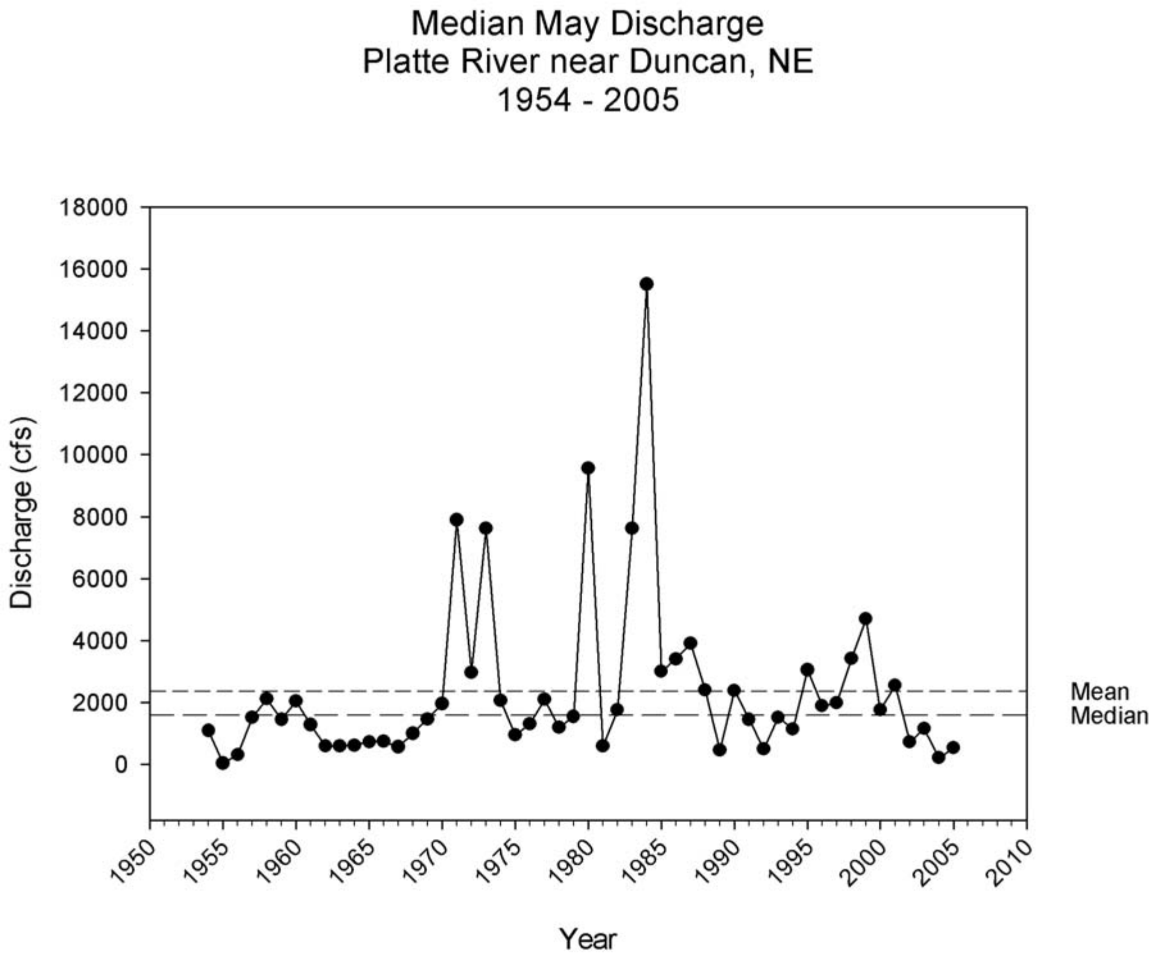

Median January Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
6000
5000
4000
3000
2000
1000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year


Median Feburary Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
10000
8000
6000
4000
2000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median

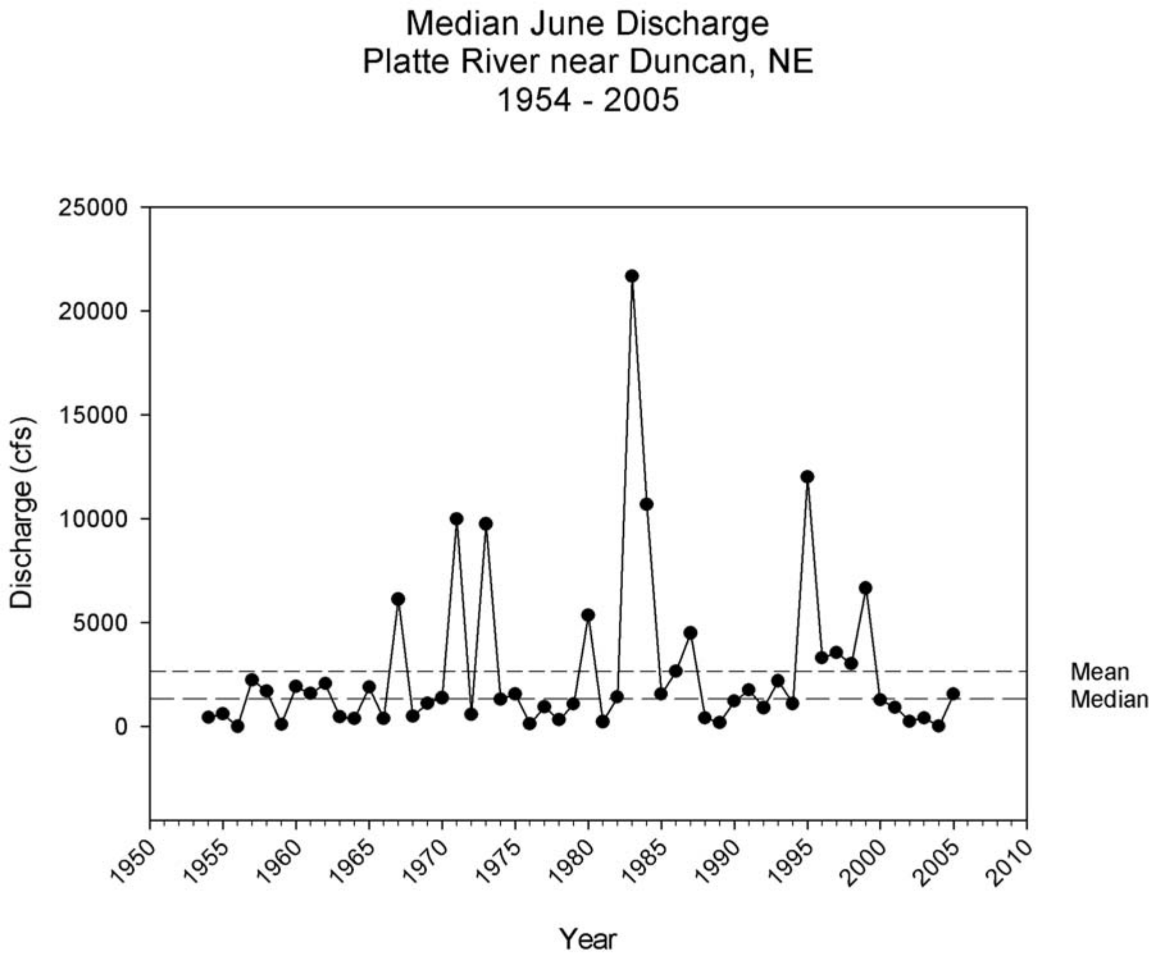

Median March Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
12000
10000
8000
6000
4000
2000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median

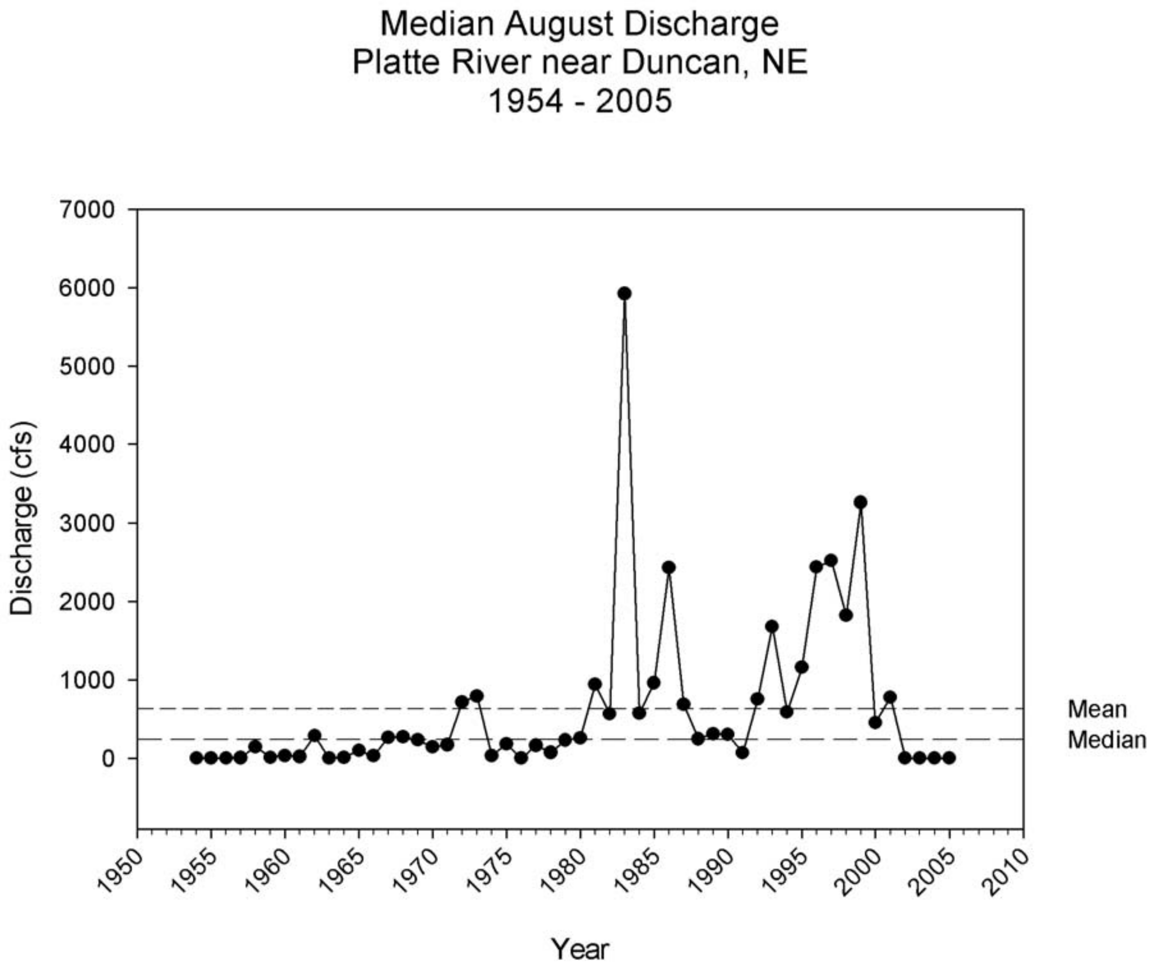


J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

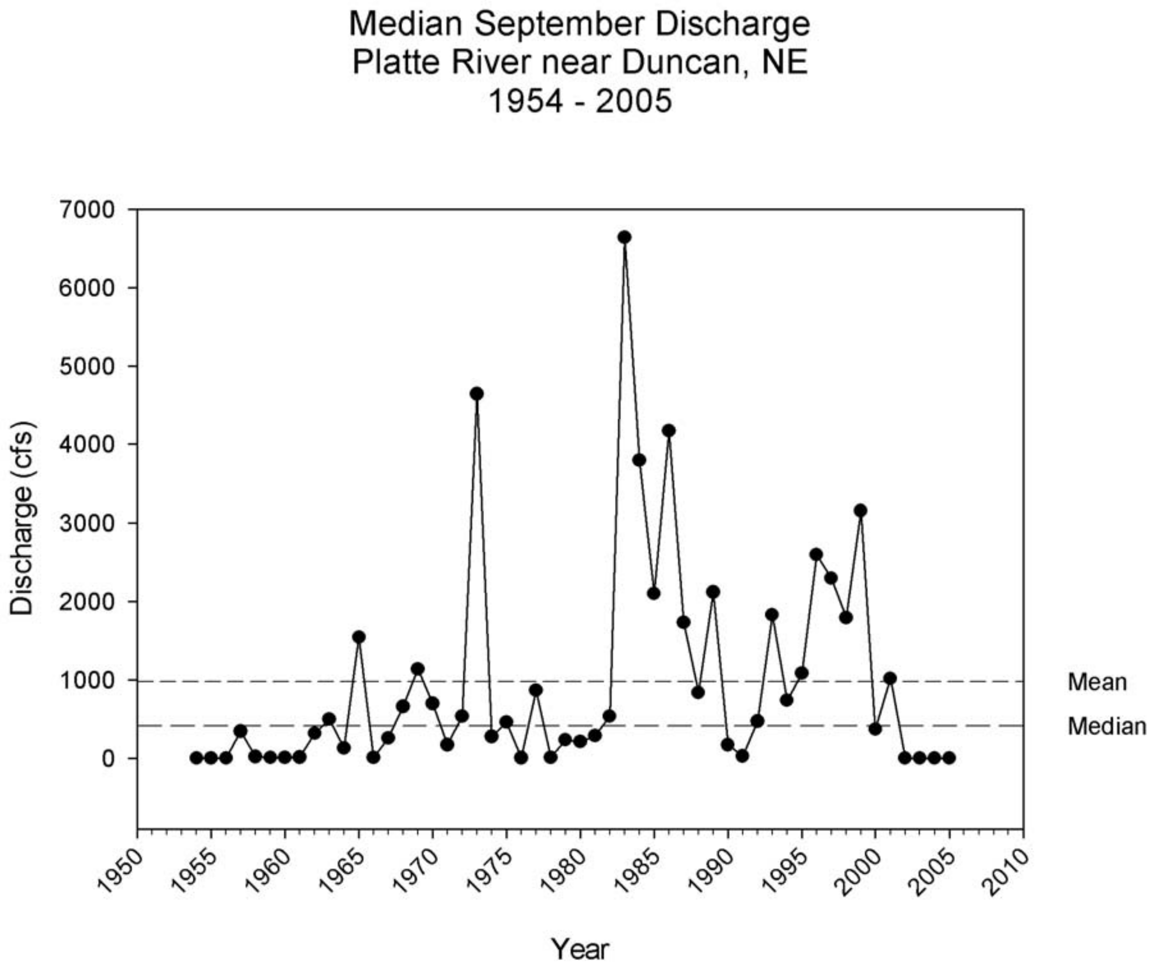


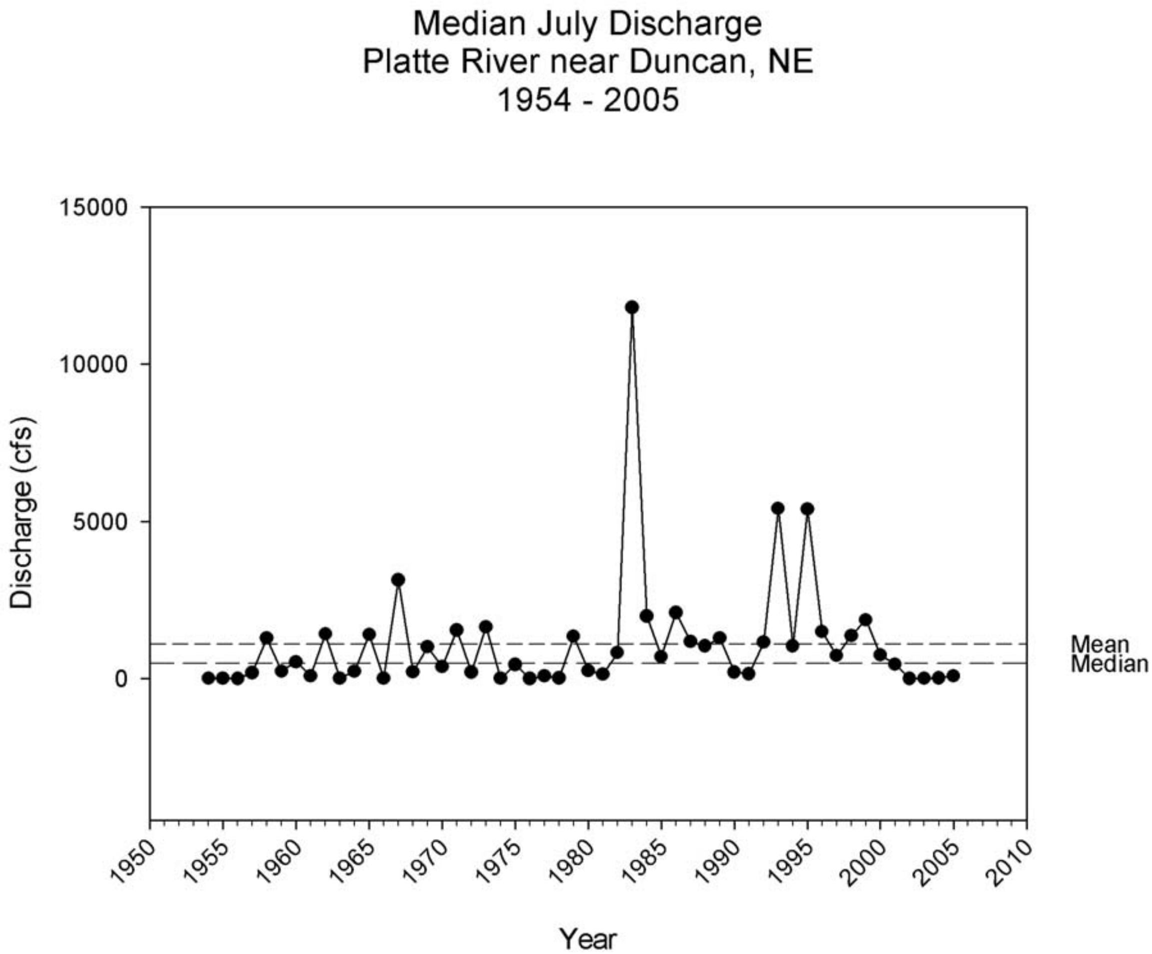
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

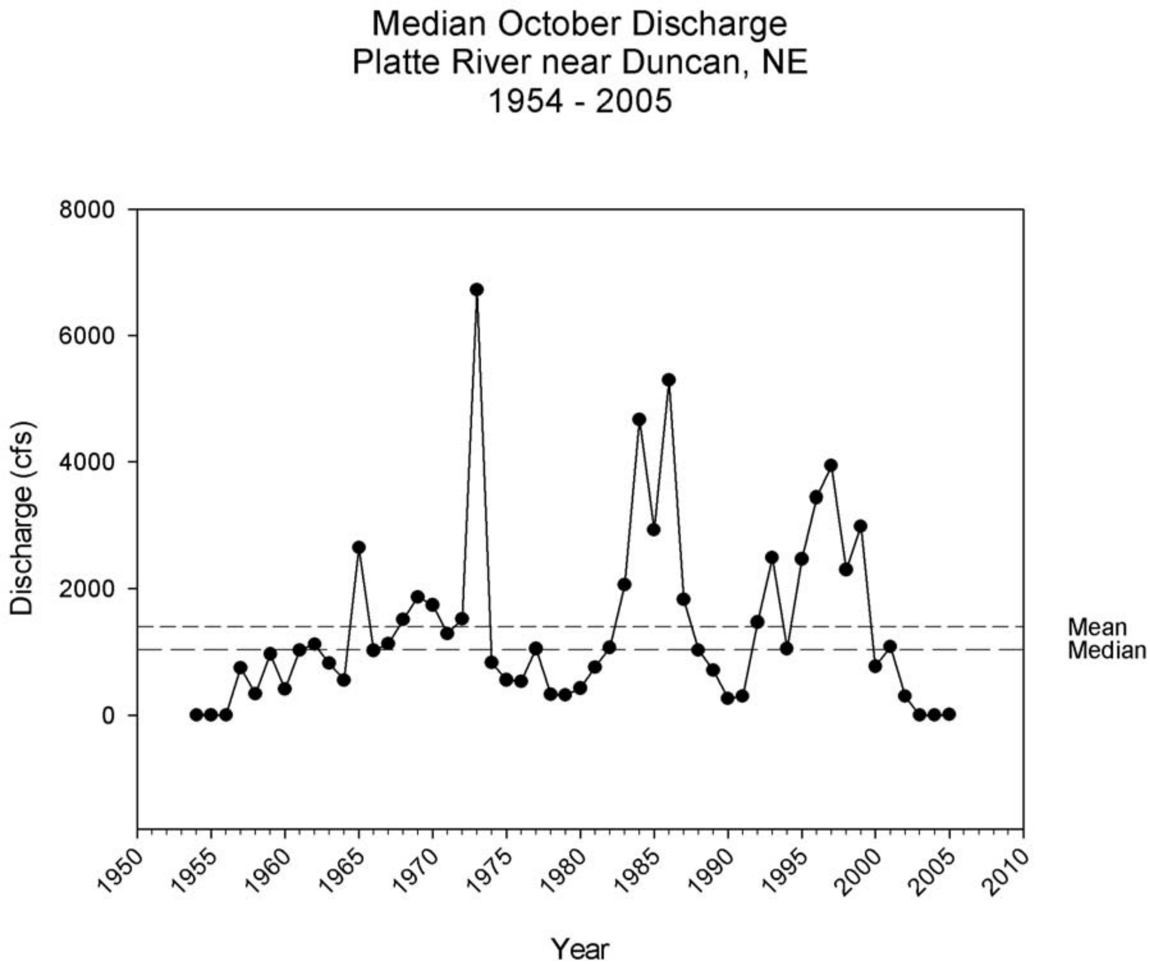

Median June Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
25000
20000
15000
10000
5000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

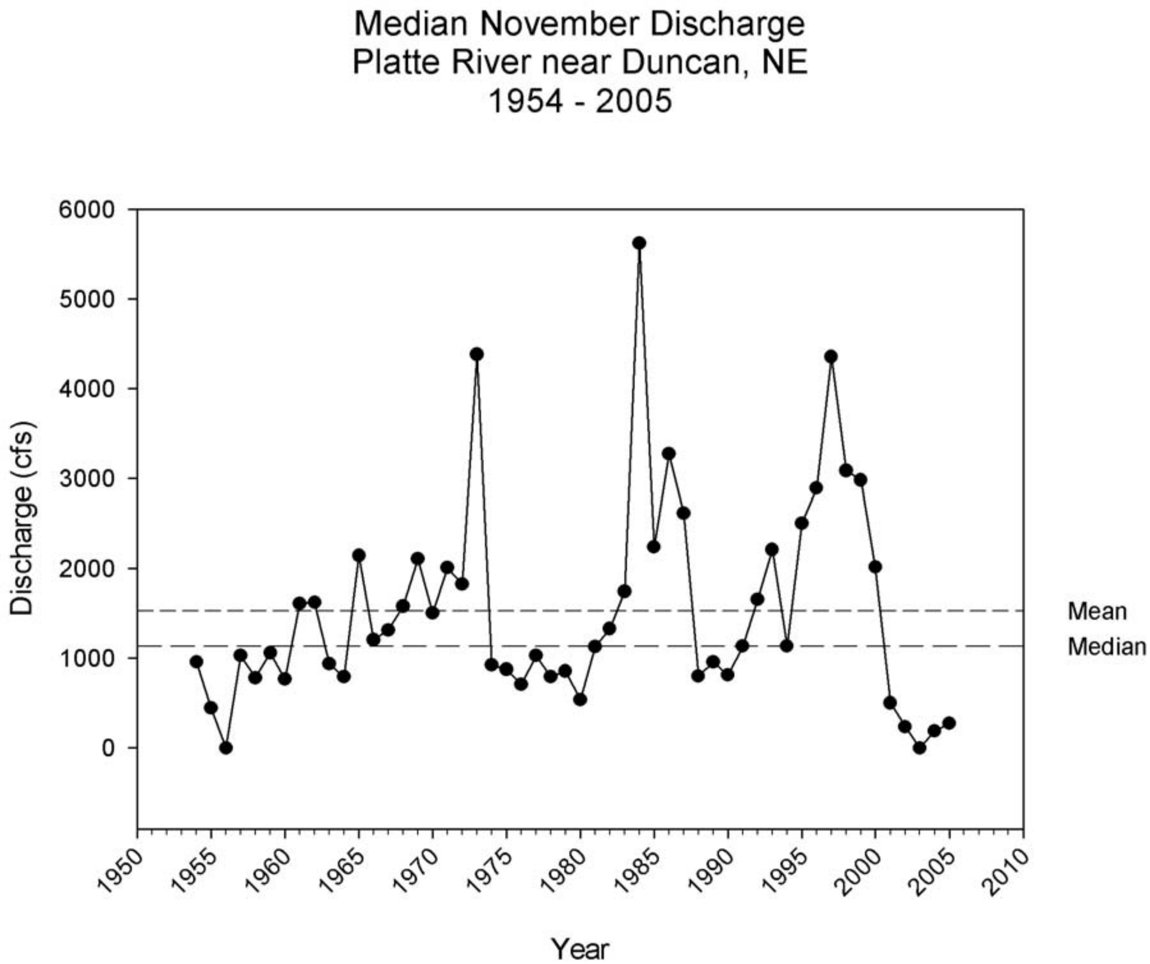


J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

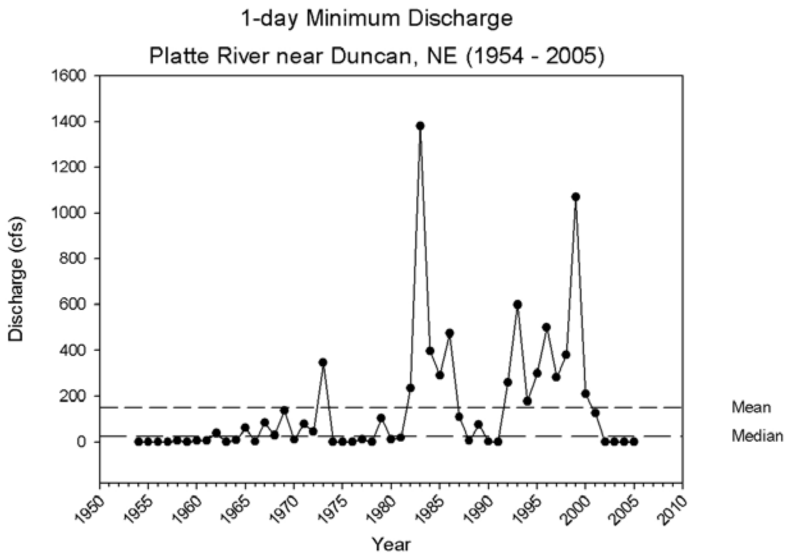

Median September Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
7000
6000
5000
4000
3000
2000
1000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

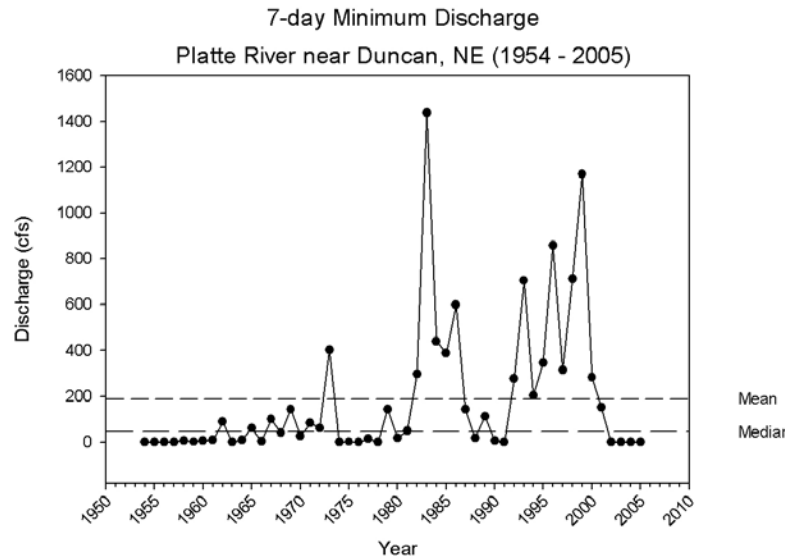

Median July Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
15000
10000
5000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

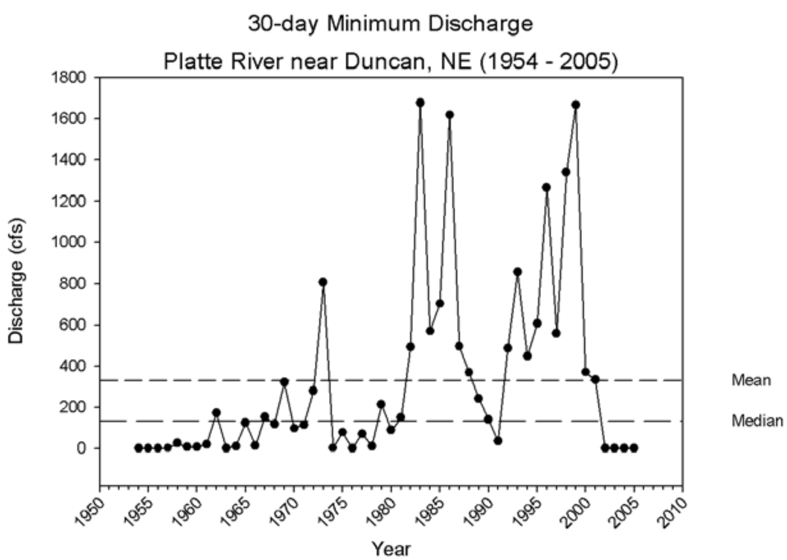

Median October Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
8000
6000
4000
2000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

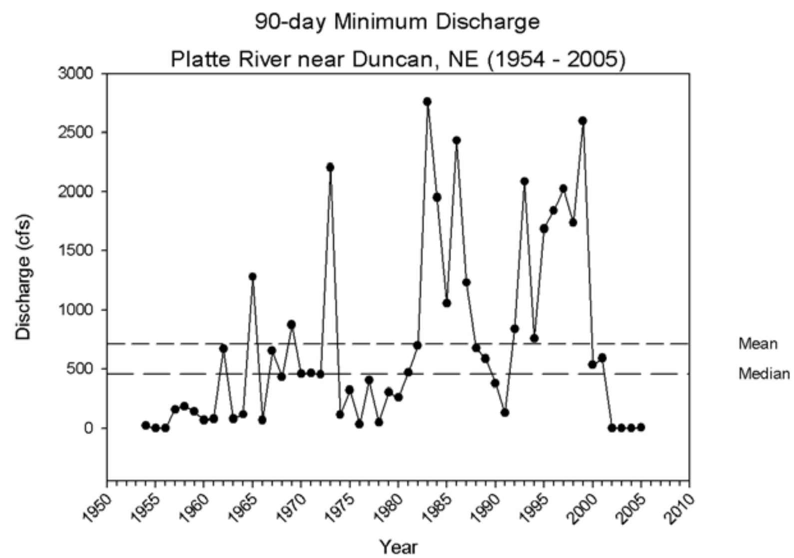


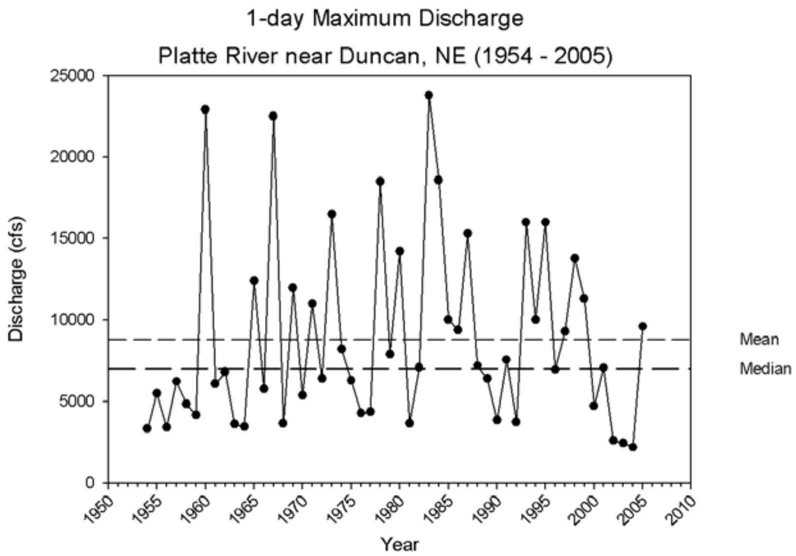
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

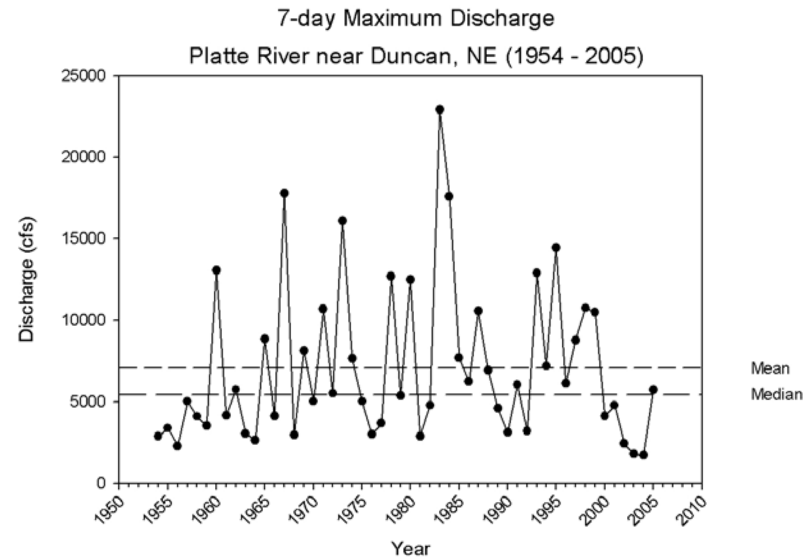

1-day Minimum Discharge
Platte River near Duncan, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median

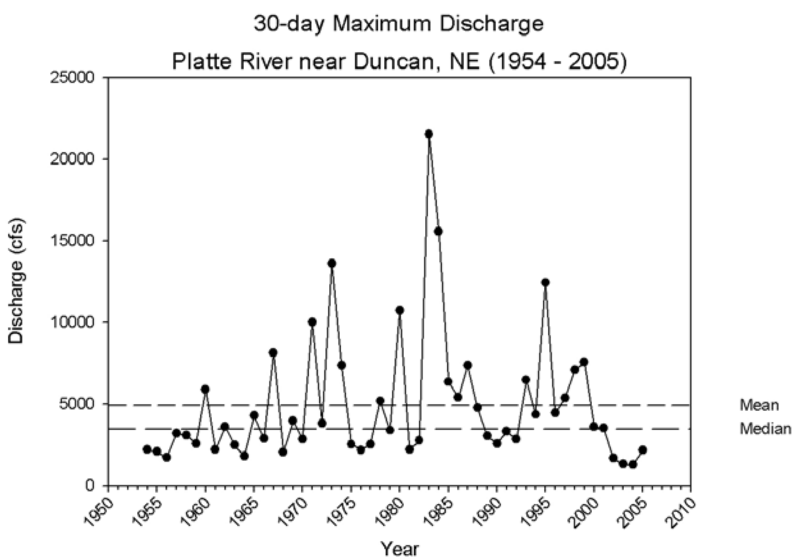

7-day Minimum Discharge
Platte River near Duncan, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median

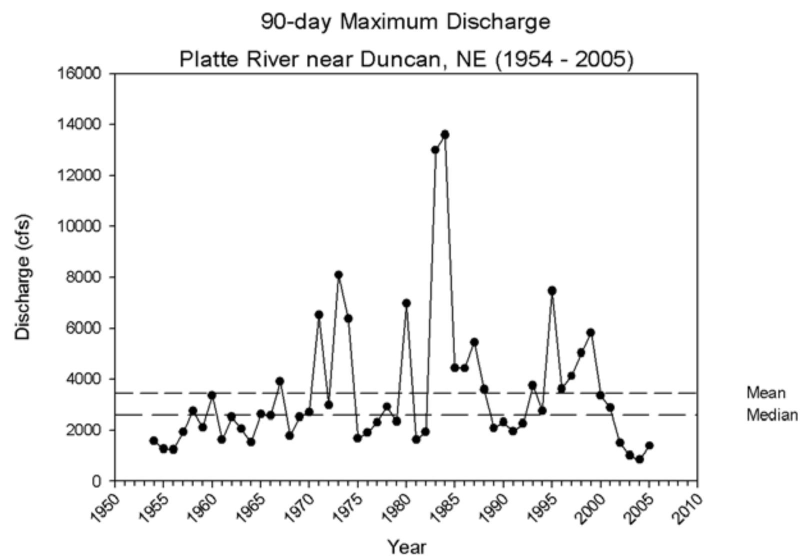

30-day Minimum Discharge
Platte River near Duncan, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median


90-day Minimum Discharge
Platte River near Duncan, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median

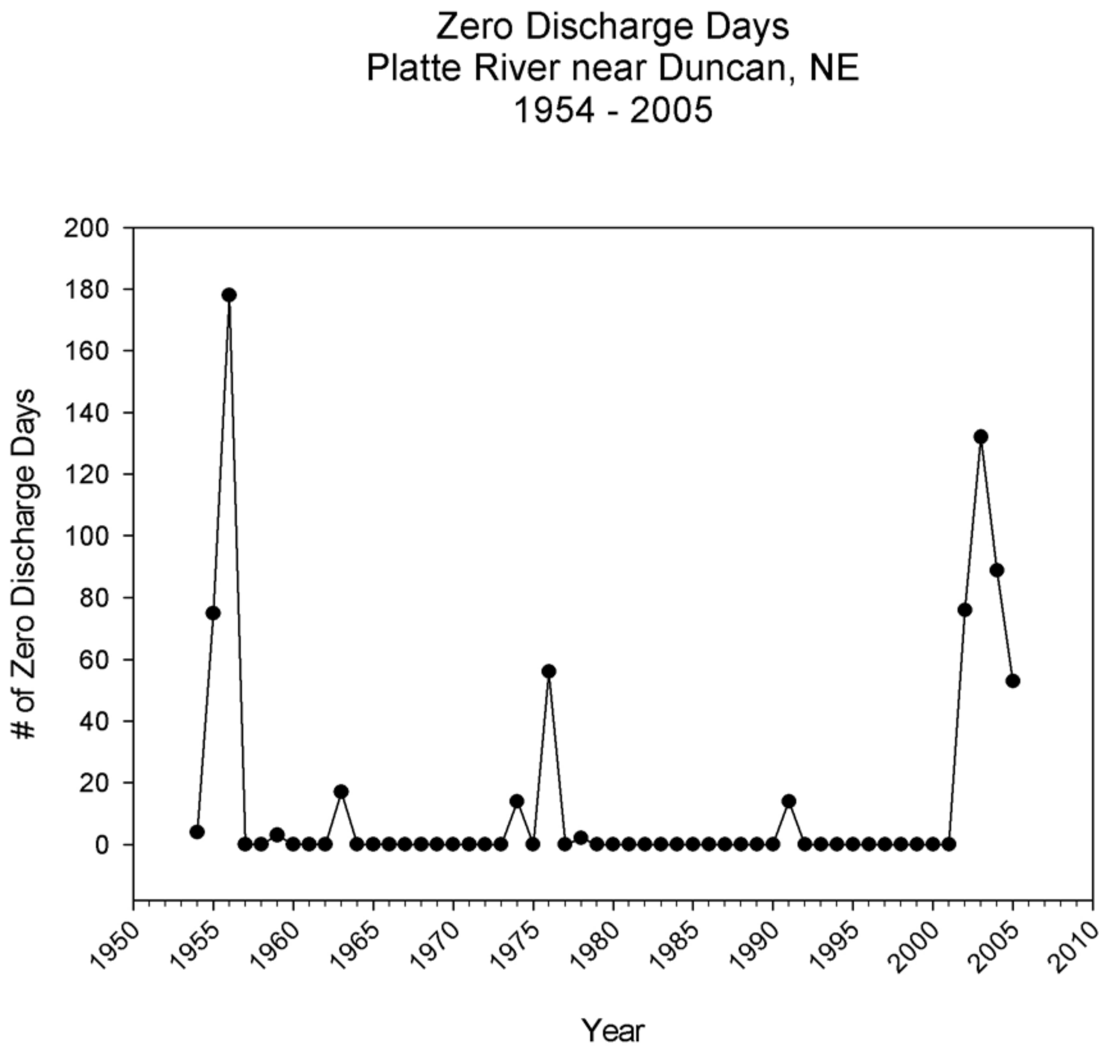




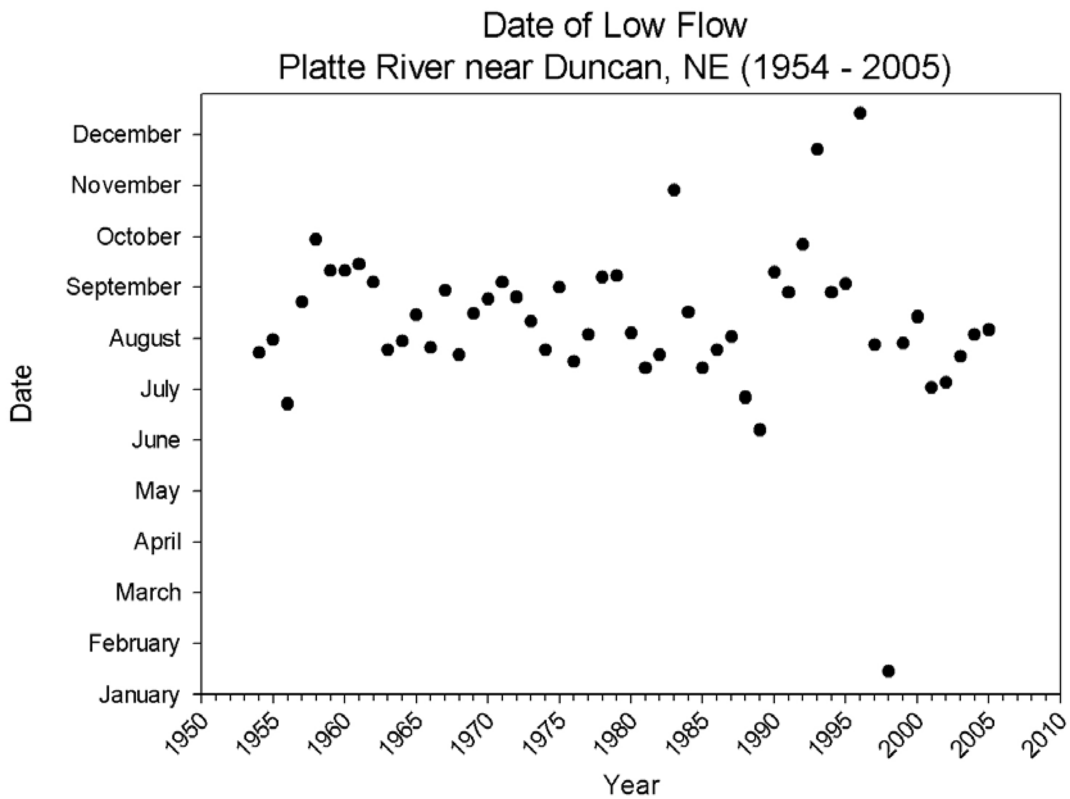


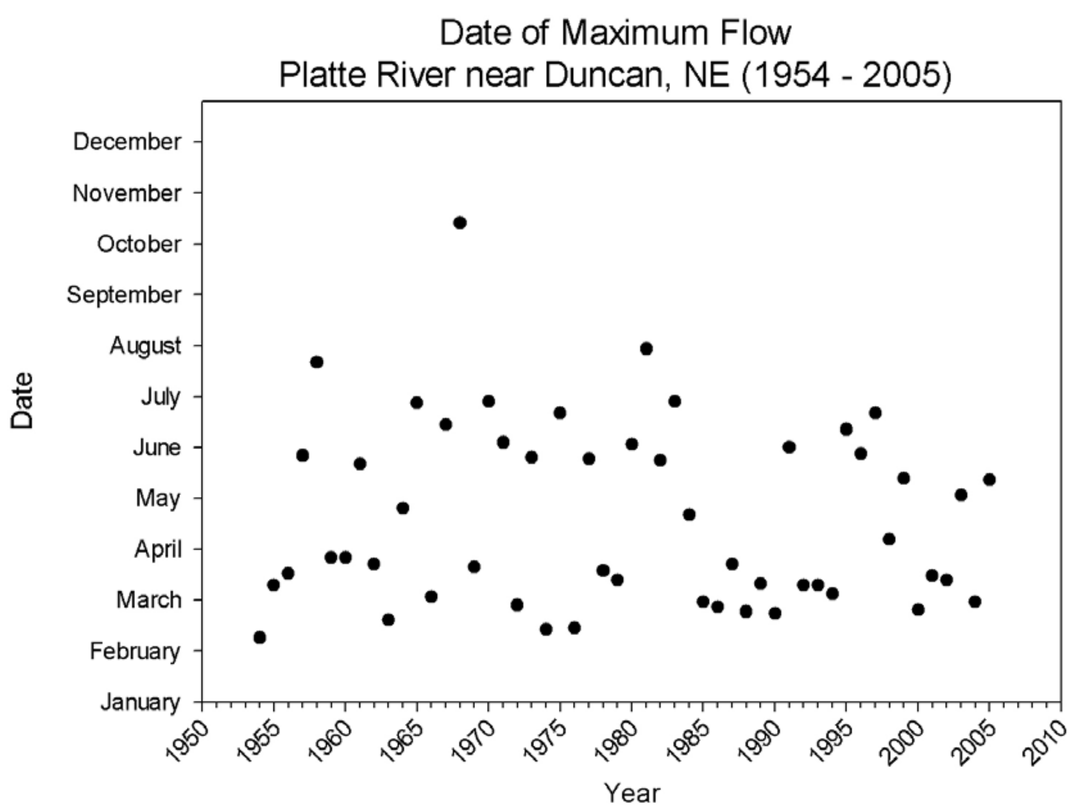


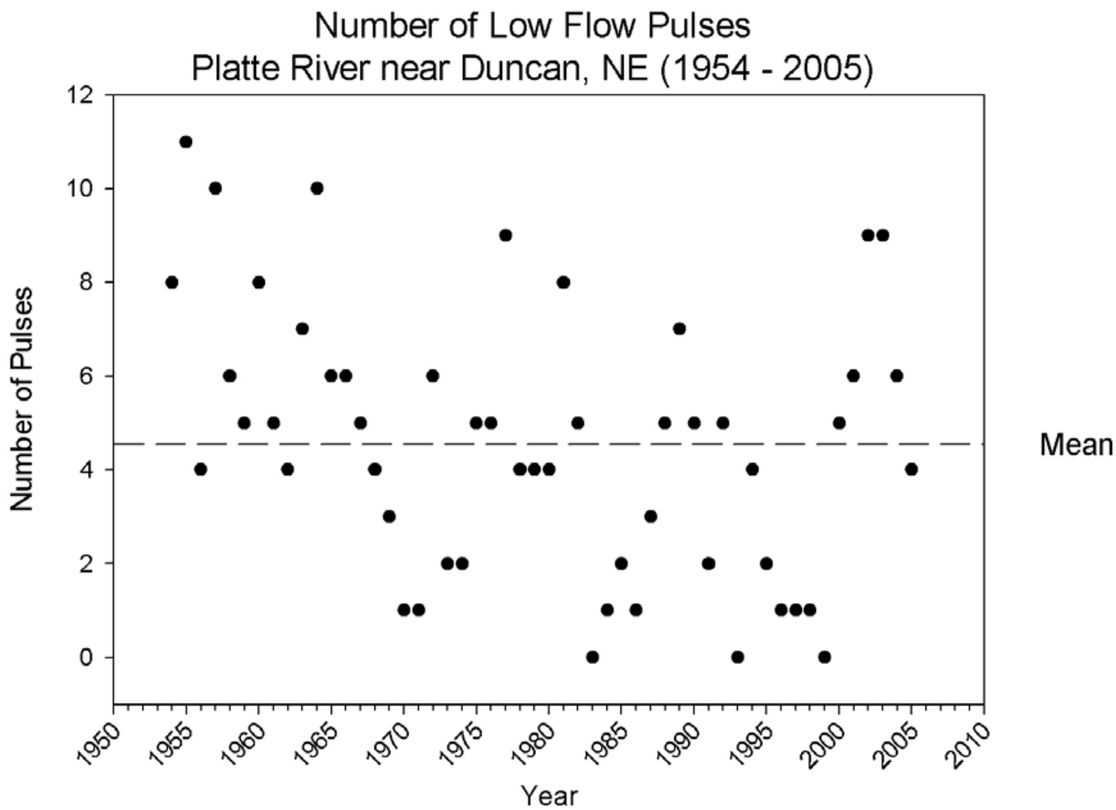
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

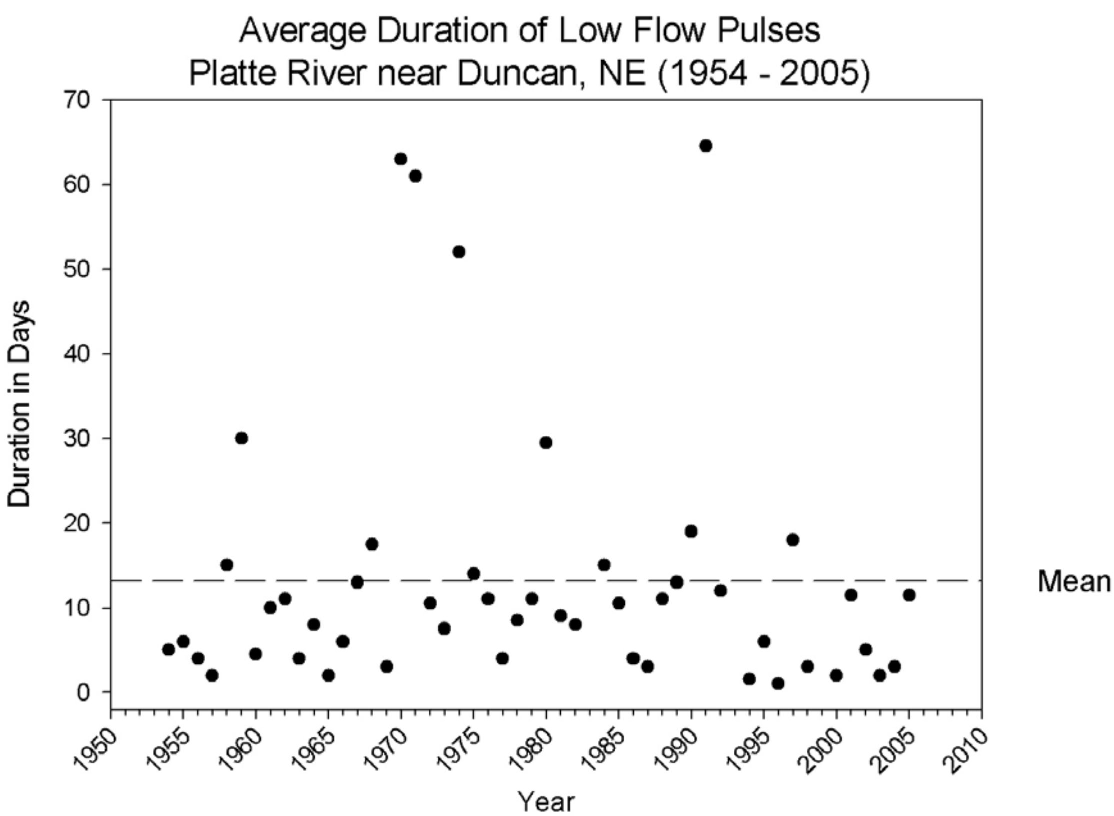


J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.


Date of Low Flow
Platte River near Duncan, NE (1954 - 2005)
December
November
October
September
August
July
June
May
April
March
February
January
Date
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year


Date of Maximum Flow
Platte River near Duncan, NE (1954 - 2005)
December
November
October
September
August
July
June
May
April
March
February
January
Date
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year





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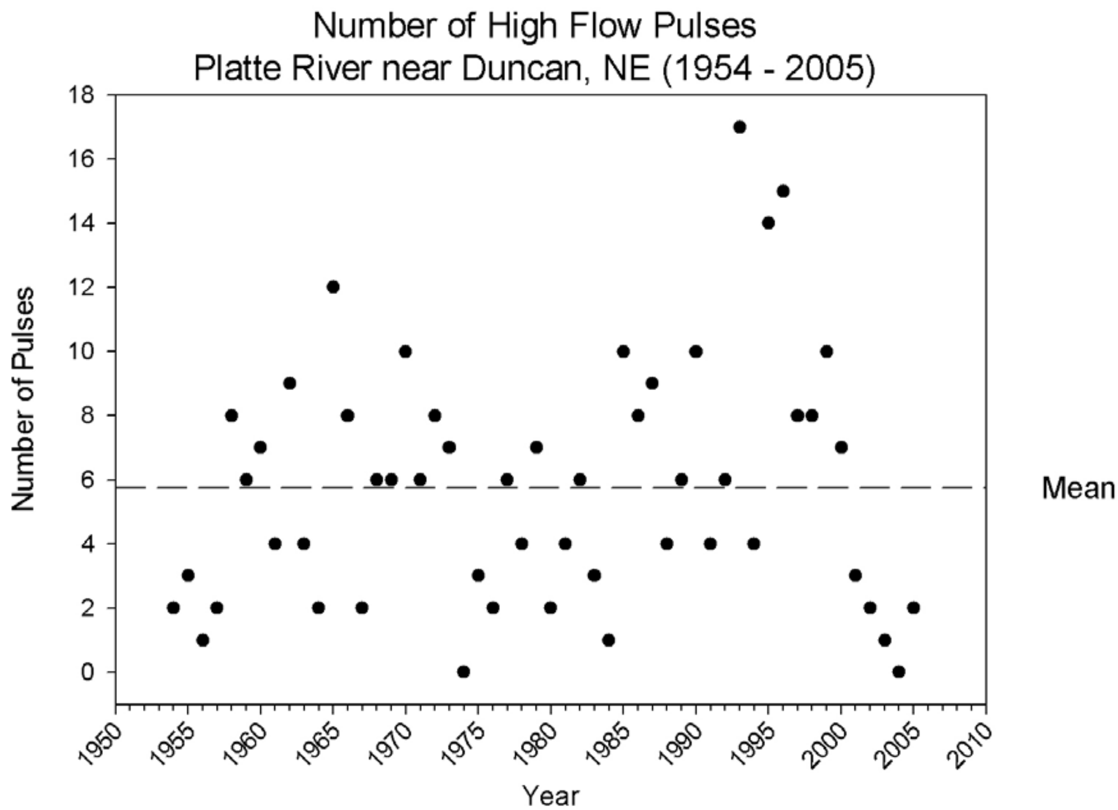
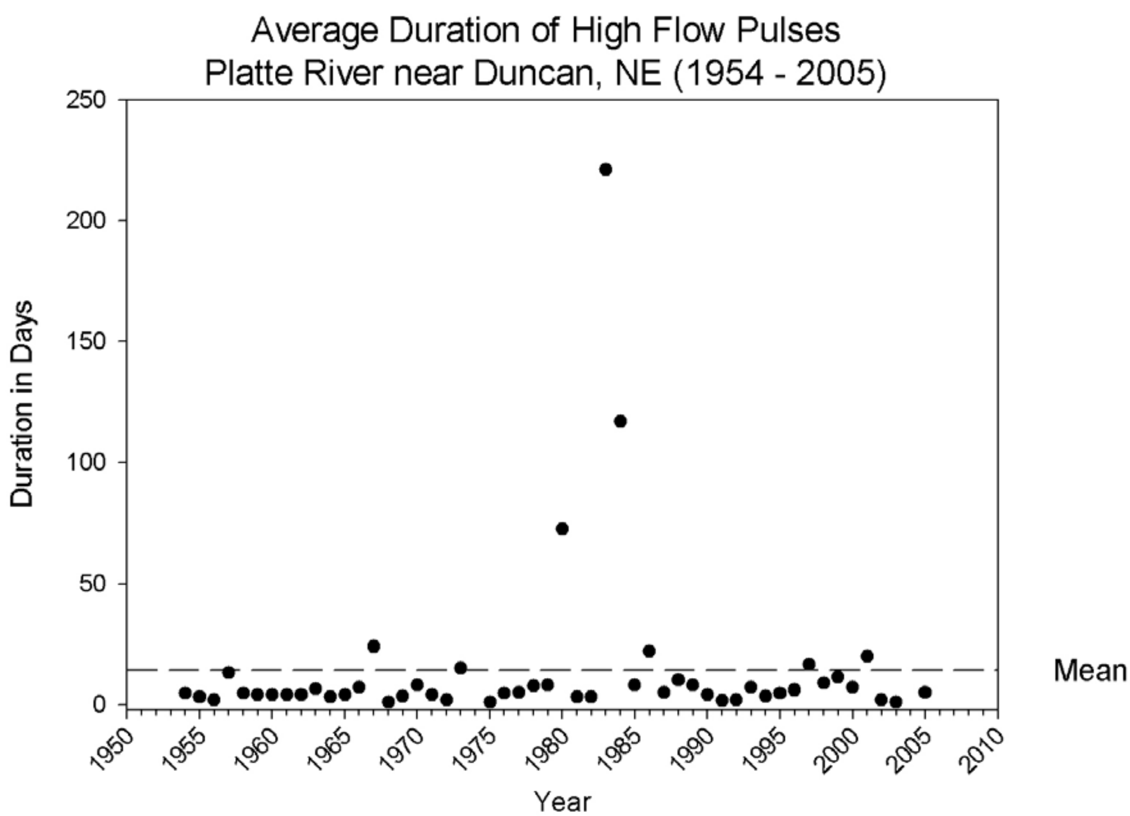
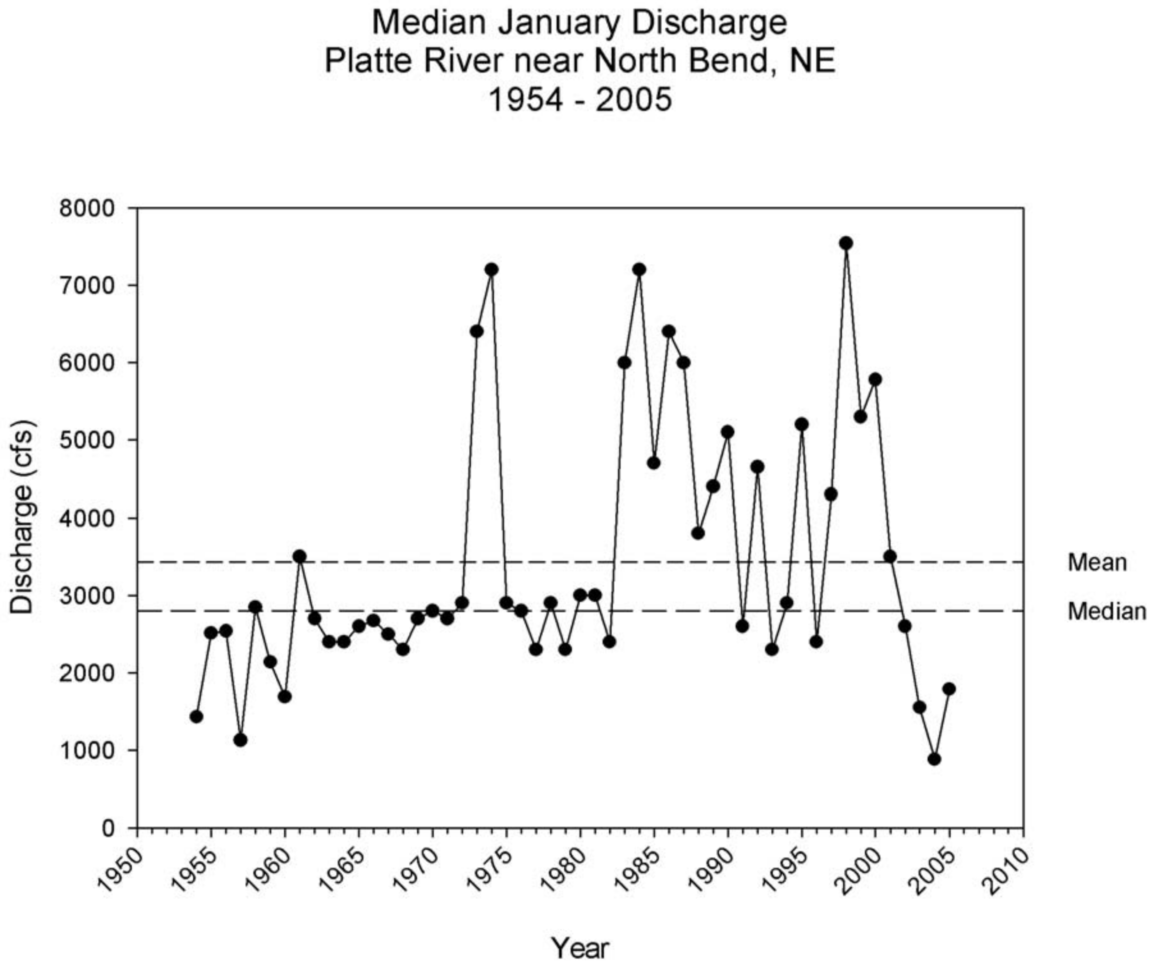

Number of High Flow Pulses
Platte River near Duncan, NE (1954 - 2005)
Number of Pulses
Mean
Year
0
2
4
6
8
10
12
14
16
18
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


Average Duration of High Flow Pulses
Platte River near Duncan, NE (1954 - 2005)
Duration in Days
Mean
Year
0
50
100
150
200
250
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010



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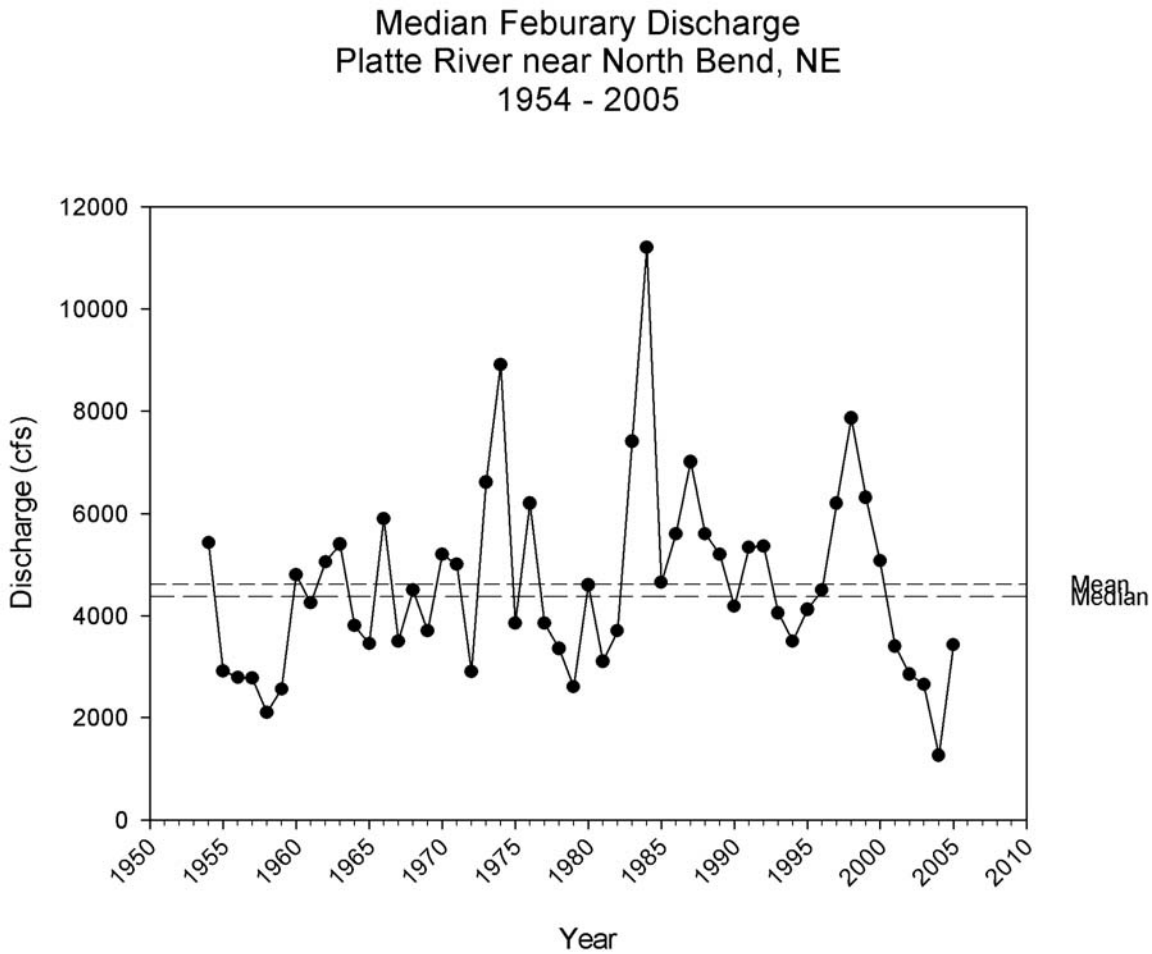
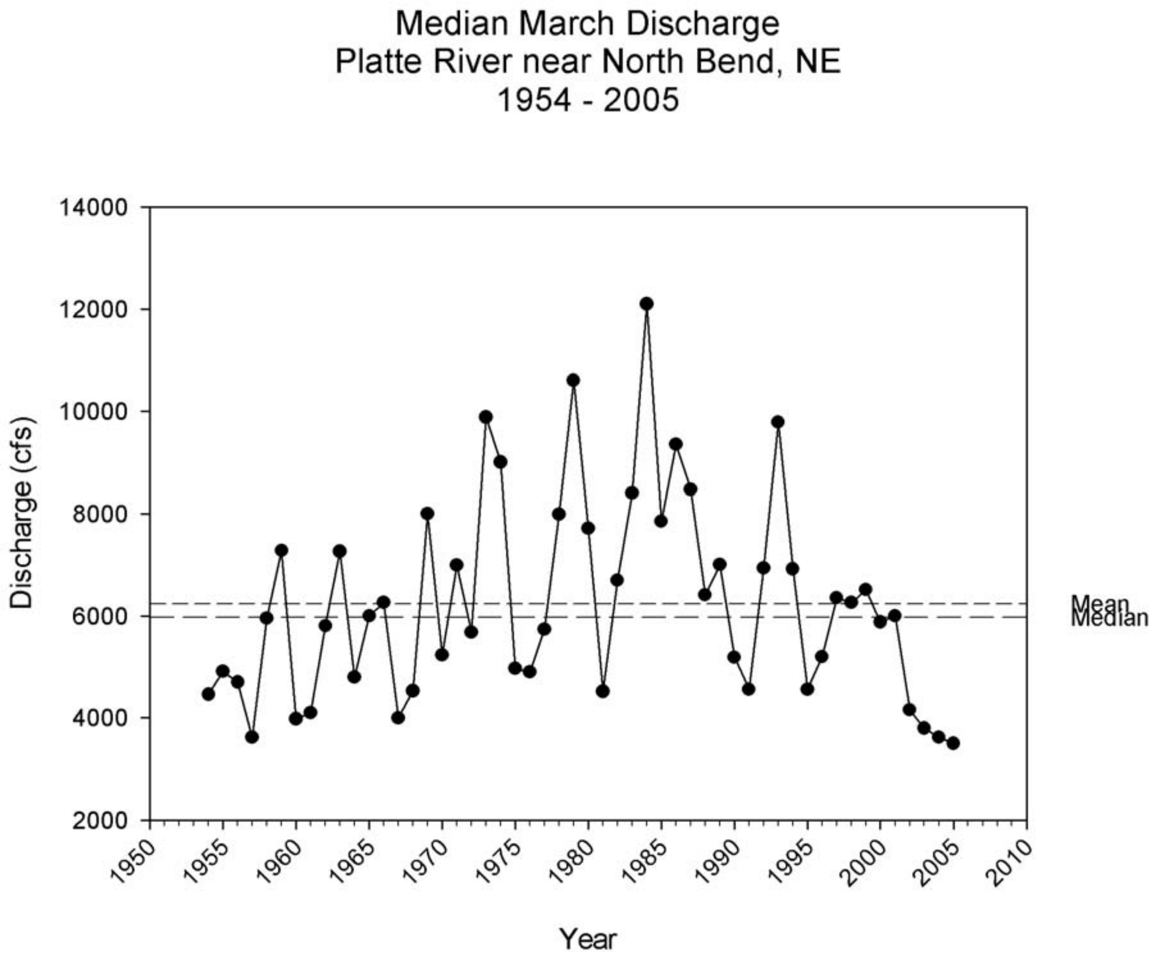
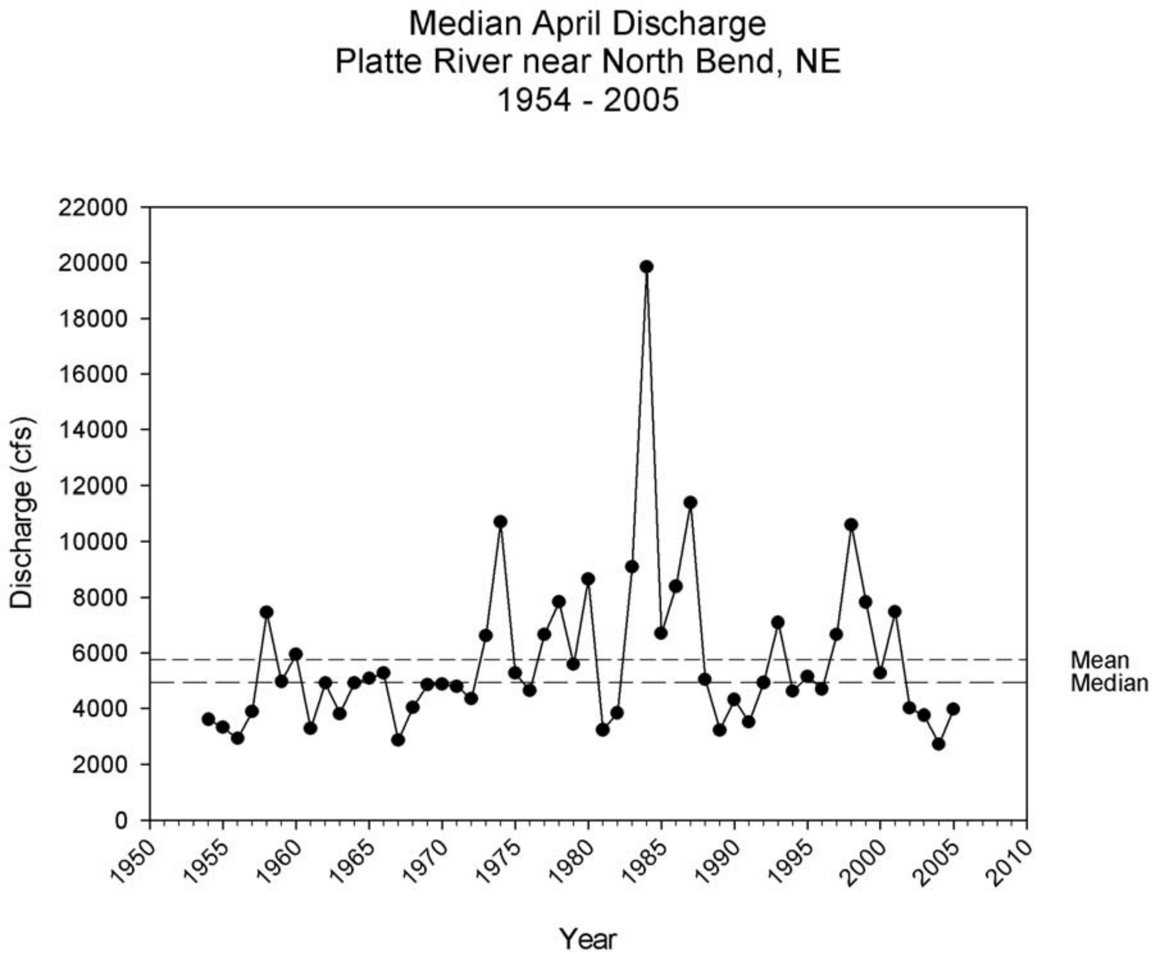


J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



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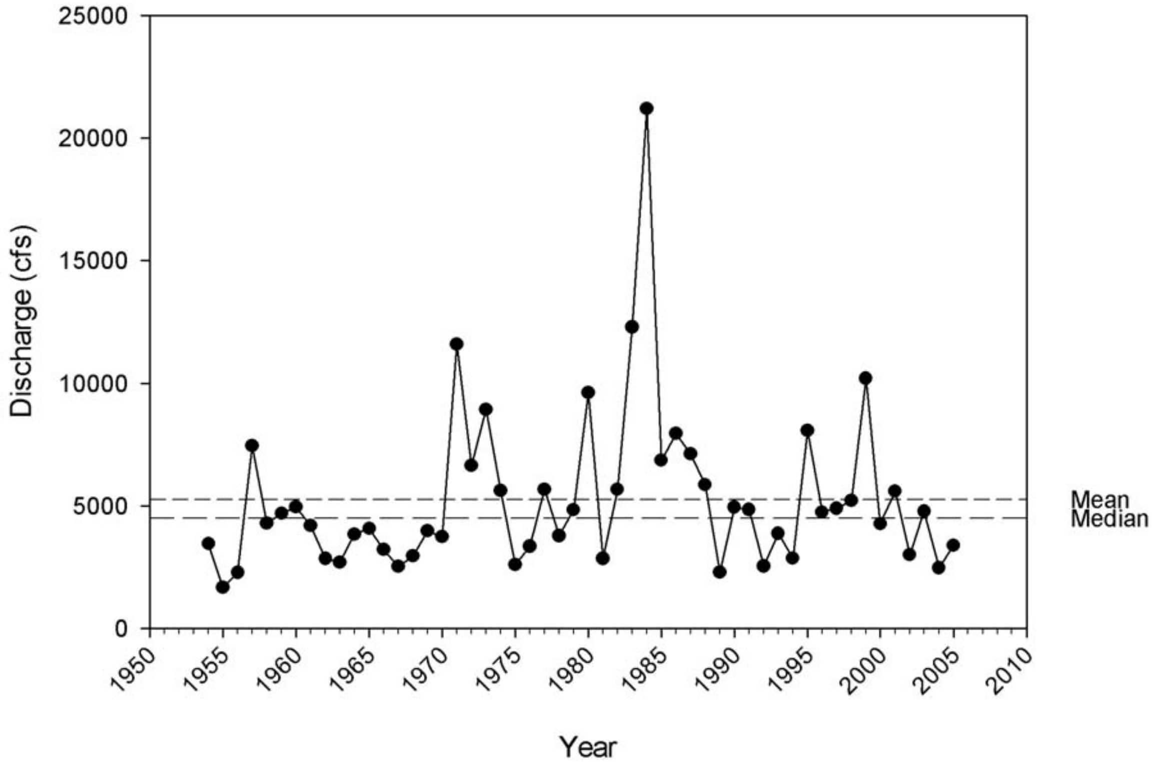
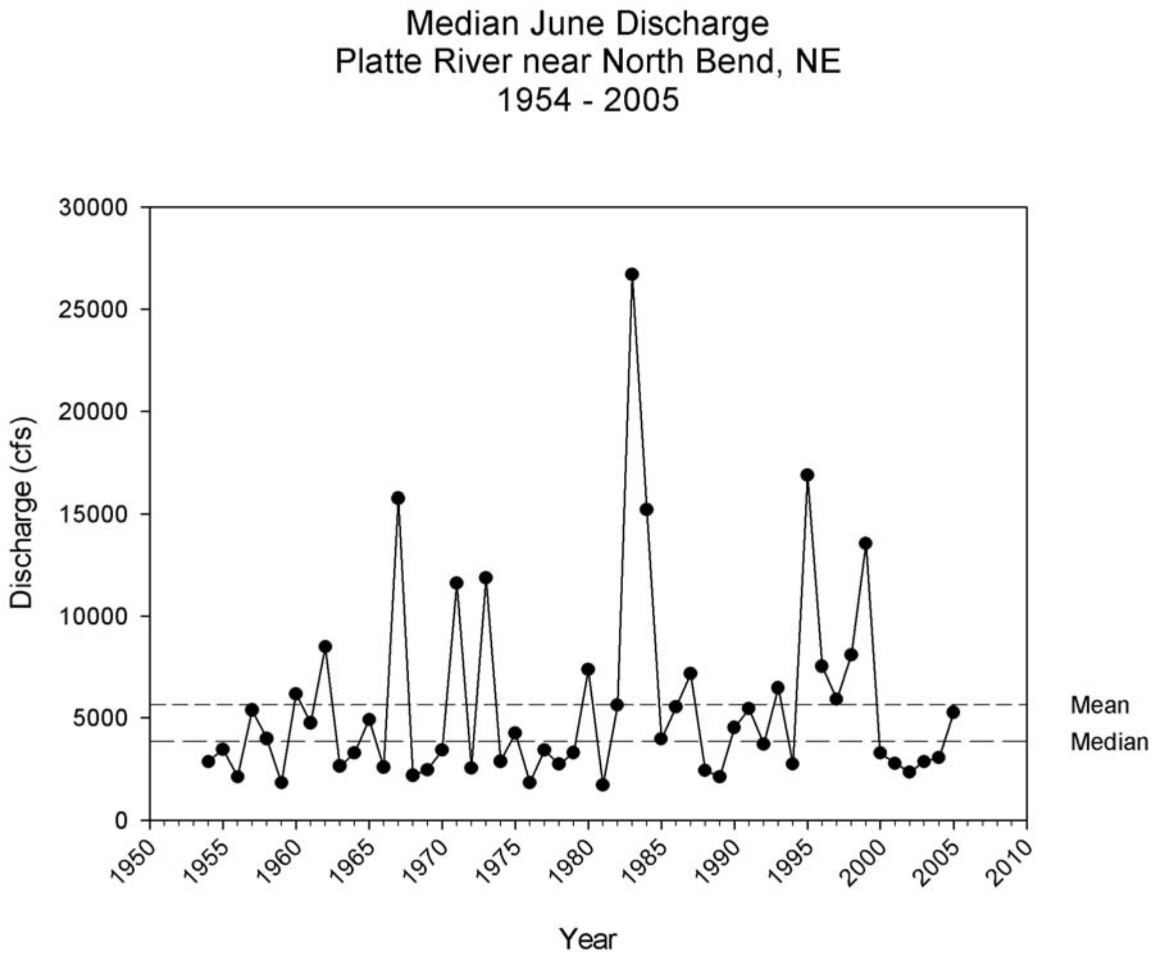
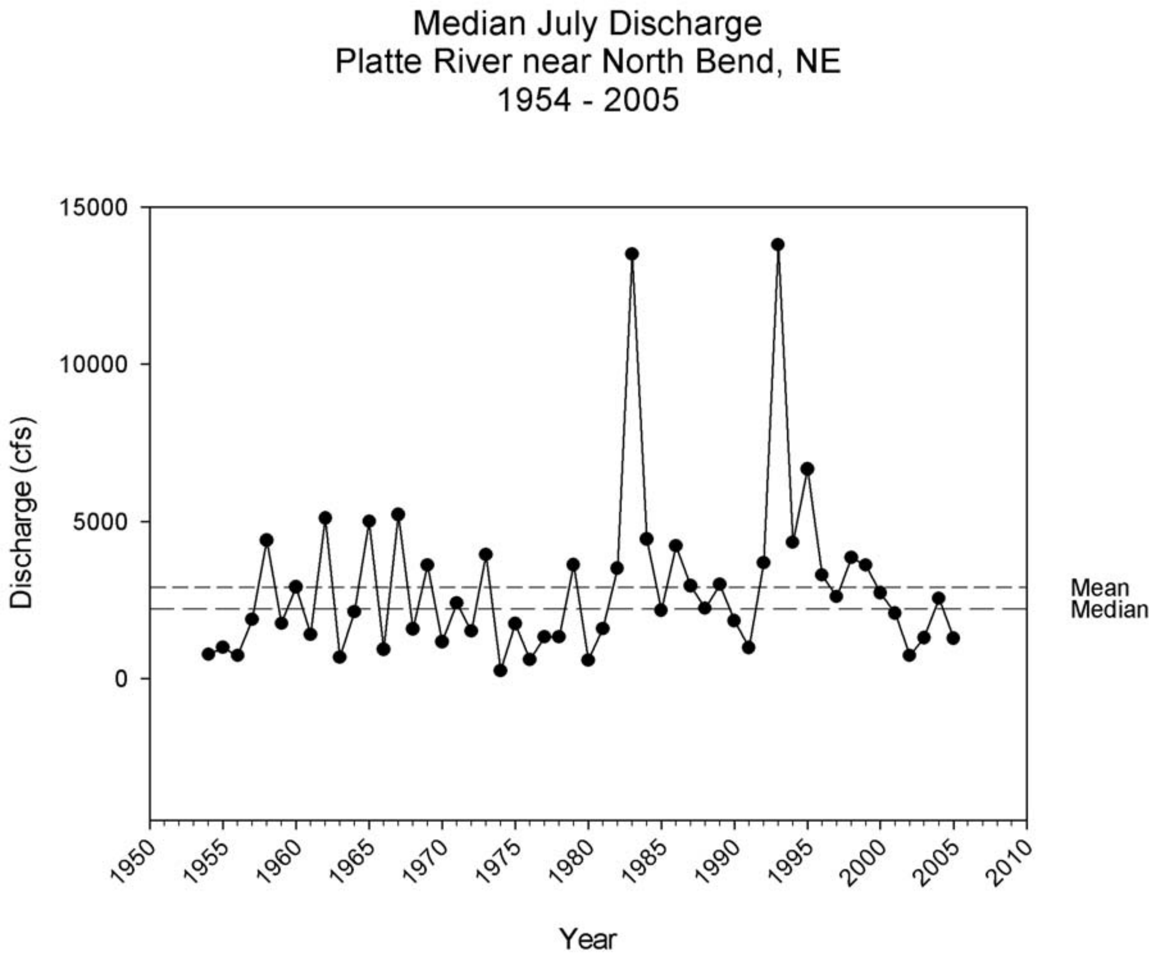
Median May Discharge
Platte River near North Bend, NE
1954 - 2005



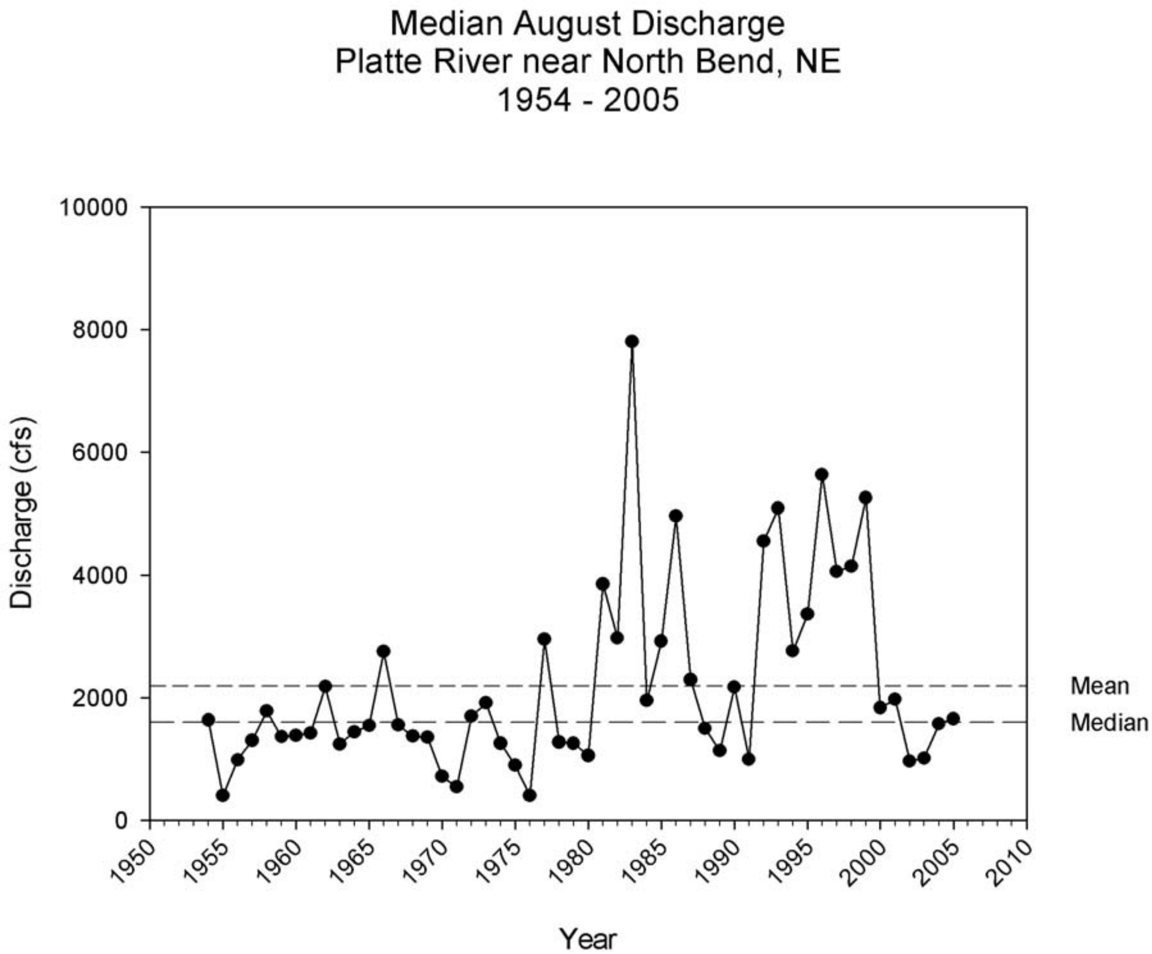
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



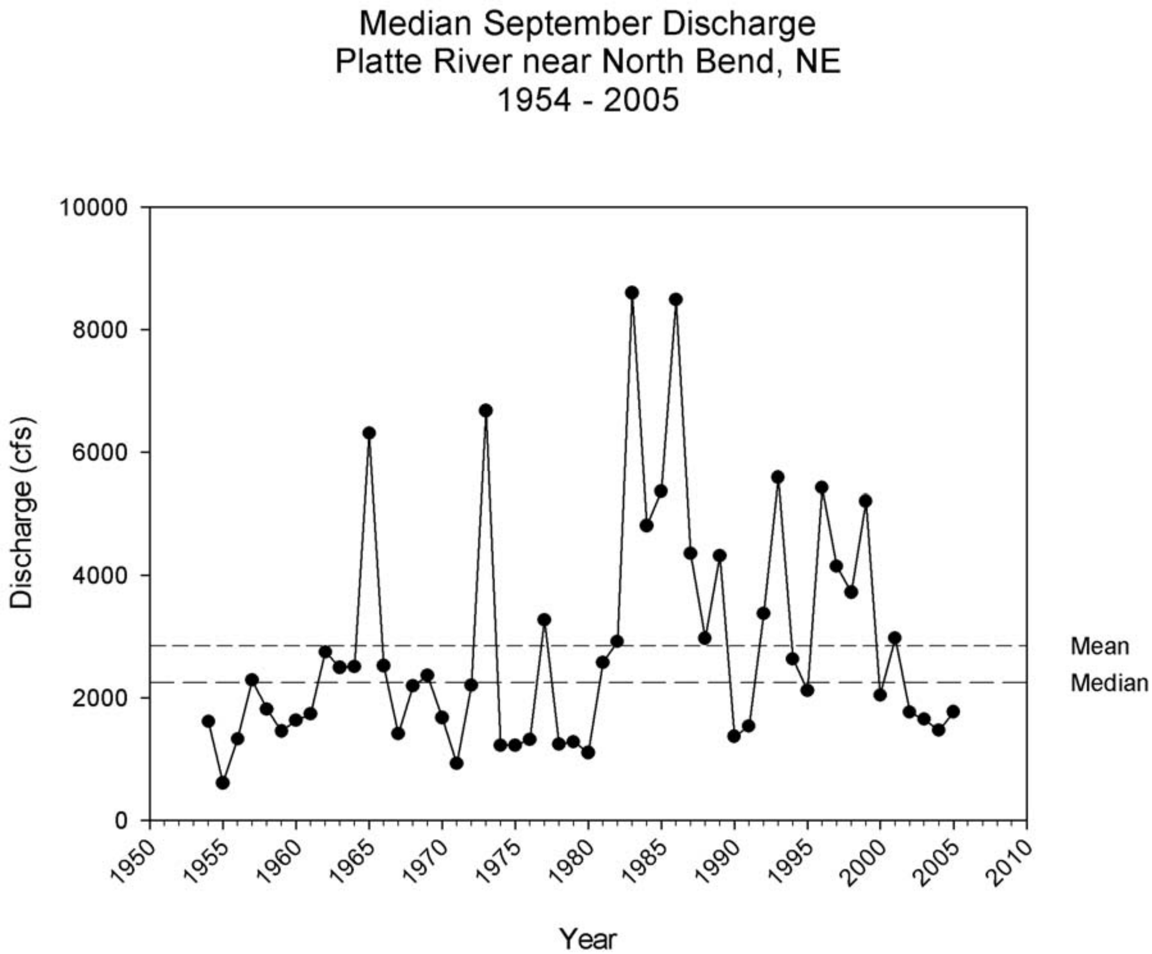
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



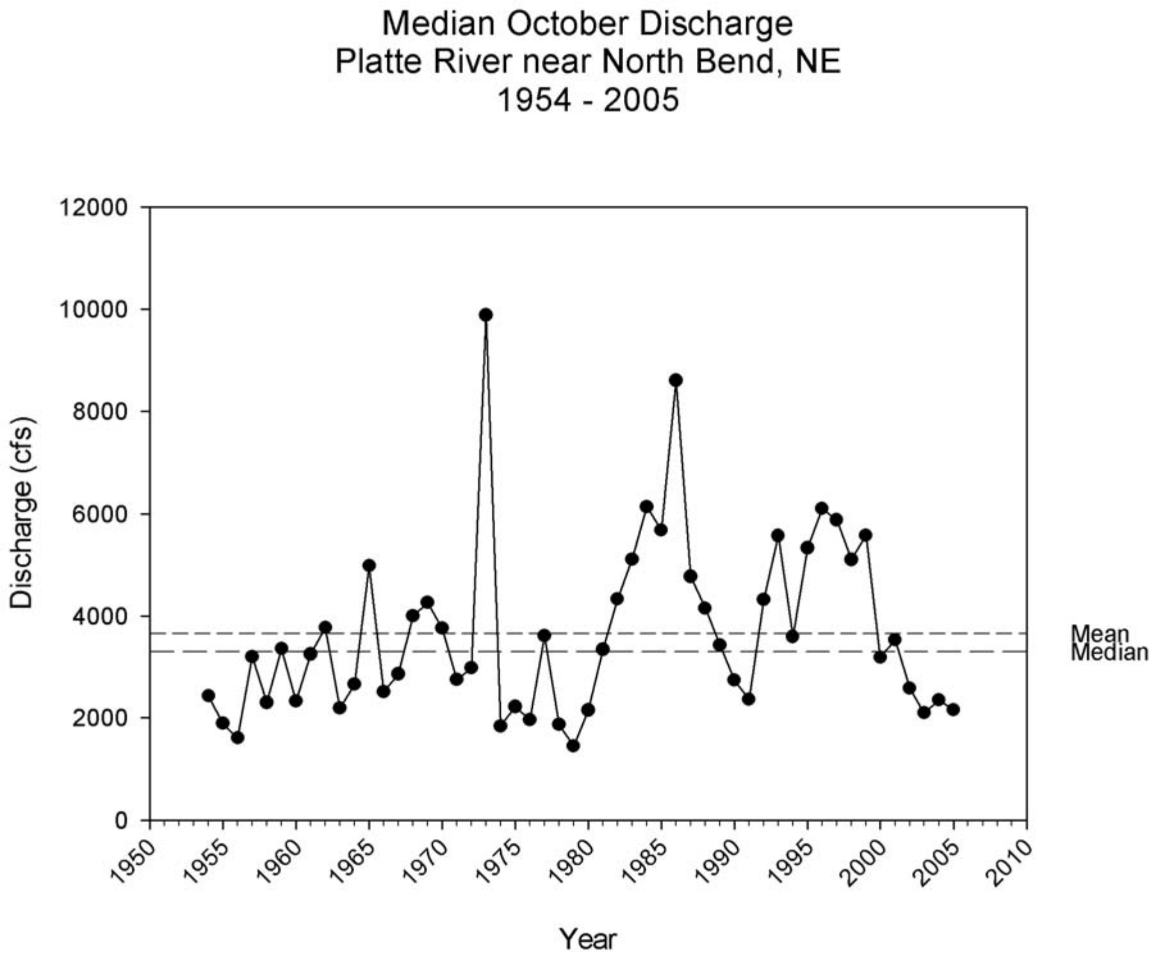
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

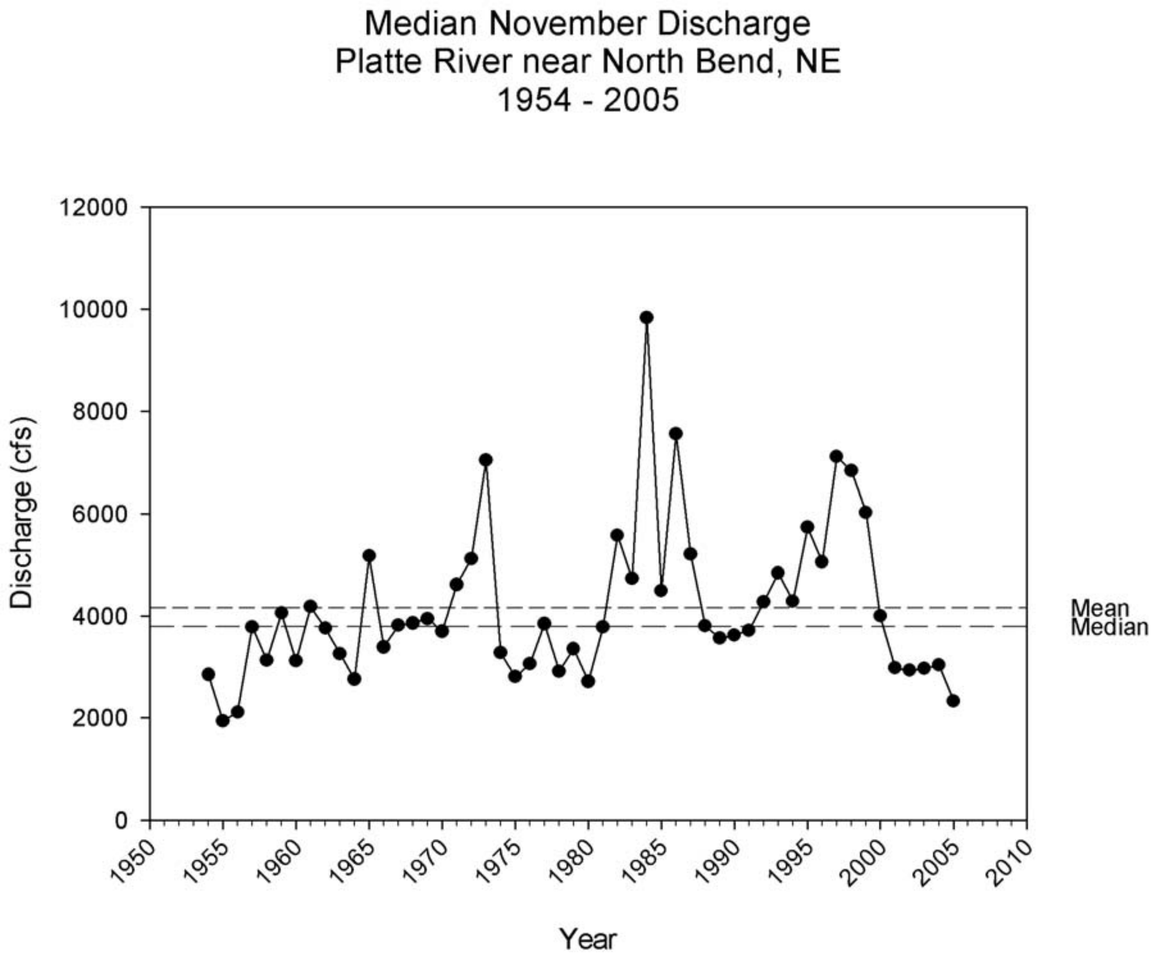


J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

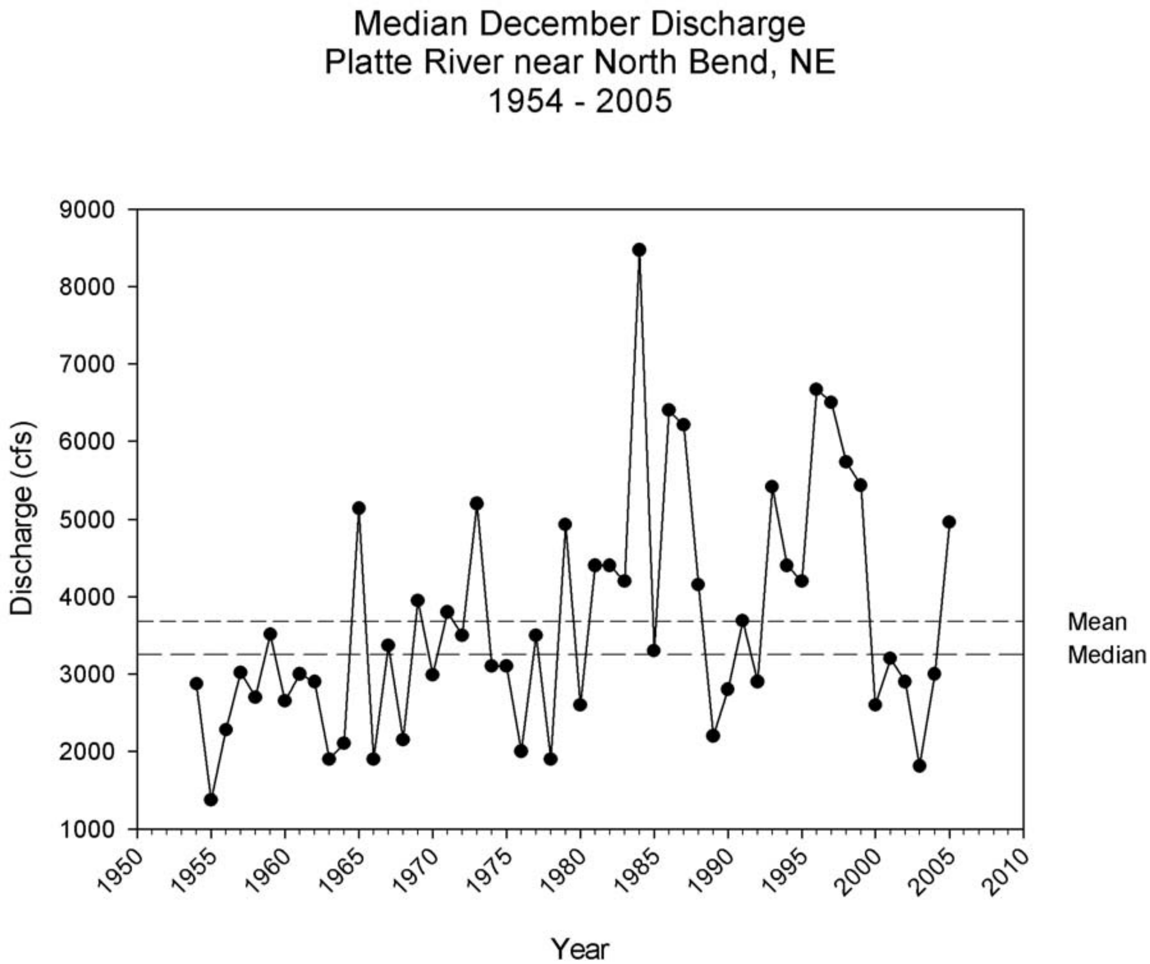


Median September Discharge
Platte River near North Bend, NE
1954 - 2005
Discharge (cfs)
10000
8000
6000
4000
2000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

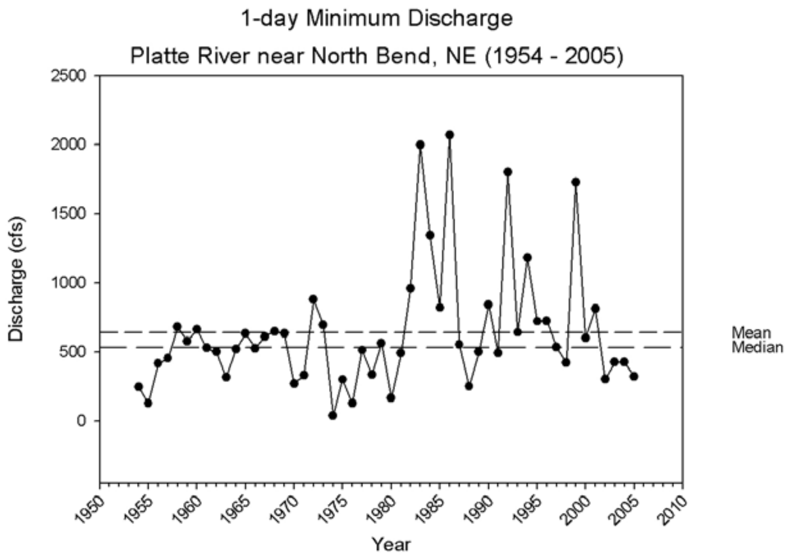

Median October Discharge
Platte River near North Bend, NE
1954 - 2005
Discharge (cfs)
12000
10000
8000
6000
4000
2000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median

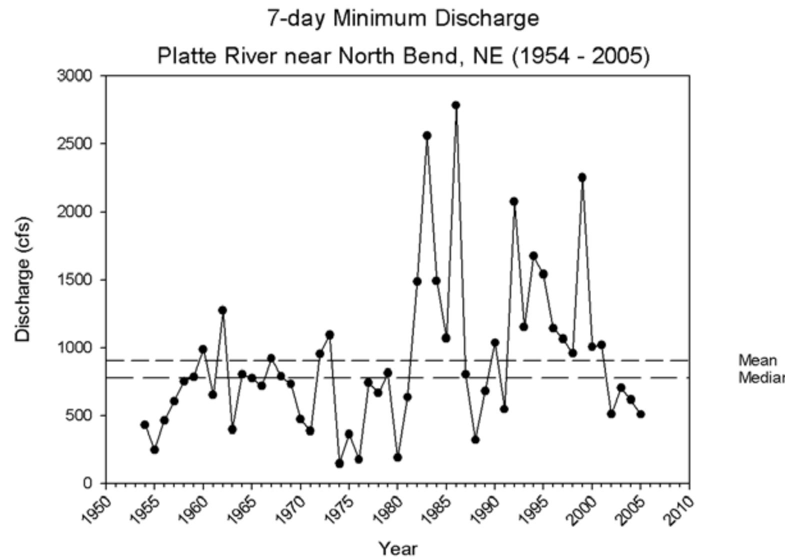


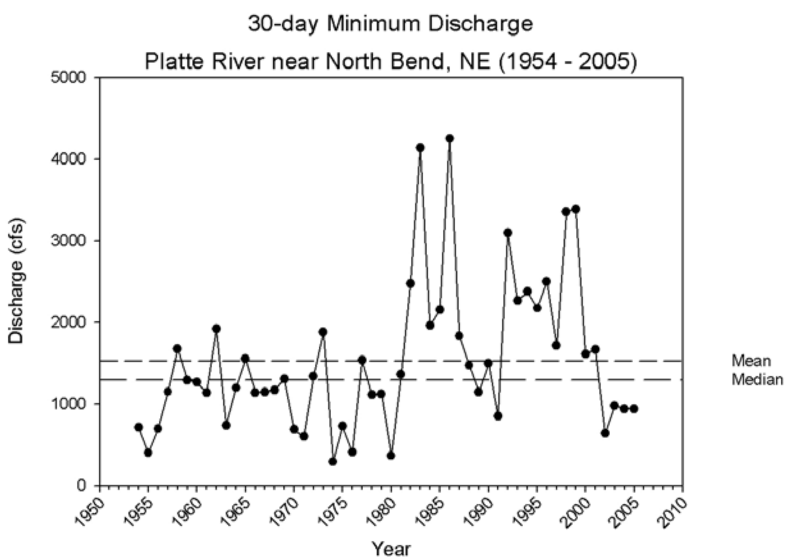
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

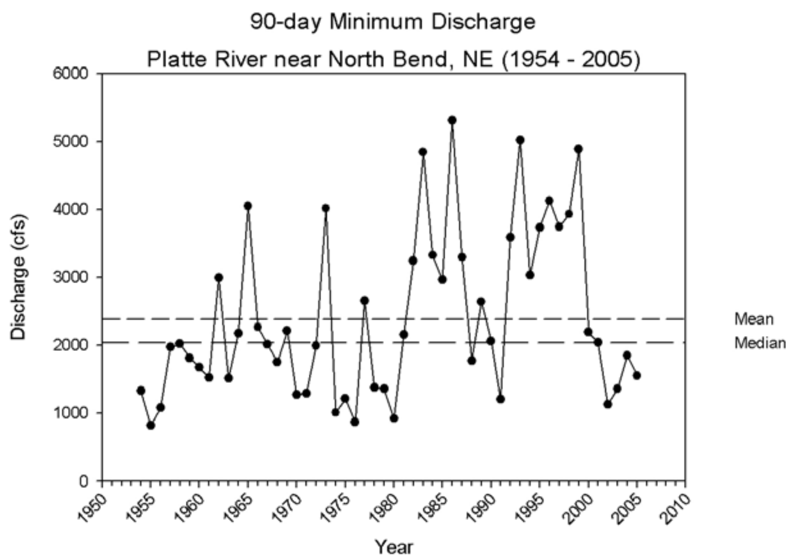


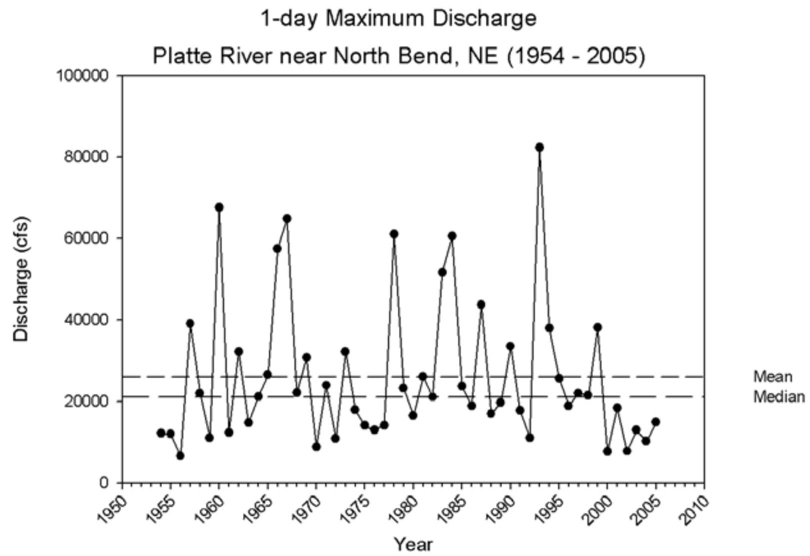
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

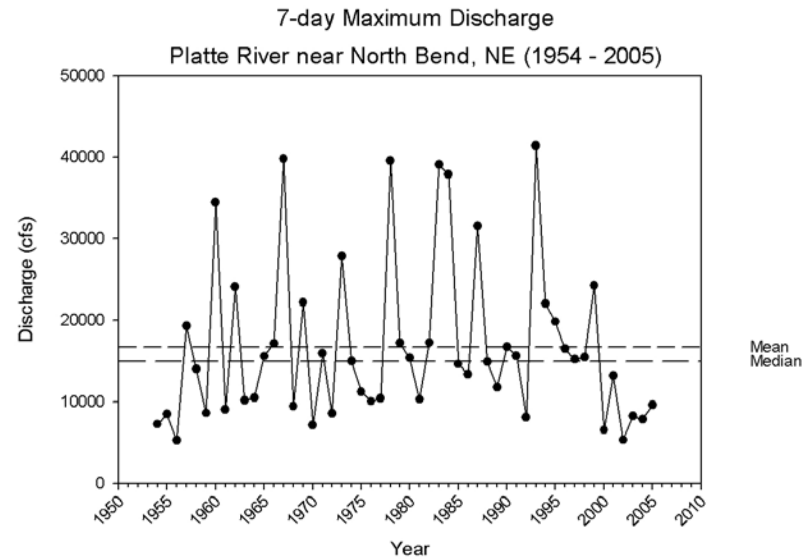

1-day Minimum Discharge
Platte River near North Bend, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median

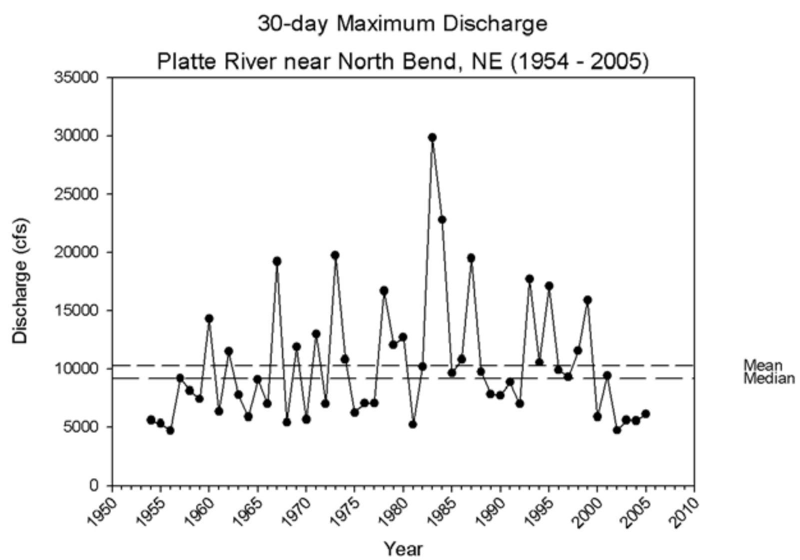

7-day Minimum Discharge
Platte River near North Bend, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median

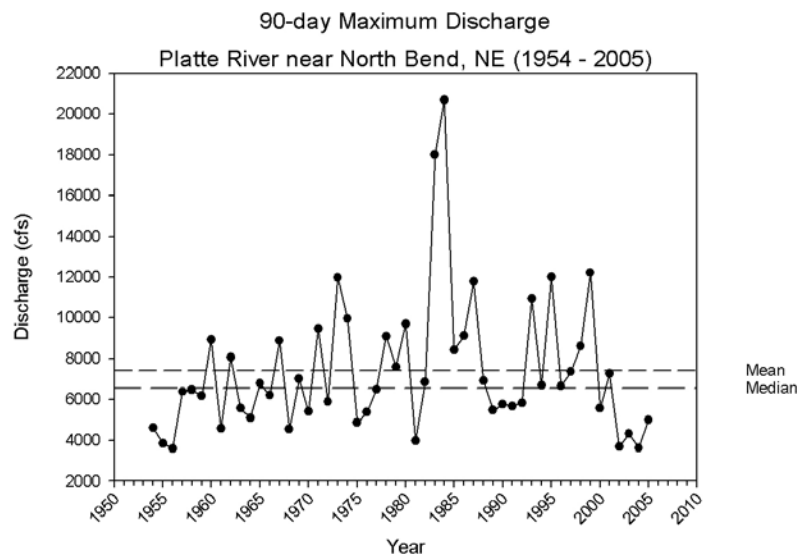

30-day Minimum Discharge
Platte River near North Bend, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median

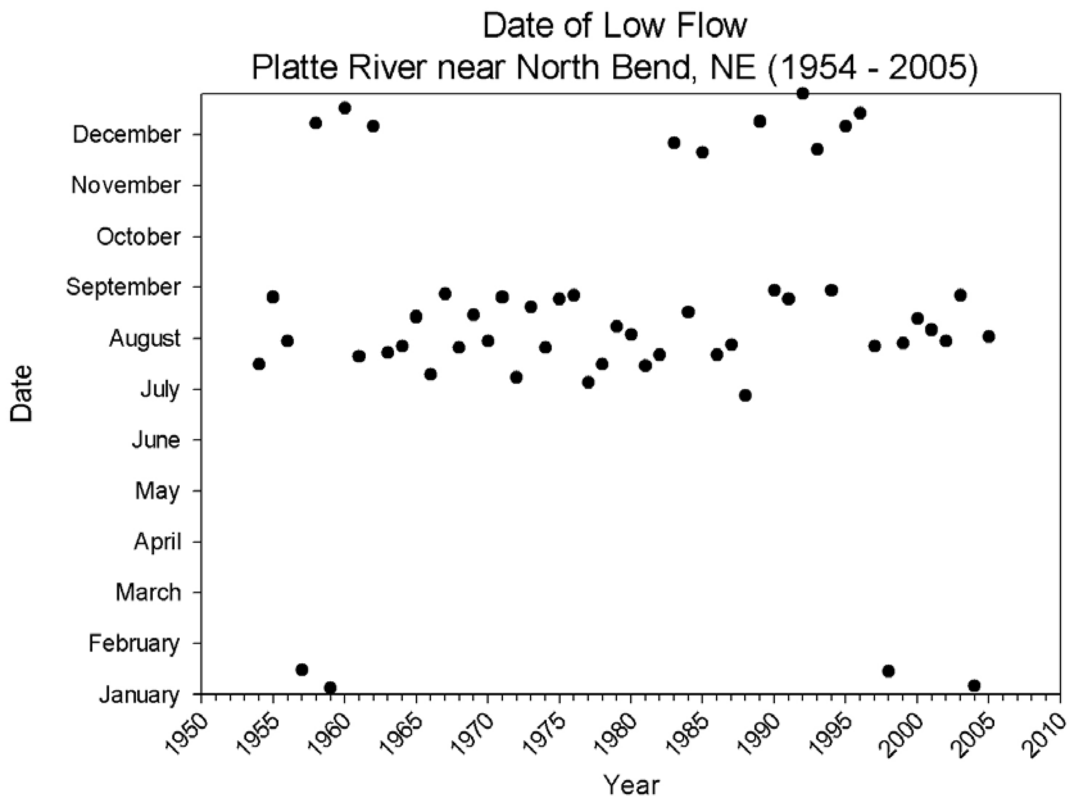

90-day Minimum Discharge
Platte River near North Bend, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median

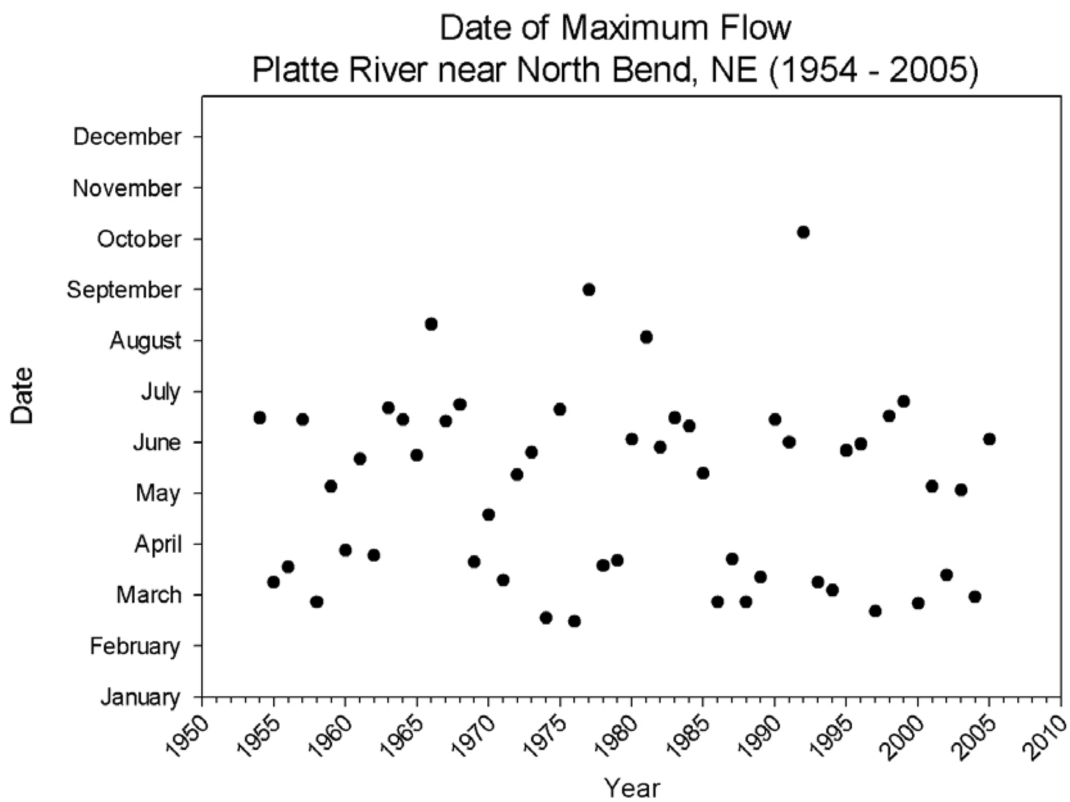

1-day Maximum Discharge
Platte River near North Bend, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median

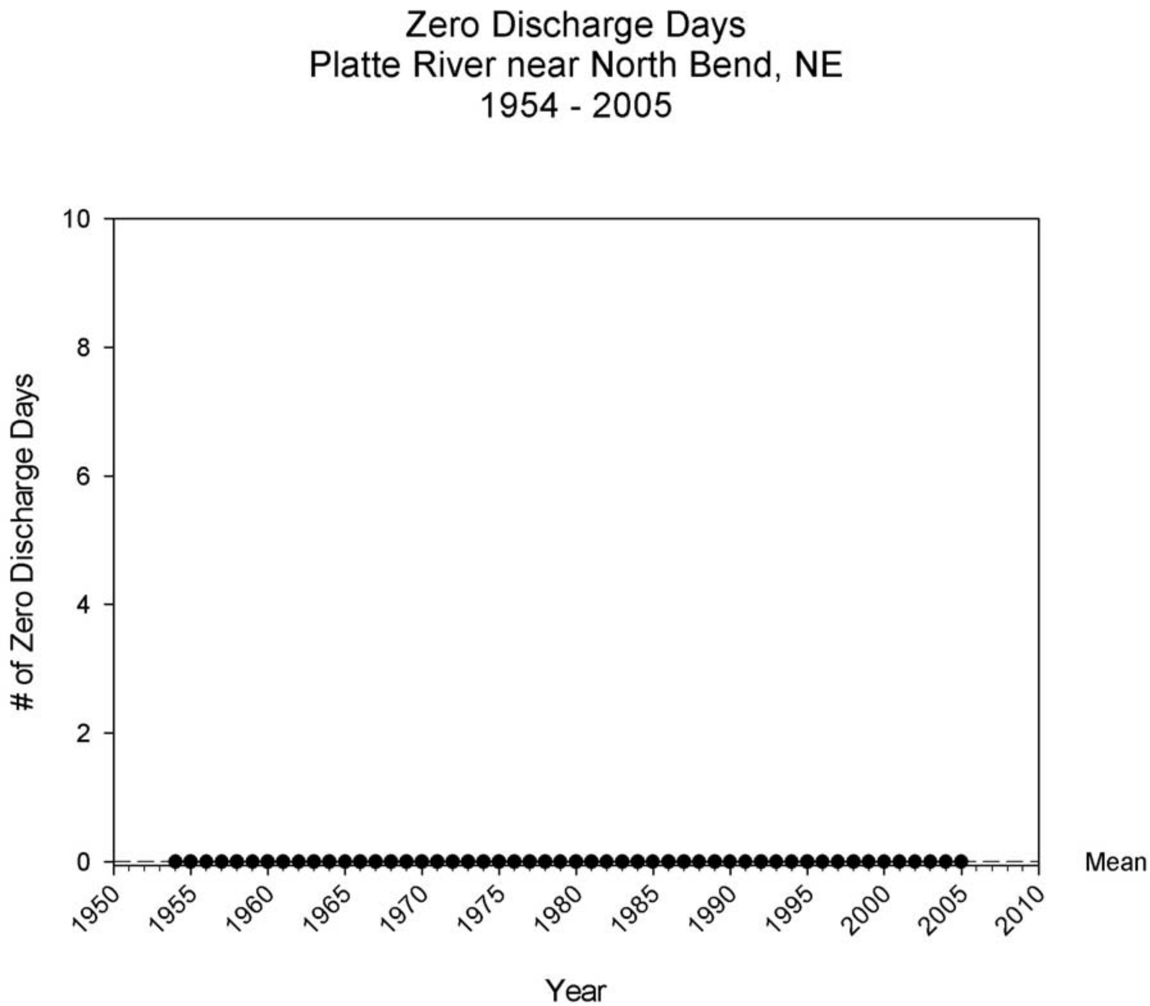

7-day Maximum Discharge
Platte River near North Bend, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median

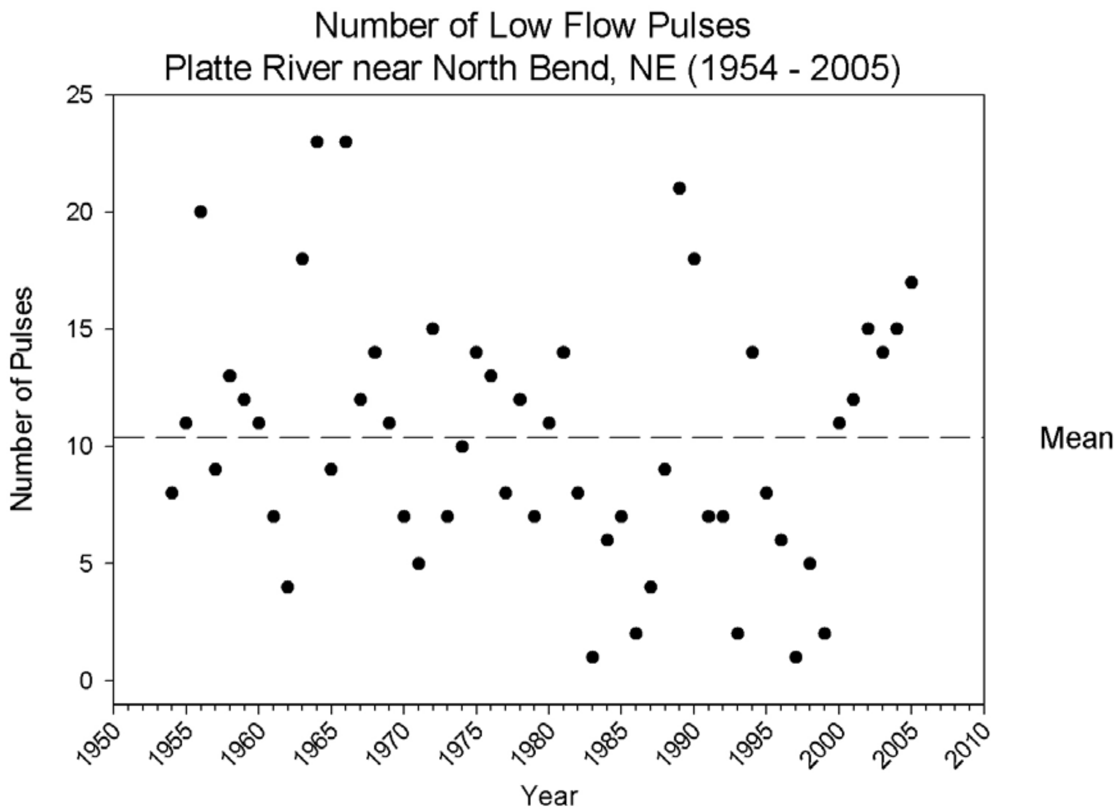

30-day Maximum Discharge
Platte River near North Bend, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median

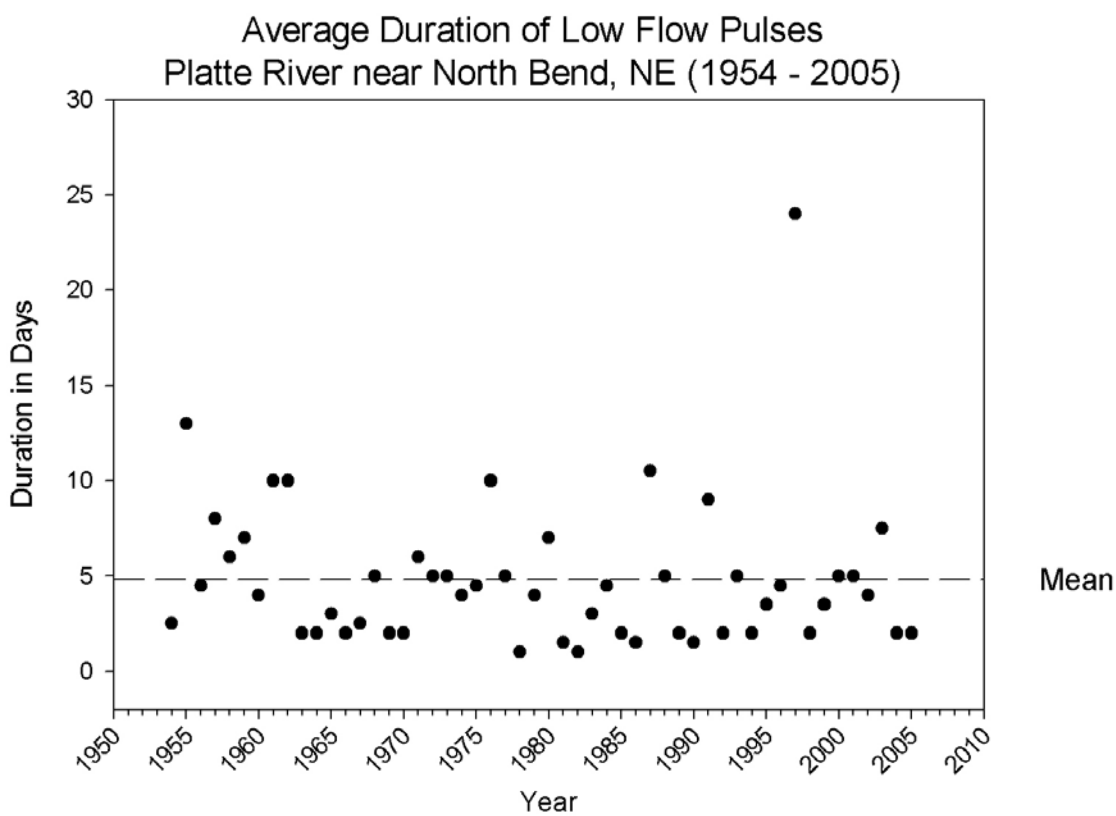

90-day Maximum Discharge
Platte River near North Bend, NE (1954 - 2005)
Discharge (cfs)
Year
Mean
Median


Date of Low Flow
Platte River near North Bend, NE (1954 - 2005)
Date
December
November
October
September
August
July
June
May
April
March
February
January
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

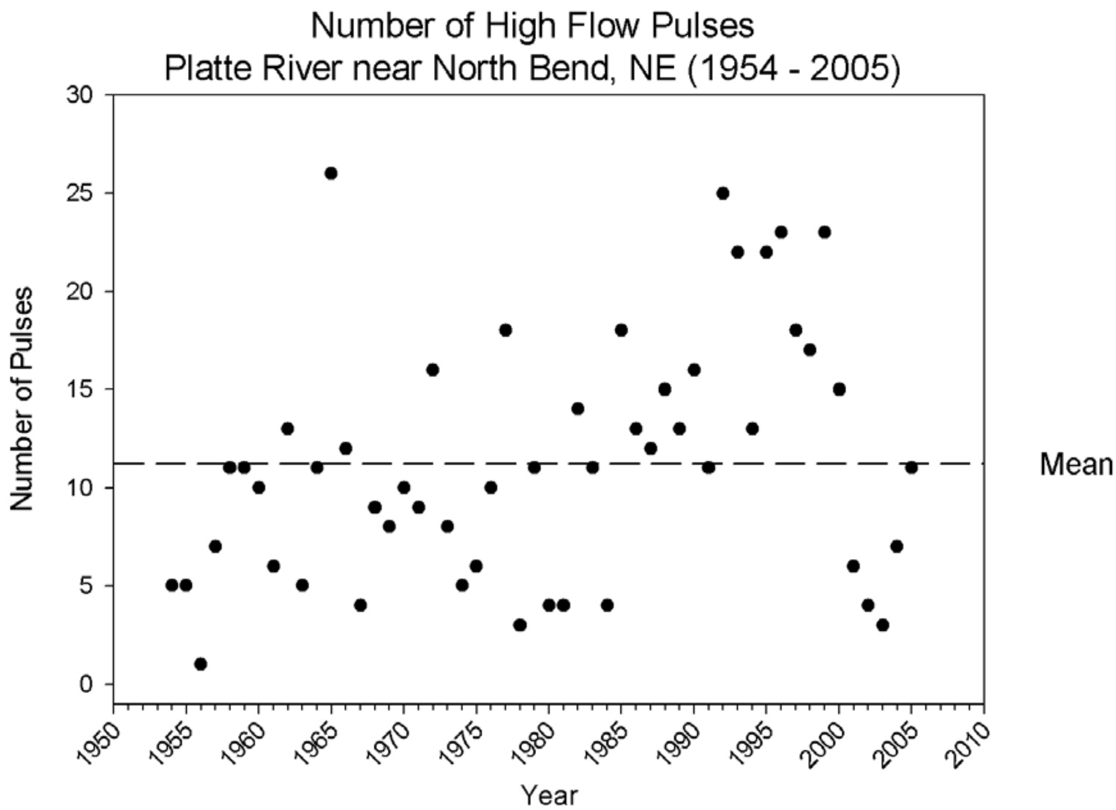

Date of Maximum Flow
Platte River near North Bend, NE (1954 - 2005)
Date
December
November
October
September
August
July
June
May
April
March
February
January
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

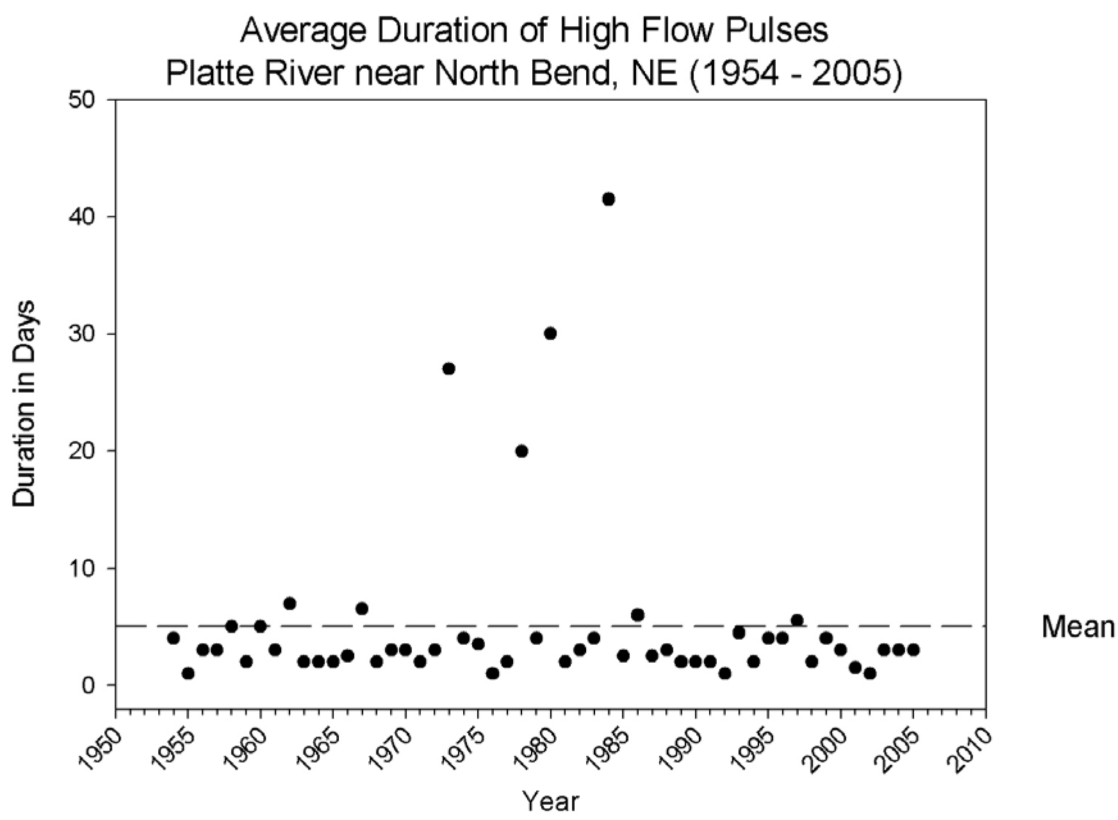

Zero Discharge Days
Platte River near North Bend, NE
1954 - 2005
# of Zero Discharge Days
Year
Mean
0
2
4
6
8
10
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010



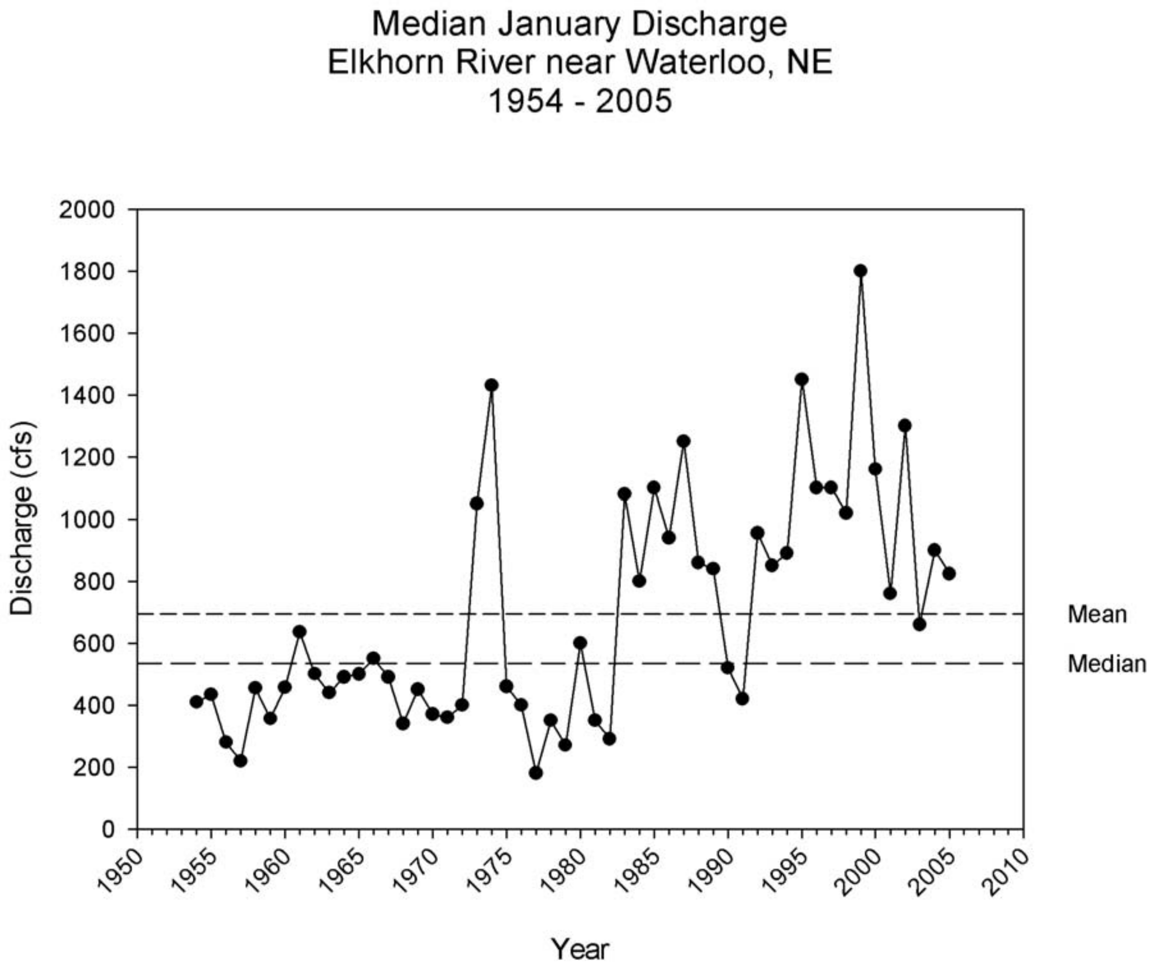


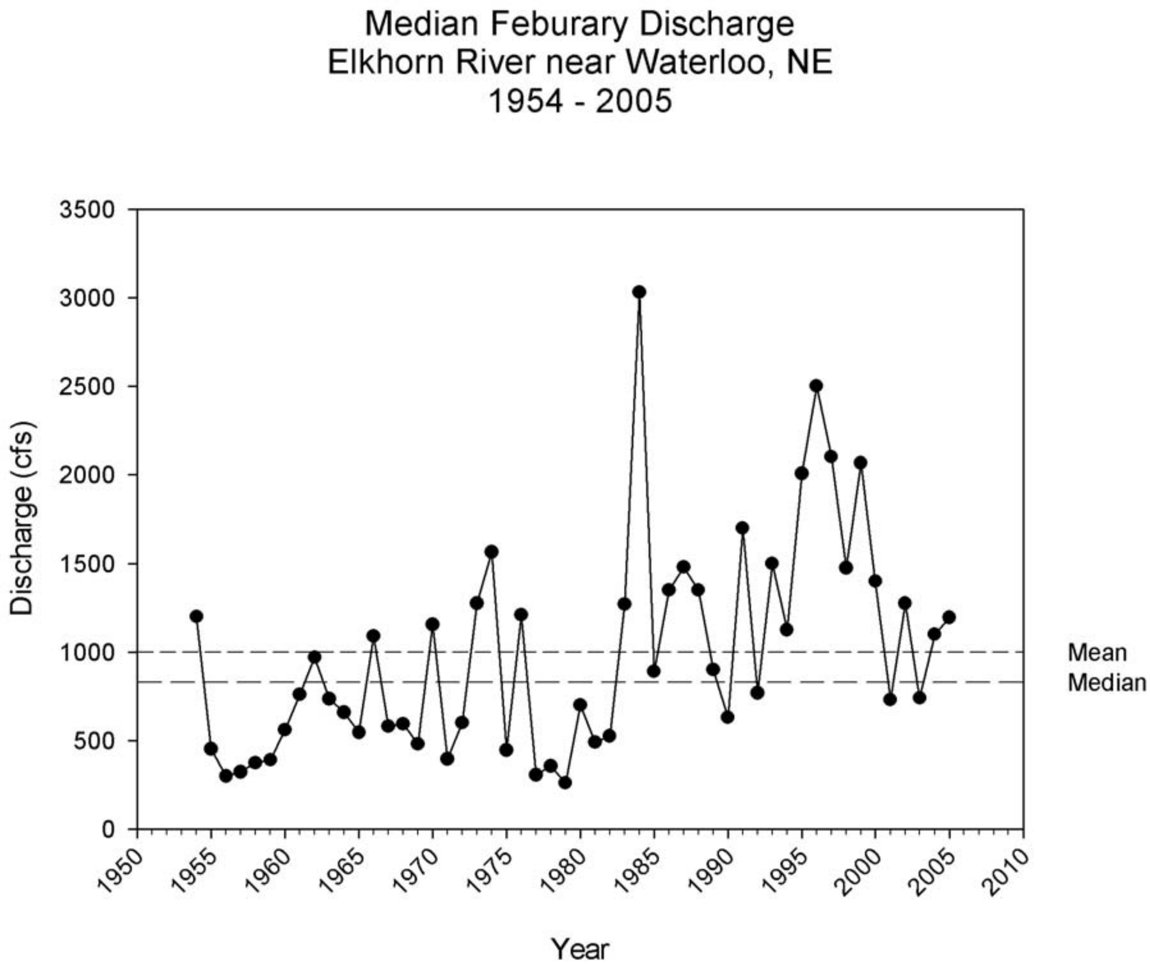
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

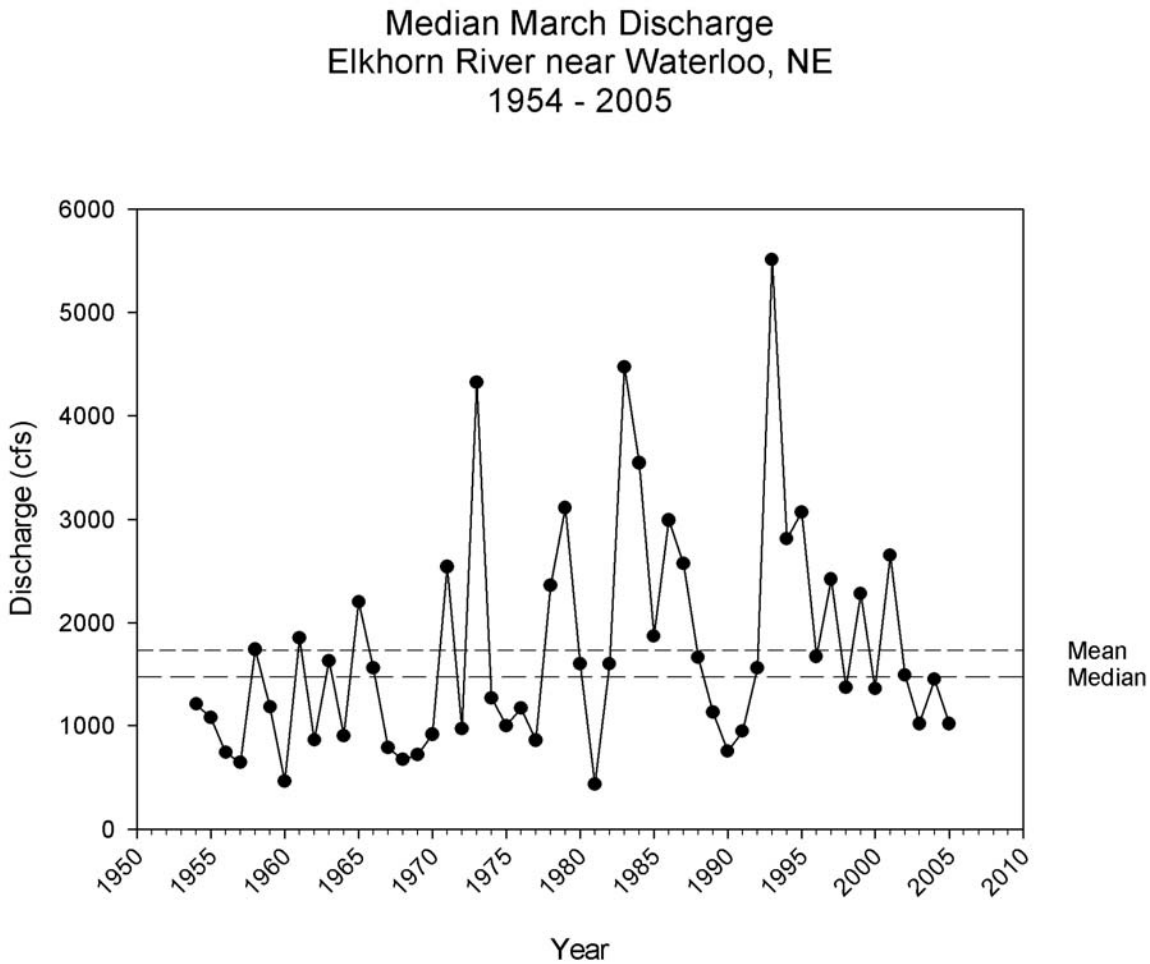


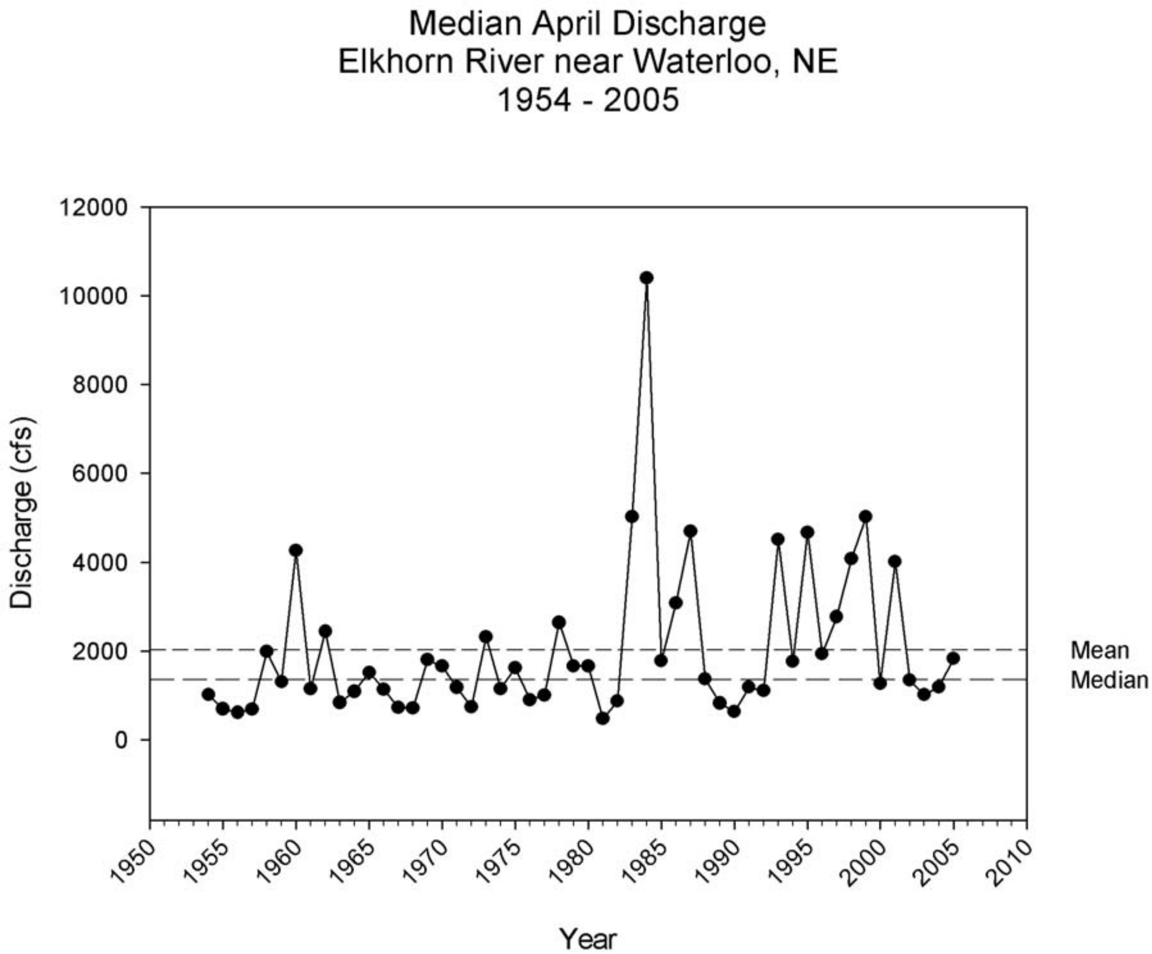


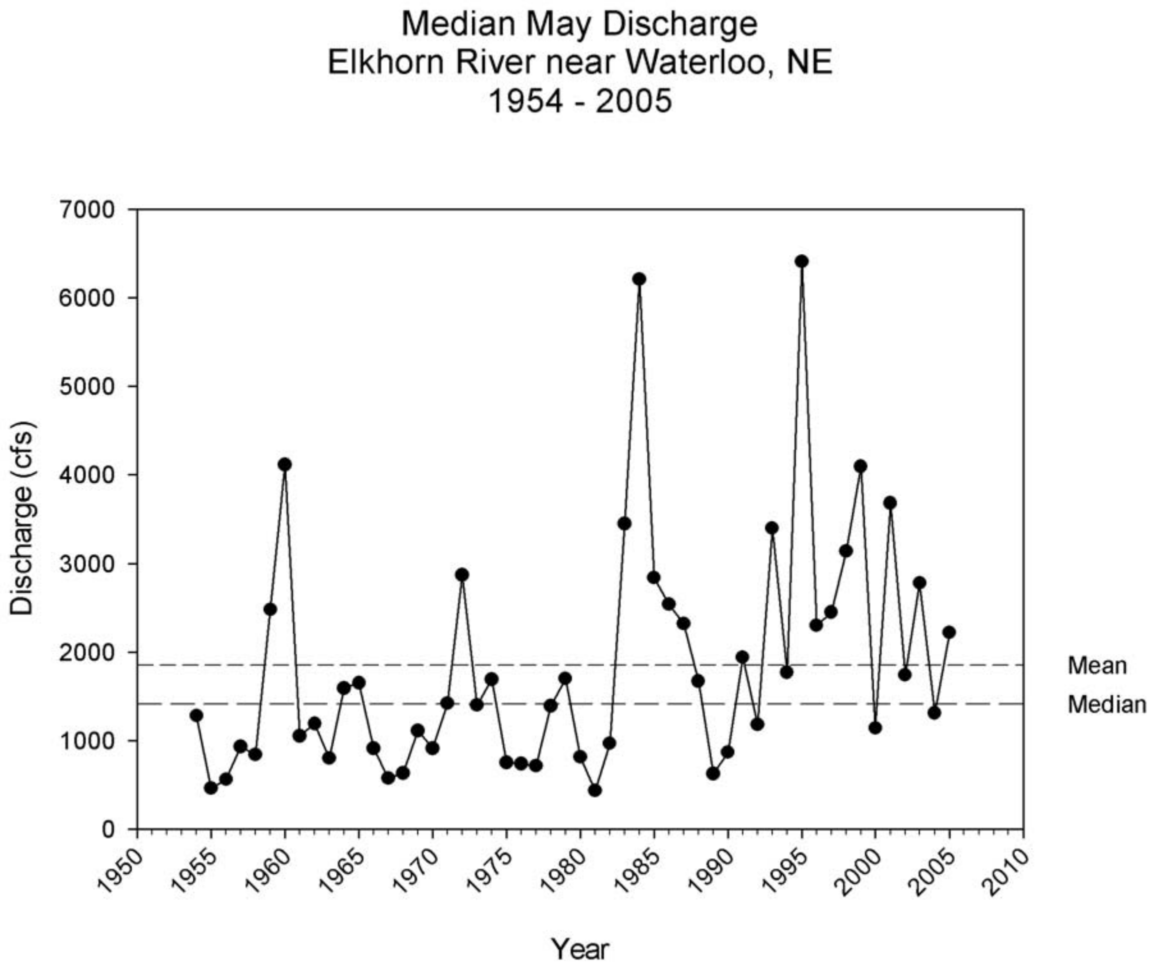
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.


Median January Discharge
Elkhorn River near Waterloo, NE
1954 - 2005
Discharge (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

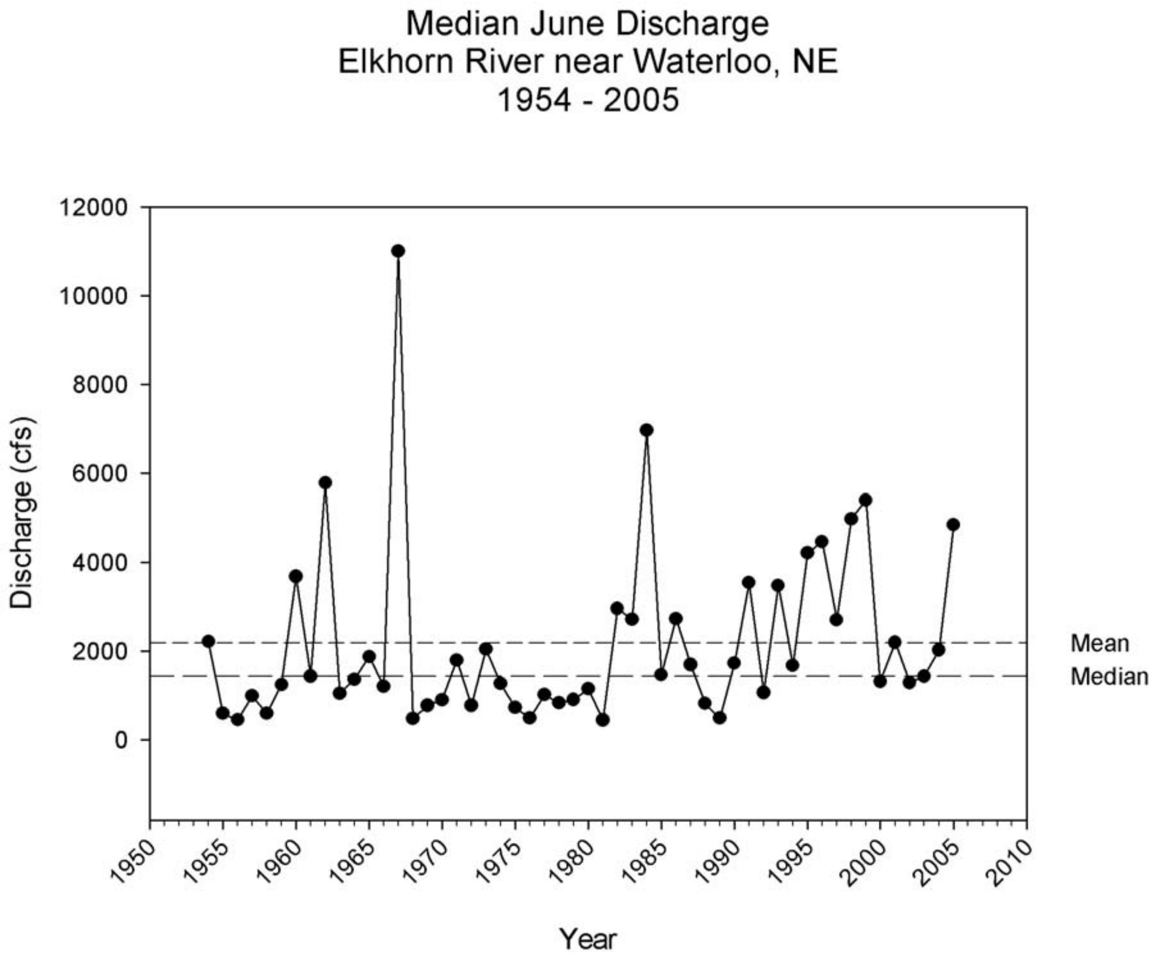

Median Feburary Discharge
Elkhorn River near Waterloo, NE
1954 - 2005
Discharge (cfs)
0
500
1000
1500
2000
2500
3000
3500
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median

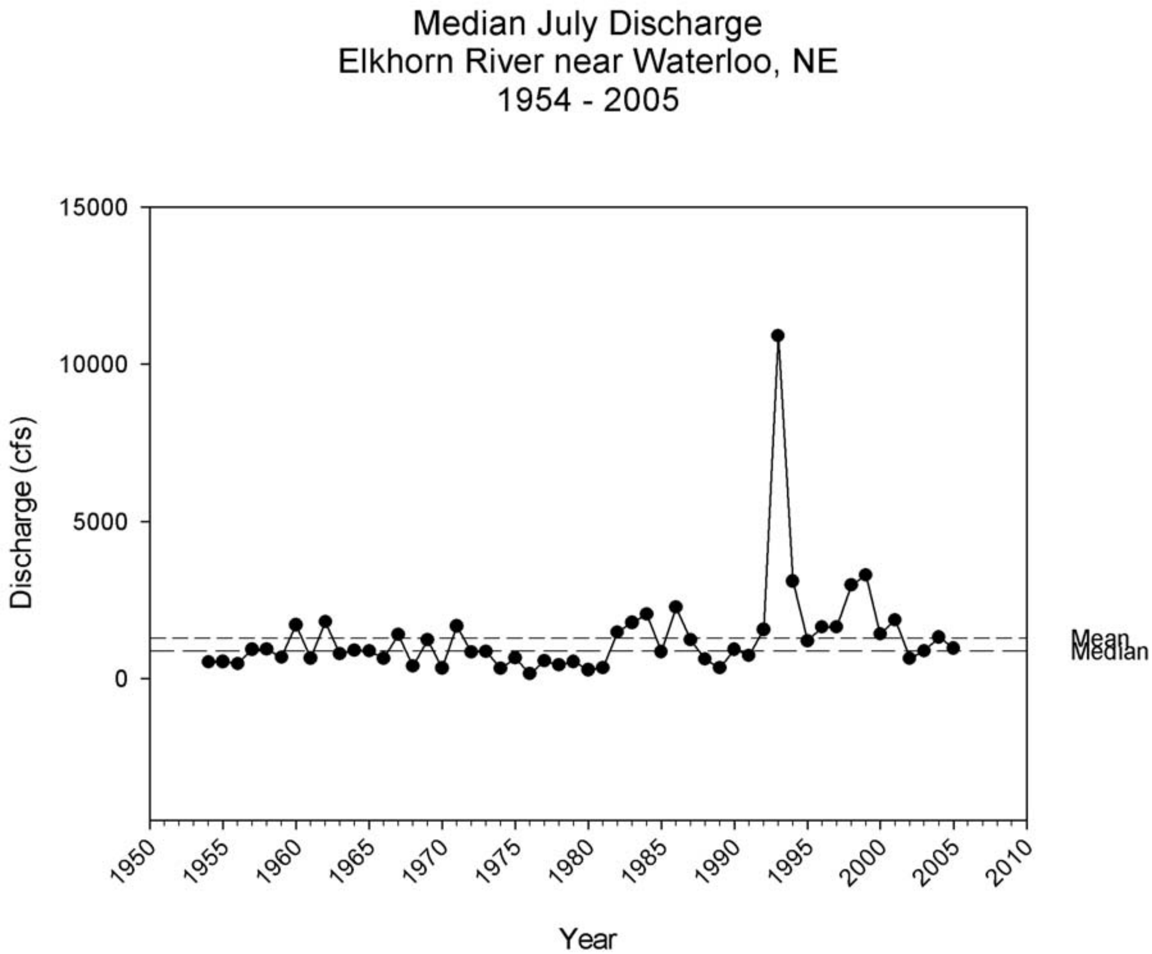

Median March Discharge
Elkhorn River near Waterloo, NE
1954 - 2005
Discharge (cfs)
0
1000
2000
3000
4000
5000
6000
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Mean
Median

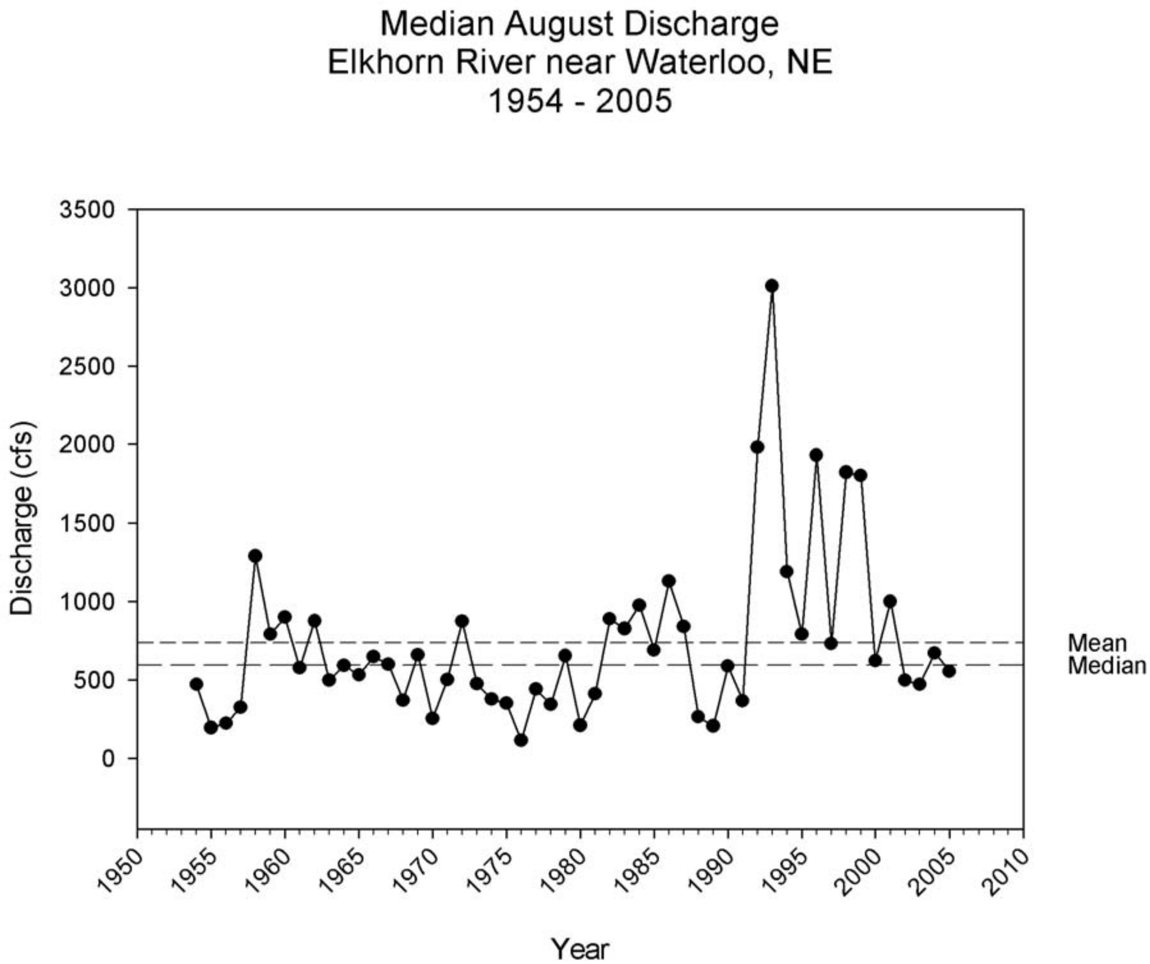

Median April Discharge
Elkhorn River near Waterloo, NE
1954 - 2005
Discharge (cfs)
12000
10000
8000
6000
4000
2000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

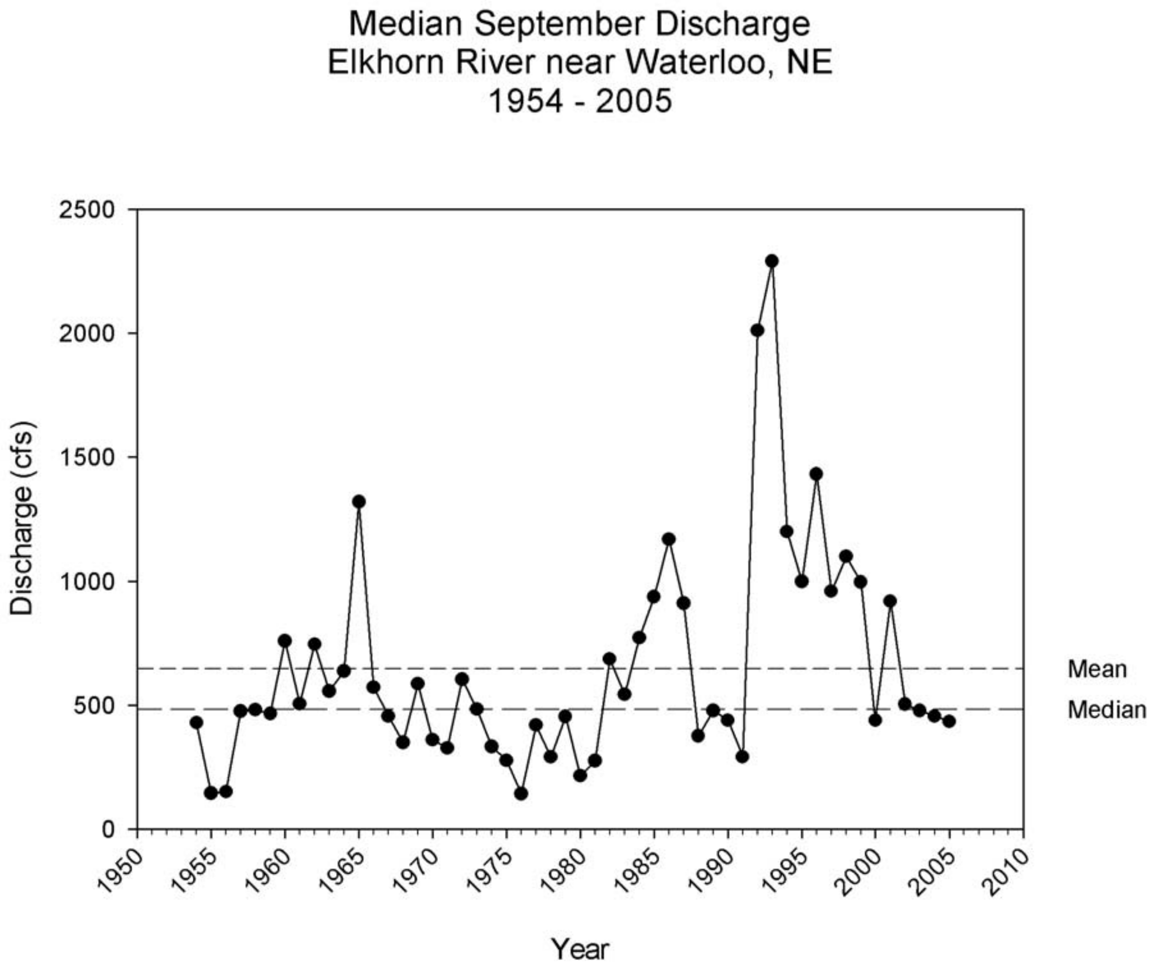


J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

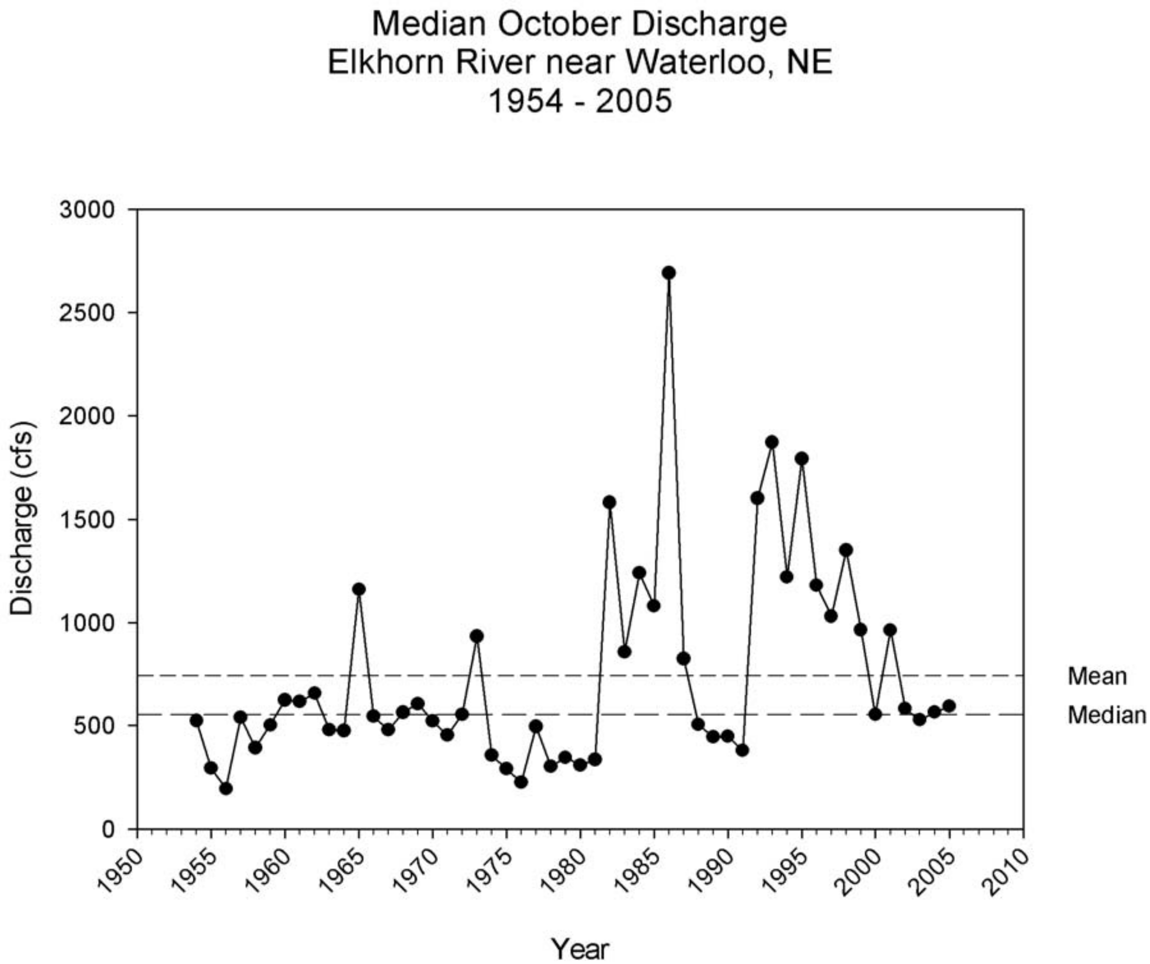

Median June Discharge
Elkhorn River near Waterloo, NE
1954 - 2005
Discharge (cfs)
12000
10000
8000
6000
4000
2000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year


Median July Discharge
Elkhorn River near Waterloo, NE
1954 - 2005
15000
10000
5000
0
Discharge (cfs)
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

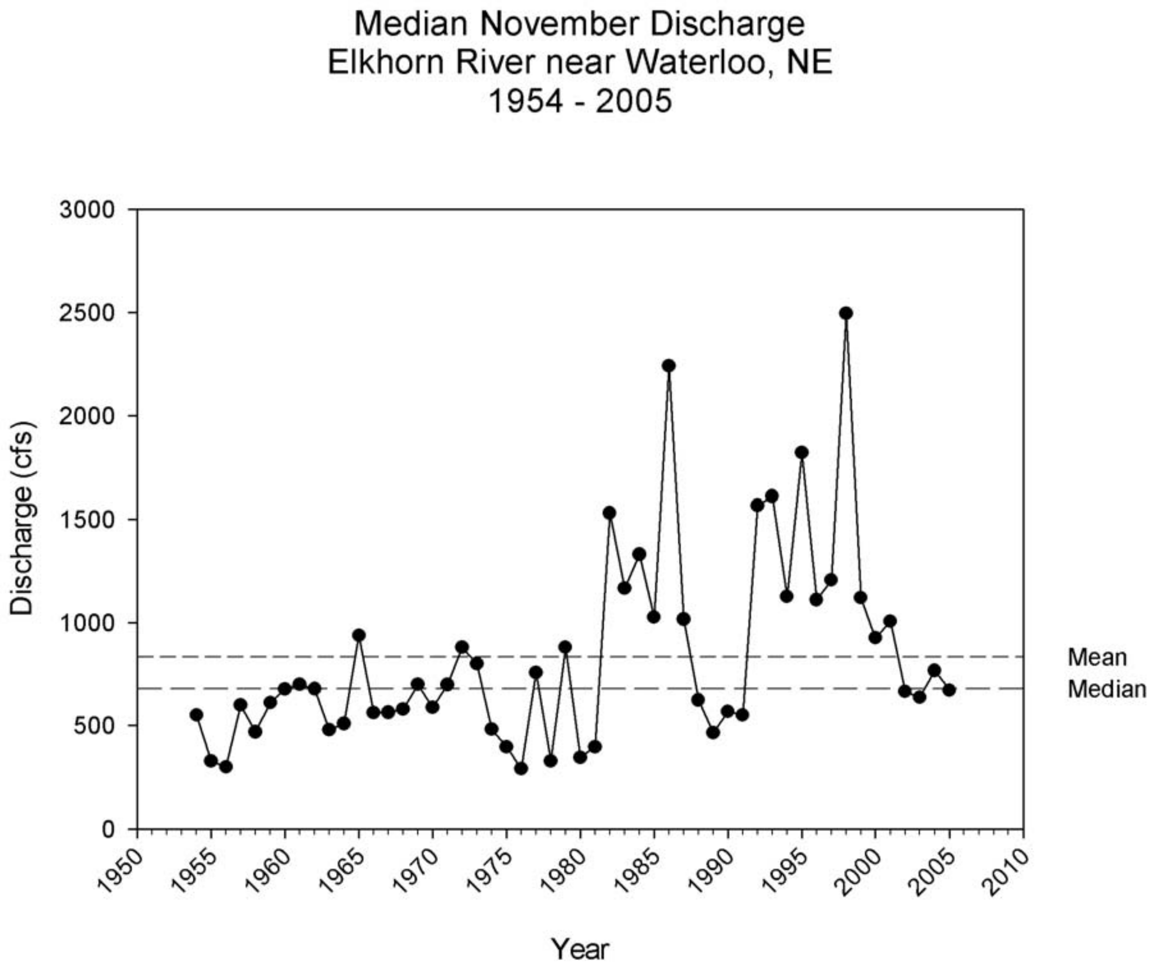

Median August Discharge
Elkhorn River near Waterloo, NE
1954 - 2005
Discharge (cfs)
3500
3000
2500
2000
1500
1000
500
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median

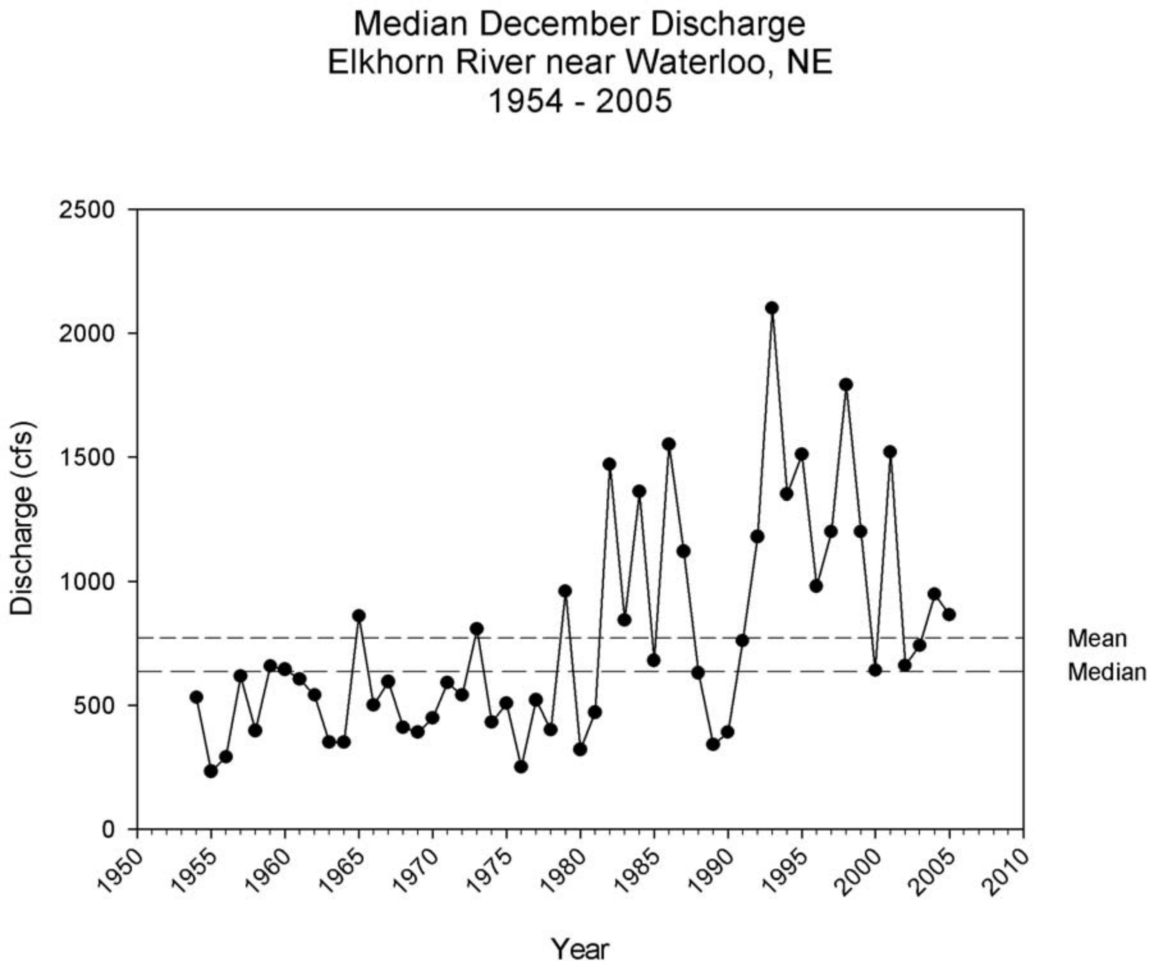


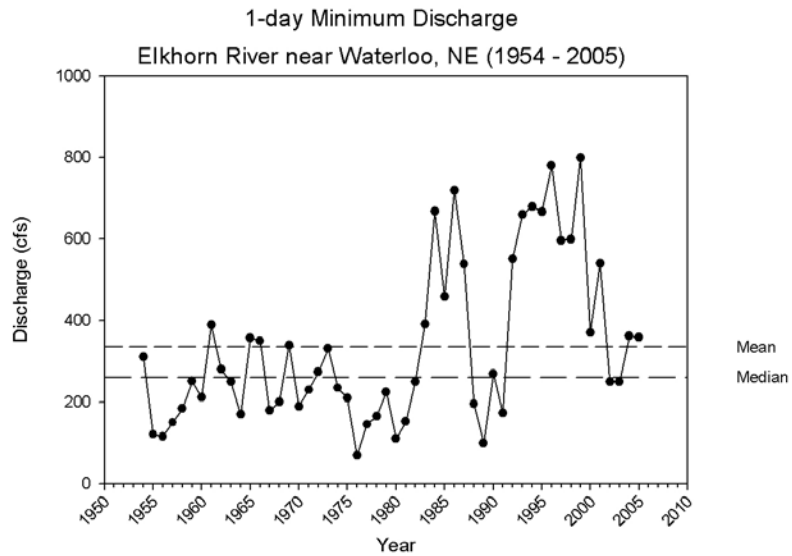
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

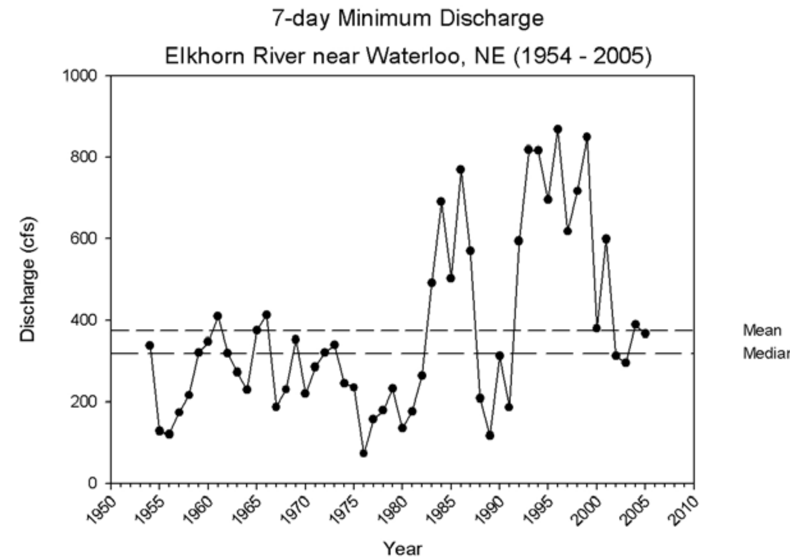


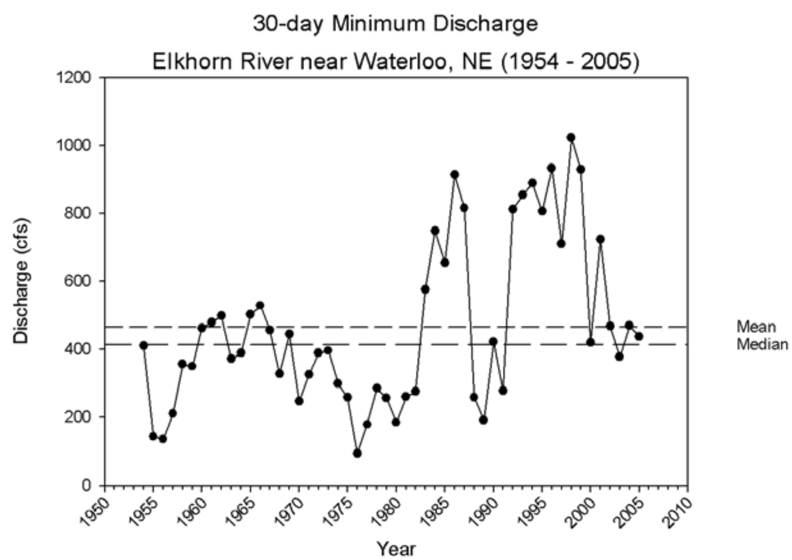
Median October Discharge
Elkhorn River near Waterloo, NE
1954 - 2005
Discharge (cfs)
3000
2500
2000
1500
1000
500
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median

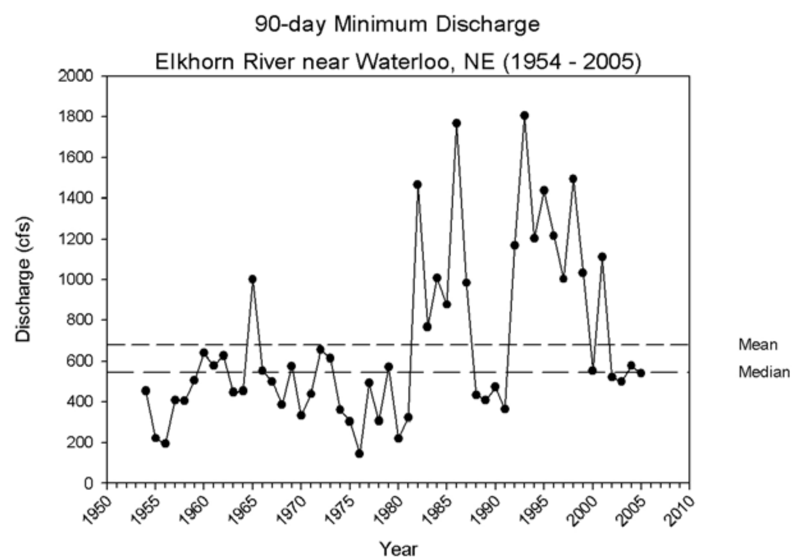

Median November Discharge
Elkhorn River near Waterloo, NE
1954 - 2005
Discharge (cfs)
0
500
1000
1500
2000
2500
3000
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median


Median December Discharge
Elkhorn River near Waterloo, NE
1954 - 2005
Discharge (cfs)
2500
2000
1500
1000
500
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

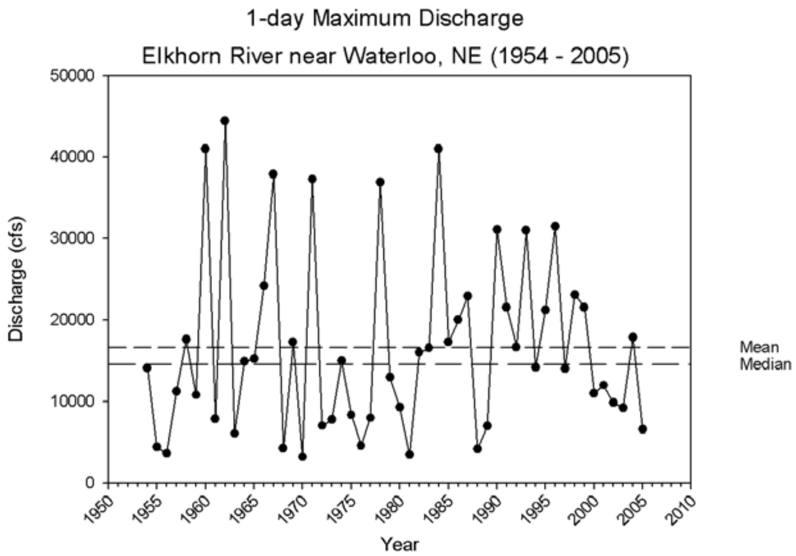


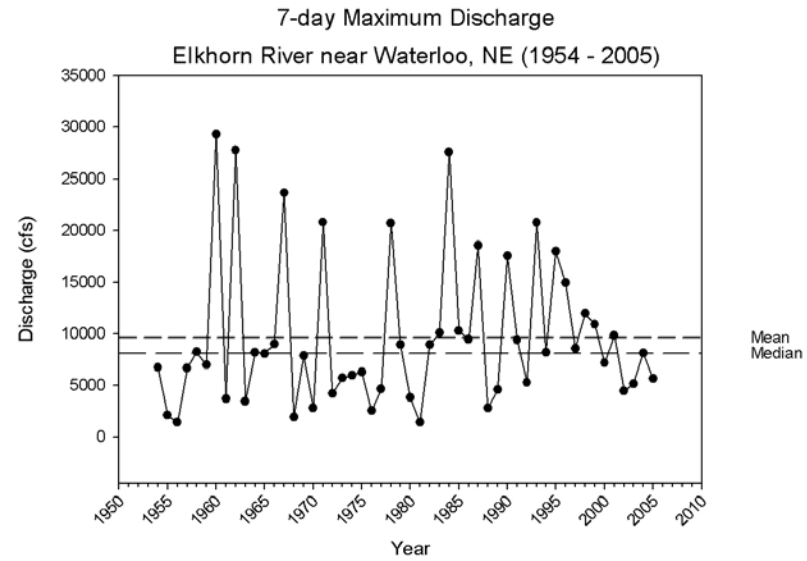


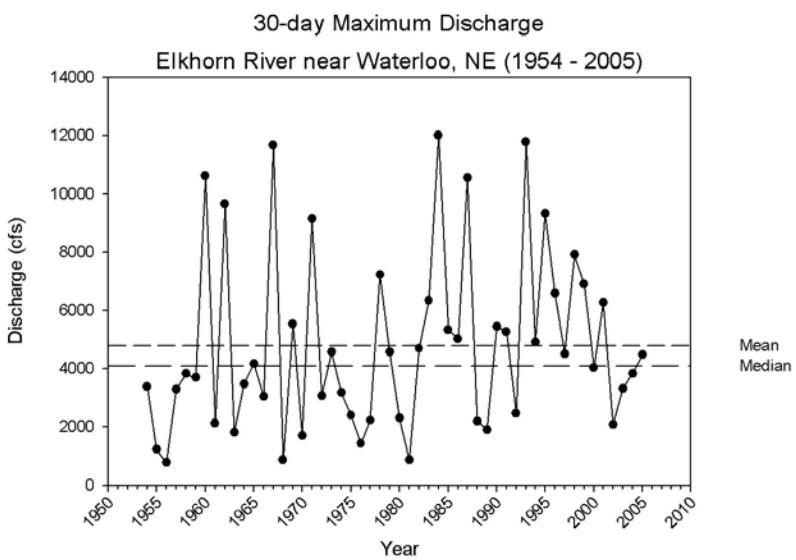


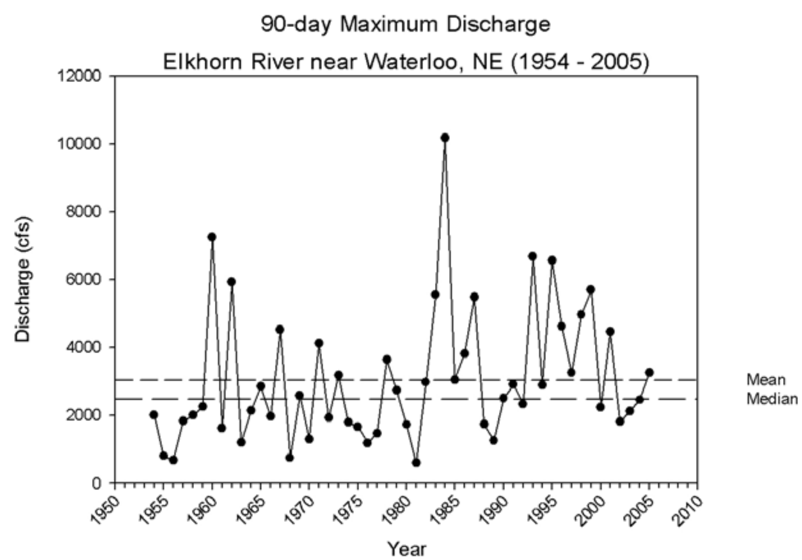


J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

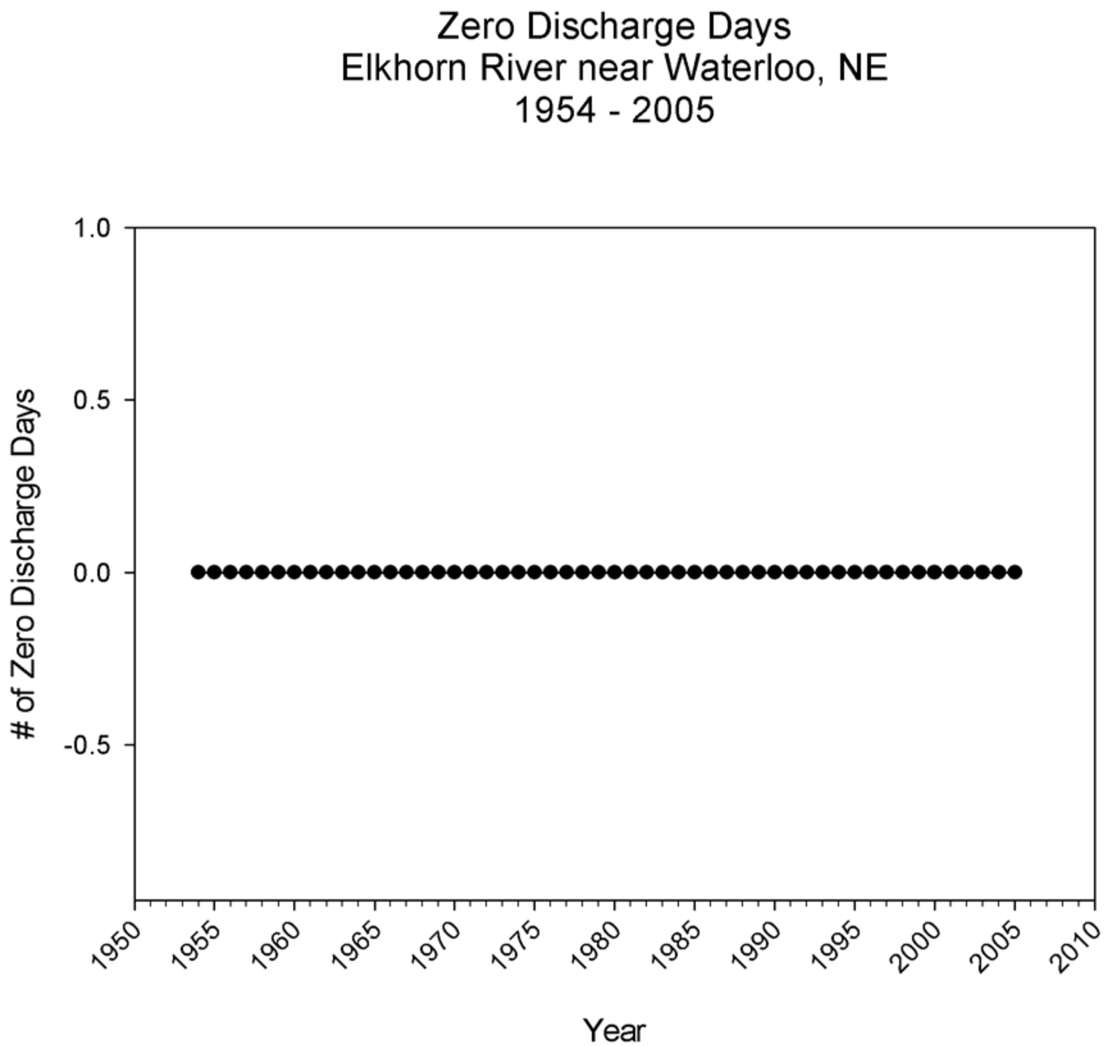


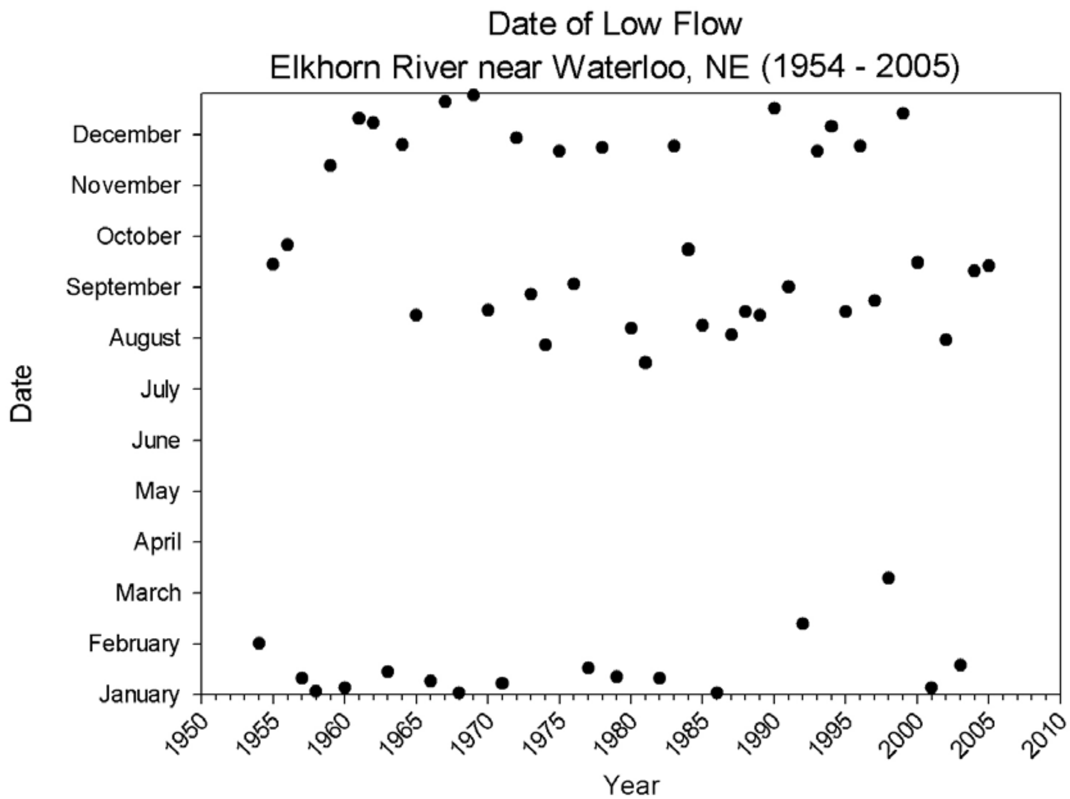


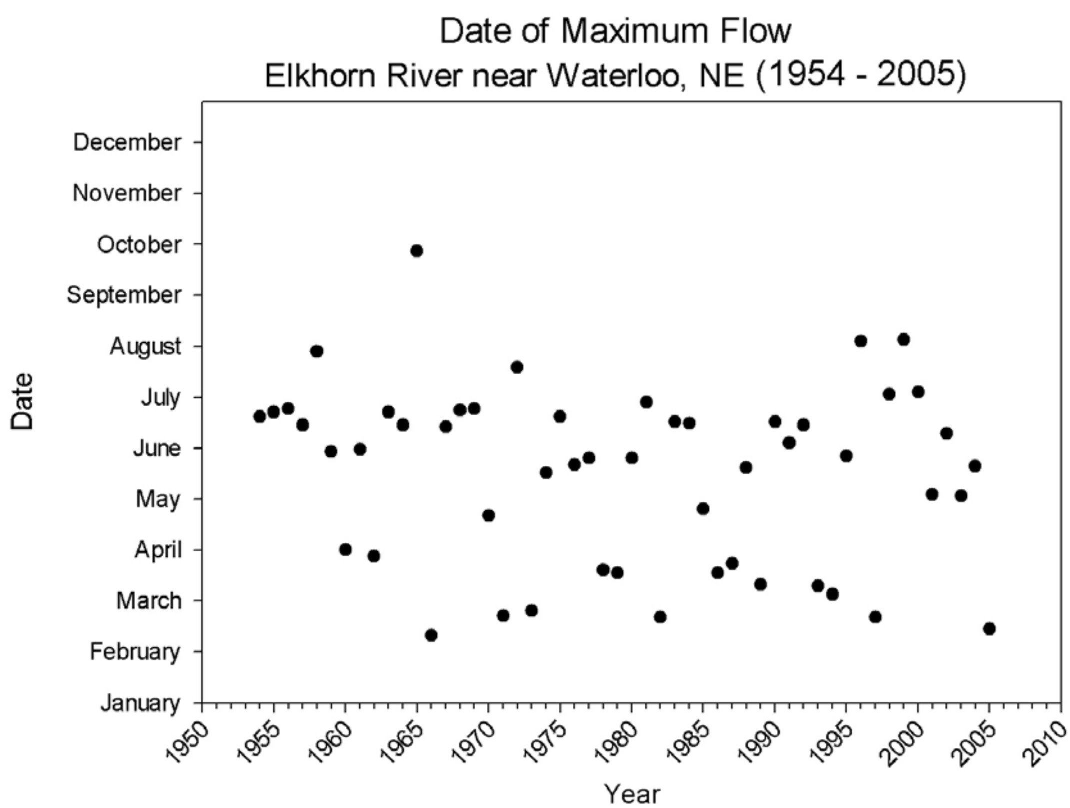


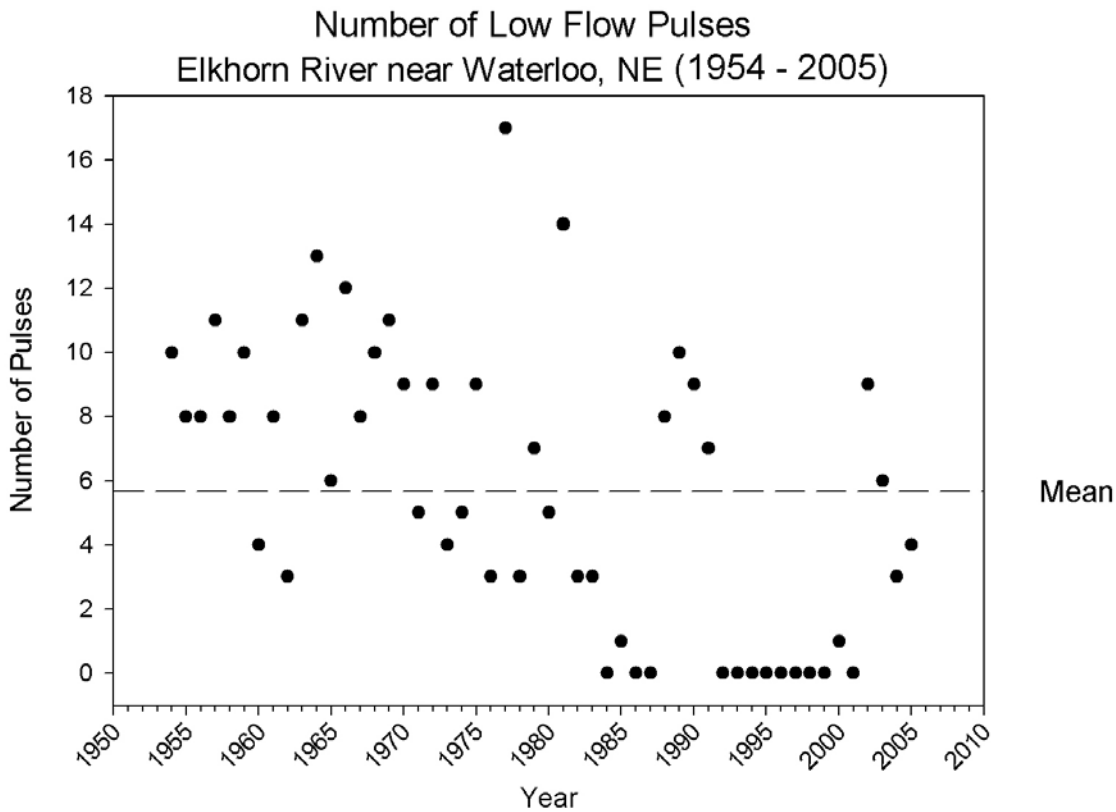


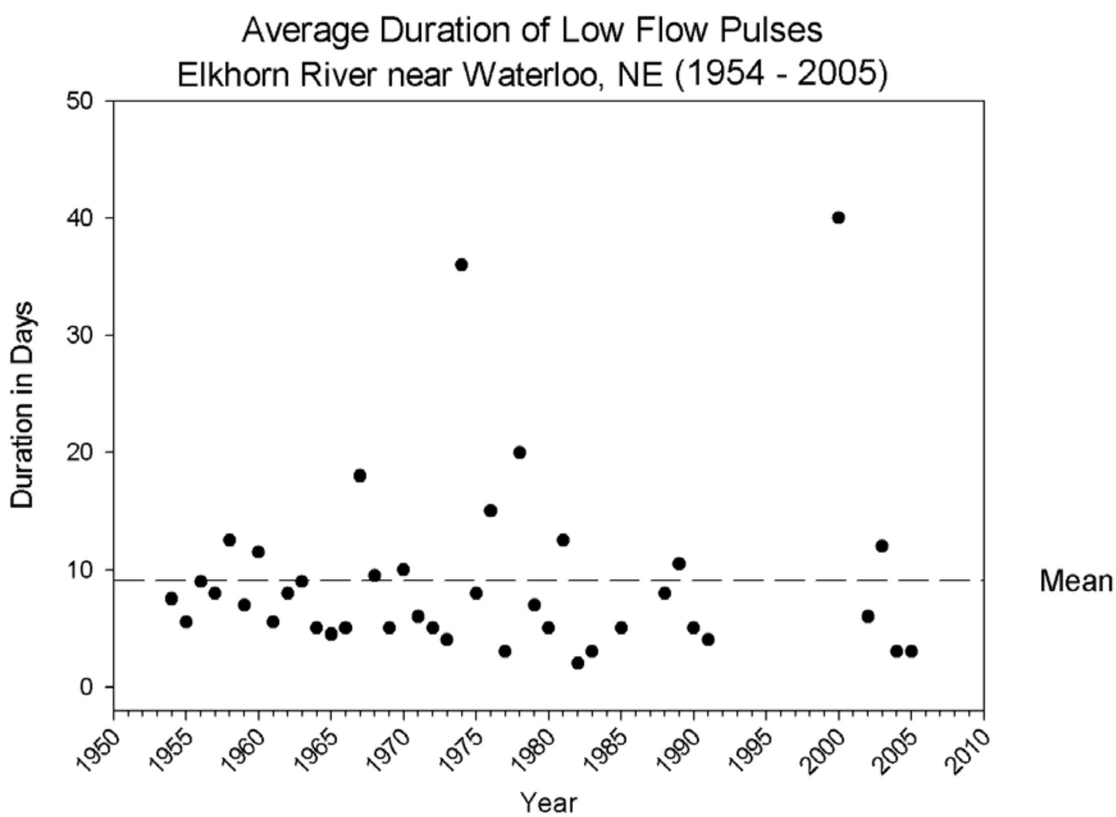
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.


Zero Discharge Days
Elkhorn River near Waterloo, NE
1954 - 2005
1.0
0.5
0.0
-0.5
# of Zero Discharge Days
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

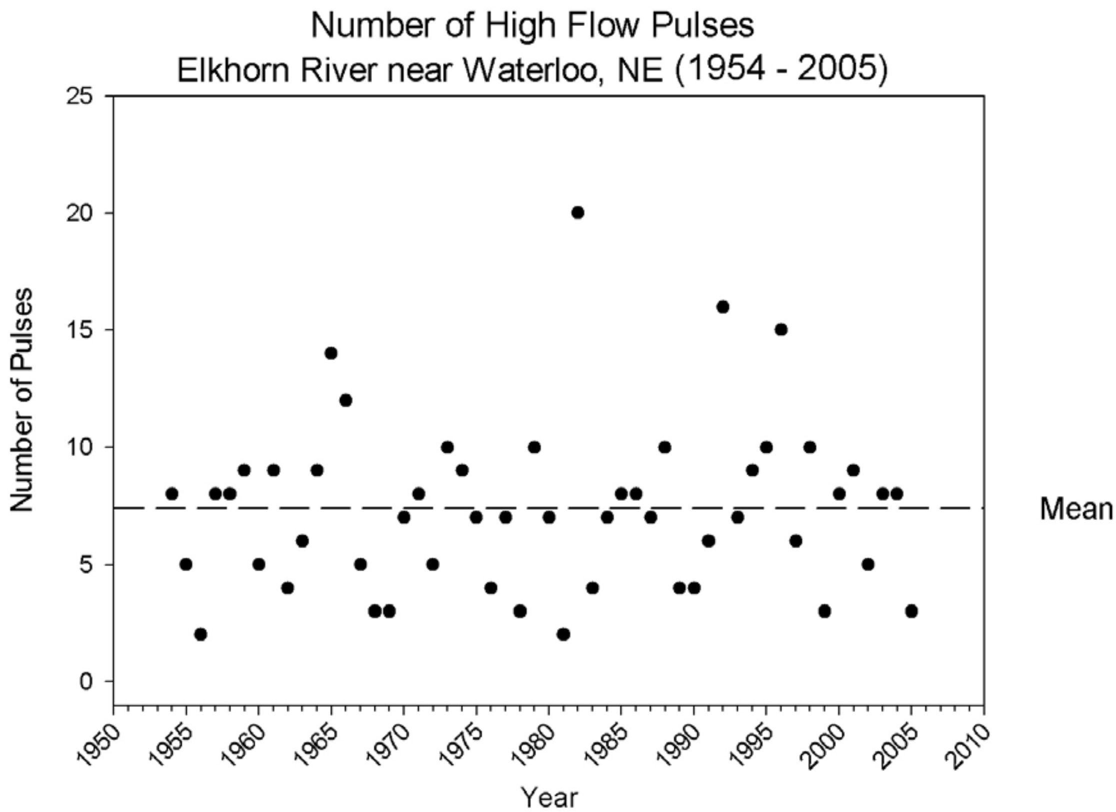

Date of Low Flow
Elkhorn River near Waterloo, NE (1954 - 2005)
Date
December
November
October
September
August
July
June
May
April
March
February
January
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

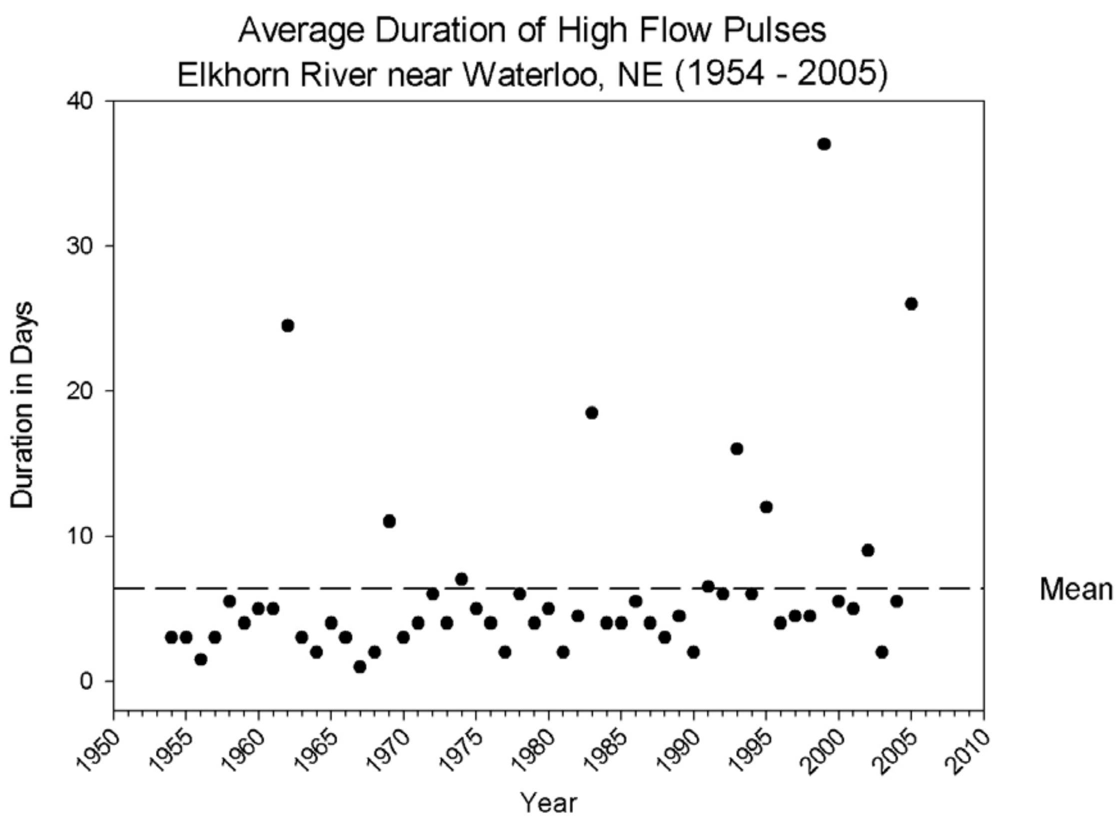

Date of Maximum Flow
Elkhorn River near Waterloo, NE (1954 - 2005)
Date
December
November
October
September
August
July
June
May
April
March
February
January
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year



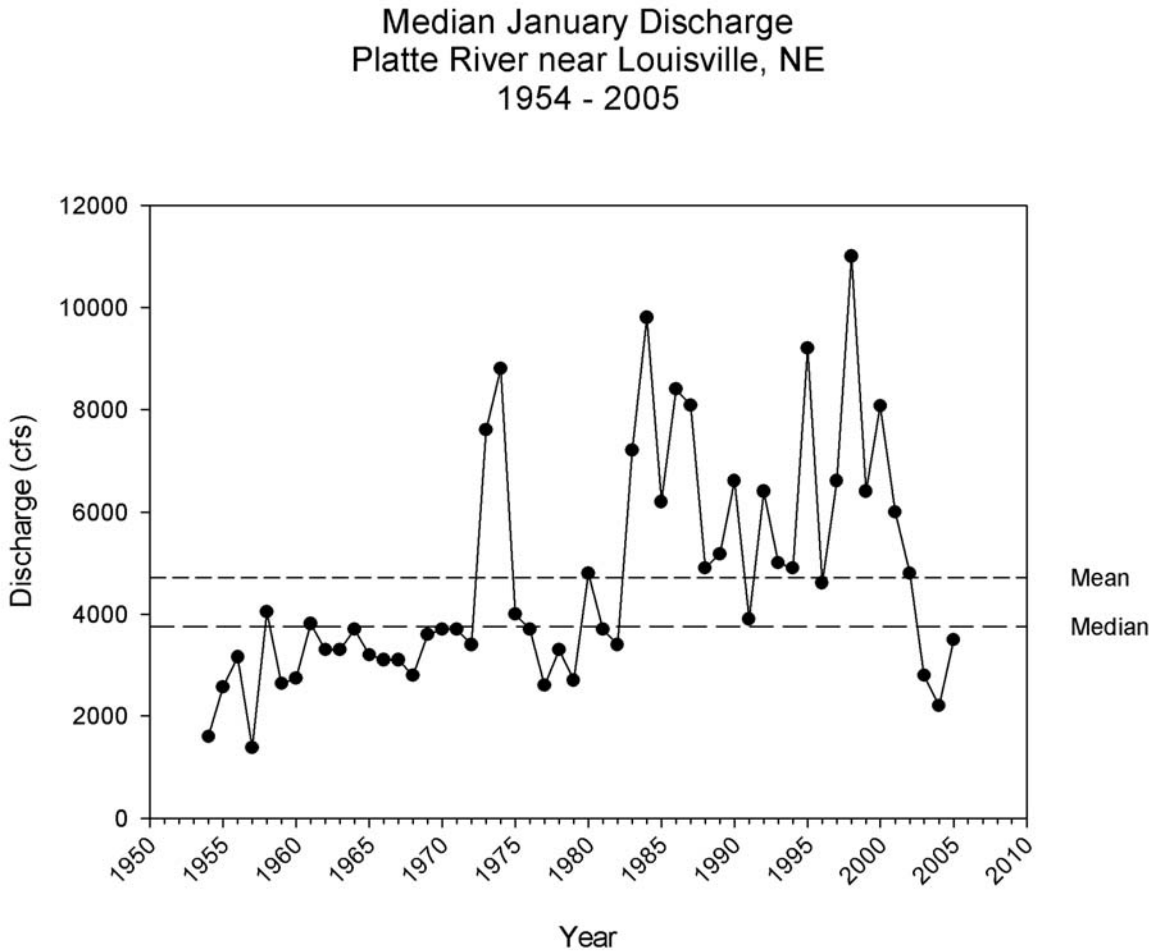


J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

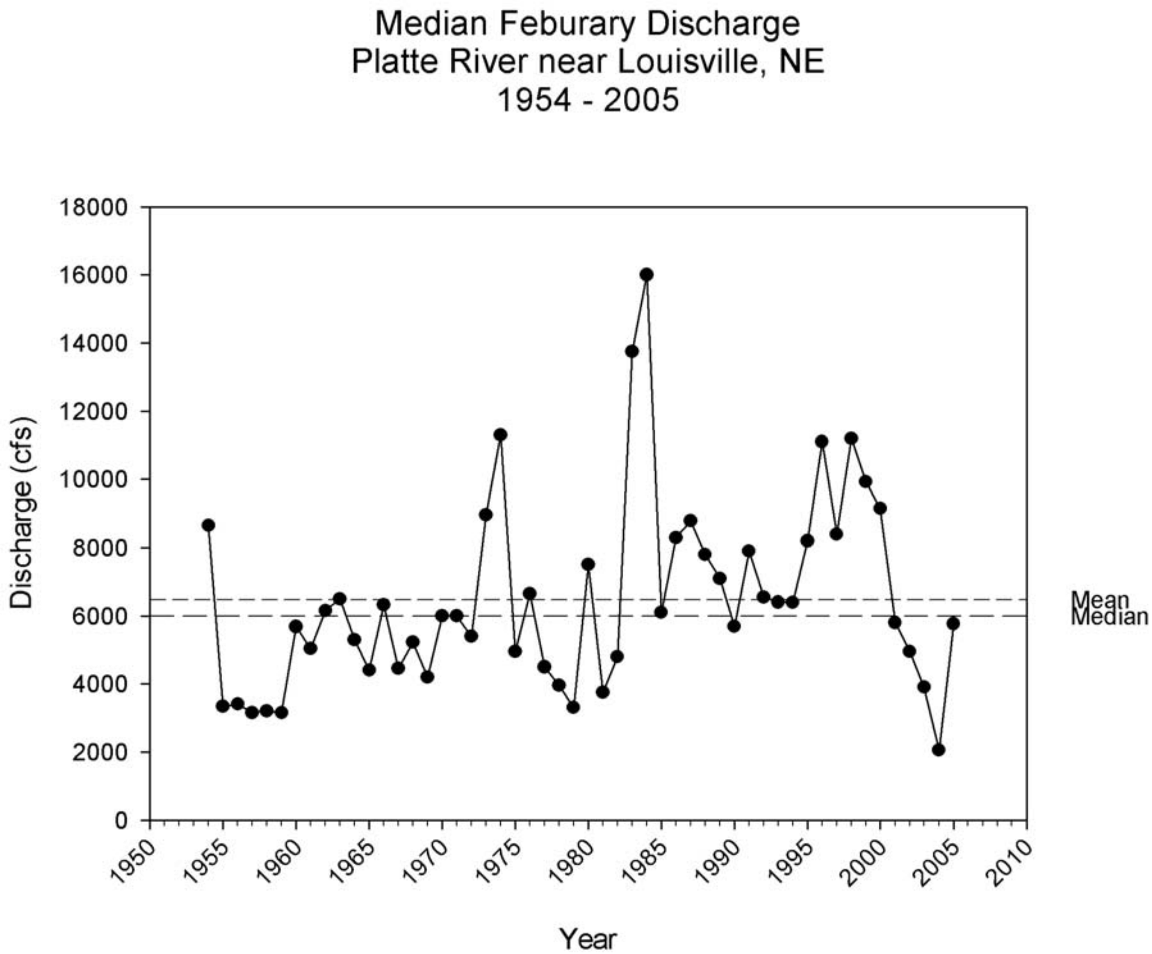




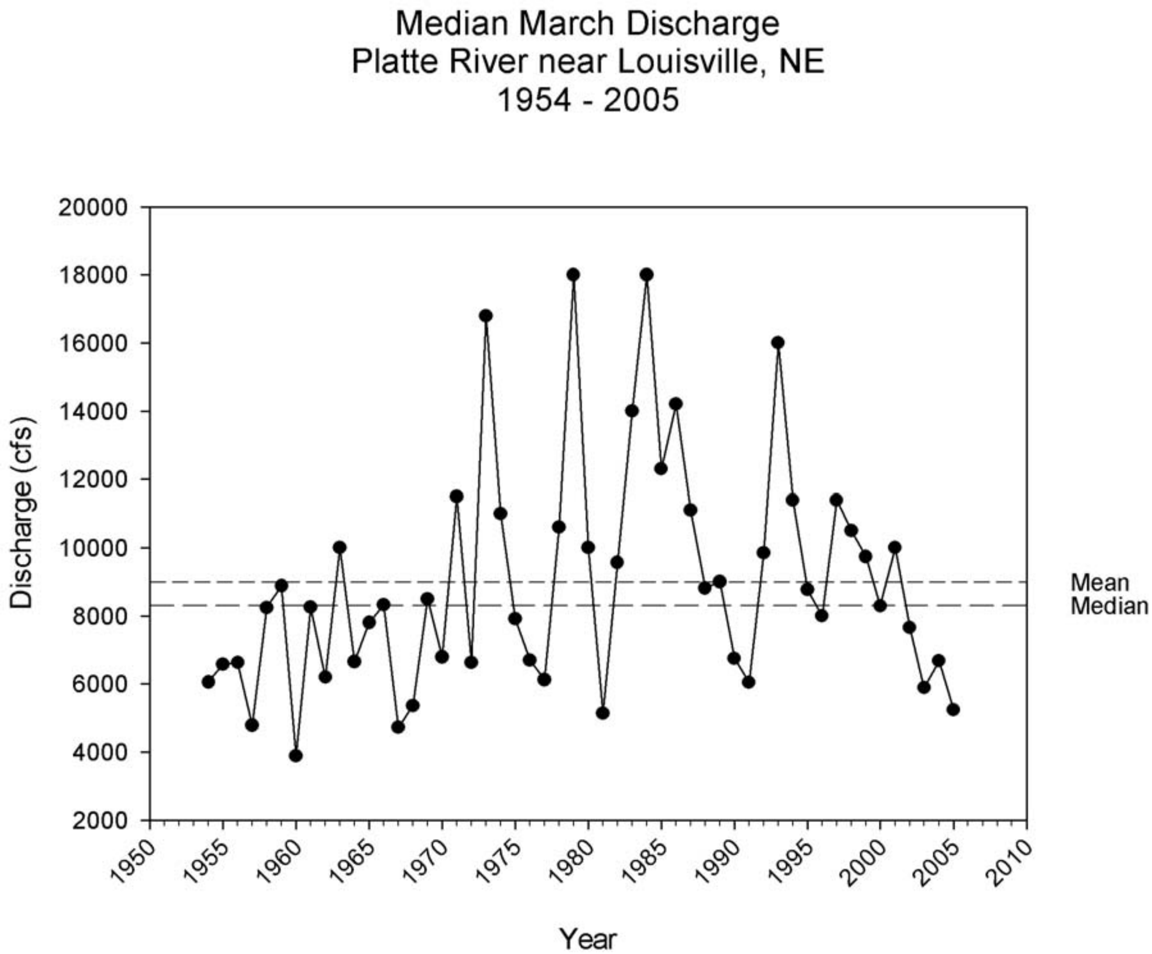
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



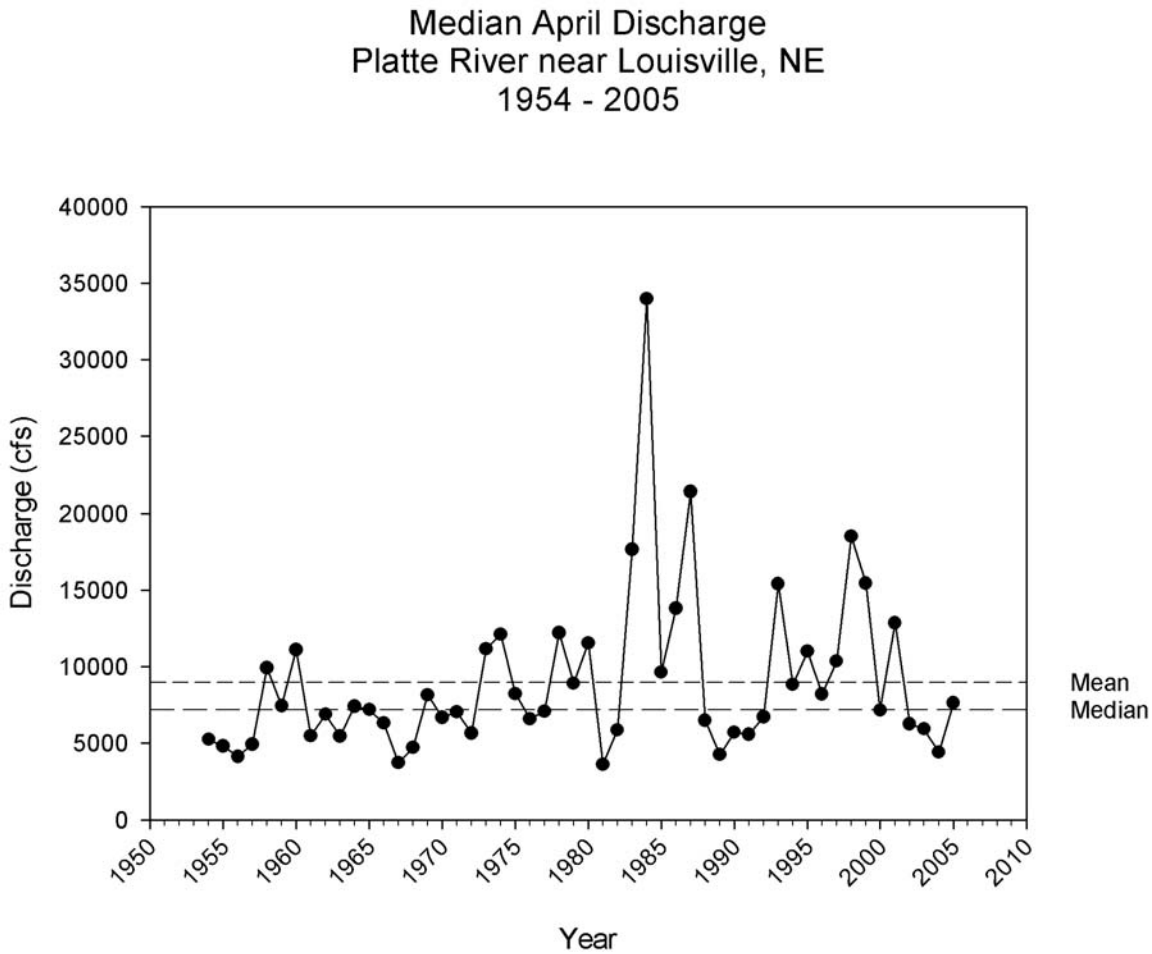
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



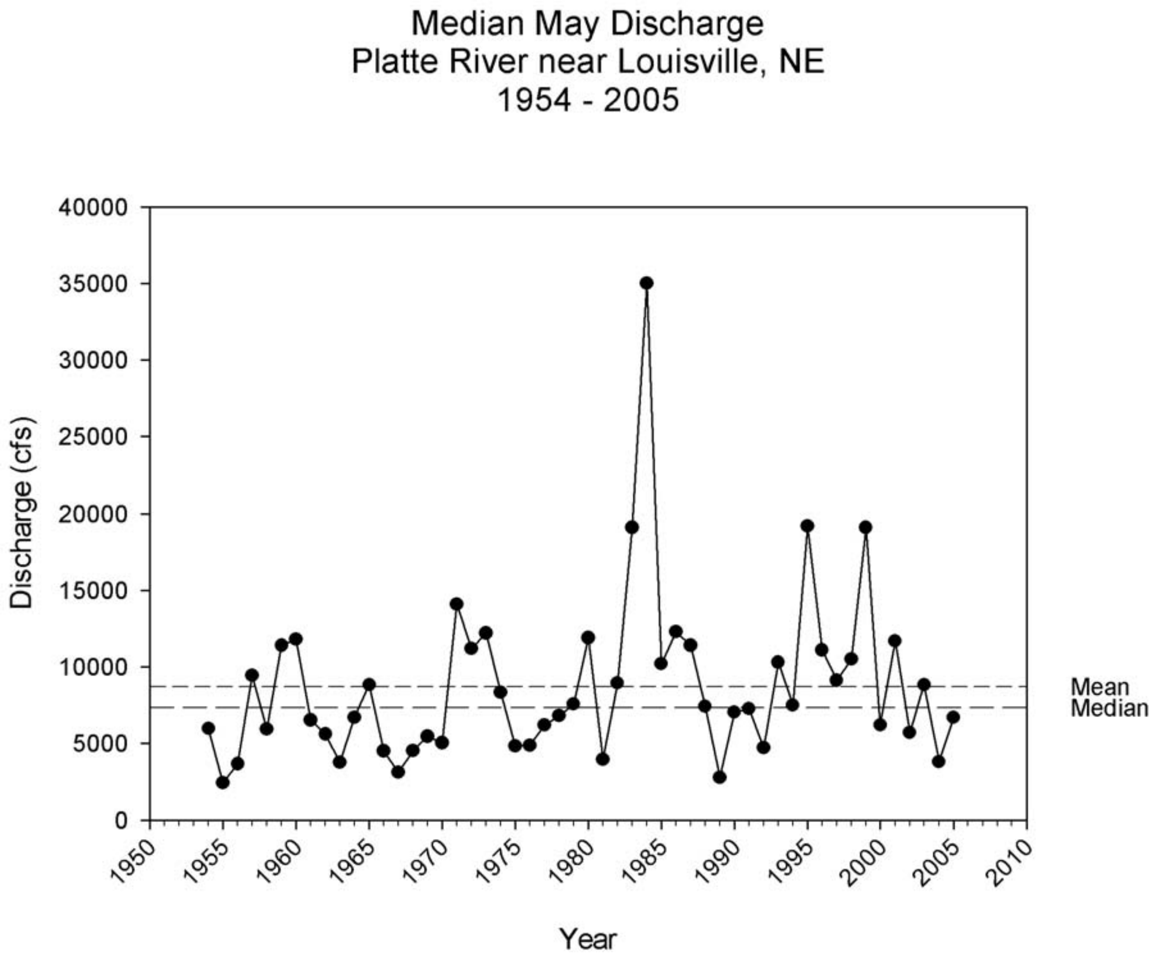
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



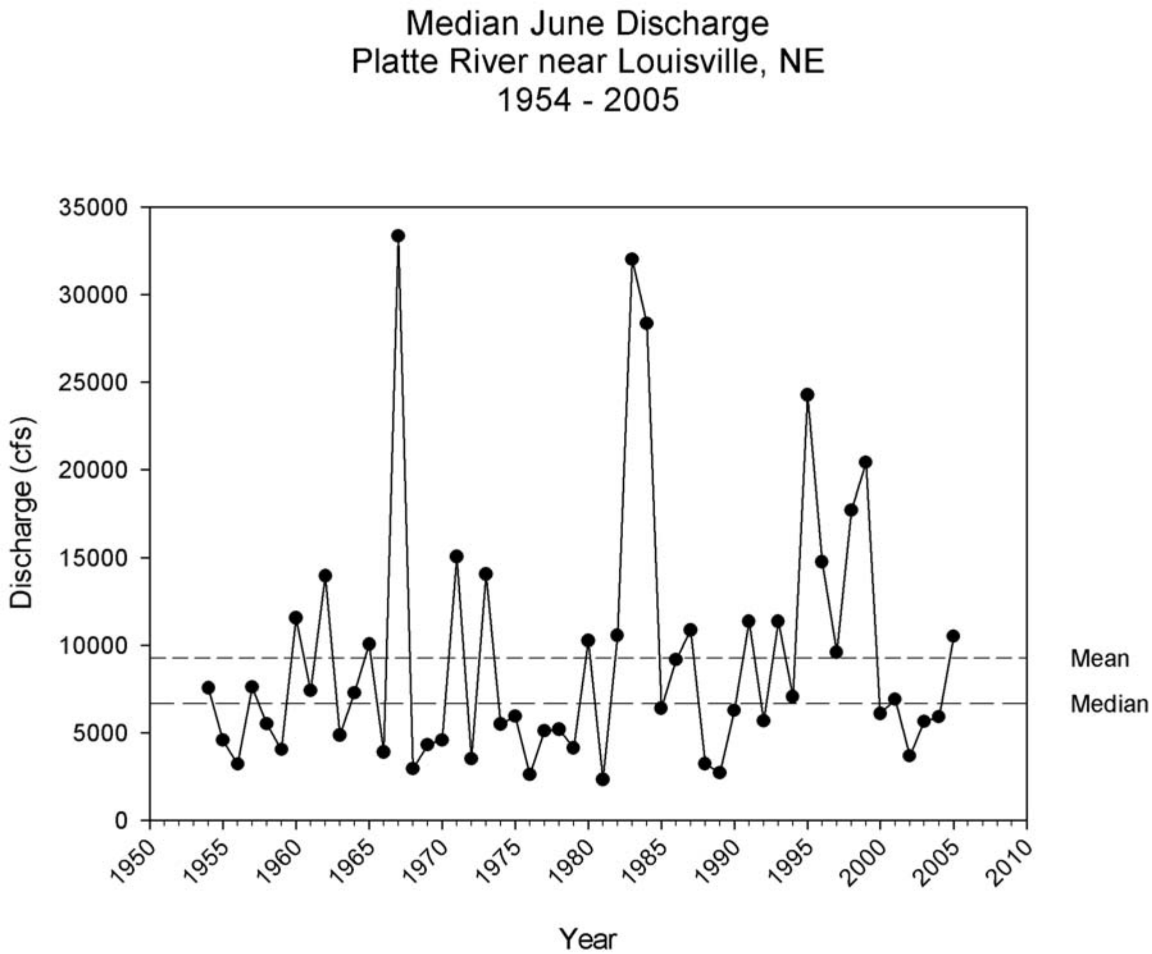
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



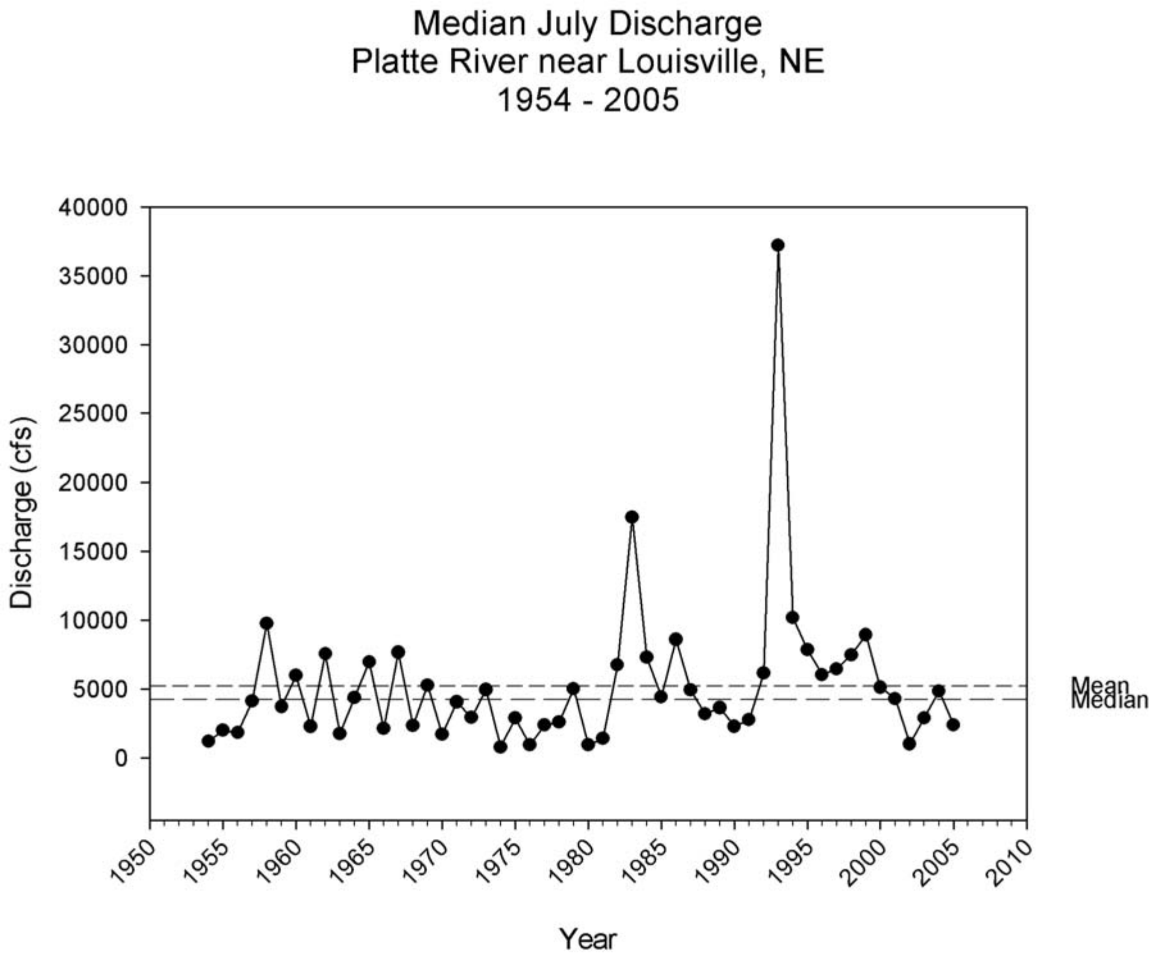
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



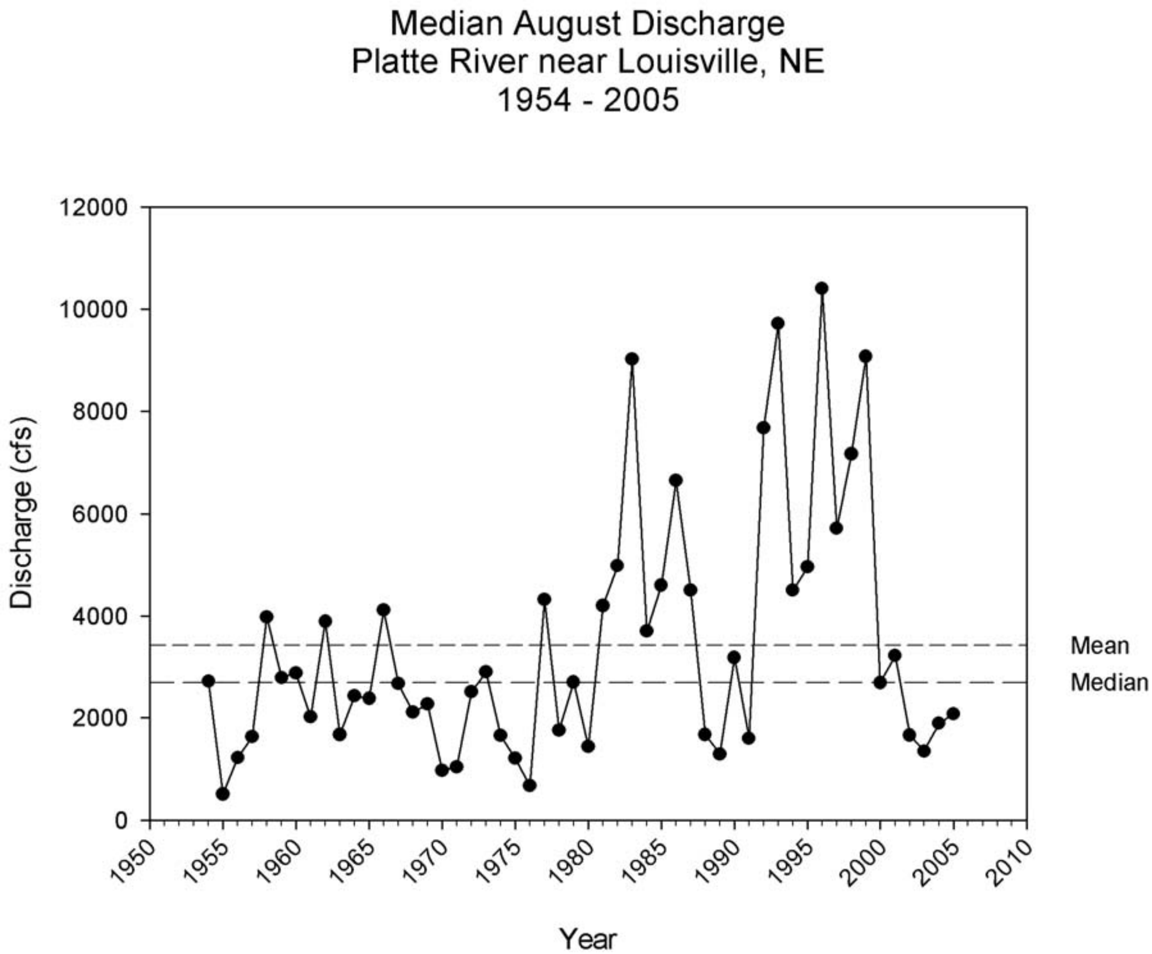
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



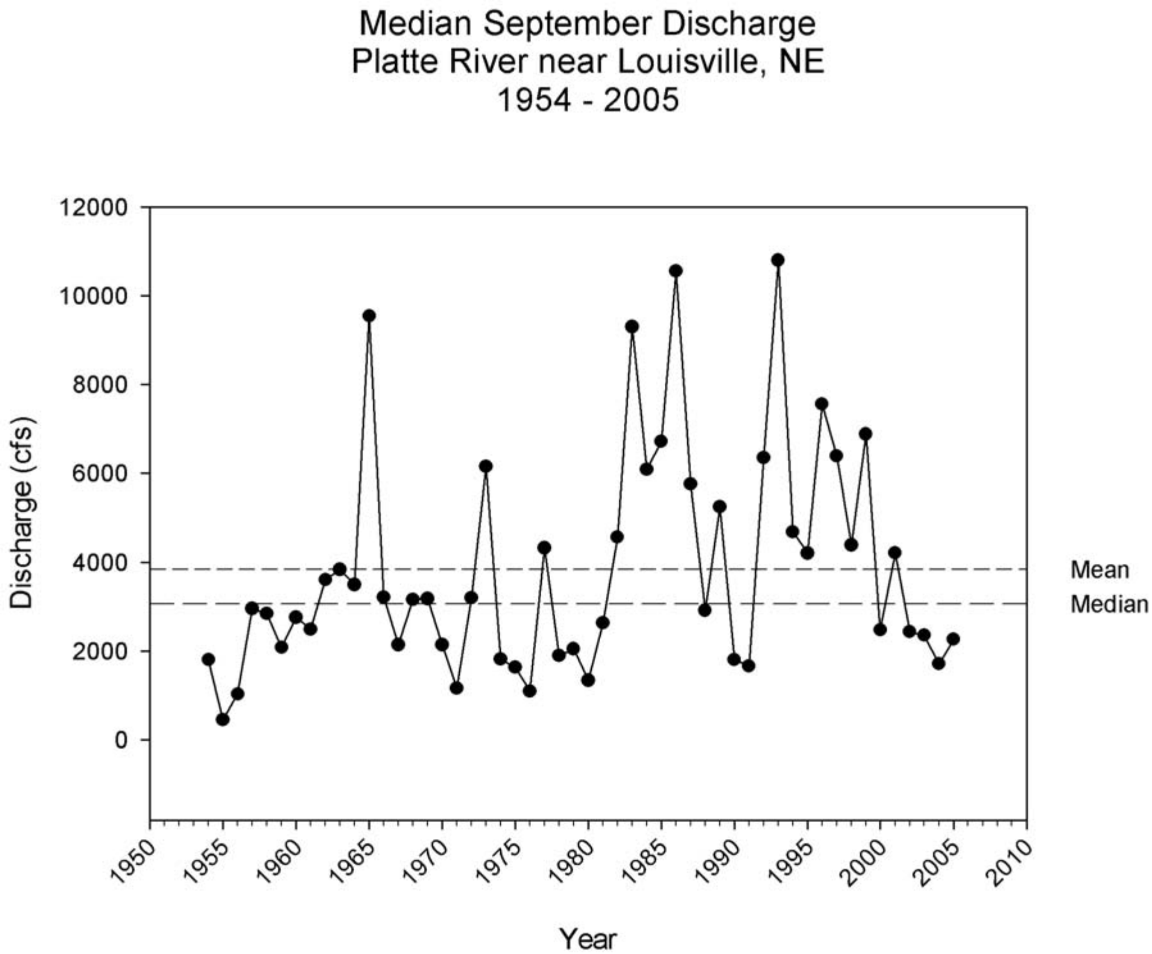
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



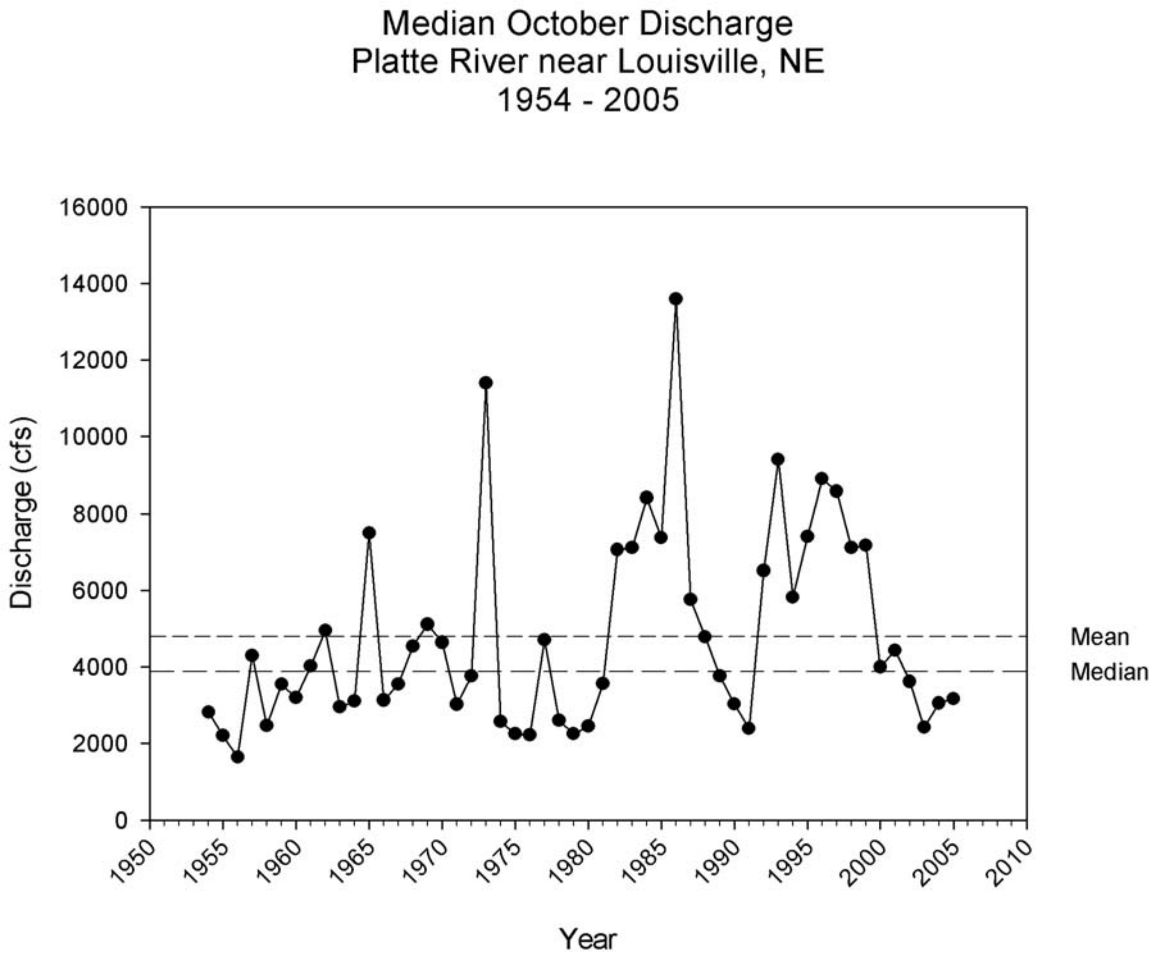
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.



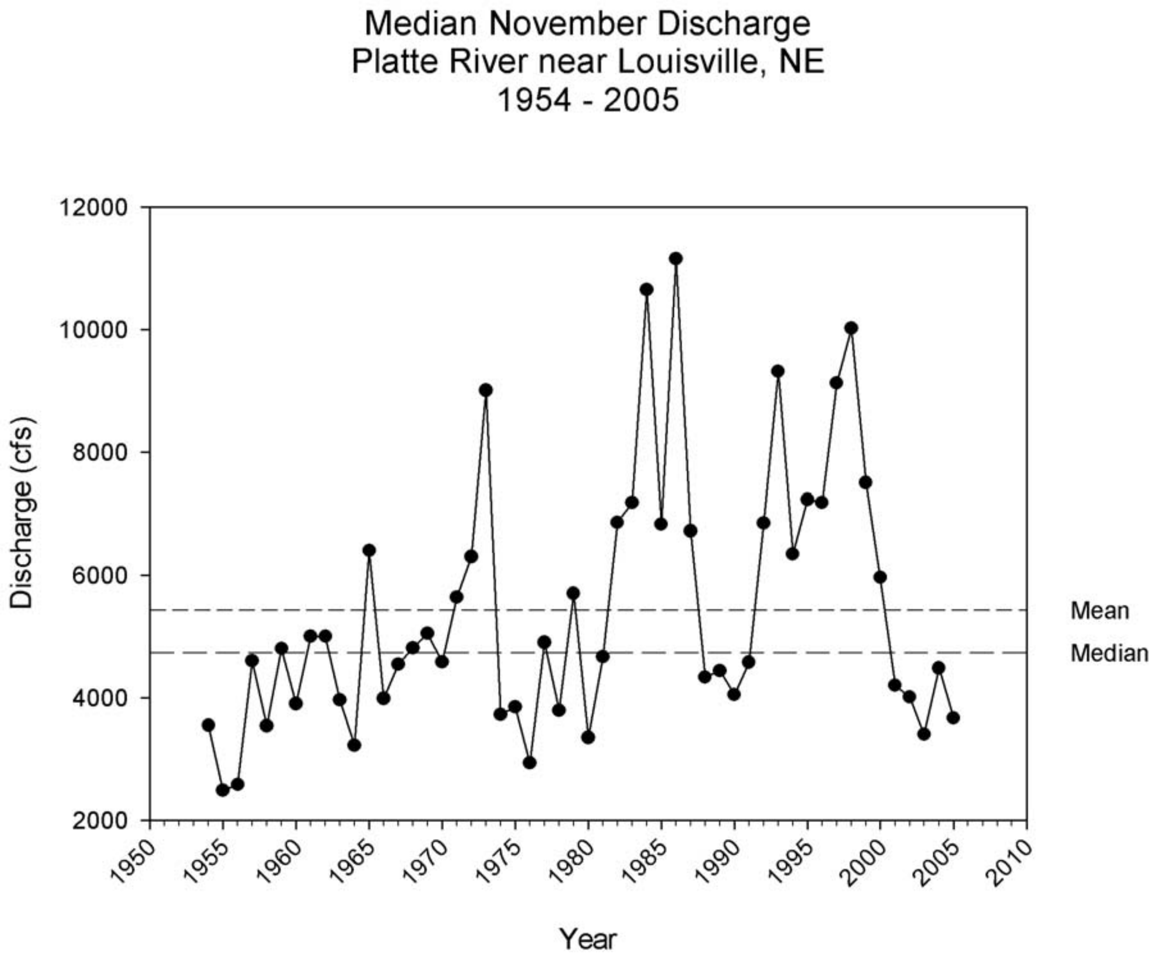
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

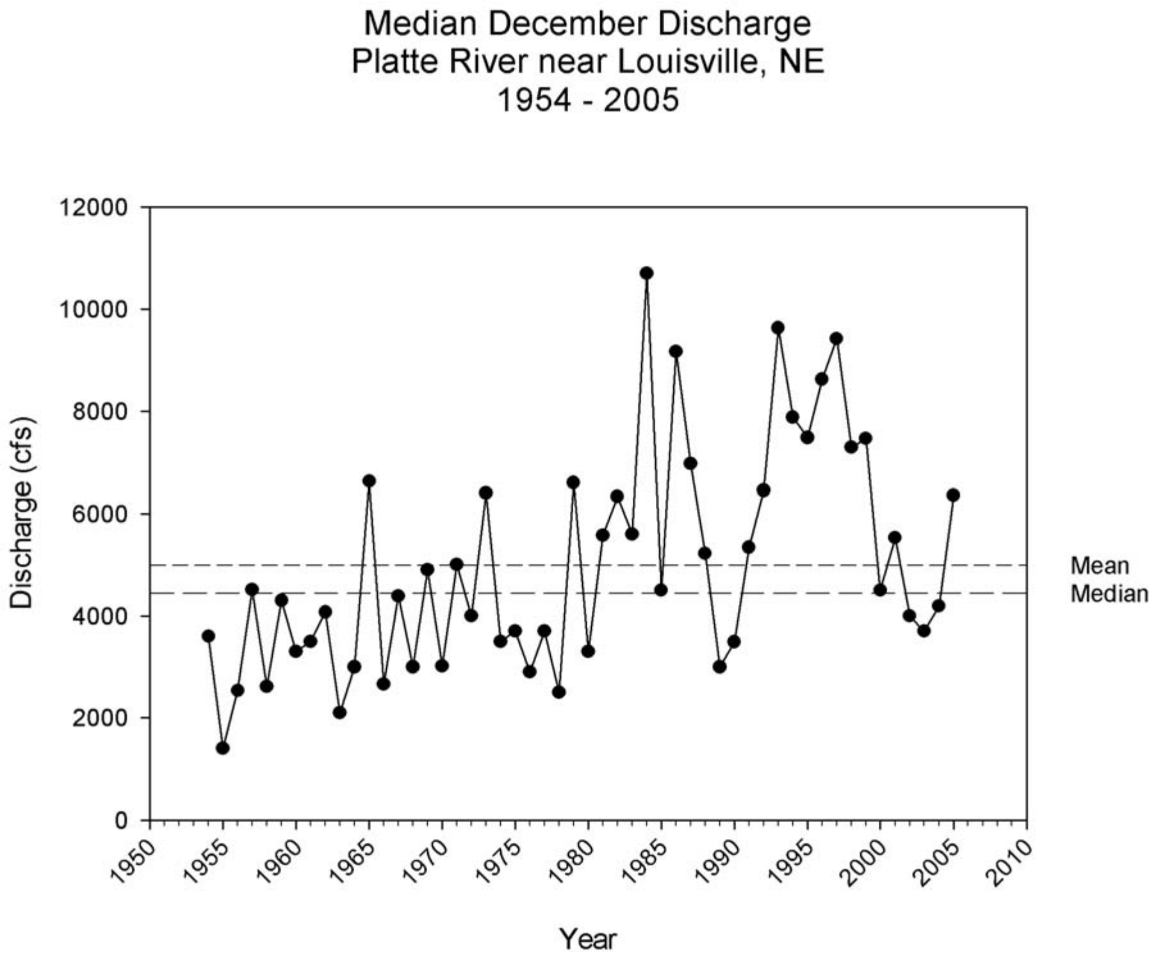


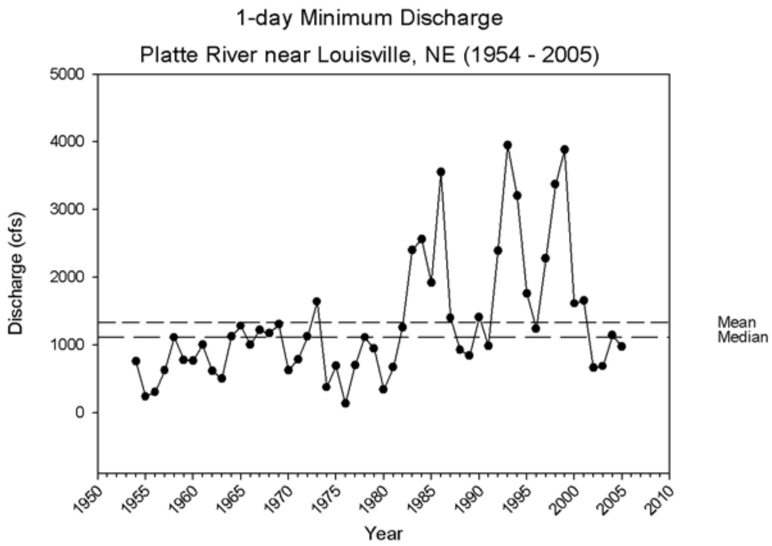
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

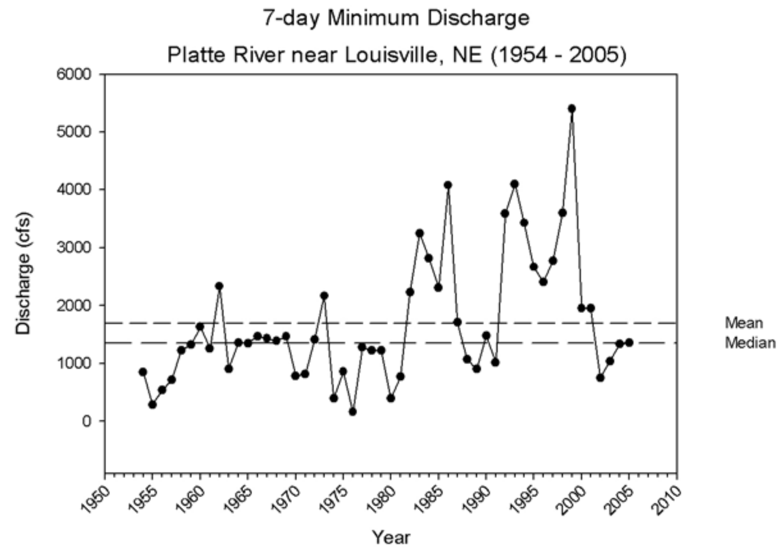

Median October Discharge
Platte River near Louisville, NE
1954 - 2005
Discharge (cfs)
16000
14000
12000
10000
8000
6000
4000
2000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median

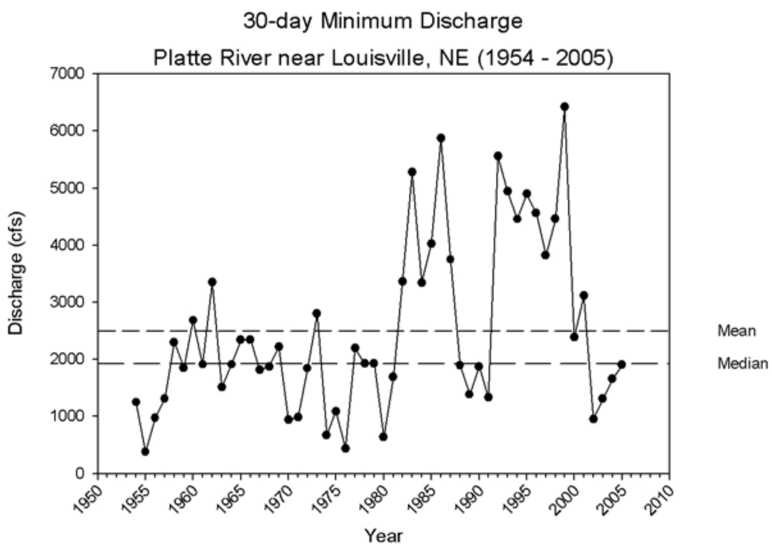
trrtr

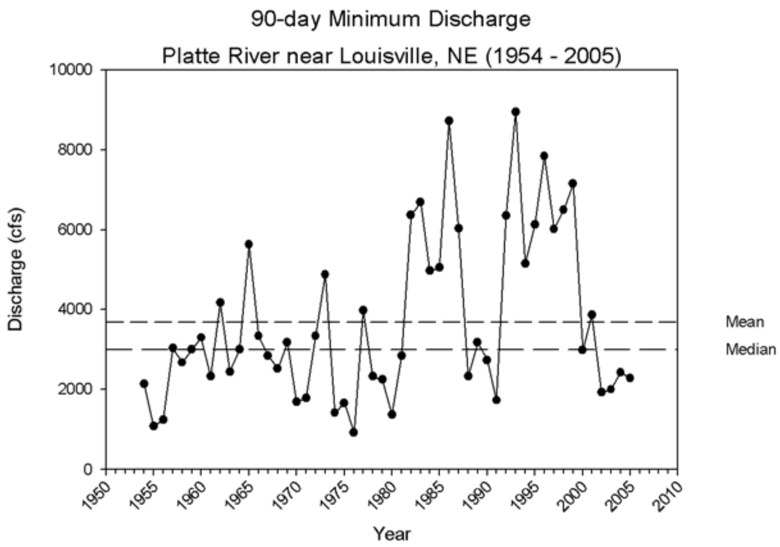

Median November Discharge
Platte River near Louisville, NE
1954 - 2005
Discharge (cfs)
12000
10000
8000
6000
4000
2000
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year


Median December Discharge
Platte River near Louisville, NE
1954 - 2005
Discharge (cfs)
0
2000
4000
6000
8000
10000
12000
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median









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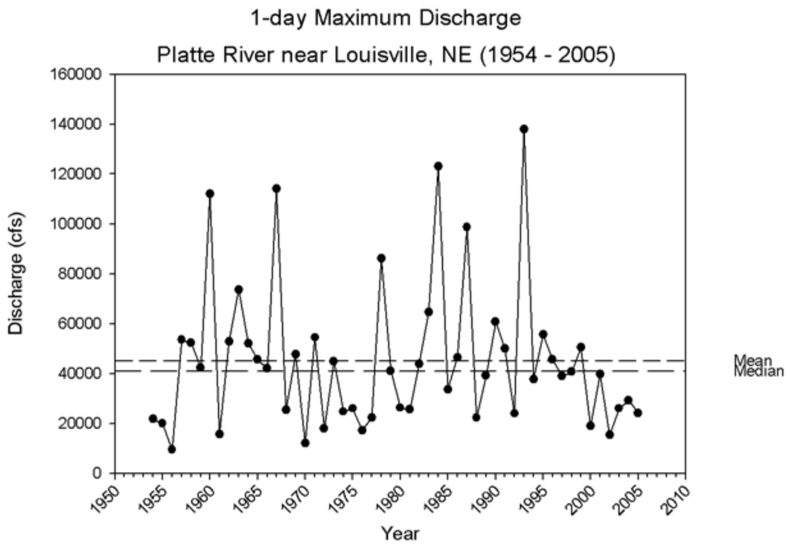

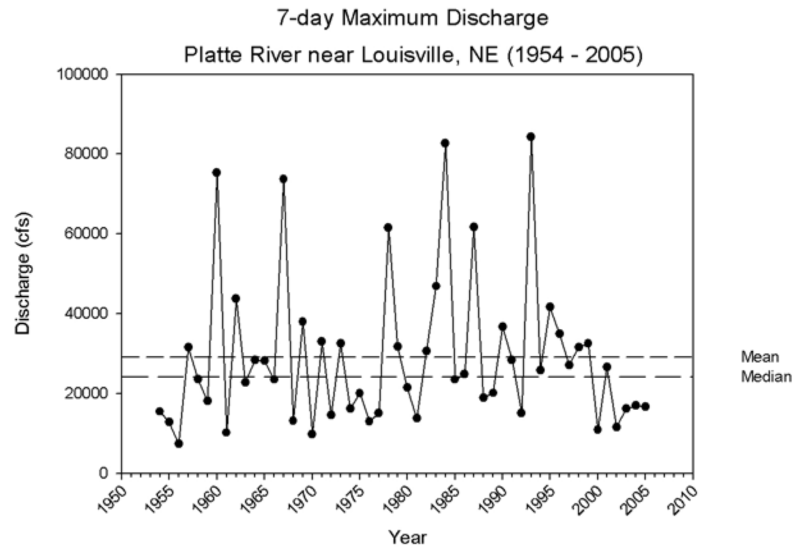

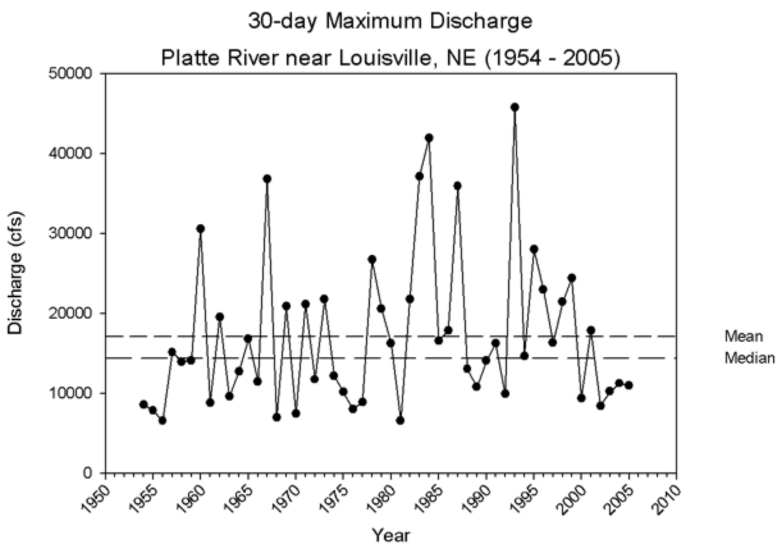

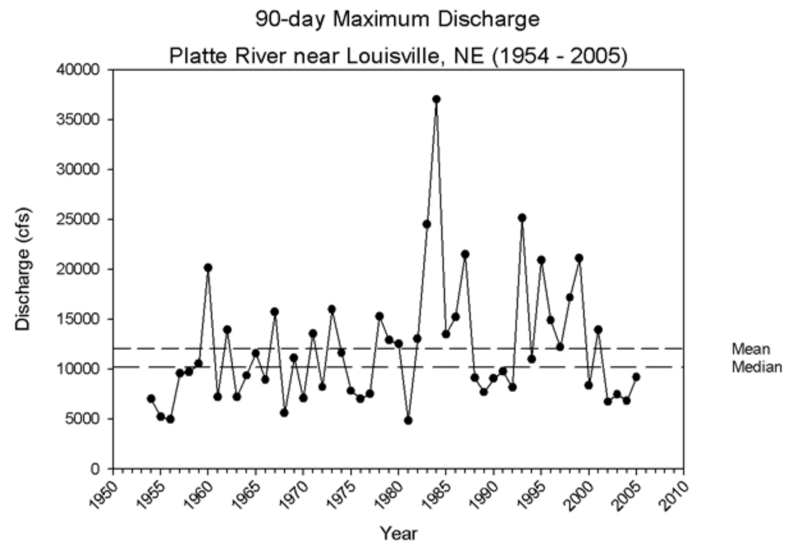

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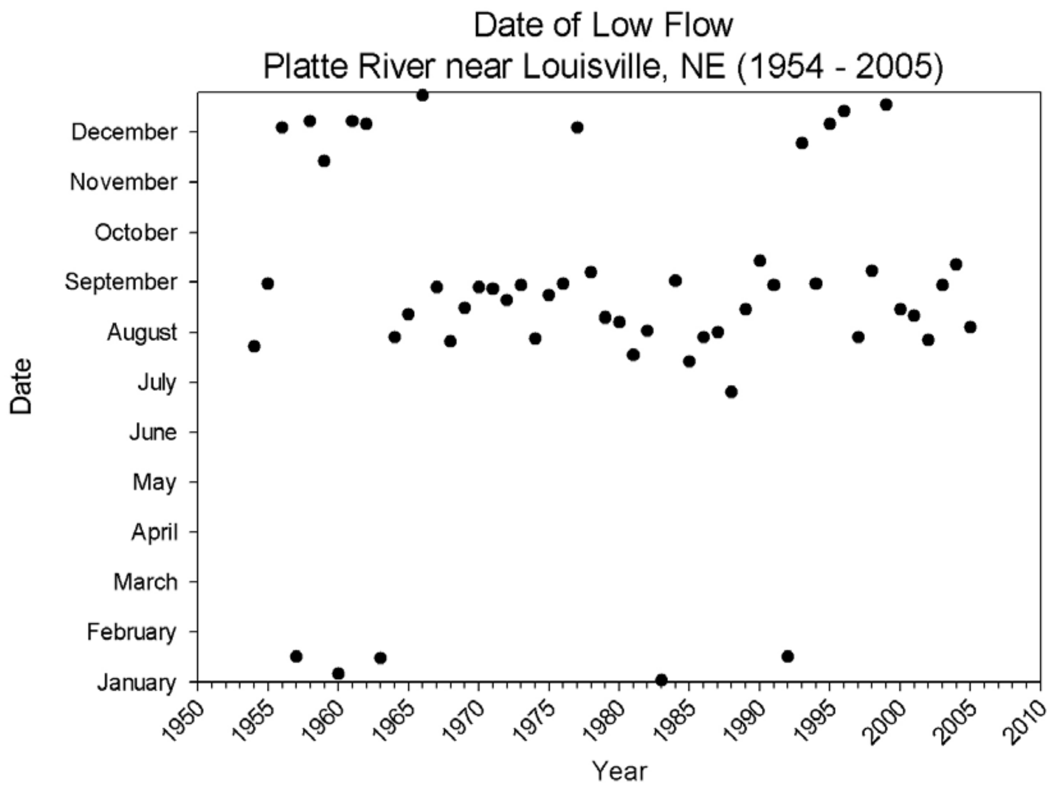
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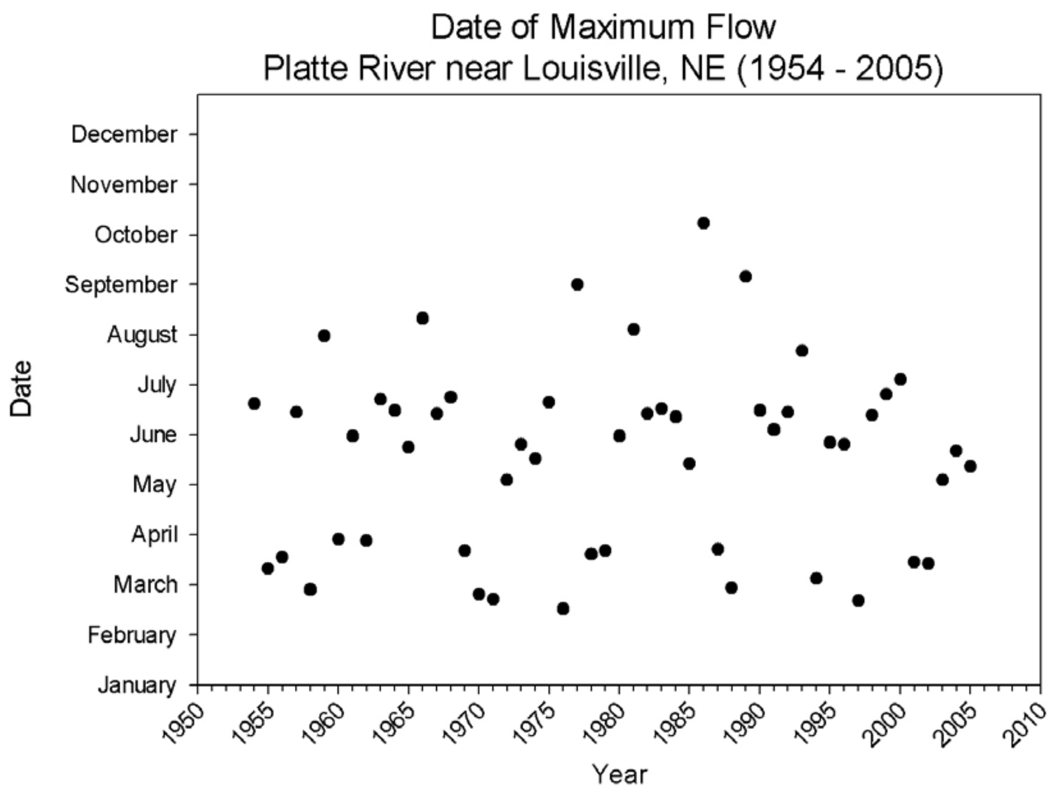
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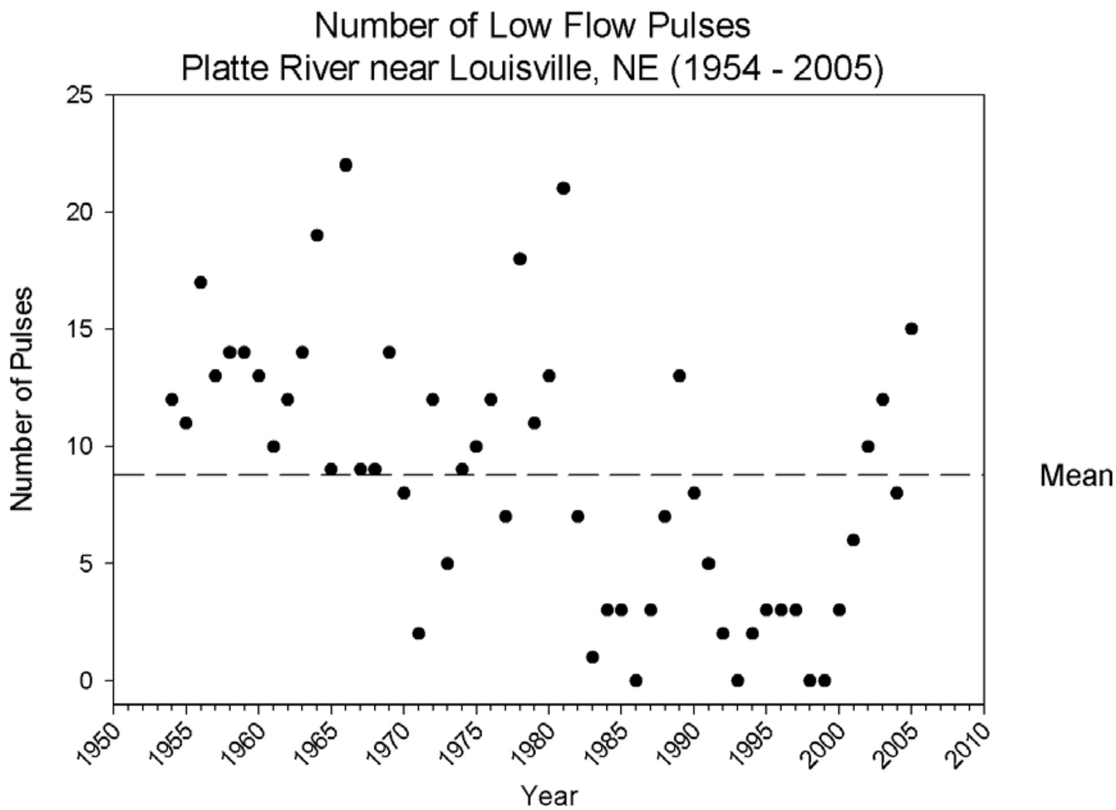
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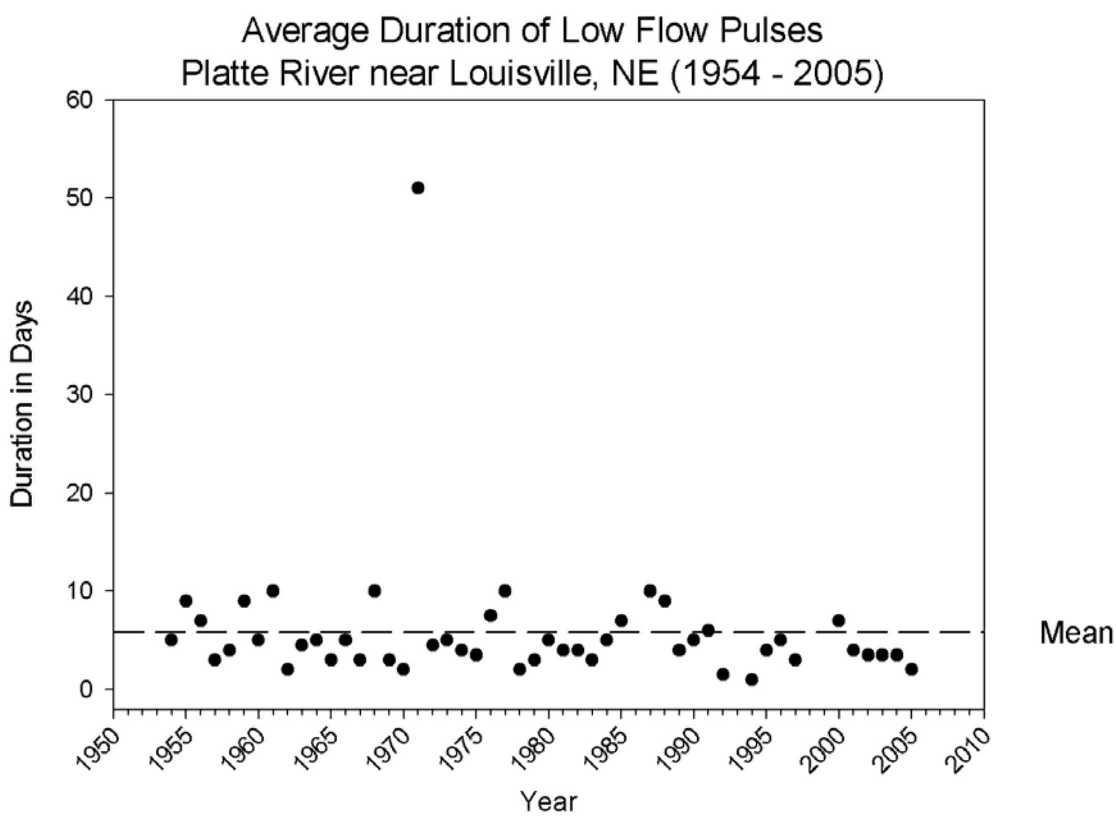
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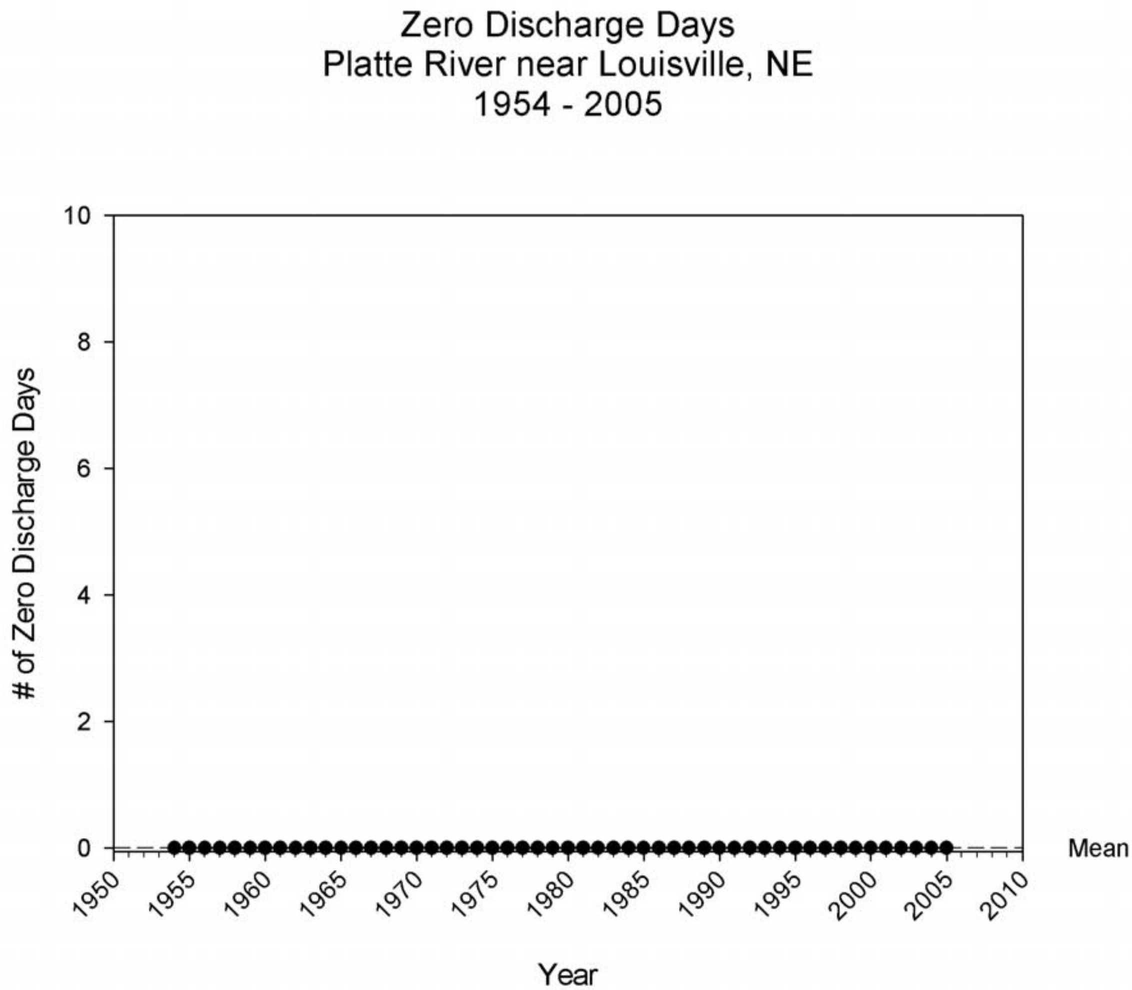
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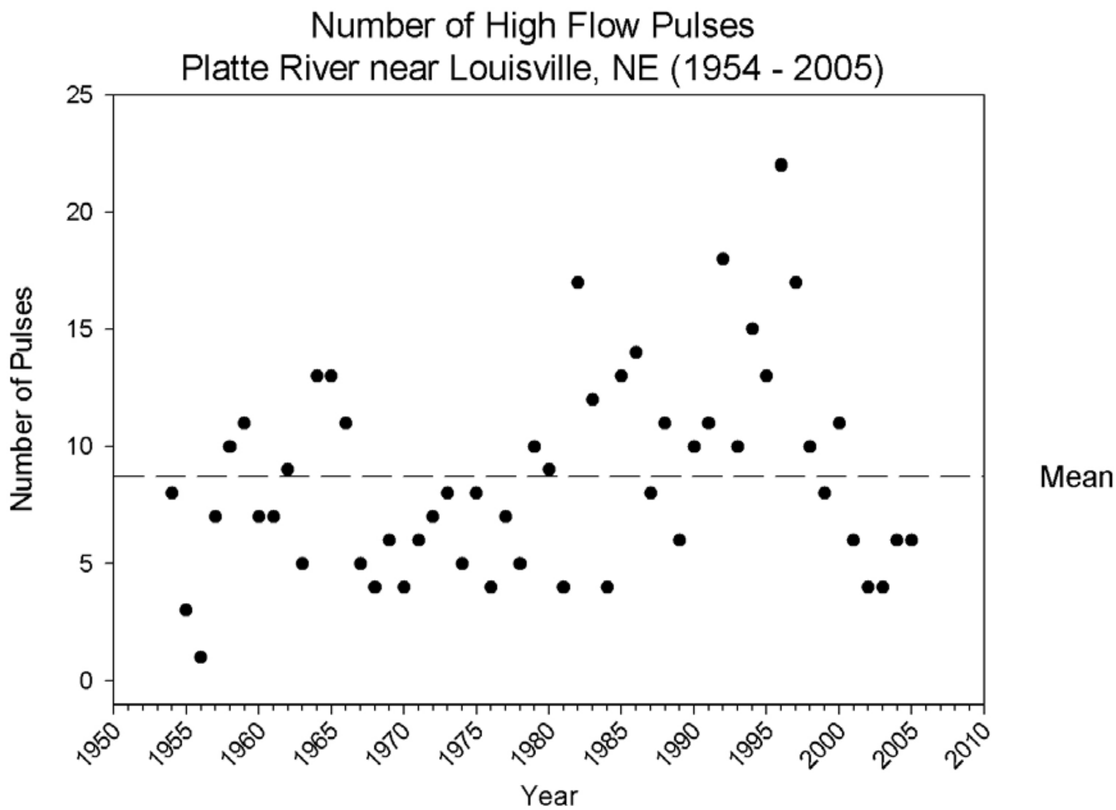
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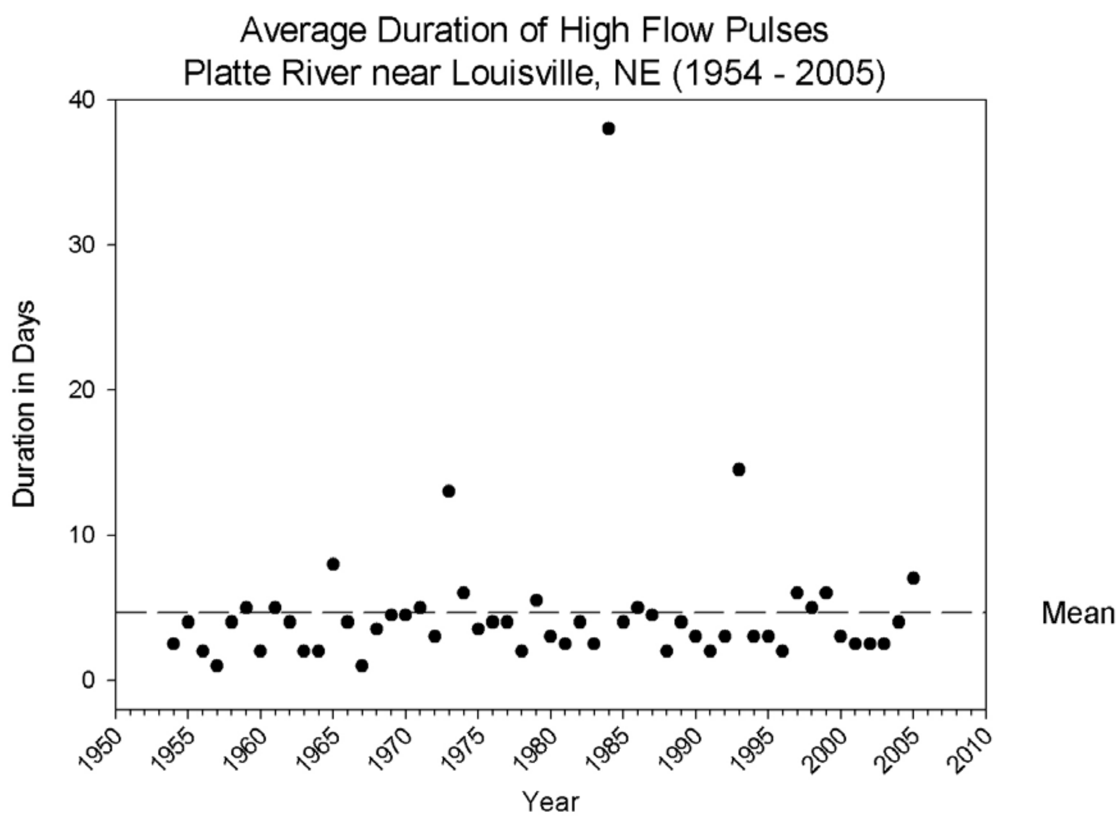
Average Duration of High Flow Pulses
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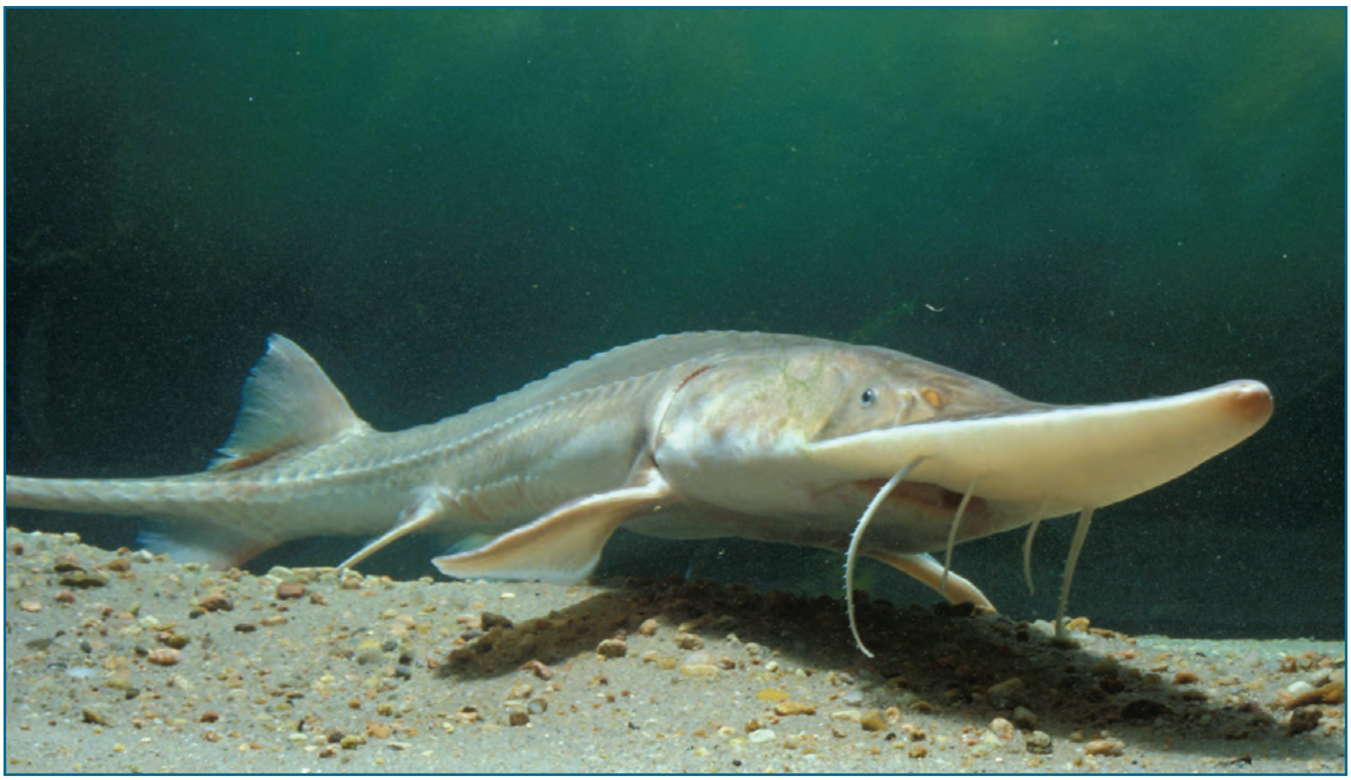
Ecology and Management of Sturgeon in the Lower Platte River, Nebraska



Ecology and Management of Sturgeon in the Lower Platte River, Nebraska

by

Edward J. Peters

and

James E. Parham

Nebraska Technical Series No. 18

Nebraska Game and Parks Commission
Lincoln, Nebraska

2008

A contribution of Federal Aid in Sport Fish Restoration
Project F-141-R, Nebraska

FORWARD

The research and findings described in Technical Series No. 18 (Ecology and Management of Sturgeon in the Lower Platte River, Nebraska) was initiated in response to two issues concerning pallid sturgeon that surfaced in the late 1990's. One issue dealt with continuing applications to the Nebraska Department of Natural Resources for new surface water appropriations to divert water in the lower Platte River Basin and their potential depletion effects on pallid sturgeon, a state and federal listed species. These concerns raised questions about whether or not sufficient water remained in the river to support a viable pallid sturgeon population. The Nebraska Game and Parks Commission is required under the Nebraska Nongame and Endangered Species Conservation Act to review applications for surface water appropriation effects on listed species. The second issue revolved around incidental angler harvest of pallid sturgeon while fishing for shovelnose sturgeon and the potential threat of closure of the shovelnose sturgeon sport fishery by the US Fish and Wildlife Service (USFWS). At the time, the Nebraska Game and Parks Commission (NGPC) concluded that insufficient information existed on sturgeon in the river to adequately address these issues. A research program coordinated by Drs. Edward Peters and James Parham at the University of Nebraska-Lincoln was developed to address this lack of information. It was cooperatively supported with funds from: NGPC (Federal Aid to Sport Fish Restoration Project F141R and State Wildlife Grants), Nebraska Environmental Trust, USFWS via a cooperative agreement with the Bureau of Reclamation; the Pallid Sturgeon, Sturgeon Chub (PS/SC) Task Force and the University of Nebraska-Lincoln.

Throughout the entire study period, this research program was continuously exposed to intensive peer-review. Project objectives and initial methodologies were extensively reviewed and approved by several independent sturgeon researchers and subsequently approved by program sponsors and funding agencies prior to initiation of research activities. In January 2002, a workshop on "Potential Approaches to Habitat/Hydraulic Modeling in the lower Platte River, Nebraska" was held in Lincoln and a group of national experts in stream hydrology, fisheries and riverine habitat modeling were engaged to critique and discuss the research program being implemented. Output from this workshop was incorporated into the research program to increase effectiveness in answering its objectives. In addition, preliminary research results were presented by the program principal investigators and graduate students at a number of national and regional scientific meetings which garnered questions and input from a wide variety of scientists which aided sampling methodologies and data analyses.

Upon completion of the research program, an initial report was written and submitted to Federal Aid (Final Report for Federal Aid Project F141R; May 2005) and to the PS/SC Task Force. The PS/SC Task Force funded an extensive peer-review of the report from a number of national experts in fisheries, hydrology and statistics. Drs. Peters and Parham received these peer-reviews and incorporated them and the required PS/SC Task Force changes into a final report (Pallid sturgeon and sturgeon chub in the lower Platte River 2000 to 2004) to the PS/SC Task Force which was formally accepted on 23 June 2006. Not all research results and analyses prepared by the University of Nebraska-Lincoln were included in the final PS/SC Task Force report. In an effort to allow these researchers to completely report the results of this important five-year program, the NGPC contracted with them to produce Technical Series No. 18. This publication incorporates all components of the initial program objectives and takes into account the full range of peer-reviews that the program undertook. It is our hope that by allowing the complete publication of the work that Drs. Peters and Parham completed, we will further the management and protection of the sturgeon, associated species and their habitats of the lower Platte River.

Richard Holland
Assistant Fisheries Division Administrator, Research

ACKNOWLEDGEMENTS

We wish to thank the people and organizations that made this research possible. All projects require the involvement and dedication of many people and organizations to be successful and this one has involved more than most. First of all there are those who asked what was being done on pallid sturgeon in the Platte River and then asked how we could do more. The people who asked those questions were: Kirk Nelson, Larry Hutchinson, Gene Zuerlein, and Richard Holland of the Nebraska Game and Parks Commission, thank you for your foresight. Besides the people listed above, Mark Czaplewski, Mark Peyton and John Shadle provided extensive reviews of this report. Dianne Peters provided invaluable assistance in the editorial process and Steve O'Hare was responsible for the layout and design. Thank you all for your dedication.

The answers came through the involvement of the local and regional natural resources management, irrigation, public power districts along the Platte River and its tributaries. These groups are: the Upper Elkhorn NRD, the Lower Elkhorn NRD, the Lower Loup NRD, the Central Platte NRD, the Lower Platte North NRD, the Lower Platte South NRD, and the Papio-Missouri NRD, the Nebraska Public Power District, the Central Nebraska Public Power and Irrigation District, the Loup Public Power District, the Twin Loups Reclamation District, the North Loup and Middle Loup Public Power and Irrigation Districts, and the Farwell and Sargent Irrigation Districts, thank you for your support over the past five years. In addition, the US Fish and Wildlife Service, especially Steve Lydick, and the Nebraska Association of Resources Districts, especially Dean Edson, provided guidance and assistance.

On the ground (in the water) and in the labs, there were many people who carried out the work summarized in these pages. To the graduate students, Benjamin Swigle, Dane Shuman, and Stacey Kopf, thanks for your hard work and dedication. To the former full time employees, Jason Olnes, Cory Reade ,Vaughn Snook, Cara Ewell-Hodkin, Larry Vrtiska, Mike Kaminski, Ryan Ruskamp, Amy Erie, and Josh Gonsior, thank you for enduring the long hours, cold water and hot sun and even longer hours checking and re-checking the data. To the student workers who spent long hours in the lab picking samples, entering data, collecting larval fish or tracking fish for telemetry surveys; Tom van Denberg, Clayton Ridenour, Keller Kopf, Matt Neukirch, Lynne Klawer, Chris Thode, Dave Putensen, Kent Fricke, Doug Ekberg, Amanda Keep, and Justin Dawson, thanks so very much! And finally to the students in ichthyology and fisheries science classes over the past five years who participated in the weekend field trips to the Platte River, I hope that you gained some insights to what it takes to do science.

This research was supported by funding from the Federal Aid to Sport Fish Restoration (Project No. F-141-R), through the Nebraska Game and Parks Commission, the Pallid Sturgeon, Sturgeon Chub Task Force (with grants from the Nebraska Environmental Trust and State Wildlife Grant), and the U. S. Fish and Wildlife Service (Cooperative Agreement No. 1448-60181-99-J459). The University of Nebraska, Institute of Agriculture and Natural Resources, Agricultural Research Division and the School of Natural Resources provided administrative support, facilities, and salary for E. J. Peters.

All Photos courtesy of Edward J. Peters except the cover, page 145 and 167 are courtesy of NEBRASKAland Magazine/Nebraska Game and Parks Commission.

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Figure 10.15. Mean suitable habitat for pallid sturgeon in relation to average daily discharge recorded at three gage locations in the lower Platte River. Average daily discharge is based on the complete published record from the USGS for each gage site.

Figure 10.16. Mean suitable habitat for shovelnose sturgeon in relation to average daily discharge recorded at three gage locations in the lower Platte River. Average daily discharge is based on the complete published record from the USGS for each gage site.

Figure 10.17. Curve of best fit for river connectivity vs. discharge (Equation 10.6) for the lower Platte River. The solid line represents the fitted line, the dashed lines are the 95% confidence intervals about the line, and the dots are the observations.

Figure 10.18. River connectivity for average monthly conditions in January for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.19. River connectivity for average monthly conditions in February for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.20. River connectivity for average monthly conditions in March for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.21. River connectivity for average monthly conditions in April for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.22. River connectivity for average monthly conditions in May for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.23. River connectivity for average monthly conditions in June for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.24. River connectivity for average monthly conditions in July for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.25. River connectivity for average monthly conditions in August for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.26. River connectivity for average monthly conditions in September for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.27. River connectivity for average monthly conditions in October for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.28. River connectivity for average monthly conditions in November for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

Figure 10.29. River connectivity for average monthly conditions in December for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

LIST OF EQUATIONS

LIST OF SCIENTIFIC NAMES USED IN THIS PUBLICATION

Family	Common name	Scientific name
Sturgeons	lake sturgeon	*Acipenser fulvescens*
	pallid sturgeon	*Scaphirhynchus albus*
	shovelnose sturgeon	*Scaphirhynchus platorynchus*
Paddlefish	paddlefish	*Polyodon spathula*
Gars	longnose gar	*Lepisosteus osseus*
	shortnose gar	*Lepisosteus platostomus*
Mooneyes	goldeye	*Hiodon alosoides*
Herrings	gizzard shad	*Dorosoma cepedianum*
Minnows	red shiner	*Cyprinella lutrensis*
	spotfin shiner	*Cyprinella spiloptera*
	western silvery minnow	*Hybognathus argyritis*
	brassy minnow	*Hybognathus hankinsoni*
	plains minnow	*Hybognathus placitus*
	shoal chub	*Macrhybopsis hyostoma*
	sturgeon chub	*Macrhybopsis gelida*
	sicklefin chub	*Macrhybopsis meeki*
	silver chub	*Macrhybopsis storeriana*
	emerald shiner	*Notropis atherinoides*
	river shiner	*Notropis blennius*
	bigmouth shiner	*Notropis dorsalis*
	sand shiner	*Notropis stramineus*
	suckermouth minnow	*Phenacobius mirabilis*
	fathead minnow	*Pimephales promelas*
	flathead chub	*Platygobio gracilis*
	western blacknose dace	*Rhinichthys obtusus*
	longnose dace	*Rhinichthys cataractae*
	creek chub	*Semotilus atromaculatus*
Asian carps	grass carp	*Ctenopharyngodon idella*
	common carp	*Cyprinus carpio*
	bighead carp	*Hypophthalmichthyes nobilis*

	silver carp	*Hypophthamichthyes molitrix*
Suckers	river carpsucker	*Carpiodes carpio*
	quillback	*Carpiodes cyprinus*
	longnose sucker	*Catostomus catostomus*
	white sucker	*Catostomus commersonii*
	blue sucker	*Cycleptus elongatus*
	smallmouth buffalo	*Ictiobus bubalus*
	bigmouth buffalo	*Ictiobus cyprinellus*
	shorthead redhorse	*Moxostoma macrolepidotum*
Catfishes	black bullhead	*Ameiurus melas*
	blue catfish	*Ictaluras furcatus*
	channel catfish	*Ictaluras punctatus*
	flathead catfish	*Pylodictus olivaris*
Silversides	brook silverside	*Labidesthes sicculus*
Killifishes	plains topminnow	*Fundulus sciadicus*
	northern plains killifish	*Fundulus kansae*
Livebearers	western mosquitofish	*Gambusia affinis*
Sticklebacks	brook stickleback	*Culaea inconstans*
Temperate basses	white perch	*Morone americana*
	white bass	*Morone chrysops*
Sunfishes	green sunfish	*Lepomis cyanellus*
	orangespotted sunfish	*Lepomis humilis*
	bluegill	*Lepomis macrochirus*
	largemouth bass	*Micropterus salmoides*
	white crappie	*Pomoxis annularis*
	black crappie	*Pomoxis nigromaculatus*
Perches	johnny darter	*Etheostoma nigrum*
	yellow perch	*Perca flavescens*
	sauger	*Sander canadensis*
	walleye	*Sander vitreus*
Drums	freshwater drum	*Aplodinotus grunniens*

CHAPTER 1
GENERAL INTRODUCTION

In 1999, the Nebraska Game and Parks Commission along with a consortium of Natural Resources Districts and Public Power and Irrigation districts developed a committee to investigate the possibilities of funding to supplement research on the Platte River dealing with pallid sturgeon. This developed into an organization known as the Pallid Sturgeon / Sturgeon Chub Task Force and on 18 May 2000, they approved the funding of a five-year study on pallid sturgeon, sturgeon chub and associated species in the lower Platte River. This funding dove-tailed with a Federal Aid to Sportfish Restoration project that focused on the ecological relationship of sturgeons with fish species typical of shifting sand-bed rivers. This report presents the results and conclusions of these integrated studies.

Goals and Objectives:

The goal of the Federal Aid to Sportfish Restoration study was to quantitatively describe the habitats used by sturgeons and the ecological relationships of sturgeons with fish species typical of shifting sand-bed rivers.

To accomplish these goals the study delineated five objectives.

Objective 1 was to document habitat use, relative habitat preference and species assemblages associated with adult and juvenile sturgeon in the lower Platte River.

Objective 2 was to document the phenology and relative abundance of larval recruitment for sturgeon and associated species in the lower Platte River.

Objective 3 was to determine how changes in river discharge influence habitat use by sturgeon life stages in the lower Platte River.

Objective 4 was to document the catch of sturgeon by anglers in the lower Platte River.

Objective 5 was to develop educational materials and management recommendations for the sturgeon fishery in the lower Platte River.

The goal of the Pallid Sturgeon / Sturgeon Chub Task Force (Task Force) study was to quantitatively describe habitat use by pallid sturgeon and sturgeon chub in the lower Platte River. The study also included an analysis of the ecological relationships among pallid sturgeon and sturgeon chub, and other fish species typical of shifting sand-bed rivers, exemplified by the Platte River.

To accomplish these goals, the Task Force study delineated five objectives.

Objective 1 was to document habitat use, relative habitat preference and species assemblages associated with adult and juvenile pallid sturgeon and sturgeon chub in the lower Platte River.

Objective 2 was to document the phenology and relative abundance of larvae for pallid sturgeon, sturgeon chub and associated species in the lower Platte River.

Objective 3 was to determine if changes in ambient river habitat conditions influence habitat use by pallid sturgeon and sturgeon chub life stages in the lower Platte River.

Objective 4 was to document the catch of sturgeon by anglers in the lower Platte River.

Objective 5 was to develop management recommendations and educational materials to facilitate appropriate recovery efforts for pallid sturgeon and sturgeon chub in the lower Platte River.

Study Area:

The Platte River has been a significant feature in the central Great Plains of North America since before the end of the last glacial advance. From its origin on the east slope of the Rocky Mountains in Colorado and extending east across Nebraska it drains over 230,000 km^2 (Galat et al. 2005a, NRC 2005). Flows in the Platte River system have been modified greatly by power generation facilities and municipal and irrigation diversions, which are facilitated by dams on the main stem as well as on major tributaries (Eschner et al.1983, Randle and Samad 2003). Even with the alterations in discharge that have accompanied the diversions from upstream sources, the lower Platte River has retained many of the braided channel characteristics of the historic river. In particular, the active channel of the lower Platte near Ashland, Nebraska was nearly 90 percent as wide with shallow, shifting sand bars in 1980 as it was in 1860 (Eschner et al.1983). This is in contrast to the narrowing of the active channel that has occurred at upstream sites. Eschner et al. (1983) found that in 1980 the active river channel near Duncan, NE was 50% of its 1860 width and near Cozad, NE the active channel was less than 10% of its 1860 width. This kind of habitat, now found in only a small proportion of the middle Missouri River and its tributaries, may have been preferred by pallid sturgeon and sturgeon chub. Channel stabilization activities of the Reclamation Act of 1904 and dam construction by the Pick-Sloan Plan of 1944 changed the middle Missouri River from a braided river with shifting sand bars to its present channelized form (Galat et al. 2005a). Other laws that contributed to the channelization and bank stabilization of the lower Missouri River included, in 1912 Public Law 62-241, in 1925 Public Law 68-585, in 1927 Public Law 70-560, and in 1945 Public Law 79-14.

The lower Platte River begins at the confluence of the Platte and Loup Rivers near the city of Columbus, Nebraska and extends downstream approximately 162 km to the Missouri River near Plattsmouth, Nebraska (Figure 1.1). In this reach, the Platte River is characterized by a wide, gently sloping channel of shifting sandbars. Riparian vegetation and stabilized sand bars are generally covered by a combination of cottonwood and eastern red cedar interspersed with areas of grasses and croplands (Peters et al. 1989, NDEQ 1990). Table 1.1 lists the major study locations and their river mile (RM) designations along the lower Platte River. These RM values were measured from a set of U.S. Army Corps of Engineers aerial photos (April 21, 1979).

In the lower Platte River, water temperatures of over 40 °C have been recorded in June, July, and August, but average monthly temperatures range from near 0 °C in January to about 25 °C in July (Peters et al. 1989). United States Geological Survey (USGS) records document typical pH values of 8.0, alkalinity of 153.5 mg $CaCO_3$/L, nitrate

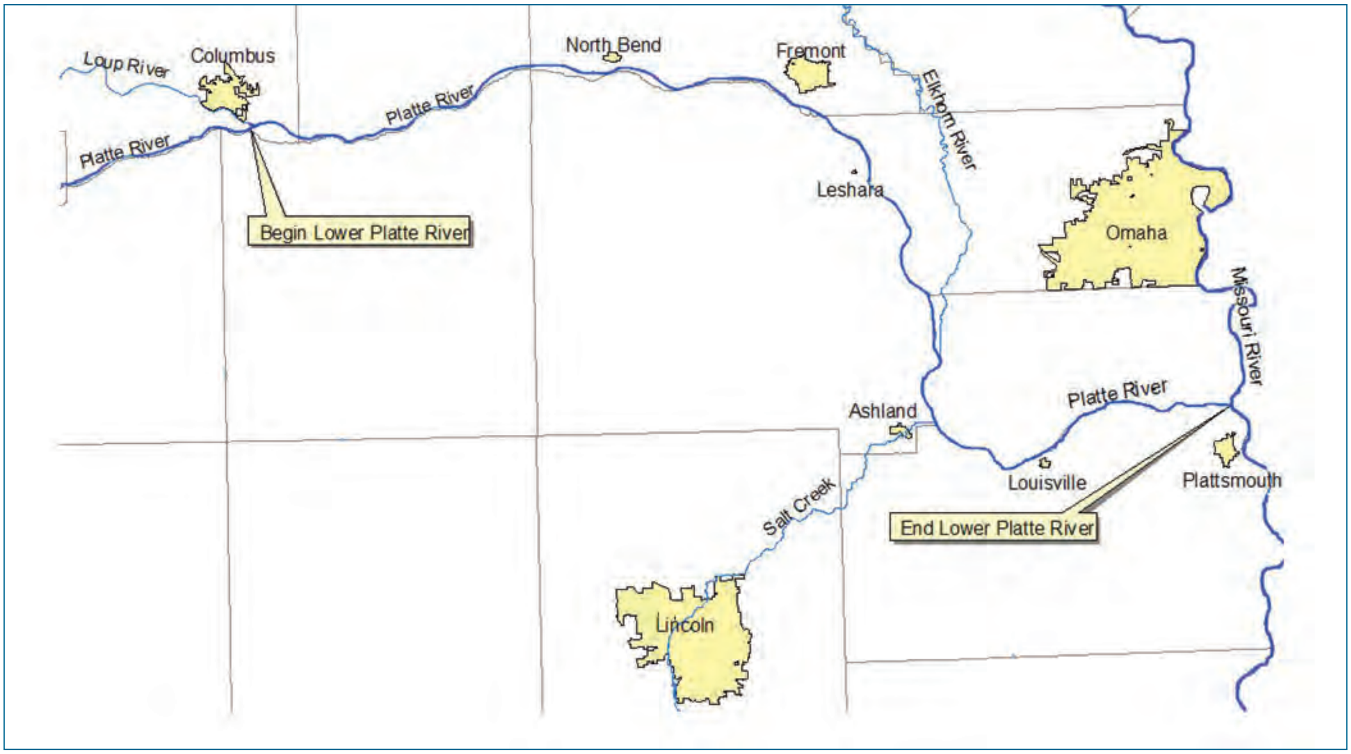


Figure 1.1 Map of the lower Platte River showing major tributaries and important landmarks used to reference study sites.

Table 1.1. Location of study sites and points of reference along the lower Platte River, Nebraska indicating river miles (RM) from the confluence of the Platte and Missouri Rivers (US Army Corps of Engineers aerial photography, April 21, 1979).

LOCATION	RM	TYPE OF SAMPLING or POINT OF REFERENCE
US Highway 81 bridge	106.1	Larval fish sampling
Confluence of Loup River with the Platte River	103	POINT OF REFERENCE
Confluence of the Loup Power Canal with the Platte River	101.5	POINT OF REFERENCE
Nebraska Highway 15 bridge	88.5	POINT OF REFERENCE
Nebraska Highway 79 bridge	72.4	Larval fish sampling Substrate sampling
US Highway 77 bridge	56. 8	POINT OF REFERENCE
Nebraska Highway 64 bridge	48.8	Substrate sampling Water chemistry sampling Access point for trawling
Nebraska Highway 92 bridge	41.5	POINT OF REFERENCE
Two Rivers State Recreation area	40.8	Larval fish sampling
Confluence of Elkhorn River with the Platte River	32.8	POINT OF REFERENCE
US Highway 6 bridge	27.8	Larval fish sampling site Substrate and water chemistry sampling site
Confluence of Salt Creek with the Platte River	25.9	POINT OF REFERENCE
Interstate Highway 80 bridge	25	POINT OF REFERENCE
Schramm Park	22	Upstream access point for creel survey
Louisville Lakes State Recreation Area	17-18	Access point for creel survey
Nebraska Highway 50 bridge	16.3	Access point for creel survey Substrate and water chemistry sampling site
Sand bar and deep run downstream from Louisville	15.5	Larval fish sampling site
Omaha Metropolitan Utilities District Cedar Island Well Field	5-7	POINT OF REFERENCE
US Highway 73,75 bridge	2.6	POINT OF REFERENCE
Schilling Wildlife Management Area	0 – 0.5	Downstream access point for creel survey Larval fish sampling site

nitrogen of 1.35 mg/L and phosphate phosphorous of 0.73 mg/L (Galat et al. 2005a). The Platte River basin, which originally was dominated by grasslands (Galat et al. 2005a, NRC 2005), has been highly modified for agricultural production which occupies approximately 90% of the land area. Irrigated agriculture in the central and lower sub-basins of the Platte River in Nebraska consumes 1,366,400 acre-feet of surface water each year (NRC 2005). The majority of this water is used to grow corn.

River Discharge (contributions of tributaries to the Platte River)

At its upstream end, the lower Platte River receives water from the Platte River and the Loup River. Mean monthly discharge records for the common time period of 1954 to 2004 were examined for all gages except the Platte River at Ashland, NE (USGS Gage: 6801000, 1954 – 1960 and 1989 – 1999). Table 1.2 (Mean monthly discharges) and Table 1.3 (Percentages of Louisville discharge) show that mean monthly discharge records from the Platte River near Duncan, NE (USGS Gage: 677400) average about 27% of the mean monthly discharge at the Louisville, NE gage (USGS Gage: 6805500). The highest monthly percentage of discharge, between Duncan and Louisville, occurs during January (34%), December (33%) and February (31%). The lowest percentage monthly discharge at Duncan occurs during August and is 18% of discharge at the Louisville gage.

During dry periods, especially during the summer, most or all of the flow in the Platte River comes from the Loup River system. The Loup River system drains approximately 15,230 square miles of sandy and loess soils in central

Nebraska. Most of the sandy soils support rangeland agriculture, while most of the loess soils are devoted to cultivated cropland agriculture (NDEQ 1990). Mean monthly discharge records from the Loup River near Genoa, NE (USGS gage: 679300) averages about 10 % of the Louisville gage and the Loup River Power Canal near Genoa, NE (USGS Gage: 6792500) over its period of record from 1937 to present averages 24 % of the Louisville Gage. The sum of these two gages, which would represent the total flow of the Loup River at the mouth of the Loup River, therefore averages, about 34 % of the discharge at the Louisville gage. The percentage that the Loup River contributes to the Platte River discharge at Louisville ranges from 25 % during June to 46 % during January.

Between the Loup River and the Elkhorn River the lower Platte receives small additions to its flow from the Shell Creek and Lost Creek drainages. However, on some occasions heavy rains in the Shell Creek Drainage can contribute large volumes of runoff to the lower Platte River. This runoff is typically silt-laden and has been noted to carry pesticides and nutrients at concentrations that are ranked "among the highest in the Nation" (Frenzel et al. 1998). This section of the lower Platte River also receives inflow from several drainage ditches that were dug to lower water tables on the north side of the river.

The Elkhorn River drains about 7,000 square miles from the eastern Sandhills, which produces considerable amounts of hay from grasses and alfalfa (NDEQ 1990). The eastern portion of the basin produces large quantities of corn and soybeans on loess soils in northeast Nebraska. Irrigation in most of the Elkhorn River drainage depends heavily on ground water withdrawals. Discharge from the Elkhorn River at Waterloo, NE (USGS Gage: 6800500) averages 21 % of the discharge for the Platte River at Louisville and ranges from 15 % during January to 27 % during June. This means that the Elkhorn River is an important contributor to summer flows in the lower Platte River.

Downstream from the Elkhorn River, Salt Creek, which includes the flows from the Wahoo Creek Drainage, enters the lower Platte River from the south side. Discharge from Salt Creek at Greenwood, NE (USGS Gage: 6803555) averages 5 % of the Platte River discharge at Louisville and ranges from 3 % during November through January to 8% during July and August. This is the only major tributary that drains land on the south side of the Platte River in Nebraska. Salt Creek receives flows from sewage treatment facilities in Lincoln, Nebraska and saline water from salt marshes in Lancaster County and therefore has water chemistry characteristics that are quite different from the other tributaries to the lower Platte River.

Overall, the inputs from these gaged sources account for an annual average of 88% of the discharge at Louisville and ranges from a low of 83% during May to July to a high of 99% during January. In contrast to these sources of water for the lower Platte River, the well fields for the cities of Lincoln and Omaha withdraw water from aquifers along and under the Platte River. The Lincoln well fields extend from just downstream of the confluence of the Platte River and the Elkhorn River (RM 32.8) to just upstream from the confluence of the Platte River and Salt Creek (RM 25.9). The operating Omaha well field is located in

Table 1.2. Mean monthly discharge (cfs) from 1954 to 2004 for selected gage stations associated with the lower Platte River, Nebraska. All gages have complete records except the Platte River at Ashland, NE where the period of record is 1954-1960 & 1989-1999.

				Discharge (cfs)				
Gage Location	USGS Gage Number	JAN	FEB	MAR	APR	MAY	JUN	JUL
Platte River near Duncan, NE	6774000	1633	2328	2923	2552	2601	2891	1432
Loup River near Genoa, NE	6793000	1043	1360	1661	732	612	727	293
Loup River Power Canal near Genoa, NE	6792500	1155	1604	1939	2191	2035	1960	1371
Platte River near North Bend, NE	6796000	3409	5164	7285	5992	5858	6562	3573
Elkhorn River near Waterloo, NE	6800500	713	1396	2421	2381	2321	2998	1616
Platte River near Ashland, NE	6801000	4047	6012	8610	8299	8298	9523	6186
Salt Creek near Greenwood, NE	6803555	159	262	496	393	608	716	508
Platte River near Louisville, NE	6805500	4742	7455	11013	9819	9823	11166	6278

				Discharge (cfs)			
Gage Location	USGS Gage Number	AUG	SEP	OCT	NOV	DEC	Yearly Mean
Platte River near Duncan, NE	6774000	729	1025	1487	1602	1596	1900
Loup River near Genoa, NE	6793000	241	258	148	470	1165	726
Loup River Power Canal near Genoa, NE	6792500	1262	1587	2024	1926	986	1670
Platte River near North Bend, NE	6796000	2452	3049	3837	4169	3606	4580
Elkhorn River near Waterloo, NE	6800500	989	789	827	871	770	1508
Platte River near Ashland, NE	6801000	3963	3652	4421	5076	4599	6057
Salt Creek near Greenwood, NE	6803555	314	261	258	180	149	359
Platte River near Louisville, NE	6805500	4105	4285	5164	5500	4894	7020

Table1.3. Percentage of discharge compared with Louisville discharge from 1954 to 2004 for selected gage stations associated with the lower Platte River, Nebraska. All gages have complete records except the Platte River at Ashland, NE where the period of record is 1954-1960 & 1989-1999.

				Discharge (%)				
Gage Location	USGS Gage Number	JAN	FEB	MAR	APR	MAY	JUN	JUL
Platte River near Duncan, NE	6774000	34%	31%	27%	26%	26%	26%	23%
Loup River near Genoa, NE	6793000	22%	18%	15%	7%	6%	7%	5%
Loup River Power Canal near Genoa, NE	6792500	24%	22%	18%	22%	21%	18%	22%
Platte River near North Bend, NE	6796000	72%	69%	66%	61%	60%	59%	57%
Elkhorn River near Waterloo, NE	6800500	15%	19%	22%	24%	24%	27%	26%
Platte River near Ashland, NE	6801000	85%	81%	78%	85%	84%	85%	99%
Salt Creek near Greenwood, NE	6803555	3%	4%	5%	4%	6%	6%	8%
Platte River near Louisville, NE	6805500	100%	100%	100%	100%	100%	100%	100%

				Discharge (%)			
Gage Location	USGS Gage Number	AUG	SEP	OCT	NOV	DEC	Yearly Mean
Platte River near Duncan, NE	6774000	18%	24%	29%	29%	33%	27%
Loup River near Genoa, NE	6793000	6%	6%	3%	9%	24%	10%
Loup River Power Canal near Genoa, NE	6792500	31%	37%	39%	35%	20%	24%
Platte River near North Bend, NE	6796000	60%	71%	74%	76%	74%	65%
Elkhorn River near Waterloo, NE	6800500	24%	18%	16%	16%	16%	21%
Platte River near Ashland, NE	6801000	97%	85%	86%	92%	94%	86%
Salt Creek near Greenwood, NE	6803555	8%	6%	5%	3%	3%	5%
Platte River near Louisville, NE	6805500	100%	100%	100%	100%	100%	100%

the area downstream from the Nebraska highway 50 bridge approximately from RM 7 downstream to RM 5. A new well field for the Omaha metropolitan area is being developed in the area upstream from the confluence of the Platte River and Elkhorn River between RM 33 and 38. Specific depletions of flows in the Platte River have not, to our knowledge, been measured, but water system officials from both Lincoln and Omaha have expressed concern when flows in the Platte River are low, especially during the summer.

Comparison of Historic Discharge Records to the 2000 to 2004 study period:

The period of 2000 to 2004 was one of very low precipitation in the Platte River drainage (US Drought Monitor: http://drought.unl.edu/dm). This resulted in depletions in the amount of water stored and released from reservoirs of the North and South Platte River system and resulted in periods of zero discharge in many sections of the Platte River from Columbus upstream to Elm Creek, Nebraska. An examination of the mean monthly discharge records at the Louisville gage as displayed in Table 1.4 (Comparison of mean monthly discharges) and Table 1.5 (Percentages) shows that discharge during the 2000 to 2004 period of study averaged 74% of pre-2000 flows and ranged from 53% of pre-2000 flows during June to 98% of pre-2000 flows during January. Discharge during the period of the study at the Duncan gage on the Platte River was proportionally the lowest, averaging 55% of pre-2000 flows while discharge during the period of the study at the Elkhorn River at Waterloo gage was proportionally the highest, averaging 102% of pre-2000 flows.

Mean daily discharge values from USGS gaging stations for the Platte River at Leshara, the Elkhorn River at Waterloo, Salt Creek at Greenwood, and the Platte River at Louisville for July 2001 through June 2004 on the dates those sites were sampled for water quality parameters are displayed on Figures 1.2, 1.3, 1.4 and 1.5, respectively (note that the scales on the Y-axes vary at each site).

HISTORICAL CONTEXT:

Over the years since the first European settlement of the Platte River basin, many conflicts have arisen over the use and allocation of its water resources. These conflicts have included the need for water to support the habitat of endangered and threatened species under the US Endangered Species Act. The US Fish and Wildlife Service has issued jeopardy opinions for activities that would affect the central Platte River, including one for the Narrows Project on the South Platte River in 1983, for water diversions on the Front Range in Colorado in 1994, and for relicensing the Kingsley hydroelectric project in 1997 (NRC 2005). In 1997, the states of Colorado, Wyoming, and Nebraska and the Department of the Interior entered into a Cooperative Agreement. As part of this agreement the parties have developed a program to reduce shortages to U.S. Fish and Wildlife Services target flows at Grand Island by 130,000 to 150,000 acre-feet per year and to protect or restore 10,000 acres of habitat in the central Platte region during the program's first 13 year increment (USDOI, Bureau of Reclamation, US Fish and Wildlife Service 2006).

Fish Species:

One hundred species of fish (76 native, 24 exotic) have

Table 1.4. Mean monthly discharge prior to and during study period for selected gage stations associated with the lower Platte River, Nebraska.

				Discharge (cfs)					
Gage Location	USGS Gage Number	Time Period	JAN	FEB	MAR	APR	MAY	JUN	JUL
Platte River, Duncan, NE	6774000	1929-1999	1506	2310	3019	2429	2560	2872	1259
		2000-2004	1587	1719	1918	1495	1324	592	337
Loup River, Genoa, NE	6793000	1944-1999	957	1377	1667	680	638	928	376
		2000-2004	1254	976	1634	887	501	129	139
Loup River Power Canal, Genoa, NE	6792500	1937-1999	1158	1513	1810	2107	1969	1921	1367
		2000-2004	835	1331	1621	2028	1898	1674	1266
Platte River, North Bend, NE	6796000	1950-1999	3466	5411	7510	6113	6020	6778	3778
		2000-2004	2828	3466	4912	4732	4462	3037	2075
Elkhorn River, Waterloo, NE	6800500	1929-1999	608	1198	2281	2061	2040	2857	1421
		2000-2004	922	1231	1838	1949	2847	2115	1841
Platte River, Ashland, NE	6801000	1928-1960 & 1989-1999	3732	5837	9007	7514	7675	9905	5385
		2000-2004	3255	5022	7354	6573	7997	5539	3743
Salt Creek, Greenwood, NE	6803555	1952-1999	159	269	518	423	595	725	537
		2000-2004	141	171	276	178	619	542	211
Platte River, Louisville, NE	6805500	1954-1999	4751	7610	11270	10071	9949	11706	6513
		2000-2004	4654	6030	8648	7498	8661	6193	4115

Table 1.4 (continued). Mean monthly discharge prior to and during study period for selected gage stations associated with the lower Platte River, Nebraska.

				Discharge (cfs)				
Gage Location	USGS Gage Number	Time Period	AUG	SEP	OCT	NOV	DEC	Yearly Mean
Platte River, Duncan, NE	6774000	1929-1999	563	903	1314	1479	1441	1140
		2000-2004	248	271	570	764	1022	575
Loup River, Genoa, NE	6793000	1944-1999	260	237	151	436	1072	431
		2000-2004	82	223	167	688	1342	500
Loup River Power Canal, Genoa, NE	6792500	1937-1999	1239	1546	1942	1853	992	1514
		2000-2004	1126	1530	1852	1713	970	1438
Platte River, North Bend, NE	6796000	1950-1999	2588	3129	3873	4219	3666	3495
		2000-2004	1464	2137	2897	3338	2664	2500
Elkhorn River, Waterloo, NE	6800500	1929-1999	964	735	730	752	655	767
		2000-2004	704	645	701	909	876	767
Platte River, Ashland, NE	6801000	1928-1960 & 1989-1999	3557	3428	3971	4529	3980	3893
		2000-2004	1908	2565	3406	4212	3851	3188
Salt Creek, Greenwood, NE	6803555	1952-1999	321	263	255	178	148	233
		2000-2004	203	171	191	163	124	170
Platte River, Louisville, NE	6805500	1954-1999	4298	4437	5287	5586	4947	4911
		2000-2004	2327	2887	3740	4507	4288	3550

been recorded from the Platte (Schainost and Koneya 1999, Peters and Schainost 2005). Of particular interest to this study are the pallid sturgeon, shovelnose sturgeon, and sturgeon chub, but all species encountered during this study have been evaluated in these results.

STRUCTURE OF THIS REPORT:

This report is divided into chapters each of which encompasses all or part of one of the major objectives.

Chapter 2 details the sampling effort for adult and juvenile fish and compares the efficacy of each method.

Chapter 3 details the study effort for water quality sampling.

Chapter 4 details the studies of habitat use, movement, and population characteristics for pallid sturgeon in the lower Platte River.

Chapter 5 details the studies of habitat use, movement, and population characteristics for shovelnose sturgeon in the lower Platte River.

Chapter 6 presents the information on shovelnose sturgeon food habits in the lower Platte River.

Chapter 7 details the habitat use and population characteristics for chubs in the lower Platte River.

Chapter 8 details the sampling effort for larval fish in the lower Platte River.

Chapter 9 details the creel survey in the lower Platte River.

Chapter 10 details the development of models of relationships between Platte River discharge and sturgeon and chub habitat and habitat connectivity in the lower Platte River.

Chapter 11 presents the conclusions drawn from the analyses of the data collected during this study.

Table 1.5. Percentage of discharge for study period (2000-2004) compared with discharge prior to study period for selected gage stations associated with the lower Platte River, Nebraska.

				% of pre-study flows			
Gage Location	USGS Gage Number	JAN	FEB	MAR	APR	MAY	JUN
Platte River near Duncan, NE	6774000	105	74	64	62	52	21
Loup River near Genoa, NE	6793000	131	71	98	131	79	14
Loup River Power Canal near Genoa, NE	6792500	72	88	90	96	96	87
Platte River near North Bend, NE	6796000	82	64	65	77	74	45
Elkhorn River near Waterloo, NE	6800500	152	103	81	95	140	74
Platte River near Ashland, NE	6801000	87	86	82	87	104	56
Salt Creek near Greenwood, NE	6803555	89	63	53	42	104	75
Platte River near Louisville, NE	6805500	98	79	77	74	87	53

				% of pre-study flows				
Gage Location	USGS Gage Number	JUL	AUG	SEP	OCT	NOV	DEC	Yearly Mean
Platte River near Duncan, NE	6774000	27	44	30	43	52	71	55
Loup River near Genoa, NE	6793000	37	32	94	111	158	125	91
Loup River Power Canal near Genoa, NE	6792500	93	91	99	95	92	98	92
Platte River near North Bend, NE	6796000	55	57	68	75	79	73	67
Elkhorn River near Waterloo, NE	6800500	130	73	88	96	121	134	102
Platte River near Ashland, NE	6801000	70	54	75	86	93	97	81
Salt Creek near Greenwood, NE	6803555	39	63	65	75	91	84	68
Platte River near Louisville, NE	6805500	63	54	65	71	81	87	74

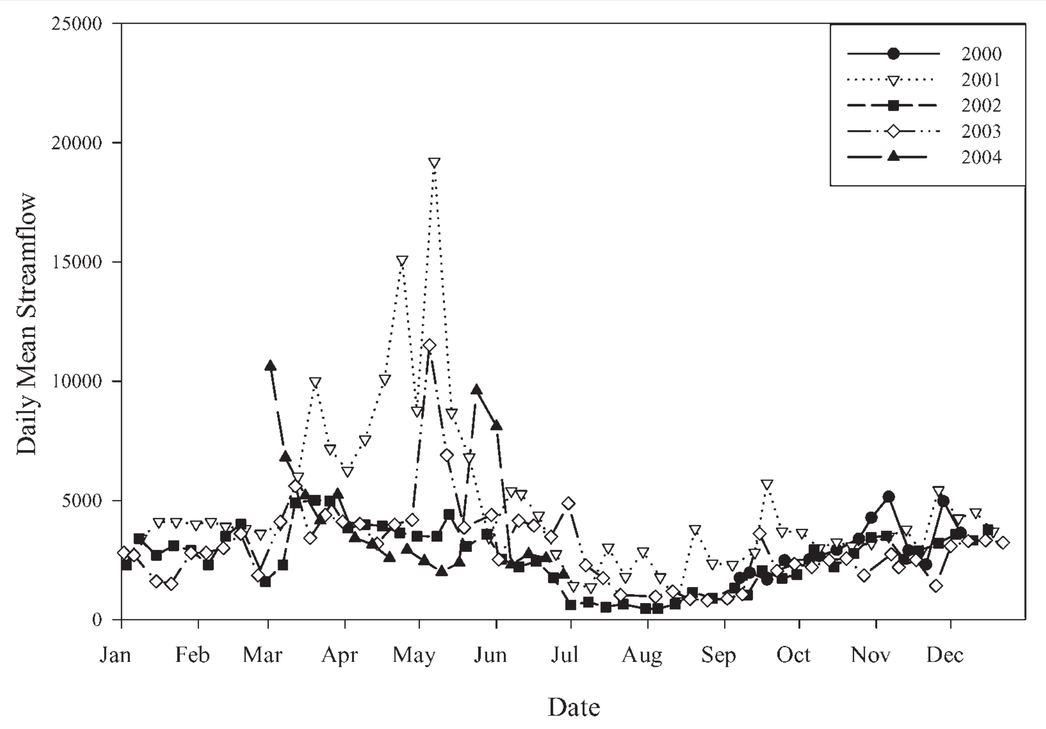


Figure 1.2. Daily mean streamflow (cfs) in the Platte River at Leshara, September 2000 to June 2004 (USGS data).

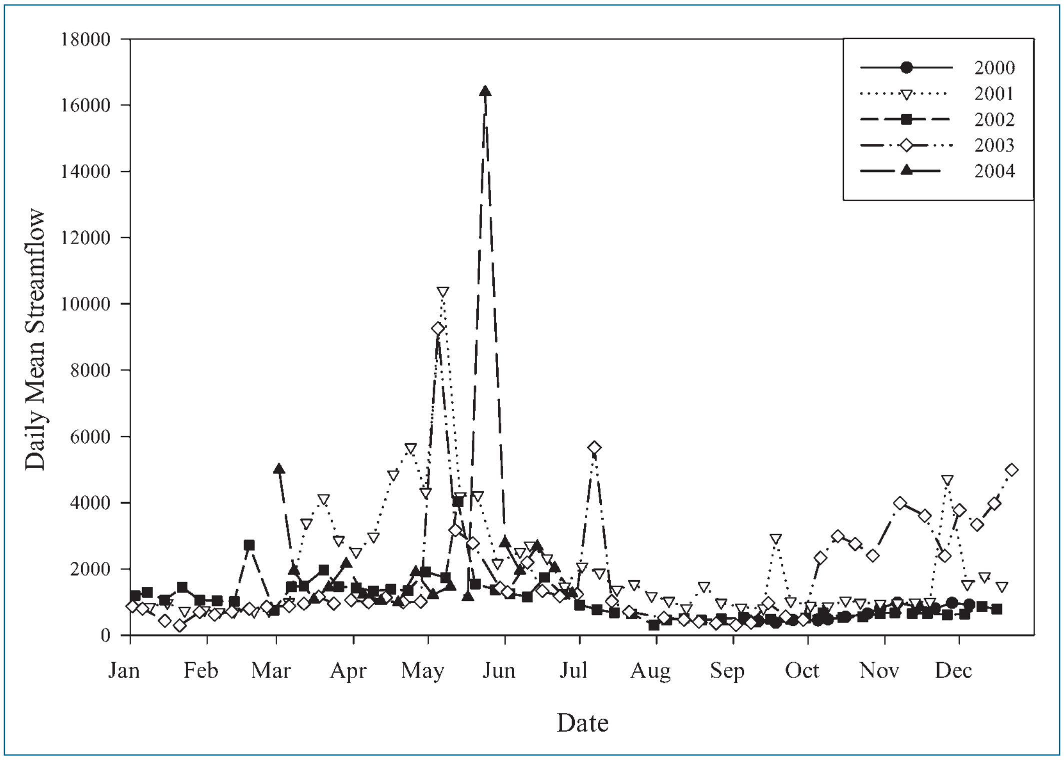


Figure 1.3. Daily mean streamflow (cfs) in the Elkhorn River at Waterloo, September 2000 to June 2004 (USGS data).

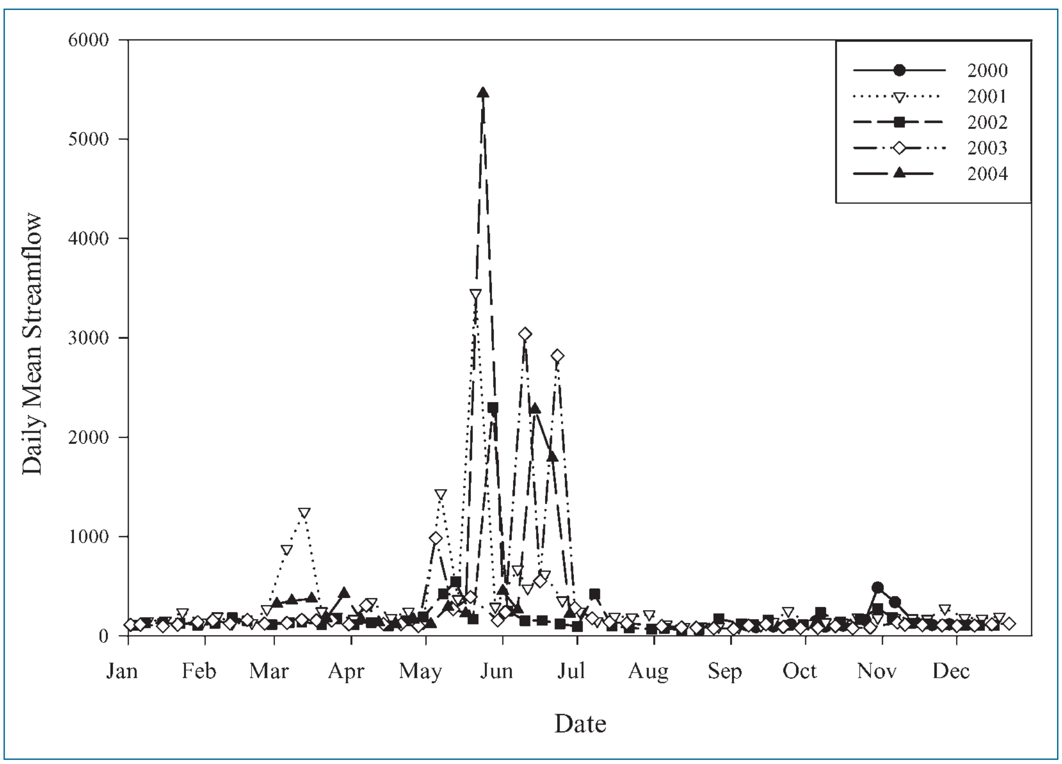


Figure 1.4. Daily mean streamflow (cfs) in Salt Creek at Greenwood, September 2000 to June 2004 (USGS data).

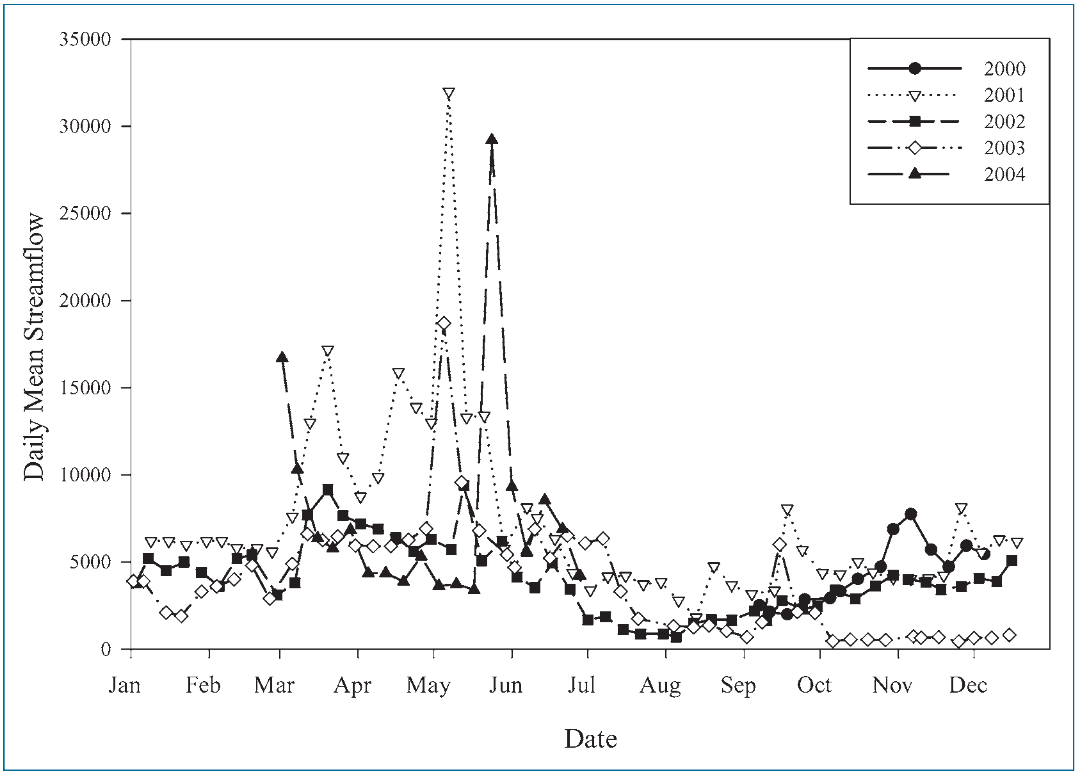


Figure 1.5. Daily mean streamflow (cfs) in the Platte River at Louisville, September 2000 to June 2004 (USGS data).

Lower Platte River sandbars

CHAPTER 2

OVERVIEW OF FIELD METHODS, CATCH AND A COMPARISON OF GEAR EFFORT

INTRODUCTION

To determine habitat use for pallid sturgeon, shovelnose sturgeon, sturgeon chubs, and associated species in the lower Platte River, we sampled for fish using a range of gear types. The gear types included drifted gill nets, drifted trammel nets, stationary gill nets, trotlines, trawls, seines, and minnow traps. Since pallid sturgeon, shovelnose sturgeon and sturgeon chub life stages are typically captured in different habitats and by different types of sampling gear, we used the gear to sample different Platte River habitats, but our efforts centered on those areas where previous research and literature suggested that pallid sturgeon, shovelnose sturgeon, and sturgeon chub would most likely be found. Previous studies (Peters et al. 1989, Peters and Holland 1994, Yu 1996) intensively sampled shallow water habitats and shoreline habitats in the lower Platte River between 1986 and 1995 and the results suggested that pallid sturgeon, shovelnose sturgeon or sturgeon chub do not use shallow water or shoreline habitats extensively. In addition, other studies on sturgeon and shovelnose pallid (Hofpar 1997, Snook et al. 2002) indicated that much of our sampling effort should be focused in the deepest and swiftest sections of the river.

Realizing that much of the sampling effort for this study was intentionally aimed at capturing the rare pallid sturgeon and sturgeon chub, it is important to understand that the sampling strategy was not a random or stratified random sampling design where samples were collected in proportion to their availability in the river. As stated earlier, previous studies had intensively sampled shallow water and shoreline habitats (Peters et al. 1989, Peters and Holland 1994, Yu 1996) and few sturgeon or sturgeon chubs were captured. Most of the different gears used were deployed near or in the deeper or swifter sections of the river. To understand the distribution of gear effort, we compared the distribution of samples to the habitat availability studies conducted by NGPC in the 1980s. These studies used a standardized transect data collection method to determine habitat availability over different discharge rates. While we have not directly tested to see if the transect data are still representative of the lower Platte River, in the view of the senior author (who was associated with the transect effort) the transect data are still a valid description of habitat availability in the river.

FIELD METHODS

Fish collection protocols:

Pallid sturgeon or shovelnose sturgeon that weighed at least 300 grams were deemed sufficiently large enough to hold a transmitter. Pallid sturgeon that were captured at times during the year when water temperatures were 16 °C or less were implanted with radio-telemetry transmitters and were tracked during the time they remained in the Platte River. This maximum temperature criterion for implanting transmitters in pallid sturgeon was stipulated by the federal endangered species permit from the U.S. Fish and Wildlife Service. There was no specific temperature restriction for implanting transmitters in shovelnose sturgeon, but most were implanted at temperatures below 25 °C. In general, all fish captured in any effort using the different gear types were identified, weighed, and measured using fork length for sturgeon and total length for other species. Habitat was characterized by recording information on habitat variables at several locations. Starting in 2000, all sturgeon collected were measured following Sheehan et al.(1999) to calculate the morphometric character index (mCI). In addition, a set of two digital photos was taken of each fish as a visual record for future analysis. These photos included a ruler for reference. Each fish was also PIT tagged and this number or alpha-numeric code was used to reference each individual. Starting in 2003, we added the measurements, new head length 1 and new head length 2 along with point to point in an attempt to improve our ability to distinguish pallid from shovelnose sturgeon (Figure 2.1).

All other larger fishes were identified to species, measured for total length, weighed to the nearest tenth of a kilogram, and released. Smaller fishes (less than approximately 6 inches) were identified to species, counted, and released. If identification was not possible in the field the specimens were fixed in a 10% formalin solution and returned to the laboratory for identification. Sturgeon chub and other similar species were fixed in 10% formalin for identification, measurement and other laboratory studies.

Fish Sampling Methods:

Drifted Gill Nets and Trammel Nets: Gill nets were constructed of monofilament nylon, 1.8 m (6 ft) deep by 30.5 m (100 ft) long, with four 7.6 m (25 ft) long alternating panels of 2.5 cm (1 in) and 5.1 cm (2 in) bar mesh. A pallid sturgeon or any other fish may be entangled in a gill net by wedging, caught by the gills or caught by their bony scutes (sharp bony scales) or other body projections. Trammel nets used in the Platte River measured 38.1 m (125 ft) long by 1.8 m (6 ft) deep. Trammel nets consist of three panels of netting suspended from a float line and a single or double lead line. The two outer panels are a larger mesh (15.0 cm) than the inner panel (2.5 cm). Fish are either gilled in the mesh or become bagged within the smaller mesh. Generally, trammel nets are less injurious to fish than gill nets and are also less size-selective (Hubert 1996). In addition, although they are more cumbersome to operate because of multiple, heavier mesh, they tend to be more efficient at catching and retaining fish located on or near the river bottom. The conversion of gear use from drifted gill nets to drifted trammel nets was dictated by the desire to comply with the standards that are currently being used by researchers on the Missouri River Pallid Sturgeon Recovery Team.

Both gill and trammel nets were drifted with the current, with the net extended perpendicular to the flow of the current for distances up to about 200-400 m, depending on where

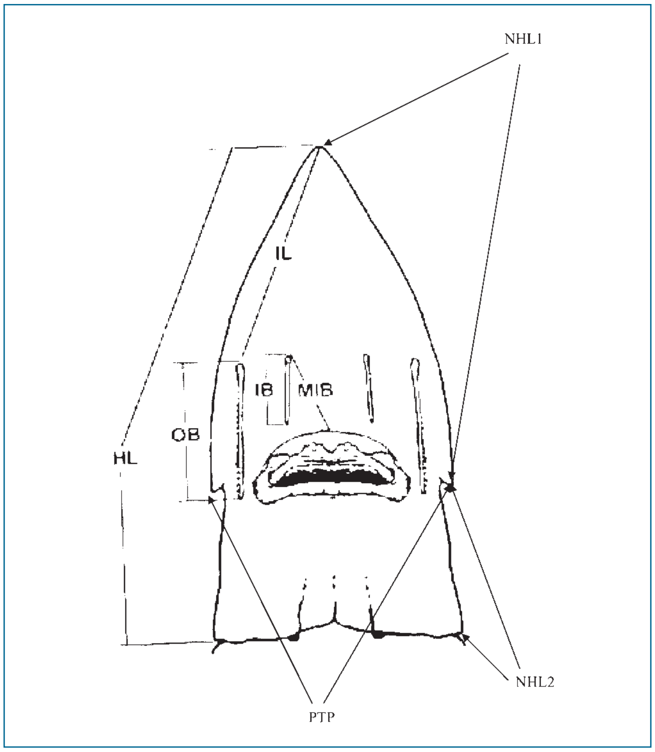


Figure 2.1. Diagram of the underside of a pallid sturgeon head showing measurements used to calculate the morphometric character index (Sheehan et al. 1999). OB = outer barbel length, IB = inner barbel length, MIB = mouth to inner barbel length, IL = interrostrum length, HL = head length, PTP = point to point length, NHL1 = new head length 1, NHL2 = new head length 2 (Total head length = NHL1+NHL2).

landing sites were available. Locations for drifting a net were determined on site to best sample the available habitat. Areas that contained high concentrations of sunken snags were typically avoided when using entanglement gear. A crew of three or more workers deployed the net at the upstream end of the area to be sampled and walked or floated with the net to keep it spread and to release it if it became snagged on underwater obstructions. Sampling locations were selected at areas along and downstream from sandbars where water currents converge, or areas of sunken sandbars (underwater areas of shifting sand dunes typically 30-200 cm under the water surface) that were identified by Snook (2001) to be important habitats for pallid sturgeon. These areas typically had a 0.5-2 m deep shelf located on the downstream end. The average width of the net fished throughout the run and total length of the run was measured with a laser range finder. The length and width measurement was then multiplied to estimate the area sampled. The location of each run was determined at the start and the end of each run using a handheld global positioning system (GPS) unit.

Measurements used to describe the habitat sampled by the drifted nets were as follows. Water depth, mean column velocity, bottom velocity, and substrate were recorded at the estimated center of the net width at the start, mid point and end of the drift. Additionally, a single measurement of water temperature, dissolved oxygen, and specific conductivity was recorded for each run. A water sample was collected to determine total suspended solids and water turbidity in the laboratory, and pictures of the area sampled were taken. The distance to the shore in each direction was measured with a laser rangefinder to provide a method to approximate channel position of the run.

Stationary Gill Nets: Stationary gill nets sets were used to attempt to capture sturgeon in the Platte River after they were recommended by researchers working in the Missouri and Mississippi Rivers. The nets were set parallel with the current in deep, slack water areas. The gill nets used were the same as the drifted gill nets, measuring 1.8 m (6 ft) deep by 30.5 m (100 ft) long, with four 7.6 m (25 ft) long alternating panels of 2.5 cm (1 in) and 5.1 cm (2 in) bar mesh and constructed of monofilament nylon. Nets were set overnight and fish were removed, identified and counted the following morning.

Trotlines: Trotlines were used to sample for sturgeon in the cold water times of the year. They were recommended by researchers working in the lower Mississippi River (Killgore; personal communication). Our trotlines were 30 m long with 24 circle hooks alternating in size (10/0 and 12/0) attached to the main line by 0.5 m drop lines at 1.0 m intervals. Hooks were baited with night crawlers. Trotlines were set in the late afternoon, allowed to fish all night and retrieved in the morning. The trotlines were fished for approximately 18 hours and all fish caught were removed, identified, measured and released. Trotlines were typically set in deep pools and runs, and near sunken sandbars. Habitat variables were recorded at the upstream and downstream ends of the trotline after the line was set and then the next day prior to removing the trotline from the water. The location of each trotline set was determined by a GPS unit.

Trawls: Benthic fish trawls were used to sample deeper run and pool habitats for pallid sturgeon, sturgeon chub and associated species. The trawl design was a modified otter trawl and it was used primarily in water over 1.0 m deep. The majority of samples were taken from channel habitat and areas of swift velocity where chubs have been found in previous research (Peters et al. 1989, Schainost and Koneya 1999). Sampling started in May and concluded in September. Sampling was timed to include the time chub spawning takes place to allow various age classes to be collected.

Habitat measurements recorded for each sample included: depth, mean column velocity, bottom velocity, dissolved oxygen, temperature, specific conductivity, total suspended solids, and GPS coordinates. Sand/gravel substrate combinations were recorded by percent of composition. Large fish were counted, measured, and released in the field and small fish were preserved in 10% formalin and brought back to the lab for further analysis.

Seines and minnow traps: Smaller fishes were also sampled using several other gears. Seines were used to sample shallow water habitats near sandbars. The seines used in this study included 1/16th in, 1/8th in, and 3/8th in mesh seines from 15 to 25 ft long. Some seines were modified by attaching a chain to the lead line to attempt to capture fish near the bottom of the river.

In addition to general seine hauls, during 2002 and 2003, we collected small-fish at the US Highway 6 Bridge using minnow traps. Rectangular minnow traps made of 6.35 mm (1/4 in) wire mesh were deployed at dusk, left undisturbed over night, and retrieved at dawn. Traps were placed in "clusters" of three traps each in four different macro habitats. Typical habitats sampled included: deeper swift channels, shallow riffle areas, snag eddies (pools), and stabilized bank runs. Each trap was held in place with a 1.8 m (6 ft) length of rebar rod. Minnow traps were typically set in a side by side by side configuration in broader habitat types (such as deep or shallow runs) or in line with one another in narrower habitats (such as along a bank or behind a snag). At sunrise, traps were removed and the fish were either identified and measured in the field or preserved in 10% formalin and processed in the laboratory.

Telemetry: Sturgeon captured using drifted gill or trammel nets and trotlines were evaluated to determine whether they could receive a radio transmitter. These fish were identified using Sheehan et al. (1999), and measured for fork length and weight. Only those sturgeon whose body weight exceeded 300 g were considered to be large enough to receive a transmitter. This corresponds to the recommendation that all transmitters weigh less than 2.0% of each individual's body weight (Winter 1996). Small transmitters weighed 15 g, measured 42 x 15 mm, and had a life expectancy of approximately 400 days. Large transmitters weighed 20 g, measured 51 x 15 mm, and had a battery life of approximately 625 days.

To insert a radio tag into a sturgeon, the fish was held belly side up over a plastic tub (65 x 42 x 25 cm) while the gills were irrigated with river water. A small mid-ventral incision was made in the peritoneal cavity to allow for insertion of the transmitter. The radio transmitter was inserted and a 30 cm radio antenna protruded from the fish's belly through a separate incision made with a large gauge hypodermic needle. Finally, the incision was closed with three or four individually tied sutures. Radio tagged fish were searched for or monitored throughout the year, from shore, boat, and aircraft to determine their locations in the Platte River. A permanent telemetry station was set up at the Schilling WMA located at the confluence with the Missouri River to monitor when radio tagged fish entered or left the Platte River.

Radio telemetry information used to evaluate habitat use was obtained exclusively from airboat surveys, while movement data came from all three contact methods (shore, boat and aircraft). Sturgeons were located by triangulating the radio signal using a directional loop antenna. Final locations were typically accomplished by removing the antenna from the receiver to find the strongest signal.

To describe the area used by a telemetry tagged sturgeon, measurements of the habitat, including water depth, mean column velocity, bottom velocity, substrate, and cover, were made at the focal point of the radio signal location and then, 2 m upstream, 2 m downstream, 2 m to the left, and 2 m to the right of the focal location (Hofpar 1997, Snook 2001, Swigle 2003). This combination of measurements was used to provide a more detailed description of the habitat conditions in the immediate vicinity of sturgeon. This set of measurement locations also encompassed the estimated range of error associated with location of radio signals determined from previous studies of sturgeon and catfish (Bunnell 1988, Chapman 1995, Hofpar 1997, Snook 2001, Swigle 2003). In addition, single measurements of dissolved oxygen, water temperature, conductivity, and suspended solids were made at each location. This protocol was consistent with those used by similar studies in Montana (Bramblett 1996, Bramblett and White 2001) and Illinois (Hurley 1998). The presence of underwater sand dunes and the proximity of radio-tagged fish to shallow sunken sandbar ledges were also recorded. Underwater sand dunes are waves in the sandy riverbed and sandbar ledges are areas with a rapid increase in water depth downstream from or lateral to shallow submerged sandbars.

Gear Comparisons:

To compare the habitat sampled by the different gear types, we compared the habitat both graphically and statistically. Gear types compared included; drifted gill nets, drifted trammel nets, trawls, trotlines, and seines. Additionally, the habitat attributes for the locations of radio-tagged shovelnose sturgeon were included to provide a comparison of the gear deployment with the observed sturgeon habitat. To estimate the available habitat in the river, we used transect data gathered by the NGPC during a previous Instream Flow Incremental Methodology (IFIM) study (NGPC 1993a, b). These data included measurements of depth and mean column velocity measured at points along several transect lines from three different localities under differing discharge conditions. Habitat sampled for each gear type was described in several ways. First the median and 25% and 75% values were reported for each habitat variable collected at the sampling time. Next, depth and mean column velocities collected during gear sampling were compared with samples of habitat availability collected by NGPC. Depth and mean column velocity was analyzed using a bivariate table with four categories of depth and four categories of mean column velocity. First, the distribution of the habitats sampled was determined by tabulating the number of samples for each cell in the table, and then calculating the percent frequency of each cell in the table. Gear selection of the depth and velocity combinations was determined by dividing the percent frequency of occurrence in each cell with the percent frequency of the habitat availability for that cell. The gear selection was normalized by dividing each cell value by the sum of all cell values. These values were standardized to a scale of 0 to 1 by dividing each cell value by the largest cell value (Bovee and Milhous 1978, Peters et al. 1989). In cases where undefined numbers would result in division by zero, the value was replaced with a zero. To provide a graphic representation of the data, scatterplots of depth and mean column velocity are also presented. To compare the habitats that each gear sampled in comparison to other gears, box plots of each habitat variable are presented.

For statistical comparisons, the distributions of the individual measurement for habitat variables were tested for normality, and if they were found to fit a normal distribution and have equal variances, then an ANOVA with pairwise comparisons with Holm-Sidak corrections were used to test for differences among group means. In most cases, the distributions were not normally distributed, so the data were rank transformed and means were compared using Kruskal-Wallis One Way Analysis of Variance on Ranks with Dunn's method of pairwise comparisons.

RESULTS AND DISCUSSION

As noted in the methods section, the sampling effort on the lower Platte River was designed to attempt to capture the rare pallid sturgeon. As a result, the sampling effort was not evenly distributed throughout the lower Platte River. Most of the effort was focused on the reach of river below the confluence with the Elkhorn River. In this area, two smaller areas, one around Louisville, NE and the other near the mouth of the Platte River received extra effort as we captured pallid sturgeon in these areas. Stationary gill nets and minnow traps are not shown or further discussed as neither method was effective at catching pallid sturgeon or sturgeon chubs and their use was discontinued after a preliminary testing period.

The types of sampling gear used also changed throughout the year. Trotlines were used during the cold water periods and then the actively deployed nets and trawls were used primarily in the warmer water periods of the year. In addition to being used in cold water, trotlines were most effective at sampling the deepest and swiftest waters in the river and captured mostly shovelnose and pallid sturgeon. As the water warmed and discharge decreased as the year progressed, trammel nets proved effective at catching a wide range of species, including many shovelnose sturgeon and a few pallid sturgeon. Trawls proved most effective for capturing sturgeon chub, although neither seines nor trawls caught many.

Drifted gill and trammel nets: Fish were captured by drifting gill nets during 2000, 2001, 2002 and 2004. Figures 2.2 a,b,c and 2.3 a,b,c show the distribution of sampling effort from drifted gill and trammel nets. Trammel nets were first used experimentally in the same fashion as drifted gill nets during 2002, and subsequently used primarily instead of drifted gill nets in 2003 and 2004. The number and timing of runs of drifted gill nets (Table 2.1) and drifted trammel nets (Table 2.2) varied among months and years.

Overall, the drifted nets sampled water approximately 0.7 m deep with 0.56 m/s mean column velocities and 0.35 m/s bottom velocities over a sand substrate. Monthly averages for the mean, minimum, and maximum of each of these physical habitat variables changed based on the overall river discharge and tended to be located in deeper and swifter waters in the spring when compared to summer samples (Table 2.3).

The mean, minimum, and maximum water quality measurements also varied throughout the year (Table 2.4). Water temperatures were generally in the low 20s °C as this sampling gear started after trotlines were suspended at 16 °C. Dissolved oxygen appears to be high for most of the samples with a low reading of 5.18 mg/L in June of 2000. Specific conductivity varied with discharge and location with the majority of the readings in the 500 – 600 µS/cm range. The highest reading of 1,566 also occurred in June of 2000. Total suspended solids readings averaged 374.7 mg/L, but showed wide fluctuations from 70 mg/L to 2,848 mg/L.

The number and type of fish caught in the drifted nets varied among months and generally reflected the changes in effort between March and October (Table 2.5), yet some species were caught either randomly throughout the sampling season (paddlefish, smallmouth buffalo, flathead catfish) or mostly in one part of the sampling season (blue suckers in spring). Average number of fish captured per run was highest in the early spring, was lowest in May, and then increased and generally stayed around 6 fish per run throughout the summer and early fall.

When viewing the fish capture data by year (Table 2.6), we see a general increase in capture after the conversion from gill nets to trammel nets in 2003 and most species' yearly capture roughly follows overall effort. Exceptions to this pattern included blue suckers which were captured in much higher numbers in 2004 than any other year, and gizzard shad were captured with declining frequency over time.

Pallid sturgon ready for release after implantation of a radio transmitter.

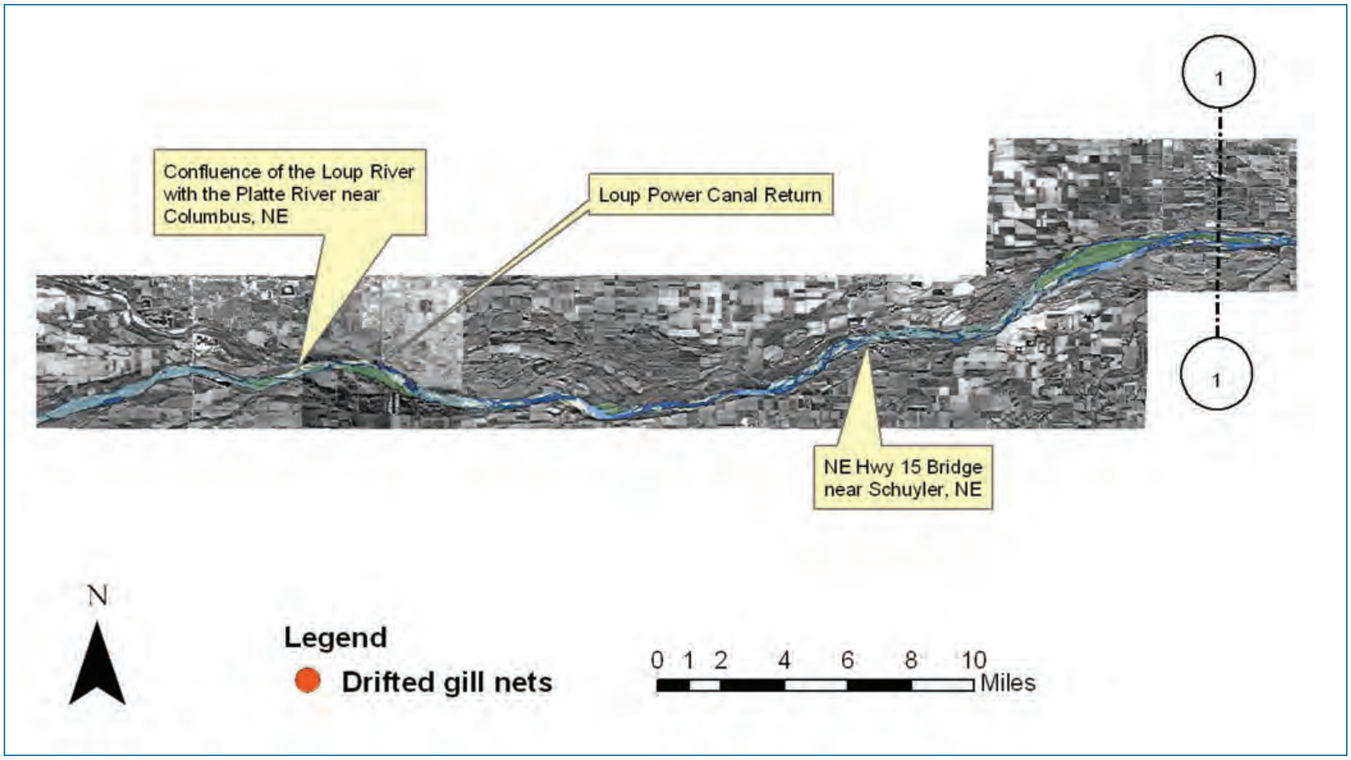


Figure 2.2a. Map of the locations of drifted gill net runs attempting to capture sturgeon and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

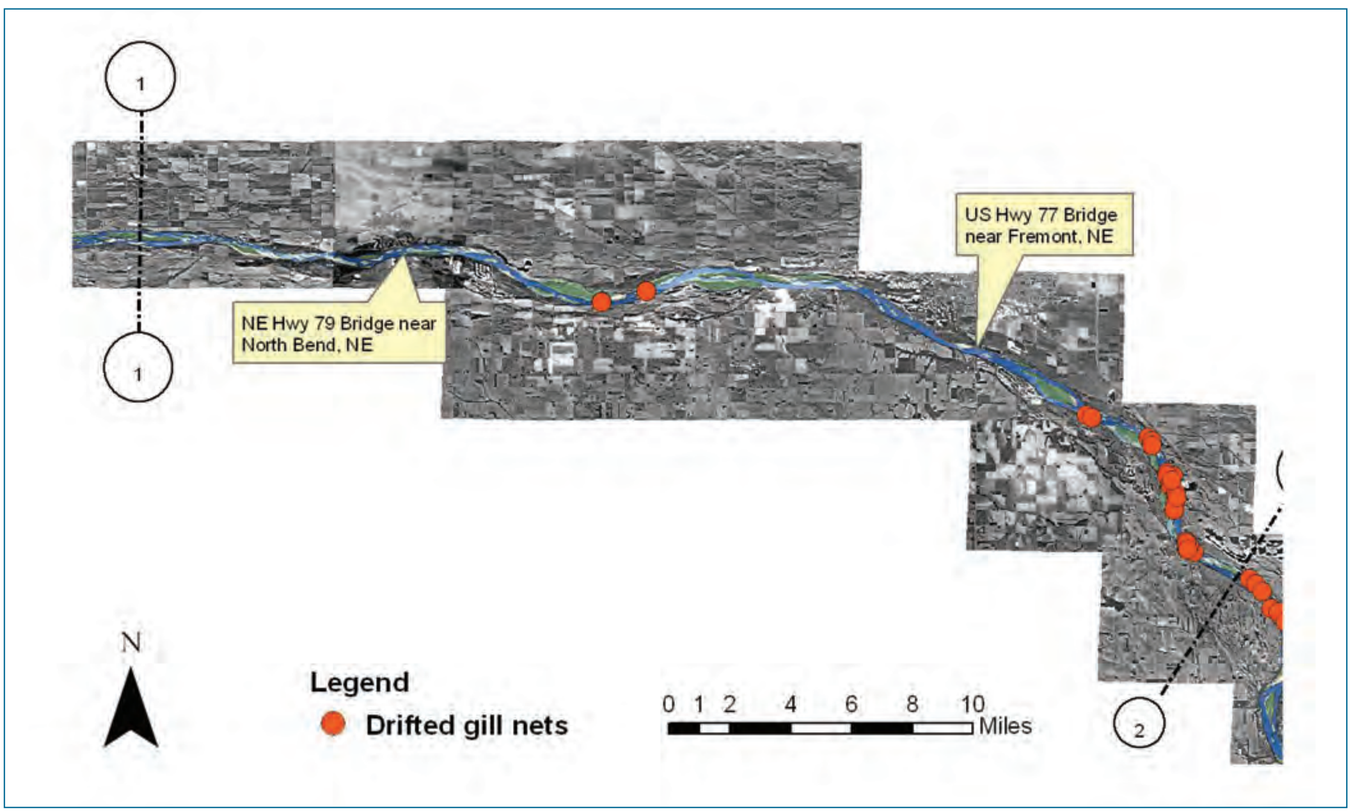


Figure 2.2b. Map of the locations of drifted gill net runs attempting to capture sturgeon and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

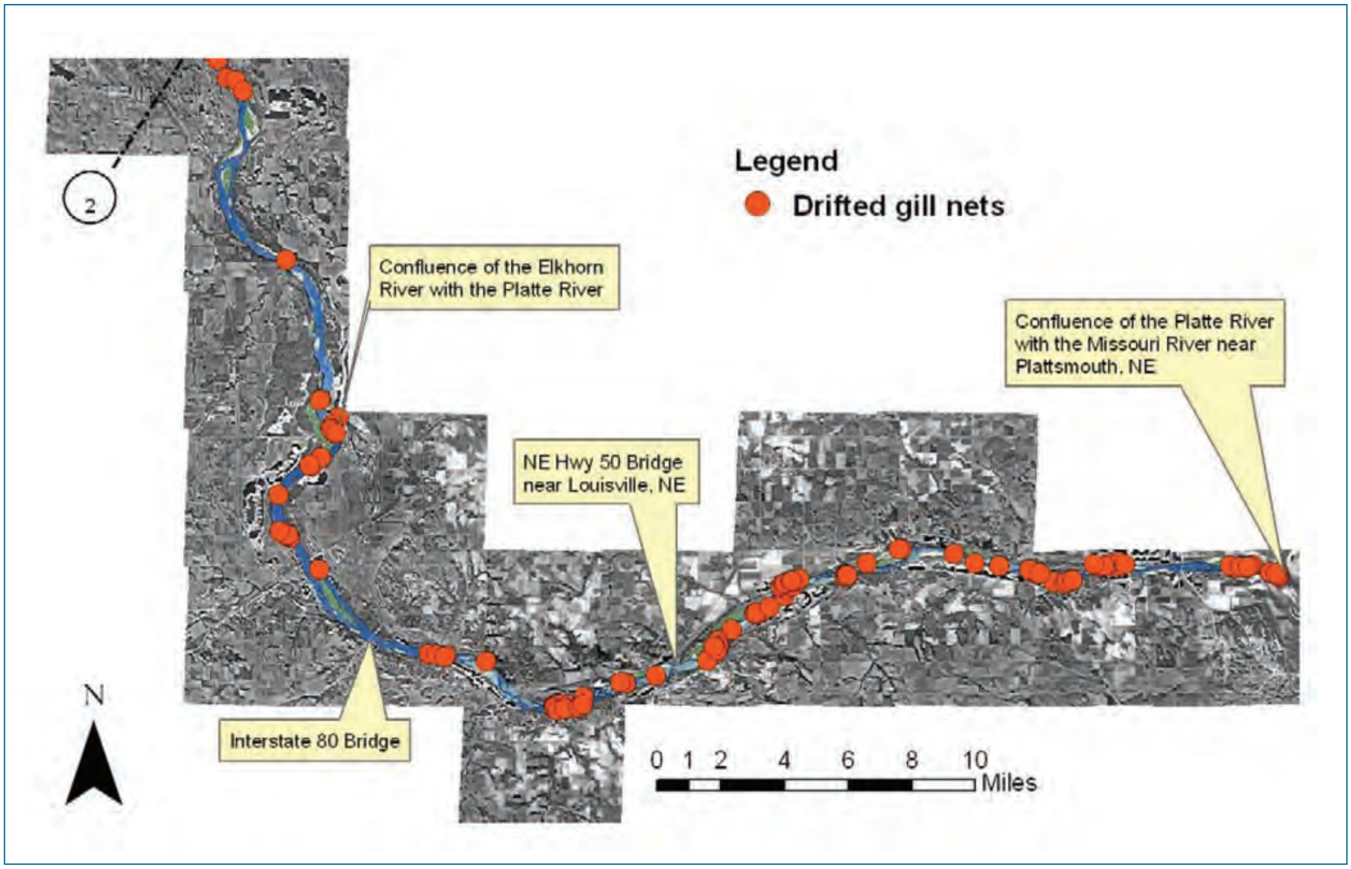


Figure 2.2c. Map of the locations of drifted gill net runs attempting to capture sturgeon and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

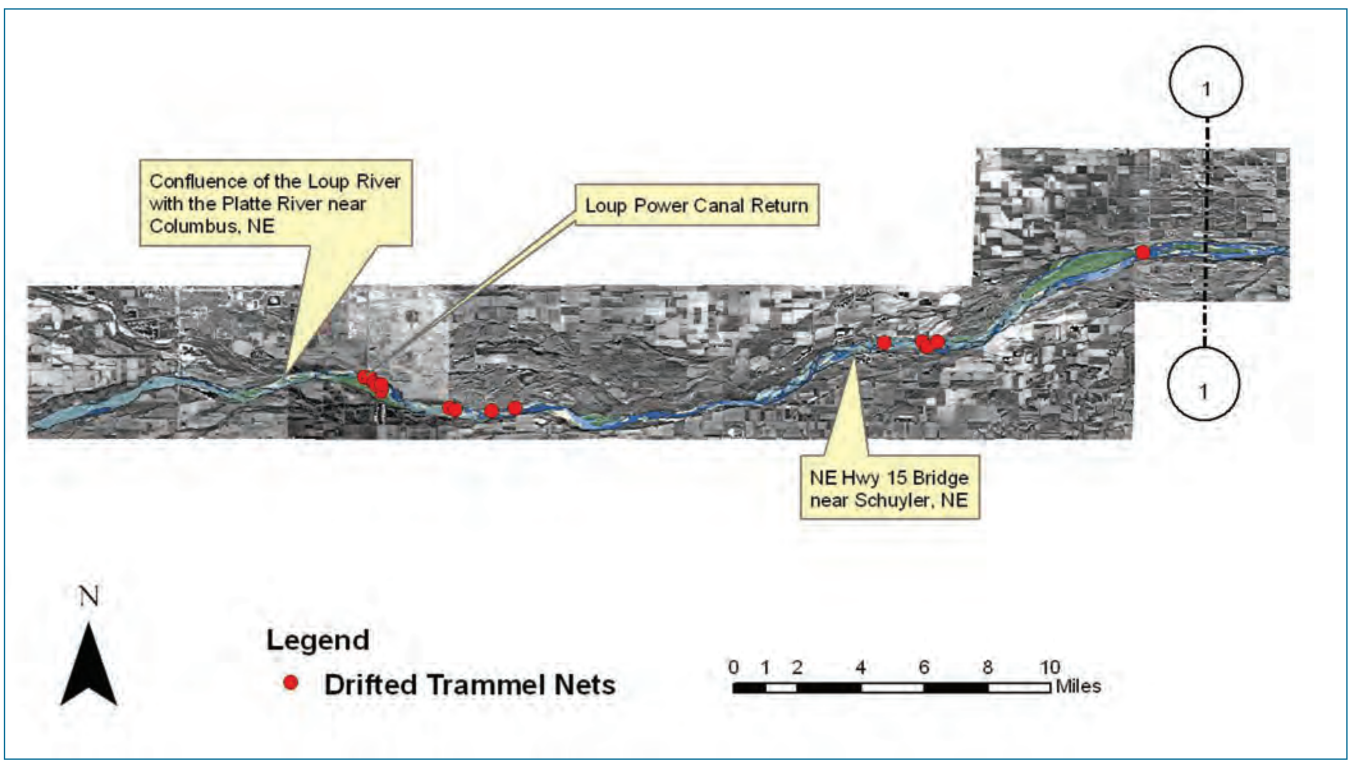


Figure 2.3a. Map of the locations of drifted trammel net runs attempting to capture sturgeon and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

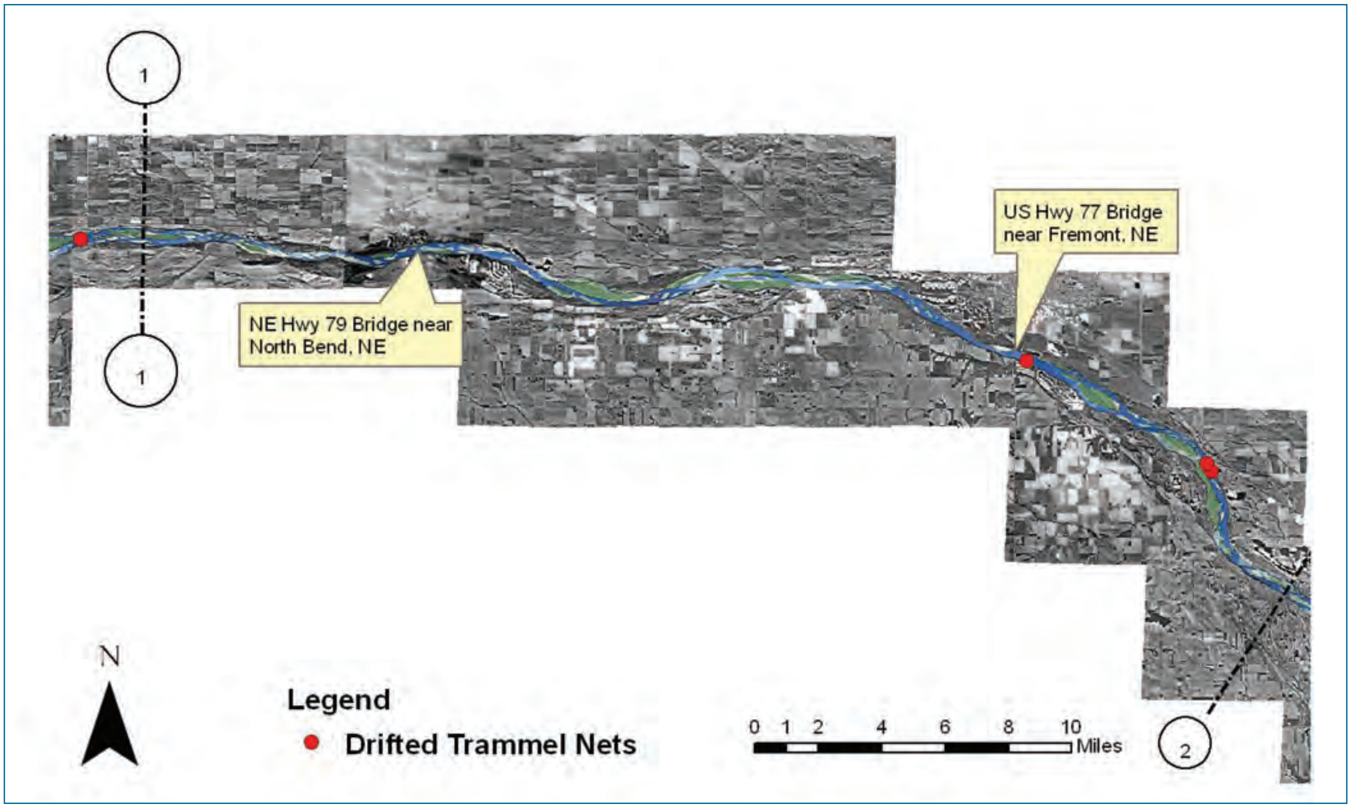


Figure 2.3b. Map of the locations of drifted trammel net runs attempting to capture sturgeon and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

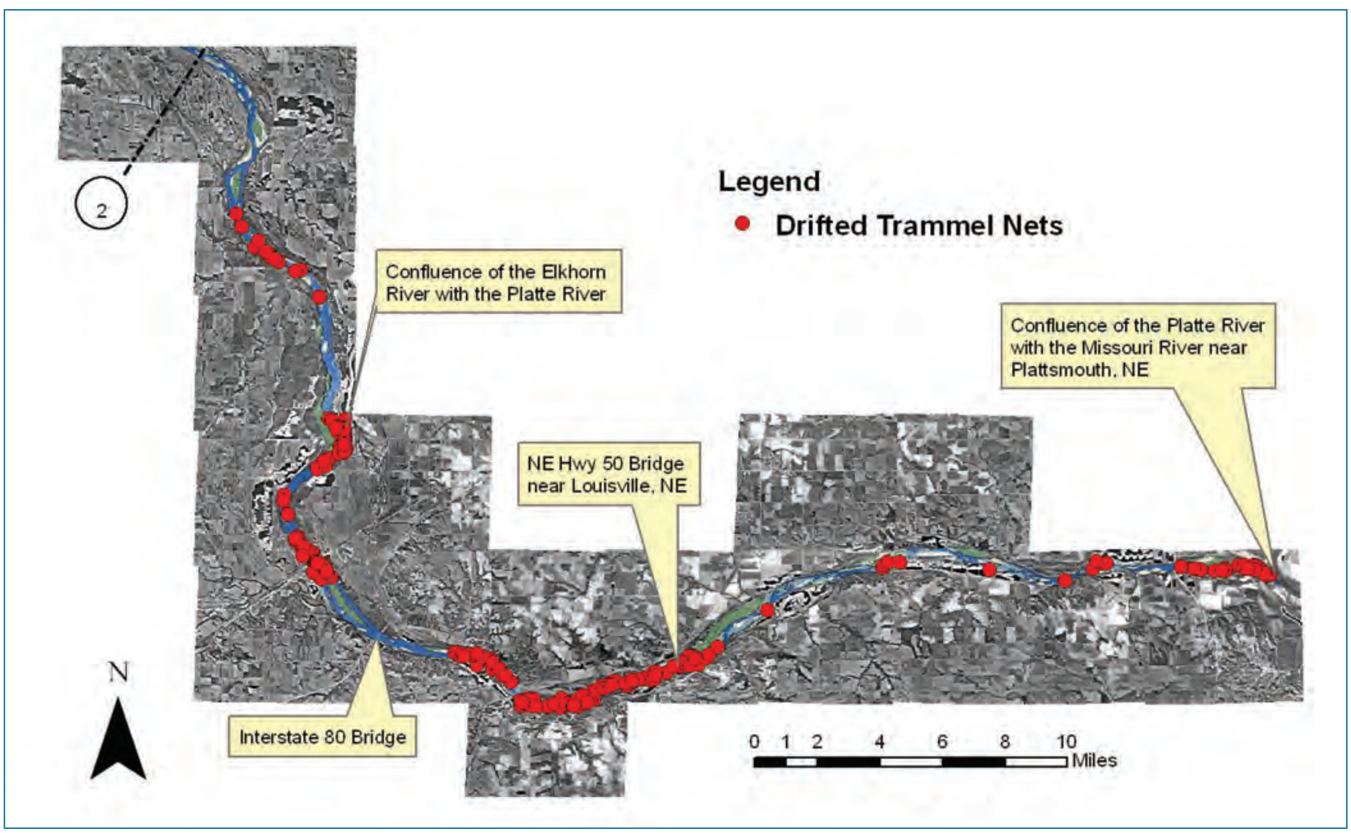


Figure 2.3c. Map of the locations of drifted trammel net runs attempting to capture sturgeon and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

Table 2.1. Average monthly habitat variables associated with drifted gill nets.

Date By Month	Average Depth (m)	Average Mean Velocity (m/s)	Average Bottom Velocity (m/s)	Number of Runs
04/2004	1.13	0.77	0.40	2
05/2000	0.70	0.64	0.29	8
05/2001	0.85	0.68	0.40	6
05/2002	0.56	0.52	0.32	63
06/2000	0.81	0.65	0.37	17
06/2001	0.86	0.61	0.38	35
06/2002	0.56	0.50	0.31	54
07/2000	0.52	0.52	0.34	26
07/2001	0.70	0.59	0.37	28
07/2002	0.54	0.47	0.34	14
08/2000	0.70	0.60	0.39	12
08/2001	0.66	0.54	0.35	22
08/2002	0.51	0.49	0.34	16
09/2001	0.67	0.54	0.35	9
09/2002	0.59	0.59	0.40	7
10/2001	0.70	0.50	0.32	2

Table 2.2. Average monthly water quality measurements associated with drifted gill nets.

Date By Month	Average Water Temp (°C)	Average Dissolved Oxygen (mg/L)	Average Specific Conductivity (µS/cm)	Average Total Suspended Solids (mg/L)	Average Turbidity (NTU)	Number of net runs
04/ 2004	17.0	11.2	619.5	91.5	41.8	2
05/ 2000	21.1	9.3	548.9	521.3		8
05/ 2001	20.9	8.9	595.0	400.6		6
05/ 2002	22.2	10.0	547.4			63
06/ 2000	24.5	8.3	658.4	448.8		17
06/ 2001	24.3	10.6	582.3	211.3		35
06/ 2002	25.6	8.6	440.3			54
07/ 2000	28.0	9.5	606.3	375.8		26
07/ 2001	26.4	8.9	626.7	337.3		28
07/ 2002	27.0	10.6	428.5			14
08/ 2000	26.1	9.0	669.0	154.9		12
08/ 2001	26.3	10.0	641.7			22
08/ 2002	24.1	9.8	536.7			16
09/ 2001	20.5	10.7	724.4			9
09/ 2002	17.7	9.9	513.0			7
10/ 2001	14.9	10.3	672.5			2

Table 2.3. Average monthly habitat variables associated with drifted trammel nets.

Date By Month	Average Depth (m)	Average Mean Velocity (m/s)	Average Bottom Velocity (m/s)	Number of Runs
03/2004	0.90	0.45	0.21	4
04/2004	1.19	0.65	0.27	23
05/2003	0.58	0.60	0.40	25
05/2004	1.21	0.66	0.34	19
06/2003	0.57	0.50	0.31	53
06/2004	0.61	0.49	0.31	15
07/2003	0.63	0.47	0.25	38
07/2004	0.84	0.66	0.50	12
09/2003	0.45	0.51	0.26	3
09/2004	0.36	0.52	0.40	2
10/2003	0.52	0.50	0.44	3

Table 2.4. Average monthly water quality measurements associated with drifted trammel nets.

Date By Month	Average Water Temp (°C)	Average Dissolved Oxygen (mg/L)	Average Specific Conductivity (µS/cm)	Average Total Suspended Solids (mg/L)	Average Turbidity (NTU)	Number of net runs
03/ 2004	17.2	10.7	698.3	126.0	63.5	4
04/ 2004	16.2	12.4	630.8	124.7	58.1	23
05/ 2003	20.8	10.5	533.1	389.5	391.7	25
05/ 2004	16.5	13.7	671.9	166.7	117.5	19
06/ 2003	24.0	10.1	463.5	468.4	412.2	53
06/ 2004	22.3	9.4	399.5	1251.3	1767.0	15
07/ 2003	29.1	8.5	476.9	532.5	568.8	38
07/ 2004	27.6	12.0	417.1			12
09/ 2002	19.3	9.1	430.4			4
09/ 2003	17.7	12.4	445.7	102.3	91.4	3
09/ 2004	20.8	10.1	678.0		1040.0	2
10/ 2003	16.6	12.7	754.0			3

Table 2.5. Number of fish caught in drifted gill net runs and drifted trammel net runs by month from 2000 to 2004.

Common Name	March	April	May	June	July	August	September	October	Total Number Of Fish
Pallid Sturgeon	0	0	3	0	1	0	1	0	5
Shovelnose Sturgeon	1	100	158	345	284	132	84	29	1133
Paddlefish	0	2	3	2	1	0	1	0	9
Longnose Gar	2	6	13	16	26	4	4	0	71
Shortnose Gar	3	19	29	57	53	44	14	7	226
Goldeye	5	39	45	125	126	37	17	32	386
Gizzard Shad	1	1	5	18	7	17	1	9	59
Grass Carp	0	2	2	4	4	0	2	0	14
Common Carp	0	6	11	22	17	4	2	2	64
Bighead Carp	0	1	1	21	8	0	0	0	31
River Carpsucker	2	10	34	41	42	9	10	7	155
Quillback	8	6	38	126	146	11	10	11	356
Blue Sucker	2	29	61	9	6	0	0	0	107
Smallmouth Buffalo	0	6	5	8	5	2	0	0	26
Bigmouth Buffalo	0	0	0	6	9	2	0	1	18
Shorthead Redhorse	1	0	1	6	3	1	2	0	14
Blue Catfish	0	0	0	1	0	0	0	0	1
Channel Catfish	11	7	17	21	29	1	1	4	91
Flathead Catfish	1	2	2	0	2	0	0	1	8
White Bass	0	0	0	2	0	0	0	0	2
Striped Bass Hybrid	0	0	0	0	1	0	1	0	2
White Crappie	0	2	0	0	0	0	1	0	3
Black Crappie	0	0	1	1	0	0	0	0	2
Sauger	0	2	7	11	5	0	0	0	25
Saugeye	0	0	2	1	1	0	0	0	4
Walleye	0	0	1	4	6	0	1	0	12
Freshwater Drum	1	1	6	4	9	0	0	5	26
Totals	38	241	445	851	791	264	152	108	2890
Drifted Gill Nets	0	2	77	106	68	50	16	4	323
Trammel Nets	4	23	44	68	50	0	9	15	213
Total # of Runs	4	25	121	174	118	50	25	19	536
Average # of fish per run	9.5	9.6	3.7	4.9	6.7	5.3	6.1	5.7	5.4

Table 2.6. Number of fish caught in drifted gill net runs and trammel net runs by year from 2000 to 2004.

Common Name	2000	2001	2002	2003	2004	Total Number Of Fish
Pallid Sturgeon	0	0	1	0	4	5
Shovelnose Sturgeon	100	185	223	357	268	1133
Paddlefish	1	1	3	2	2	9
Longnose Gar	3	16	28	12	12	71
Shortnose Gar	37	34	44	77	34	226
Goldeye	38	80	110	133	65	426
Gizzard Shad	31	2	15	9	2	59
Grass Carp	0	1	1	7	5	14
Common Carp	10	9	5	25	15	64
Bighead Carp	0	1	1	25	4	31
River Carpsucker	13	9	24	76	33	155
Quillback	5	17	61	206	67	356
Blue Sucker	5	3	6	9	84	107
Smallmouth Buffalo	2	1	5	8	10	26
Bigmouth Buffalo	1	4	3	10	0	18
Shorthead Redhorse	0	1	5	7	1	14
Blue Catfish	0	0	0	1	0	1
Channel Catfish	7	8	15	29	32	91
Flathead Catfish	1	0	1	1	5	8
White Bass	0	0	2	0	0	2
Striped Bass Hybrid	1	0	1	0	0	2
White Crappie	0	0	0	1	2	3
Black Crappie	0	0	1	1	0	2
Sauger	2	0	4	14	5	25
Saugeye	0	0	1	1	2	4
Walleye	0	1	3	7	1	12
Freshwater Drum	6	0	6	9	5	26
Totals	263	373	569	1027	658	2890
Drifted Gill Net	63	102	156	0	2	323
Trammel Net	0	0	16	122	75	213
Total # of run	63	102	172	122	77	536
Average # of fish per run	4.2	3.7	3.3	8.4	8.5	5.4

Trotlines: A total of 223 trotlines was set in the lower Platte River between 2001 and 2004. Figure 2.4 a,b,c show the distribution of sampling effort for trotlines. Trotlines were used when the water temperature was below 16 °C and were most commonly used in the spring of the year (Table 2.7). Trotlines proved to be effective at catching sturgeon with 364 of the 371 fish captured either a shovelnose sturgeon (n = 354) or pallid sturgeon (n = 10) and the trotlines averaged a little less than two fish per trotline set (Table 2.8).

Trotlines were generally set in water greater than 1 m in depth and in depths greater than 1.7 m on average in 2004. Mean velocities were generally greater than 0.5 m/s and bottom velocities greater than 0.3 m/s (Table 2.9). Trotlines were most commonly set on sand substrate and were located in the deepest, swiftest channel habitats or in deep holes adjacent to sand bars.

As a result of setting the trotlines primarily in the spring of the year, water chemistry variables approximate typical spring time conditions (Table 2.10). The water temperature averaged between 5.9 °C and 19.8 °C and dissolved oxygen was generally high (> 9 mg/L). Specific conductivity of the water was usually between 500 and 700 µS/cm with peak readings over 1,000 µS/cm. Total suspended solids readings were usually between 170 and 300 mg/L with maximum readings over 1,400 mg/L.

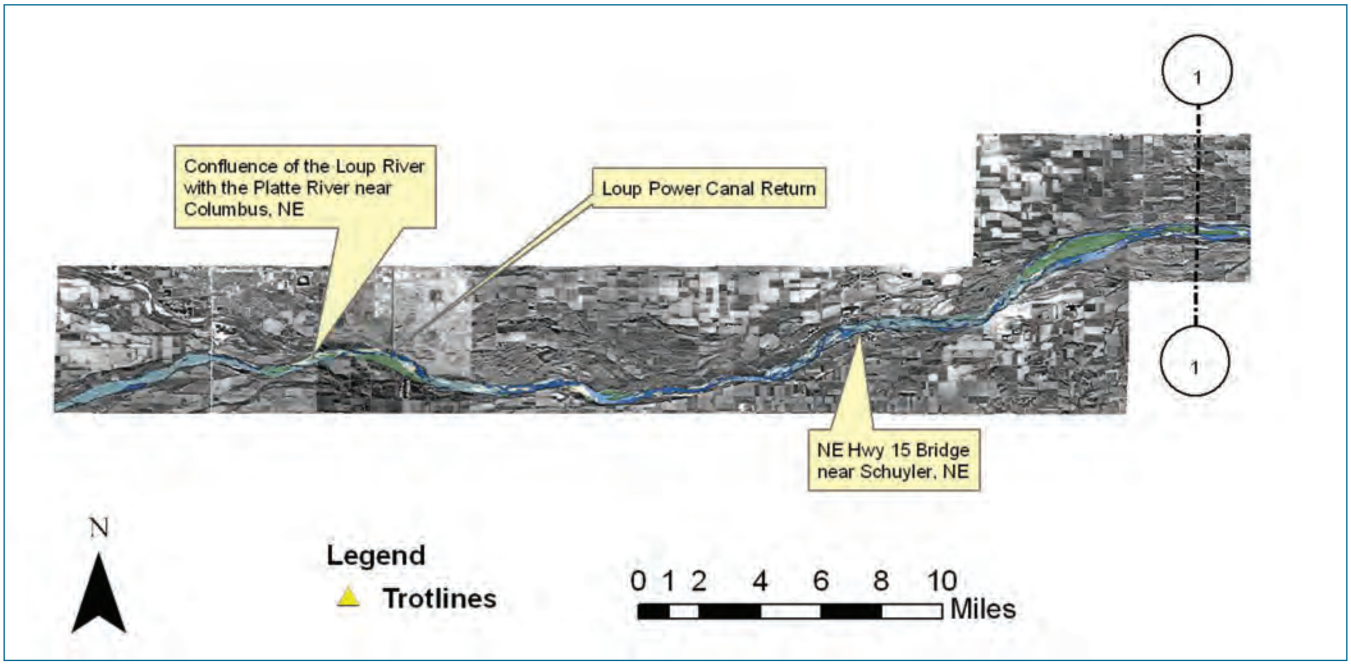


Figure 2.4a. Map of the locations of trotline sets attempting to capture sturgeon and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

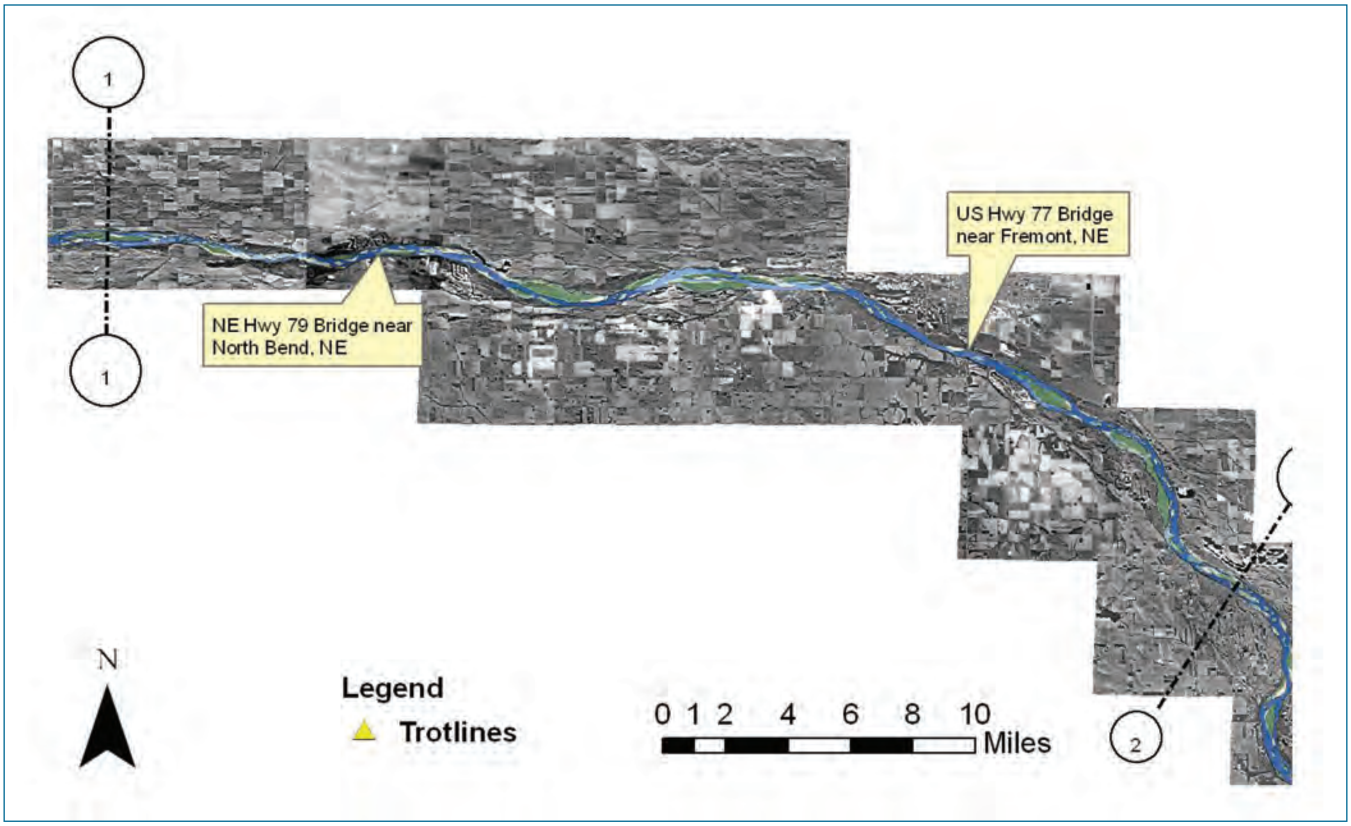


Figure 2.4b. Map of the locations of trotline sets attempting to capture sturgeon and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

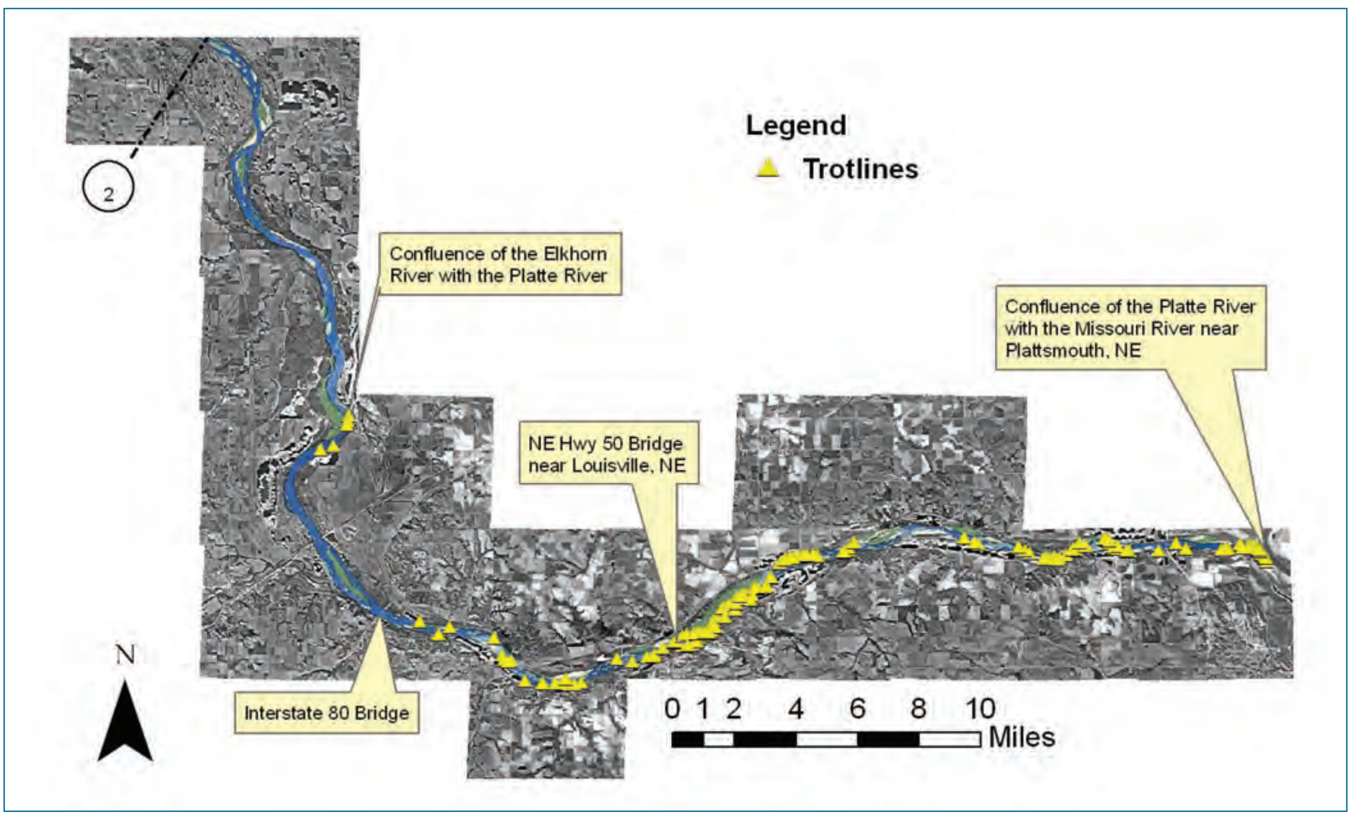


Figure 2.4c. Map of the locations of trotline sets attempting to capture sturgeon and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

Table 2.7. Number of trotline sets per month and year.

Year	MAR	APR	MAY	JUN	SEPT	OCT	NOV	Total Number Of Trotlines Set
2001	5	7	12	5	3	3	10	45
2002	3	11	7	-	-	8	5	34
2003	15	57	1	-	-	-	-	73
2004	28	43	-	-	-	-	-	71
Total	51	118	20	5	3	11	15	223

Table 2.8. Number of fish caught during trotline sets by month.

Common Name	MAR	APR	MAY	JUNE	SEPT	OCT	NOV	Total Number Of Fish Caught
Pallid Sturgeon	0	9	1	0	0	0	0	10
Shovelnose Sturgeon	93	195	36	9	0	8	13	354
Common Carp	1	1	1	0	0	0	0	3
Channel Catfish	1	1	0	0	2	0	0	4
Total	95	206	38	9	2	8	13	371
Number of Trotlines Set	51	117	20	5	3	12	15	223
Average Catch per Trotline	1.9	1.8	1.9	1.8	0.7	0.7	0.9	1.7

Table 2.9. Average monthly habitat variables associated with trotline sets.

Date By Month	Average Depth (m)	Average Mean Velocity (m/s)	Average Bottom Velocity (m/s)	Number of Runs
03/2001	1.16	0.51	0.30	5
03/2002	1.03	0.56	0.31	3
03/2003	1.12	0.74	0.39	15
03/2004	1.70	0.83	0.37	28
04/2001	0.89	0.58	0.37	7
04/2002	1.11	0.66	0.37	11
04/2003	1.36	0.69	0.35	57
04/2004	1.86	0.88	0.31	43
05/2001	1.23	0.74	0.37	13
05/2002	1.45	0.60	0.38	7
06/2001	1.15	0.65	0.56	5
09/2001	0.97	0.70	0.46	4
10/2001	0.89	0.47	0.31	3
10/2002	1.28	0.65	0.37	8
11/2001	1.30	0.71	0.40	10
11/2002	0.66	0.44	0.28	5

Table 2.10. Average monthly water quality measurements associated with trotline sets.

Date By Month	Average Water Temp (°C)	Average Dissolved Oxygen (mg/L)	Average Specific Conductivity (µS/cm)	Average Total Suspended Solids (mg/L)	Average Turbidity (NTU)	Number of net runs
03/2001	7.7	11.0	616.2		176.0	5
03/2002	6.7	12.3	845.0	55.7	117.8	3
03/2003	10.9	10.6	619.9	87.6	170.9	15
03/2004	10.0	10.9	601.1	143.3	191.6	28
04/2001	12.5	10.0	618.1		465.8	7
04/2002	14.4	12.1	725.4	63.5	125.5	11
04/2003	15.6	11.3	592.2	83.3	188.4	57
04/2004	13.7	12.1	620.6	70.6	115.7	43
05/2001	19.8	8.8	703.5		286.7	13
05/2002	16.0	9.6	654.2	426.7	533.6	7
06/2001	18.2	10.4	530.4		180.5	5
09/2001	18.6	10.3	493.5			4
10/2001	12.8	10.1	741.2	40.6	86.3	3
10/2002	10.6	11.5	602.1			8
11/2001	12.9	11.4	678.0	40.9	79.9	10
11/2002	5.9	13.9	588.7			5

Trawls: A total of 164 trawl runs was completed between 2001 and 2004 in the lower Platte River. Figure 2.5 a,b,c shows the distribution of sampling effort with trawls. The majority of these were in the 2002 sampling season (n = 93) and the 2004 sampling season (n = 51) (Table 2.11).

Trawling was principally in deeper runs of the river due to the constraints in deploying the gear and the physical habitat reflects these conditions (Table 2.12). The mean of the depths recorded for each run averaged between 1.1 and 1.6 m with a maximum depth of 4.1 m over the four sampling years. The mean column velocities averaged near 0.6 m/s and the bottom velocity ranged from 0.28 to 0.47 m/s.

The water conditions trawled reflected late spring to summer conditions in the Platte River (Table 2.13). The average temperatures were usually around 24 °C with a range from 15.1 to 30.6 °C. Dissolved oxygen was generally over 9 mg/L, and specific conductivity ranged on average from 392 to 871 µS/cm in the different sampling years. Total suspended solids varied greatly from 52 to 2,892 mg/L.

The trawls proved to be effective at catching a wide range of species from the Platte River. A total of 29 different species was collected with the most common species being sand shiner (n = 2,845), shoal chub (n = 2,021), emerald shiner (n = 1,214), and channel catfish (n = 1,170) (Table 2.14). Catch rate per trawl run varied greatly throughout the sampling season, ranging from a low of 4.1 fish per run in May to a high of 339.1 fish per run in August (Table 2.15).

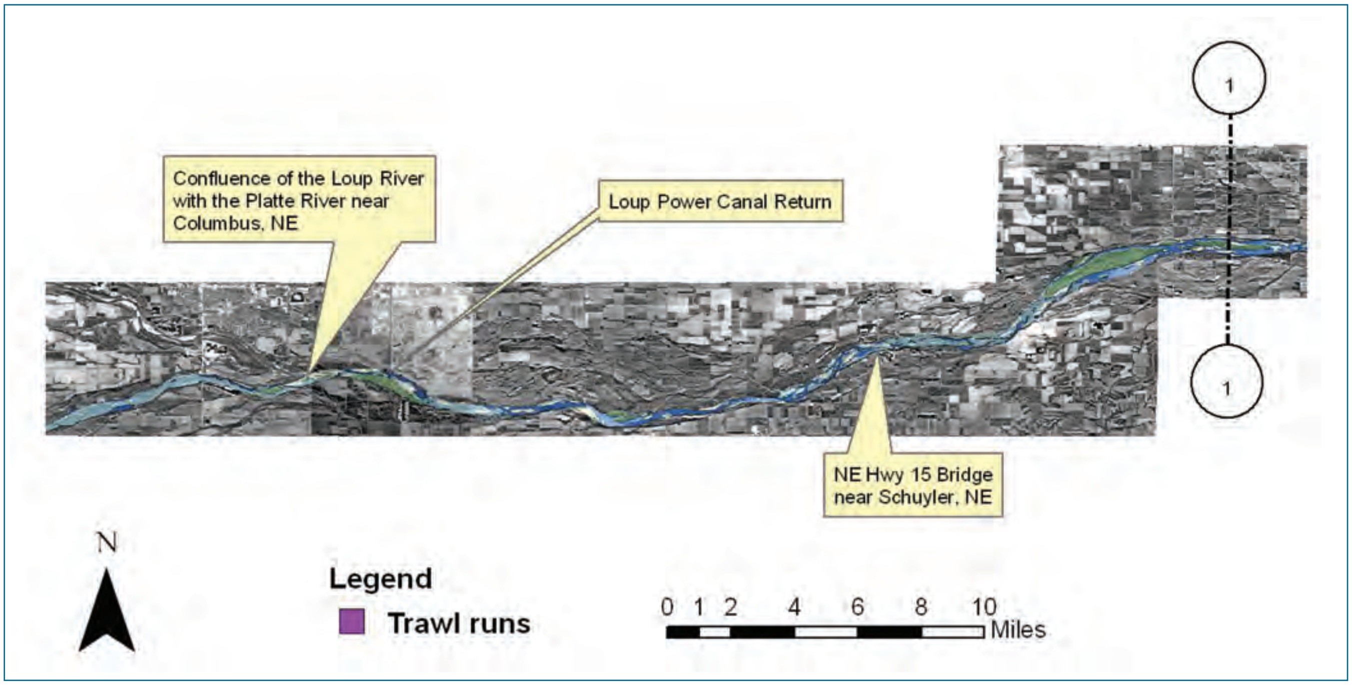


Figure 2.5a. Map of the locations of trawl runs attempting to capture sturgeon and sturgeon chub and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

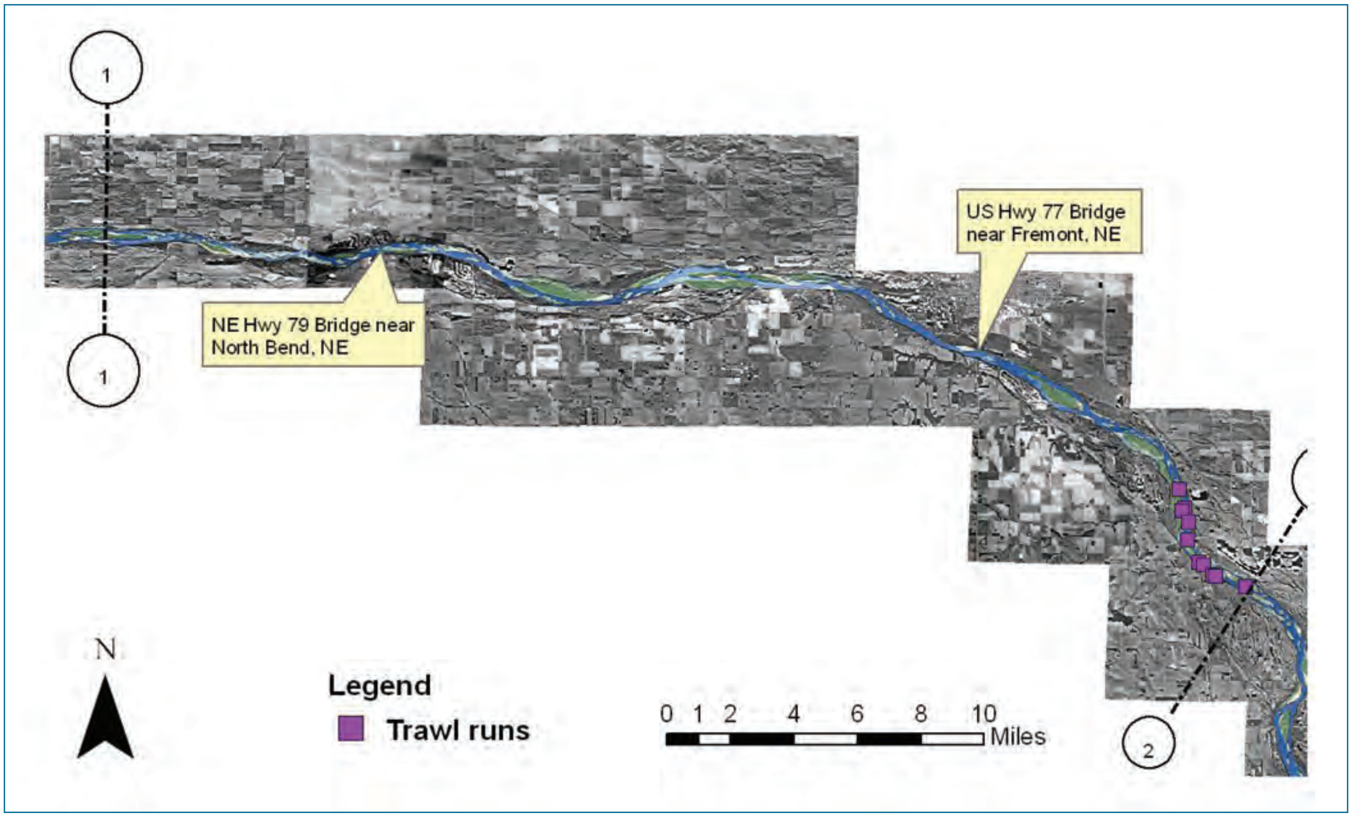


Figure 2.5b. Map of the locations of trawl runs attempting to capture sturgeon and sturgeon chub and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

Trawling in the Platte River.

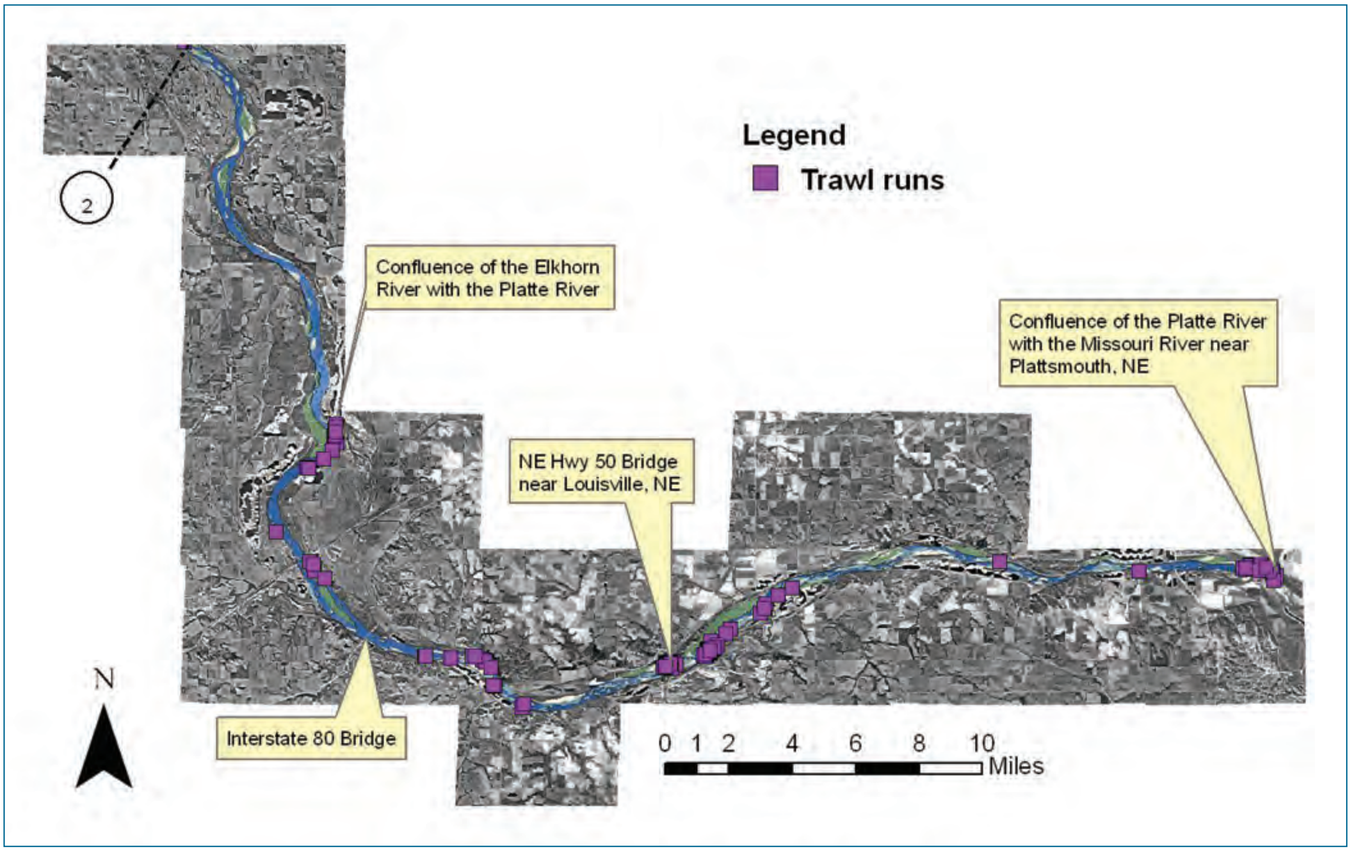


Figure 2.5c. Map of the locations of trawl runs attempting to capture sturgeon and sturgeon chub and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

Table 2.11. Number of trawl runs from 2001 to 2004.

Year	April	May	June	July	August	September	Total Number of Runs
2001	-	-	3	4	-	2	9
2002	-	20	31	17	10	15	93
2003	-	11	-	-	-	-	11
2004	1	4	42	4	-	-	51
Total	1	35	76	25	10	17	164

Table 2.12. Average monthly habitat variables associated with trawl runs.

Date By Month	Average Depth (m)	Average Mean Velocity (m/s)	Average Bottom Velocity (m/s)	Number of Runs
04/2004	1.1	0.5	0.2	3
05/2002	1.4	0.7	0.3	40
05/2003	1.4	0.5	0.4	4
05/2004	1.6	0.7	0.3	7
06/2001	1.9	0.7	0.0	6
06/2002	1.3	0.7	0.4	61
06/2004	1.7	0.8	0.5	110
07/2001	0.9	0.7	0.4	8
07/2002	0.8	0.6	0.3	34
07/2004	1.1	1.0	0.6	12
08/2002	0.7	0.5	0.2	20
09/2001	0.2	0.4	0.2	4
09/2002	0.8	0.6	0.3	30

Table 2.13. Average monthly water quality measurements associated with trawl runs.

Date By Month	Average Water Temp (°C)	Average Dissolved Oxygen (mg/L)	Average Specific Conductivity (µS/cm)	Average Total Suspended Solids (mg/L)	Average Turbidity (NTU)	Number of net runs
04/2004	13.6	11.6	696.0			3
05/2002	22.4	9.0	621.4	660.9	741.3	40
05/2003	17.5	9.0	392.9			4
05/2004	25.7	9.4	526.3			7
06/2001	27.6	8.2	647.3			6
06/2002	23.4	8.5	619.5	604.0	657.7	61
06/2004	23.1	9.4	547.5	1558.3	1973.6	110
07/2001	29.0	8.5	725.0			8
07/2002	26.0	10.5	1124.6	95.8	53.1	34
07/2004	27.6	12.0	417.1			12
08/2002	26.3	8.8	1343.7	80.7	44.1	20
09/2001	17.7	11.6	427.3			4
09/2002	23.0	10.2	1006.2	117.2	56.9	30

Table 2.14. Number of fish caught in trawl runs by year.

Common Name	Gear Type	2001	2002	2003	2004	Total
Shovelnose Sturgeon	Trawl	1	60	0	17	78
Chub	Trawl	3	1,909	2	107	2,021
Sturgeon Chub	Trawl	0	2	0	0	2
Silver Chub	Trawl	0	109	0	27	136
Flathead Chub	Trawl	1	6	0	0	7
Red Shiner	Trawl	129	89	2	5	225
Emerald Shiner	Trawl	1	8	0	2	11
River Shiner	Trawl	9	1,192	8	5	1,214
Bigmouth Shiner	Trawl	0	2	0	0	2
Sand Shiner	Trawl	0	2,822	10	13	2,845
Western Silvery Minnow	Trawl	0	1	0	0	1
Brassy Minnow	Trawl	0	1	0	0	1
Plains Minnow	Trawl	0	47	0	0	47
Suckermouth Minnow	Trawl	0	6	0	0	6
Fathead Minnow	Trawl	0	2	0	0	2
Grass Carp	Trawl	0	0	0	1	1
Common Carp	Trawl	0	0	0	2	2
River Carpsucker	Trawl	0	46	0	1	47
Quillback	Trawl	0	5	0	0	5
Blue Sucker	Trawl	0	3	0	1	4
Blue Catfish	Trawl	0	3	0	0	3
Channel Catfish	Trawl	1	1,122	11	36	1,170
Flathead Catfish	Trawl	0	3	0	1	4
White Perch	Trawl	0	2	0	0	2
Green Sunfish	Trawl	0	1	0	0	1
Bluegill	Trawl	1	1	0	1	3
Johnny Darter	Trawl	0	2	0	0	2
Sauger	Trawl	0	2	0	0	2
Freshwater Drum	Trawl	0	40	0	0	40
	Totals	146	7,486	33	219	7,884
	Total # of Trawls	9	93	11	51	164
	Average catch per Trawl	16.22	80.49	3	4.294	48.07

Table 2.15. Number of fish caught in trawl runs by month.

Common Name	Gear Type	April	May	June	July	August	September	Total
Shovelnose Sturgeon	Trawl	1	35	18	7	7	10	78
Speckled Chub	Trawl	0	40	211	730	840	200	2,021
Sturgeon Chub	Trawl	0	1	1	0	0	0	2
Silver Chub	Trawl	6	1	28	38	40	23	136
Flathead Chub	Trawl	0	1	5	0	0	1	7
Red Shiner	Trawl	0	5	64	17	2	137	225
Emerald Shiner	Trawl	0	2	4	0	0	5	11
River Shiner	Trawl	1	8	43	297	740	125	1,214
Bigmouth Shiner	Trawl	0	0	0	1	0	1	2
Sand Shiner	Trawl	0	19	38	845	1,487	456	2,845
Western Silvery Minnow	Trawl	0	0	0	1	0	0	1
Brassy Minnow	Trawl	0	0	0	0	1	0	1
Plains Minnow	Trawl	0	0	0	46	1	0	47
Suckermouth Minnow	Trawl	0	0	0	6	0	0	6
Fathead Minnow	Trawl	0	0	0	2	0	0	2
Grass Carp	Trawl	0	0	1	0	0	0	1
Common Carp	Trawl	0	0	2	0	0	0	2
River Carpsucker	Trawl	0	3	1	6	22	15	47
Quillback	Trawl	0	0	0	2	2	1	5
Blue Sucker	Trawl	0	1	1	0	2	0	4
Blue Catfish	Trawl	0	0	0	0	1	2	3
Channel Catfish	Trawl	2	46	259	479	222	162	1,170
Flathead Catfish	Trawl	0	0	1	1	1	1	4
White Perch	Trawl	0	0	0	0	2	0	2
Green Sunfish	Trawl	0	0	0	1	0	0	1
Bluegill	Trawl	0	0	1	1	0	1	3
Johnny Darter	Trawl	0	0	0	2	0	0	2
Sauger	Trawl	0	0	0	1	1	0	2
Freshwater Drum	Trawl	0	0	0	20	20	0	40
	Totals	10	162	678	2,503	3,391	1,140	7,884
	Total # of Trawls	1	35	76	25	10	17	164
	Average catch per Trawl	10	5	9	100	339	67	48

Seines: Seines were used in a variety of ways to try to catch smaller fish associated with sturgeon or to capture sturgeon chubs. Several different size mesh seines were used, including 1/8th, 1/16th, and 3/8th inch mesh. In addition to the use of different size mesh seines, different seining tactics were used for different purposes. Some seines were used to collect fish near radio-tagged sturgeon, others were used to sample near drifted entanglement gear, others were used randomly, and some were used to sample near minnow traps. As a result of this non-systematic data collection, the data analysis will be a generalized description of the catch for specific collection techniques. Although seines caught a large number of fish, seines did not prove to be an effective method to capture either sturgeon or sturgeon chubs.

A total of 252 different seine hauls were performed in the lower Platte River during this project with the majority of these samples coming from June, July, and August (Table 2.16). Figure 2.6 a,b,c show the distribution of sampling effort with seines.

The physical habitat sampled by the seines was usually less than 0.5 m deep and less than 0.3 m/s mean column velocity (Table 2.17). Compared to other gears, the substrate in which seines were used tended to be much higher in silt than typically found in the river . Given the depth, velocity, and substrate characteristics of the seine samples, the seines tended to be run in pool habitats with minimal water current. These habitats appear not to be suitable habitats for sturgeon or chubs given their low catches for the effort. Water chemistry readings associated with seine hauls show a typical pattern for water conditions found in the Platte River (Table 2.18).

A total of 33 different species was caught in the seines with red shiners (n = 26,889) by far the most common species, followed by river shiners (n = 2,527), sand shiners (n = 1,321), and emerald shiners (n = 1,026) (Table 2.19). Only 7 shovelnose sturgeon were caught in all of the seine hauls. The 1/16th inch seines accounted for most of the fish captured (n = 31,929) as a result of the large number of small red shiners captured by this small mesh net (Table 2.20). The 1/8th mesh seine also caught red shiners and Table 2.21 shows the breakdown for fish catches with this seine. The 3/8th in mesh seine was probably the best for capturing species of interest. Of the fish caught in seines, all of the sturgeon and many of the chubs were captured in the 3/8th in mesh seine (Table 2.22). This seine had a chain attached to the lead line to keep it down in deeper water and this seemed to help catch more and different species. Red shiners were still the numerically dominant fish captured, but many other species were caught in relatively higher numbers than in other seines.

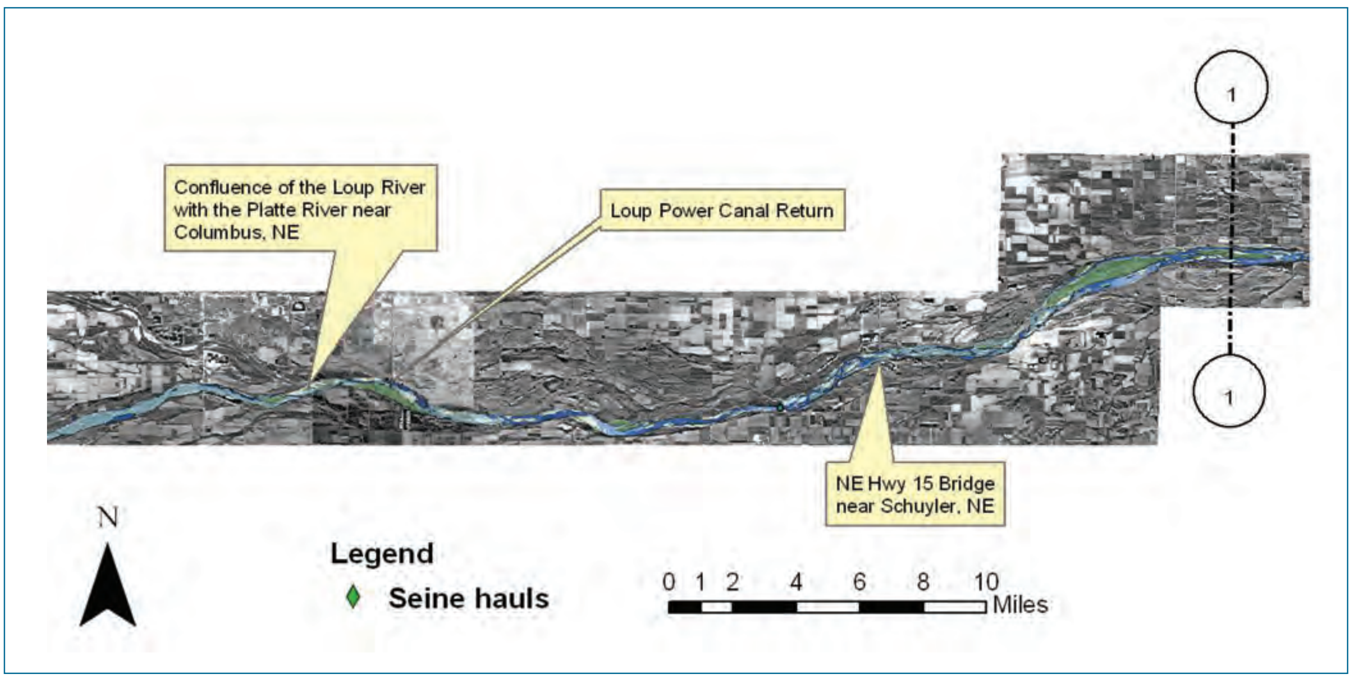


Figure 2.6a. Map of the locations of seine hauls attempting to capture pallid sturgeon and sturgeon chub in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

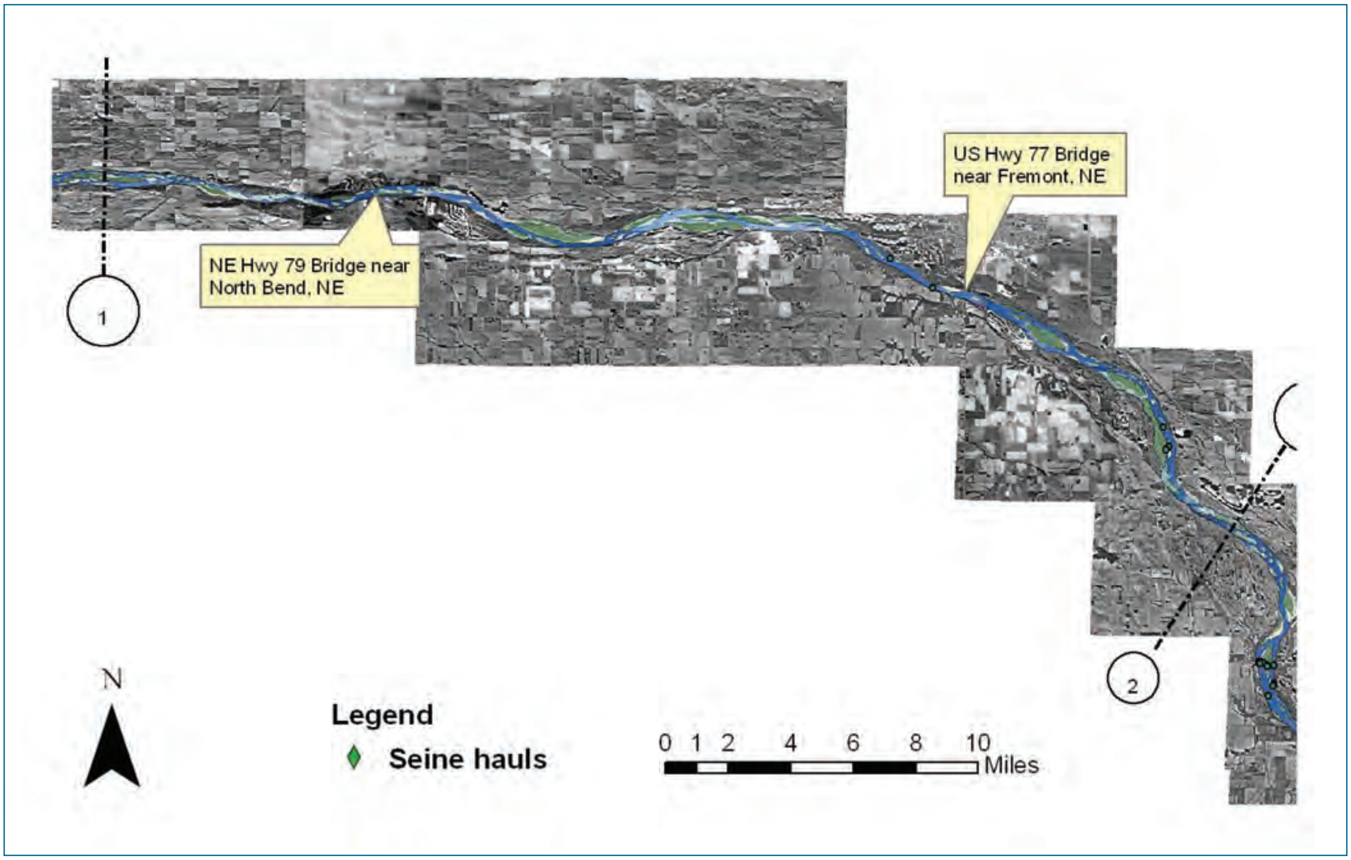


Figure 2.6b. Map of the locations of seine hauls attempting to capture pallid sturgeon and sturgeon chub in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

Radio telemetry antenna

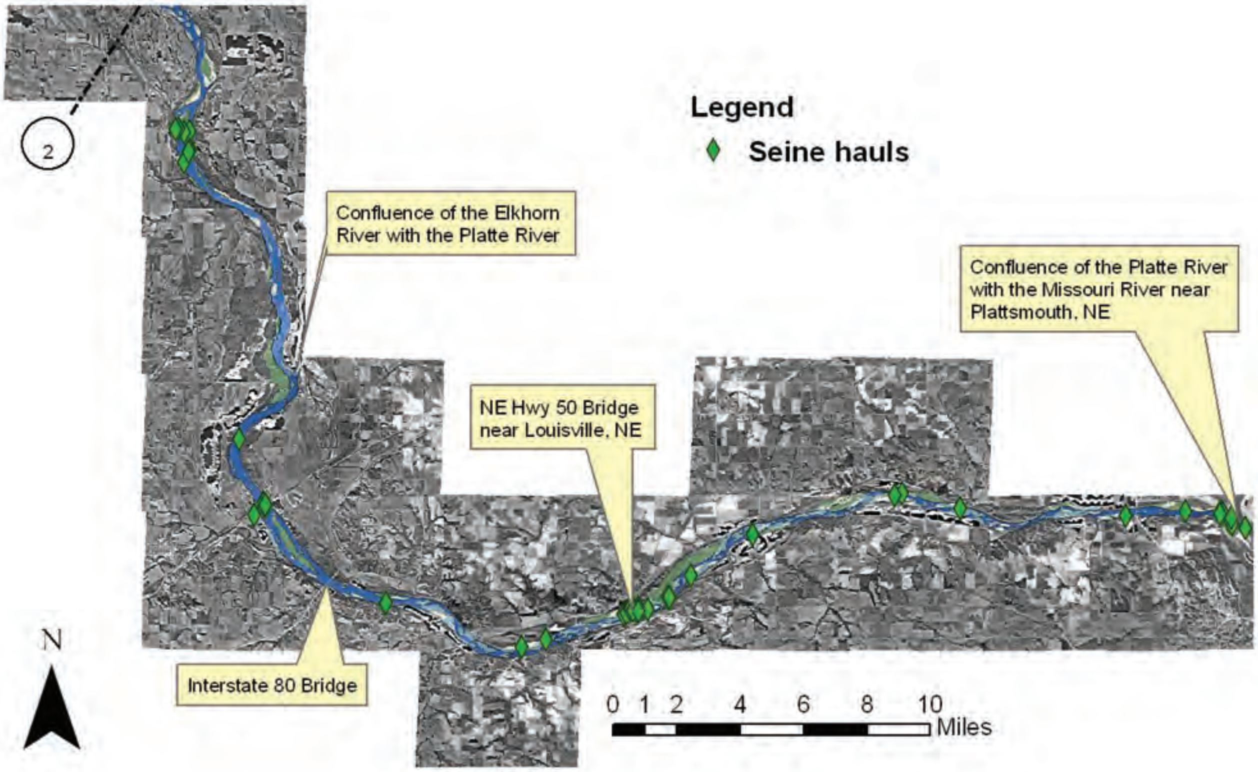


Figure 2.6c. Map of the locations of seine hauls attempting to capture pallid sturgeon and sturgeon chub in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

Table 2.16. Number of seine hauls by mesh size and month and year.

Seine Mesh	Year	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1/16th inch	2000	0	7	8	3	3	0	0	0	0	21
1/16th inch	2001	0	1	2	10	27	0	0	0	0	40
3/8th inch	2001	0	0	14	11	0	6	0	0	0	31
1/8th inch	2002	0	7	13	15	3	6	3	6	3	56
1/16th inch	2002	0	3	3	14	8	0	0	0	0	28
3/8th inch	2002	1	4	0	8	5	0	0	0	0	18
1/8th inch	2003	6	9	3	9	6	6	6	0	0	45
1/16th inch	2003	0	1	0	0	0	0	0	0	0	1
3/8th inch	2003	0	2	0	8	2	0	0	0	0	12
Total		7	34	43	78	54	18	9	6	3	252

Table 2.17. Average monthly habitat variables associated with seine hauls.

Method	Date By Month	Average Depth (m)	Average Mean Velocity (m/s)	Average Bottom Velocity (m/s)	Number of Runs
1/8" seine	04/2003	0.8	0.2	0.1	12
1/8" seine	05/2002	0.4	0.2	0.1	18
1/8" seine	05/2003	0.7	0.3	0.2	10
1/8" seine	06/2002	0.6	0.1	0.0	20
1/8" seine	06/2003	0.6			4
1/8" seine	07/2002	0.5	0.2	0.1	58
1/8" seine	07/2003	0.6	0.1	0.1	25
1/8" seine	08/2002	0.7	0.5	0.2	6
1/8" seine	08/2003	0.7	0.1	0.1	14
1/8" seine	09/2002	0.4	0.3	0.2	18
1/8" seine	09/2003	0.6	0.2	0.1	10
1/8" seine	10/2002	0.7	0.5	0.1	3
1/8" seine	10/2003	0.4	0.2	0.1	13
1/8" seine	11/2002	0.5	0.3	0.2	8
1/8" seine	12/2002	0.6	0.2	0.1	7
1/16" seine	05/1998	0.4	0.2		32
1/16" seine	05/2000	0.2	0.3		26
1/16" seine	05/2001	0.6			7
1/16" seine	05/2002	0.2	0.2		8
1/16" seine	05/2003	0.3	0.1		6
1/16" seine	06/1998	0.3	0.2		36
1/16" seine	06/1999	0.4	0.2		13
1/16" seine	06/2000	0.3	0.3		30
1/16" seine	06/2001	0.6	0.0		22
1/16" seine	06/2002	0.4			10
1/16" seine	07/1998	0.5	0.2		19
1/16" seine	07/1999	0.4	0.0		8
1/16" seine	07/2000	0.6	0.3		15
1/16" seine	07/2001	0.2	0.1		85
1/16" seine	07/2002	0.4	0.1		89
1/16" seine	08/1999	0.1	0.2		8
1/16" seine	08/2000	0.3	0.2		22
1/16" seine	08/2001	0.4			176
1/16" seine	08/2002	0.5	0.1		51
3/8" seine	04/2002	0.6	0.6	0.5	2
3/8" seine	05/2002	0.5	0.4	0.3	28
3/8" seine	05/2003	0.6	0.9		11
3/8" seine	06/2001	0.6	0.2	0.2	35
3/8" seine	07/2001	0.4	0.3	0.2	41
3/8" seine	07/2002	0.4	0.3	0.2	50
3/8" seine	07/2003	0.5	0.4		31
3/8" seine	08/2002	0.3	0.3	0.2	23
3/8" seine	08/2003	0.7	0.6		9
3/8" seine	09/2001	0.3	0.4	0.4	14

Table 2.18. Average monthly water quality measurements associated with seine hauls.

Method	Date By Month	Water Temp (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Average Turbidity (NTU)	Number of net runs
1/8" seine	04/2003	14.6	10.1	462.5	335.5		6
1/8" seine	05/2002	18.9	9.4	637.0	179.0		7
1/8" seine	05/2003	18.4	9.7	518.8	338.3		9
1/8" seine	06/2002	23.6	7.1	554.6	190.2		13
1/8" seine	06/2003	23.3	6.2	512.0			3
1/8" seine	07/2002	27.3	9.4	428.0	100.5		15
1/8" seine	07/2003	26.0	5.9	513.8	166.0		9
1/8" seine	08/2002	21.7	6.6	451.3			3
1/8" seine	08/2003	24.1	7.7	448.6	123.0		6
1/8" seine	09/2002	21.1	6.6	388.1			6
1/8" seine	09/2003	13.4	8.7	493.6	98.0		6
1/8" seine	10/2002	14.8	8.3	505.0			3
1/8" seine	10/2003	15.8	8.9	491.6	53.0		6
1/8" seine	11/2002	4.8	12.3	344.8			6
1/8" seine	12/2002	0.0	13.5				3
1/16" seine	05/1998	21.7	10.4	681.6	257.6		9
1/16" seine	05/2000	24.1	9.2	572.6	504.7		7
1/16" seine	05/2001	14.9	3.9		237.0		1
1/16" seine	05/2002	19.5	9.1	488.5	194.3		3
1/16" seine	05/2003	23.1	11.4	558.0	133.0		1
1/16" seine	06/1998	26.0	5.9	628.0	207.0		6
1/16" seine	06/1999	26.5	9.6	633.0	507.0		2
1/16" seine	06/2000	24.8	8.9	493.5	261.9		8
1/16" seine	06/2001	22.4	11.3	513.5	157.5		2
1/16" seine	06/2002	26.7	6.6	687.7	240.0		3
1/16" seine	07/1998	32.5	10.5	541.0	386.0		4
1/16" seine	07/1999	25.6	6.7	607.5	291.0		2
1/16" seine	07/2000	26.1	7.8	495.3	648.0		3
1/16" seine	07/2001	24.4	8.0	611.6	89.0		10
1/16" seine	07/2002	27.2	8.7	449.9	83.8		14
1/16" seine	08/1999	21.9	8.2	530.0	142.0		1
1/16" seine	08/2000	29.5	9.4	425.2	119.7		3
1/16" seine	08/2001						27
1/16" seine	08/2002	25.7	7.3	436.0			8
3/8" seine	04/2002	20.6	17.1	630.0			1
3/8" seine	05/2002	17.2	9.3	495.5	203.7	84.5	4
3/8" seine	05/2003						2
3/8" seine	06/2001	24.5	10.4	593.8			14
3/8" seine	07/2001	28.6	7.4	579.5	718.0		11
3/8" seine	07/2002	29.6	12.4	1665.9	95.4	52.5	8
3/8" seine	07/2003	29.8	8.7	351.9			8
3/8" seine	08/2002	27.6	11.3	715.0			5
3/8" seine	08/2003	28.3	13.8	752.5			2
3/8" seine	09/2001	17.7	11.6	426.0			6

Table 2.19. Species caught in all seines.

Common Name	2000	2001	2002	2003	Total
Shovelnose Sturgeon	0	1	6	0	7
Longnose Gar	0	1	1	0	2
Goldeye	0	0	1	1	2
Gizzard Shad	0	12	50	53	115
Speckled Chub	5	47	153	14	219
Silver Chub	0	86	90	26	202
Flathead Chub	0	10	1	0	11
Creek Chub	0	0	1	0	1
Red Shiner	1,401	15,030	8,756	1,702	26,889
Emerald Shiner	16	532	417	61	1,026
River Shiner	189	1,347	938	53	2,527
Sand Shiner	42	448	697	134	1,321
Western Silvery Minnow	0	4	0	0	4
Brassy Minnow	0	0	15	0	15
Plains Minnow	70	100	3	19	192
Fathead Minnow	4	15	13	1	33
Common Carp	0	60	1	2	63
Bighead Carp	0	1	0	0	1
River Carpsucker	14	15	140	16	185
Quillback	3	3	10	14	30
Bigmouth Buffalo	0	2	0	0	2
Shorthead Redhorse	0	1	0	0	1
Channel Catfish	17	30	306	13	366
Western Mosquitofish	0	18	52	0	70
Brook Silverside	10	51	8	8	77
White Bass	0	9	1	0	10
Green Sunfish	0	21	0	0	21
Bluegill	0	16	5	0	21
Largemouth Bass	0	2	1	1	4
White Crappie	0	13	1	0	14
Johnny Darter	0	0	4	0	4
Freshwater Drum	0	31	25	0	56
Unknown species	358	3,149	610	8	4,125
Total	2,129	21,055	12,306	2,126	37,616

Table 2.20. Fish species caught in 1/16 inch mesh seines by month.

Common Name	Seine Mesh	May	June	July	August	Total
Gizzard Shad	1/16th inch	0	6	34	1	41
Speckled Chub	1/16th inch	2	1	22	7	32
Silver Chub	1/16th inch	0	18	29	8	55
Flathead Chub	1/16th inch	0	4	0	0	4
Creek Chub	1/16th inch	0	0	1	0	1
Red Shiner	1/16th inch	1,064	712	10,762	10,994	23,532
Emerald Shiner	1/16th inch	16	5	189	695	905
River Shiner	1/16th inch	21	108	812	1,072	2,013
Sand Shiner	1/16th inch	8	69	313	326	716
Western Silvery Minnow	1/16th inch	0	0	0	4	4
Plains Minnow	1/16th inch	6	7	42	102	157
Fathead Minnow	1/16th inch	0	3	12	14	29
Common Carp	1/16th inch	0	1	4	0	5
River Carpsucker	1/16th inch	2	3	26	86	117
Quillback	1/16th inch	0	0	2	7	9
Channel Catfish	1/16th inch	20	0	23	27	70
Western Mosquitofish	1/16th inch	1	7	21	39	68
Brook Silverside	1/16th inch	0	0	28	40	68
White Bass	1/16th inch	0	0	4	6	10
Green Sunfish	1/16th inch	0	0	11	10	21
Bluegill	1/16th inch	0	0	1	20	21
Largemouth Bass	1/16th inch	0	0	1	2	3
White Crappie	1/16th inch	0	4	0	10	14
Johnny Darter	1/16th inch	0	0	4	0	4
Freshwater Drum	1/16th inch	0	7	11	13	31
Unknown species	1/16th inch	55	889	2,467	588	3,999
	Totals	1,195	1,844	14,819	14,071	31,929

Table 2.21. Fish species caught in 1/8th inch mesh seines by month.

CommonName	Seine Mesh	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Longnose Gar	1/8th inch	0	0	0	1	0	0	0	0	0	1
Goldeye	1/8th inch	0	0	0	1	1	0	0	0	0	2
Gizzard Shad	1/8th inch	0	0	0	19	0	0	0	0	0	19
Speckled Chub	1/8th inch	0	5	1	9	5	0	1	3	0	24
Silver Chub	1/8th inch	0	0	0	23	0	1	0	0	0	24
Red Shiner	1/8th inch	81	370	484	961	396	176	230	1	13	2,712
Emerald Shiner	1/8th inch	1	4	0	5	40	5	2	0	1	58
River Shiner	1/8th inch	7	28	2	50	5	37	0	5	11	145
Sand Shiner	1/8th inch	2	19	5	58	6	37	27	0	5	159
Plains Minnow	1/8th inch	0	0	0	3	0	0	0	0	0	3
Fathead Minnow	1/8th inch	0	0	0	1	0	0	0	0	0	1
River Carpsucker	1/8th inch	0	0	1	1	3	0	1	0	0	6
Channel Catfish	1/8th inch	0	9	23	21	2	0	0	0	1	56
Western Mosquitofish	1/8th inch	0	0	1	1	0	0	0	0	0	2
Brook Silverside	1/8th inch	0	0	0	3	6	0	0	0	0	9
Largemouth Bass	1/8th inch	0	0	1	0	0	0	0	0	0	1
Freshwater Drum	1/8th inch	0	0	0	9	0	0	0	0	0	9
Unknown species	1/8th inch	0	0	0	9	0	0	0	0	0	9
Total		91	435	518	1,175	464	256	261	9	31	3,240

Lower Platte River sandbars

Table 2.22. Fish species caught in 3/8th inch mesh seines by month.

Common Name	Seine Mesh	April	May	June	July	August	Sept.	Total
Shovelnose Sturgeon	3/8th inch	0	0	1	6	0	0	7
Longnose Gar	3/8th inch	0	0	1	0	0	0	1
Gizzard Shad	3/8th inch	0	0	5	50	0	0	55
Speckled Chub	3/8th inch	0	52	0	50	61	0	163
Silver Chub	3/8th inch	2	9	1	78	32	1	123
Flathead Chub	3/8th inch	0	0	0	5	0	2	7
Red Shiner	3/8th inch	0	87	100	392	10	56	645
Emerald Shiner	3/8th inch	1	16	17	8	20	1	63
River Shiner	3/8th inch	0	23	12	286	31	17	369
Sand Shiner	3/8th inch	0	46	11	287	101	1	446
Brassy Minnow	3/8th inch	0	15	0	0	0	0	15
Plains Minnow	3/8th inch	0	1	0	17	14	0	32
Fathead Minnow	3/8th inch	0	1	0	2	0	0	3
Common Carp	3/8th inch	0	0	6	51	1	0	58
Bighead Carp	3/8th inch	0	0	1	0	0	0	1
River Carpsucker	3/8th inch	0	1	2	56	3	0	62
Quillback	3/8th inch	0	6	1	14	0	0	21
Bigmouth Buffalo	3/8th inch	0	0	0	2	0	0	2
Shorthead Redhorse	3/8th inch	0	0	0	1	0	0	1
Channel Catfish	3/8th inch	0	23	0	167	44	6	240
Freshwater Drum	3/8th inch	0	0	0	16	0	0	16
Unknown species	3/8th inch	0	0	66	50	0	1	117
Total		3	280	224	1,538	317	85	2,447

Gear comparisons:

To better understand the apparent conflicts in the descriptions of some species habitat use found for different gear types, we compared the habitat sampled by the different gear types. Depth and mean column velocity are two of the more important habitat variables for describing fish habitat in the Platte River. The bivariate analysis of depth and mean column velocity along with the scatterplots with depth and mean velocity for the sampling effort show the distribution of available habitat based on IFIM habitat transect data collected by NGPC, and related to the samples for drifted gill nets, drifted trammel nets, trotlines, trawls, and seines (Tables 2.23 – 2.45 and Figures 2.7 – 2.12, respectively). Habitat availability is based on the IFIM transect data collected by NGPC at three sites (Cedar Creek, Louisville, and North Bend) at various discharges.

As planned in our original sampling strategy, all of our gear types sampled deeper and swifter water than randomly available in the river. For the variable depth (Figure 2.13), pairwise comparisons showed most gears sampled different depths on average, with the exception of trotlines and trawls, trammel nets and shovelnose sturgeon tracking, and trammel nets and gill nets. From shallowest to deepest, the average depths sampled were the IFIM transects (median = 0.31 m), seines (median = 0.40 m), drifted gill nets (median = 0.61 m), drifted trammel nets (median = 0.63 m), shovelnose sturgeon tracking (median = 0.77 m), trawls (median = 1.17 m), and trotlines (median = 1.33 m).

For the variable mean column velocity (Figure 2.14), pairwise comparisons showed most gears sampled different velocities on average, with the exception of trotlines and trawls, shovelnose sturgeon tracking and trawls, and drifted trammel nets and drifted gill nets. In order from slowest to fastest mean water column velocities, the median velocities sampled were seines (0.18 m/s), IFIM transects (0.48 m/s), drifted trammel nets (0.53 m/s), drifted gill nets (0.55 m/s), shovelnose sturgeon tracking (0.58 m/s), trawls (0.67 m/s), trotlines (0.72 m/s). For bottom velocities (Figure 2.15), seines were different from all other gear types and trammel nets were different from trotlines and shovelnose sturgeon tracking. In order from slowest to fastest, the median bottom velocities sampled were seines (0.18 m/s), drifted trammel nets (0.30 m/s), drifted gill nets (0.34 m/s), trawls (0.34 m/s), trotlines (0.35 m/s), and shovelnose sturgeon tracking (0.36 m/s).

For temperature (Figure 2.16), most of the gear types were different with the exception of drifted gill nets, seines, and trawls were not different, and drifted trammel nets were not different from trawls and shovelnose sturgeon tracking.

In order from coldest to warmest, the median temperatures sampled were trotlines (14.1 °C), shovelnose sturgeon tracking (21.1 °C), drifted trammel nets (22 °C), trawls (24.4 °C), seines (24.7 °C), and drifted gill nets (25.2 °C).

For dissolved oxygen (Figure 2.17) and specific conductivity (Figure 2.18), most gear types were different with the exception of drifted gill nets, drifted trammel nets, and seines, and trotlines and trawls. In order from lowest to highest, the median specific conductivity sampled was drifted trammel nets (504 µS/cm), seines (518 µS/cm), drifted gill nets (522 µS/cm), shovelnose sturgeon tracking (560 µS/cm), trawls (598 µS/cm), and trotlines (598 µS/cm).

For total suspended solids (Figure 2.19), drifted trammel nets and drifted gill nets were different from shovelnose sturgeon tracking, trotlines, and seines. Trawls were different than trotlines and shovelnose sturgeon tracking. In order from lowest to highest total suspended solids, the median total suspended solids sampled were shovelnose sturgeon tracking (143 mg/L), seines (150 mg/L), trotlines (157 mg/L), trawls (187 mg/L), drifted gill nets (217 mg/L), drifted trammel nets (311 mg/L).

For discharge (Figure 2.20), trotlines were sampled at different discharge levels than all other gear, and trawls and shovelnose sturgeon tracking also differed. In order from lowest to highest, the median total discharge rate at sampling times were shovelnose sturgeon tracking (3,835 cfs), drifted gill nets (4,170 cfs), drifted trammel nets (4,410 cfs), trawls (4,920 cfs), and trotlines (6,130 cfs).

Table 2.23. Descriptive statistics for the IFIM habitat availability data.

Parameter	Units	Number	Missing	Median	25%	75%
Depth	m	2200	0	0.31	0.15	0.61
Mean column velocity	m/s	2200	41	0.48	0.31	0.62

Table 2.24. Number of observations for the categories of depth and velocity for the IFIM habitat availability data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	434	560	36	0	1030
	0.30-0.60	42	310	205	3	560
	0.60-0.90	17	142	202	9	370
	>0.90	6	26	136	31	199
	Total	499	1038	579	43	2159

Table 2.25. Percent of observations for the categories of depth and velocity for the IFIM habitat availability data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	20.1	25.9	1.7	0.0	47.7
	0.30-0.60	1.9	14.4	9.5	0.1	25.9
	0.60-0.90	0.8	6.6	9.4	0.4	17.1
	>0.90	0.3	1.2	6.3	1.4	9.2
	Total	23.1	48.1	26.8	2.0	100.0

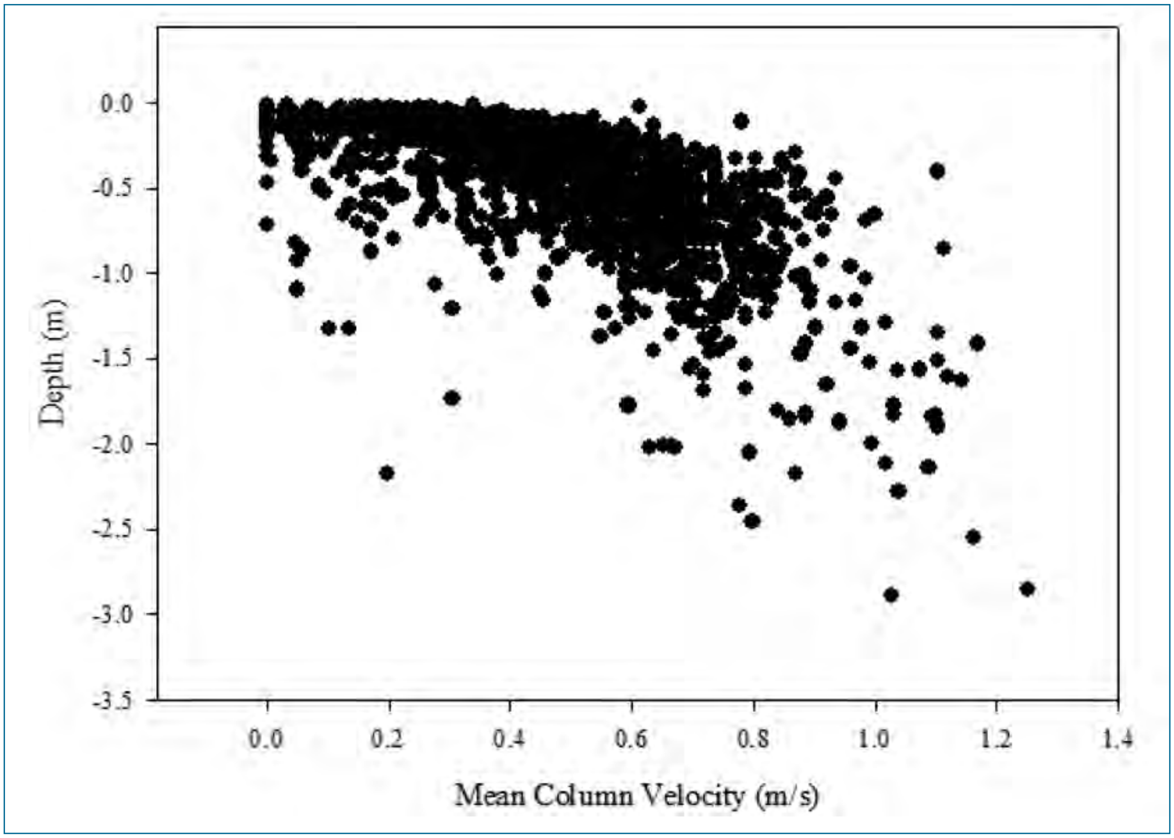


Figure 2.7. Scatter plot of depth versus mean column velocity for data measured along transects from the Instream Flow Incremental Methodology study in the lower Platte River, Nebraska (NGPC data files)

Table 2.26. Descriptive statistics for the drifted gillnet sampling data.

Parameter	Units	Number	Missing	Median	25%	75%
Depth	m	323	60	0.61	0.50	0.77
Mean column velocity	m/s	323	62	0.55	0.47	0.63
Bottom velocity	m/s	323	65	0.34	0.27	0.43
Temperature	°C	323	22	25.2	22.0	27.1
Dissolved oxygen	mg/L	323	26	9.4	8.2	10.6
Specific conductivity	µS/cm	323	31	522	439	646
Total suspended solids	mg/L	323	210	217	163	359

Table 2.27. Number of observations for the categories of depth and velocity for the drifted gillnet sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	1	4	0	0	5
	0.30-0.60	6	95	24	0	125
	0.60-0.90	1	48	50	1	100
	>0.90	1	7	23	0	31
	Total	9	154	97	1	261

Table 2.28. Percent of observations for the categories of depth and velocity for the drifted gillnet sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.4	1.5	0.0	0.0	1.9
	0.30-0.60	2.3	36.4	9.2	0.0	47.9
	0.60-0.90	0.4	18.4	19.2	0.4	38.3
	>0.90	0.4	2.7	8.8	0.0	11.9
	Total	3.4	59.0	37.2	0.4	100.0

Table 2.29. Normalized sampling effort for the categories of depth and velocity for the drifted gillnet sampling data.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.01	0.02	0.00	0.00
	0.30-0.60	0.42	0.91	0.35	0.00
	0.60-0.90	0.17	1.00	0.73	0.33
	>0.90	0.49	0.80	0.50	0.00

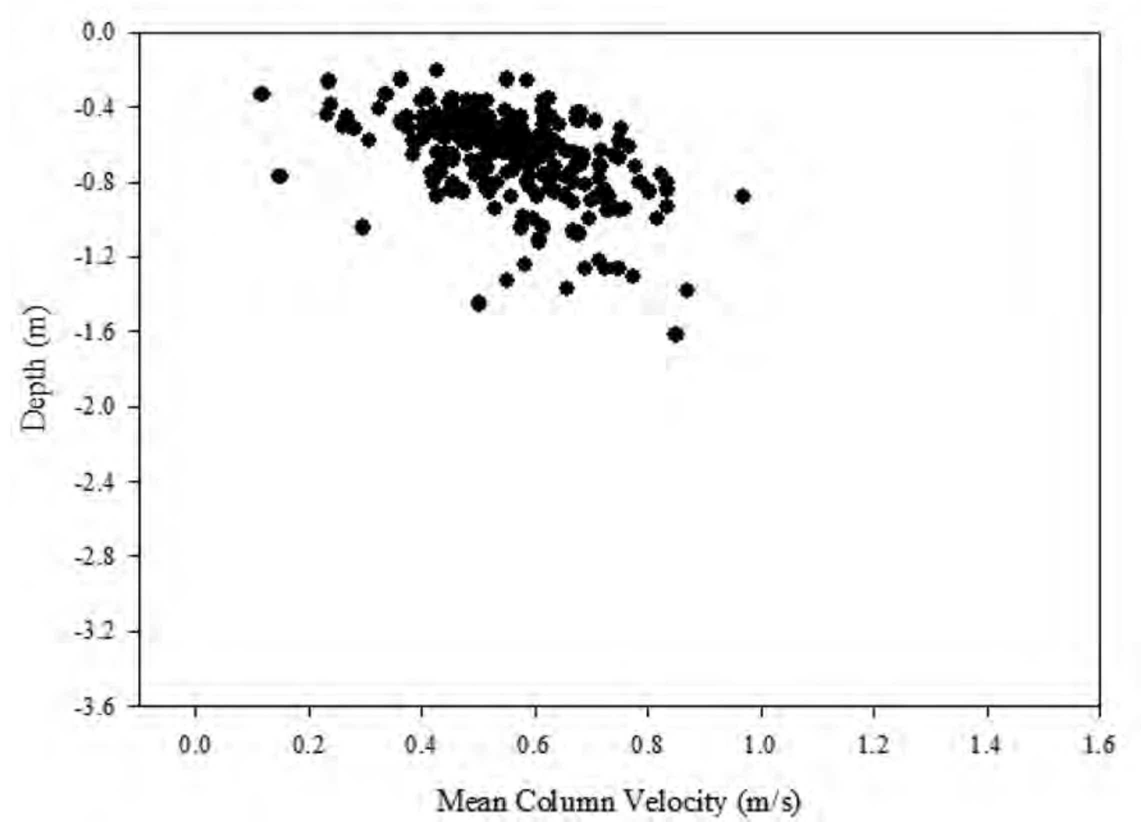


Figure 2.8. Scatter plot of depth versus mean column velocity for data measured at the location of gill net drifts in the lower Platte River, Nebraska.

Table 2.30. Descriptive statistics for the drifted trammel net sampling data.

Parameter	Units	Number	Missing	Median	25%	75%
Depth	m	213	32	0.63	0.498	0.904
Mean column velocity	m/s	213	32	0.54	0.45	0.623
Bottom velocity	m/s	213	32	0.297	0.229	0.388
Temperature	°C	213	29	21.95	17.5	26.9
Dissolved oxygen	mg/L	213	32	10.08	8.942	11.918
Specific conductivity	µS/cm	213	35	504	405	634
Total suspended solids	mg/L	213	73	310.5	150	494
Turbidity	NTU	213	71	206	75	396

Table 2.31. Number of observations for the categories of depth and velocity for the drifted trammel net sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0	6	0	0	6
	0.30-0.60	5	59	14	0	78
	0.60-0.90	0	36	15	0	51
	>0.90	0	15	28	3	41
	Total	5	116	57	3	181

Table 2.32. Percent of observations for the categories of depth and velocity for the drifted trammel net sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.0	3.3	0.0	0.0	3.3
	0.30-0.60	2.8	32.6	7.7	0.0	43.1
	0.60-0.90	0.0	19.9	8.3	0.0	28.2
	>0.90	0.0	8.3	15.5	1.7	25.4
	Total	2.8	64.1	31.5	1.7	100.0

Table 2.33. Normalized sampling effort for the categories of depth and velocity for the drifted trammel net sampling data.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.00	0.02	0.00	0.00
	0.30-0.60	0.21	0.33	0.12	0.00
	0.60-0.90	0.00	0.44	0.13	0.00
	>0.90	0.00	1.00	0.36	0.17

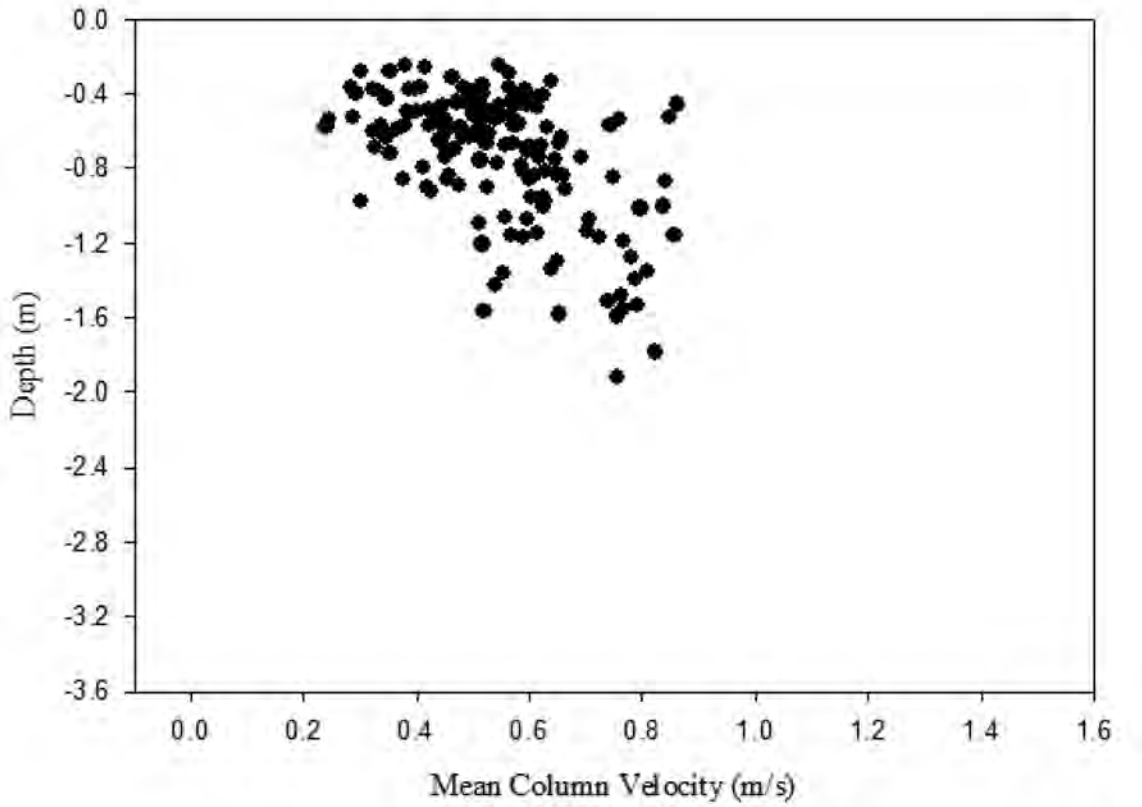


Figure 2.9. Scatter plot of depth versus mean column velocity for data measured at the location of trammel net drifts in the lower Platte River, Nebraska.

Table 2.34. Descriptive statistics for the trotline sampling data.

Parameter	Units	Number	Missing	Median	25%	75%
Depth	m	224	33	1.33	1.07	1.71
Mean column velocity	m/s	224	35	0.72	0.60	0.84
Bottom velocity	m/s	222	66	0.35	0.26	0.46
Temperature	°C	224	9	14.1	9.7	16.3
Dissolved oxygen	mg/L	224	17	11.2	10.5	12.0
Specific conductivity	µS/cm	224	14	598	537	695
Total suspended solids	mg/L	224	64	157	118	204

Table 2.35. Number of observations for the categories of depth and velocity for the trotline sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0	0	0	0	0
	0.30-0.60	1	1	0	0	2
	0.60-0.90	0	14	11	1	26
	>0.90	3	26	98	33	160
	Total	4	41	109	34	188

Table 2.36. Percent of observations for the categories of depth and velocity for the trotline sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.0	0.0	0.0	0.0	0.0
	0.30-0.60	0.5	0.5	0.0	0.0	1.1
	0.60-0.90	0.0	7.4	5.9	0.5	13.8
	>0.90	1.6	13.8	52.1	17.6	85.1
	Total	2.1	21.8	58.0	18.1	100.0

Table 2.37. Normalized sampling effort for the categories of depth and velocity for the trotline sampling data.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.00	0.00	0.00	0.00
	0.30-0.60	0.02	0.00	0.00	0.00
	0.60-0.90	0.00	0.09	0.05	0.10
	>0.90	0.47	0.94	0.68	1.00

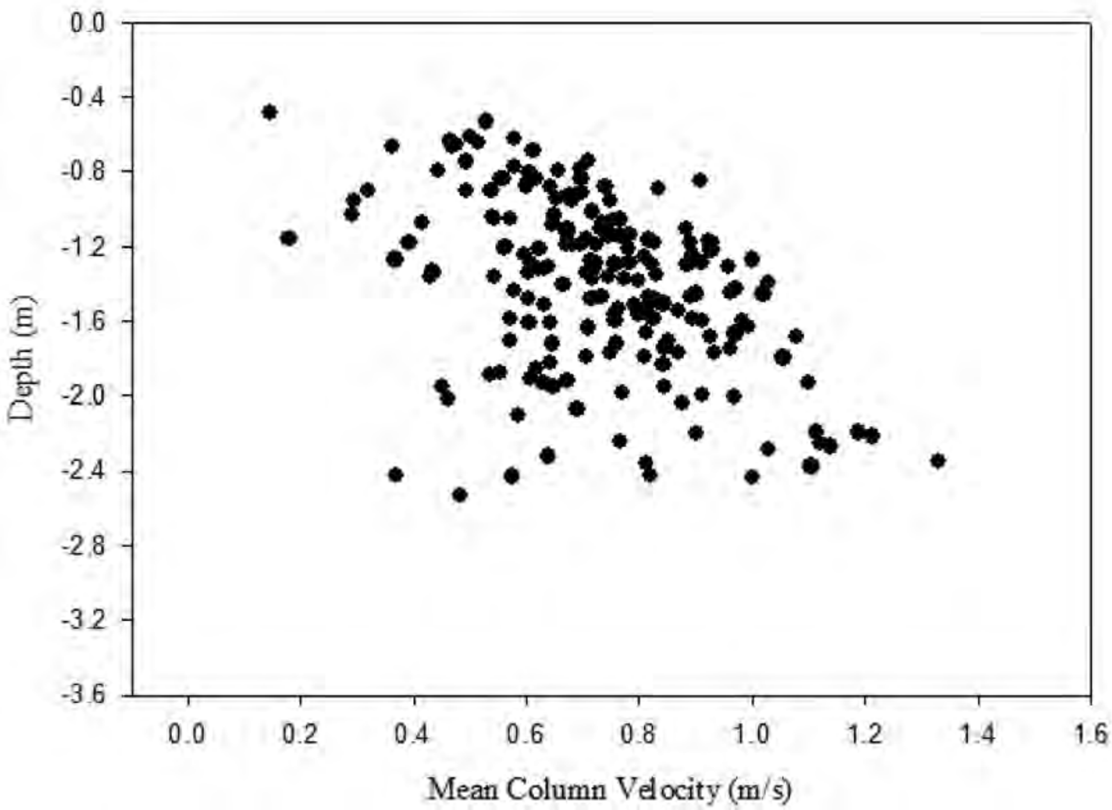


Figure 2.10. Scatter plot of depth versus mean column velocity for data measured at the location of trotline sets in the lower Platte River, Nebraska.

Table 2.38. Descriptive statistics for the trawl sampling data.

Parameter	Units	Number	Missing	Median	25%	75%
Depth	m	157	2	1.17	0.81	1.62
Mean column velocity	m/s	157	19	0.67	0.53	0.84
Bottom velocity	m/s	157	22	0.34	0.22	0.48
Temperature	°C	157	10	24.4	21.3	26.2
Dissolved oxygen	mg/L	157	10	9.3	8.3	10.4
Specific conductivity	µS/cm	157	10	598	515	871
Total suspended solids	mg/L	157	52	187	107	1224

Table 2.39. Number of observations for the categories of depth and velocity for the trawl sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	1	2	0	0	3
	0.30-0.60	1	10	0	0	11
	0.60-0.90	0	18	15	1	34
	>0.90	2	15	52	21	90
	Total	4	45	67	22	138

Table 2.40. Percent of observations for the categories of depth and velocity for the trawl sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.7	1.4	0.0	0.0	2.2
	0.30-0.60	0.7	7.2	0.0	0.0	8.0
	0.60-0.90	0.0	13.0	10.9	0.7	24.6
	>0.90	1.4	10.9	37.7	15.2	65.2
	Total	2.9	32.6	48.6	15.9	100.0

Table 2.41. Normalized sampling effort for the categories of depth and velocity for the trawl sampling data.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.00	0.01	0.00	0.00
	0.30-0.60	0.04	0.05	0.00	0.00
	0.60-0.90	0.00	0.19	0.11	0.16
	>0.90	0.49	0.85	0.56	1.00

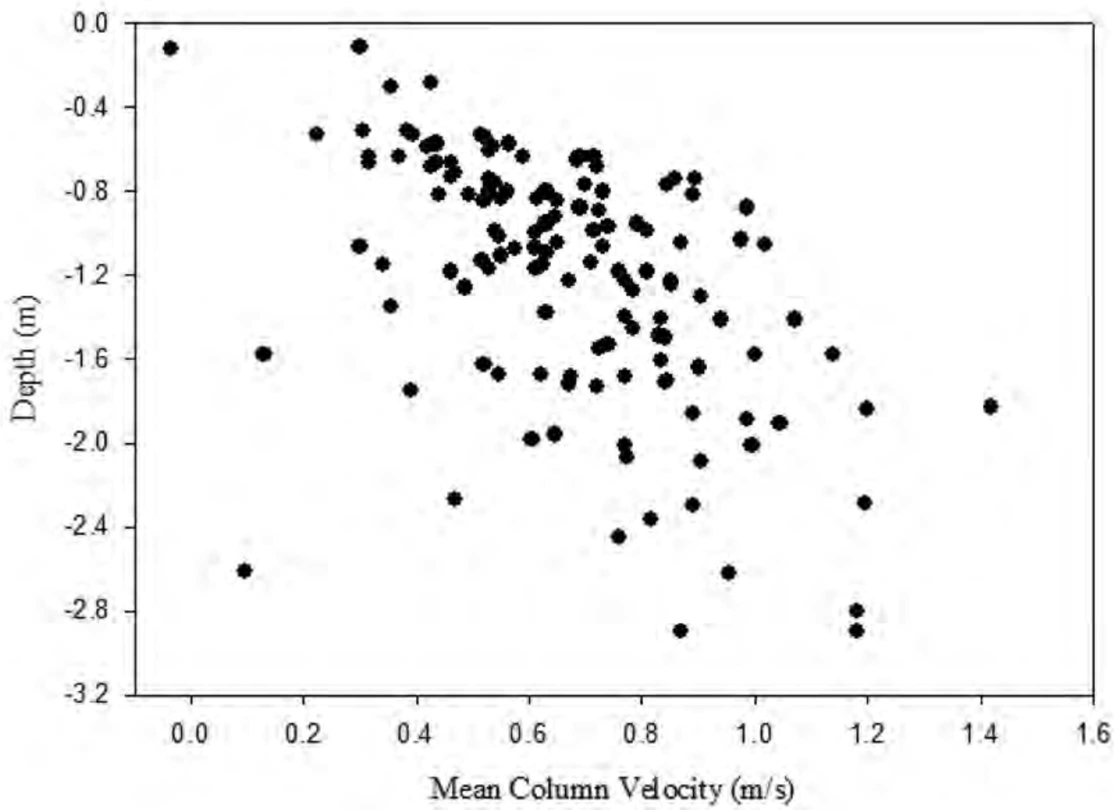


Figure 2.11. Scatter plot of depth versus mean column velocity for data measured at the location of trawl runs in the lower Platte River, Nebraska.

Table 2.42. Descriptive statistics for the seine sampling data.

Parameter	Units	Number	Missing	Median	25%	75%
Depth	m	252	40	0.46	0.30	0.66
Mean column velocity	m/s	252	61	0.27	0.12	0.44
Bottom velocity	m/s	252	116	0.18	0.07	0.30
Temperature	°C	252	57	23.7	18.2	26.4
Dissolved oxygen	mg/L	252	57	8.7	7.3	10.9
Specific conductivity	µS/cm	252	62	505	440	584
Total suspended solids	mg/L	252	147	150	111	266

Table 2.43. Number of observations for the categories of depth and velocity for the seine sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	35	14	0	0	49
	0.30-0.60	39	38	4	0	81
	0.60-0.90	31	18	1	0	50
	>0.90	3	5	3	0	11
	Total	108	75	8	0	191

Table 2.44. Percent of observations for the categories of depth and velocity for the seine sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	18.3	7.3	0.0	0.0	25.7
	0.30-0.60	20.4	19.9	2.1	0.0	42.4
	0.60-0.90	16.2	9.4	0.5	0.0	26.2
	>0.90	1.6	2.6	1.6	0.0	5.8
	Total	56.5	39.3	4.2	0.0	100.0

Table 2.45. Normalized sampling effort for the categories of depth and velocity for the seine sampling data.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.04	0.01	0.00	0.00
	0.30-0.60	0.51	0.07	0.01	0.00
	0.60-0.90	1.00	0.07	0.00	0.00
	>0.90	0.27	0.11	0.01	0.00

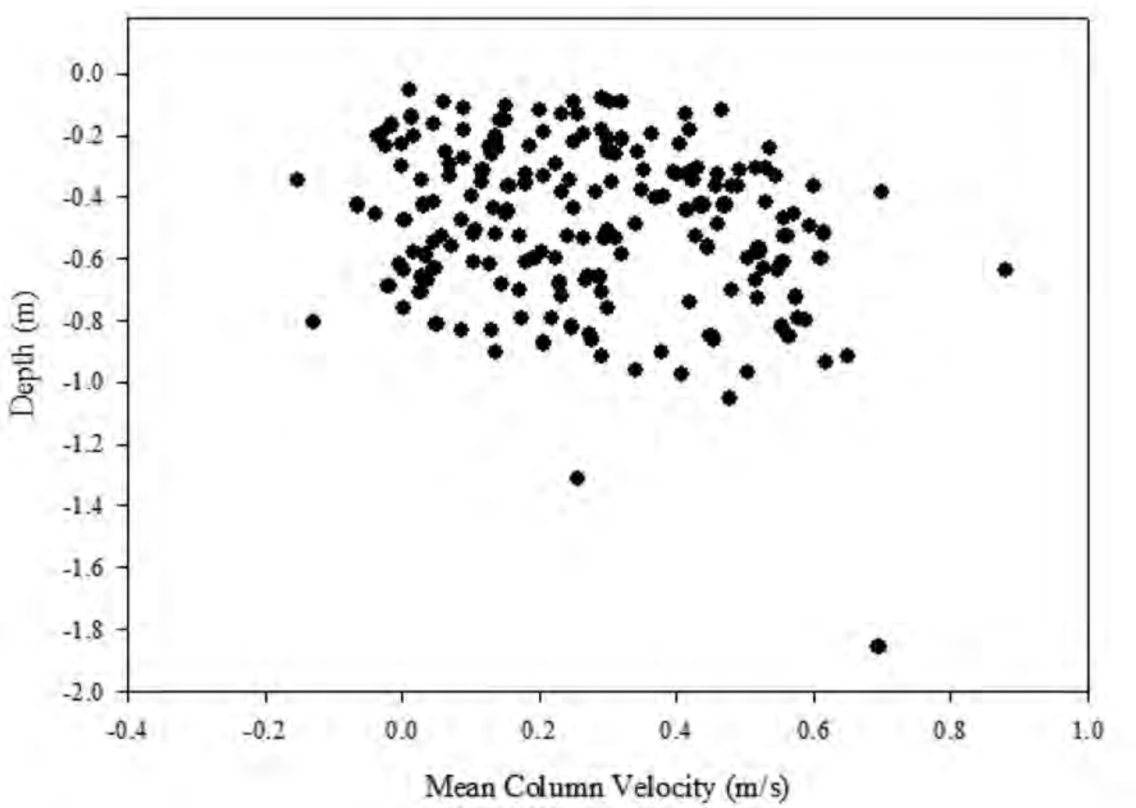


Figure 2.12. Scatter plot of depth versus mean column velocity for data measured at the location of seine runs in the lower Platte River, Nebraska.

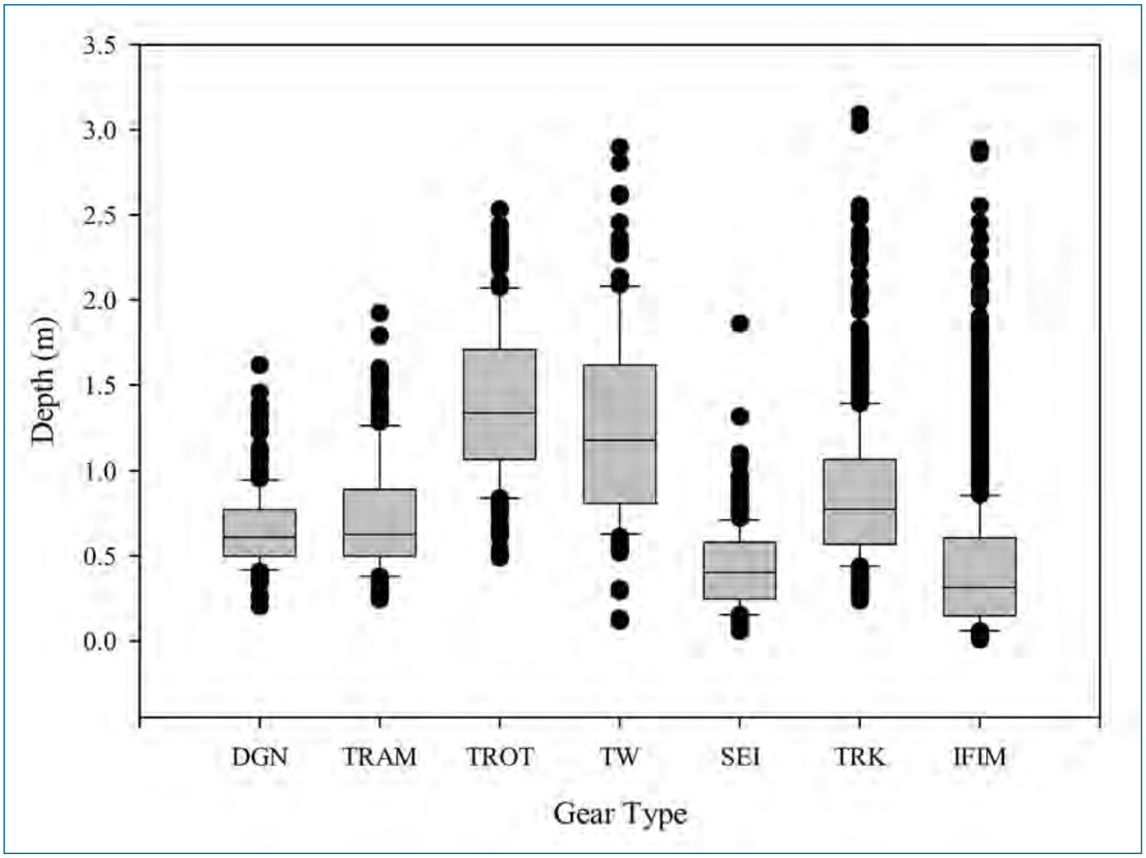


Figure 2.13. Box plots of average depth for drifted gill nets (DGN), drifted trammel nets (TRAM), trotlines (TROT), trawls (TW), seines (SEI), telemetry (TRK), and IFIM measurements (IFIM). The box boundaries indicate the 25th and 75th percentiles, the line within the box denotes the median, whiskers (error bars) indicate the 10th and 90th percentiles and the dots indicate values out to the limits of the observations

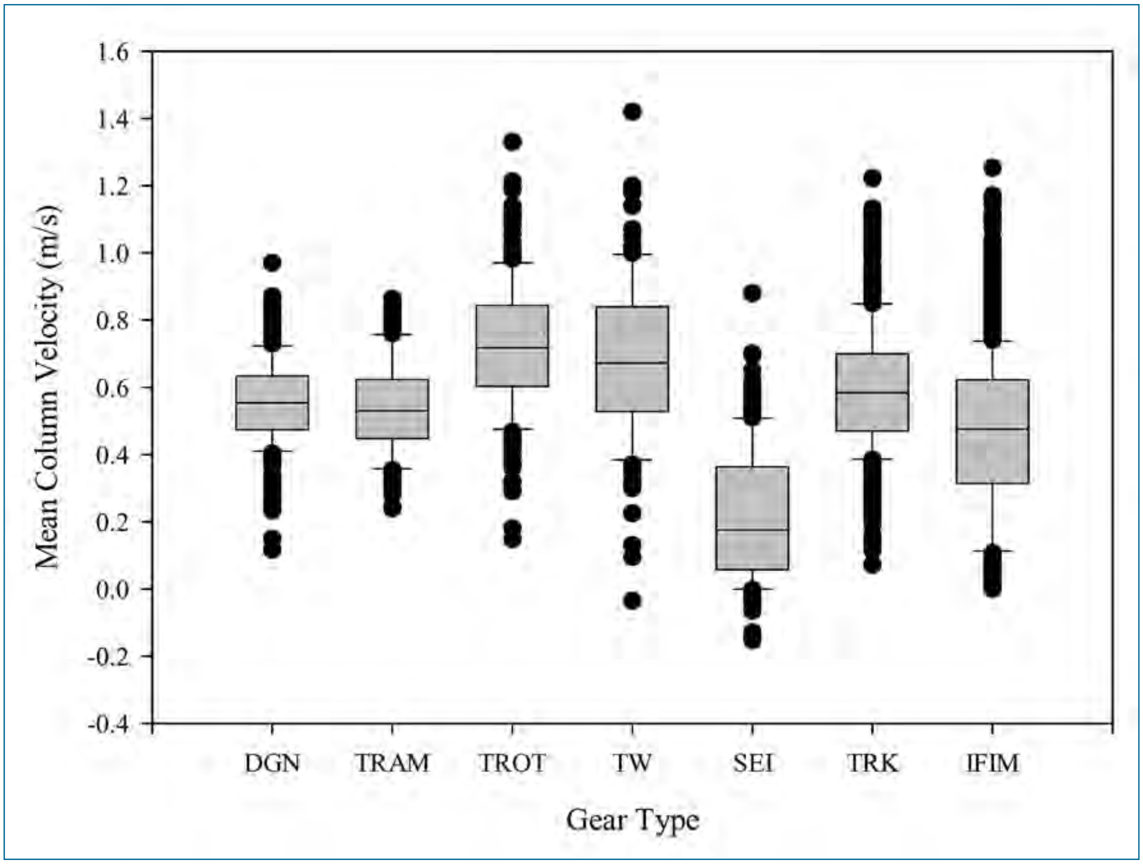


Figure 2.14. Box plots of average mean column velocity for drifted gill nets (DGN), drifted trammel nets (TRAM), trotlines (TROT), trawls (TW), seines (SEI), telemetry (TRK), and IFIM measurements (IFIM). The box boundaries indicate the 25th and 75th percentiles, the line within the box denotes the median, whiskers (error bars) indicate the 10th and 90th percentiles and the dots indicate values out to the limits of the observations

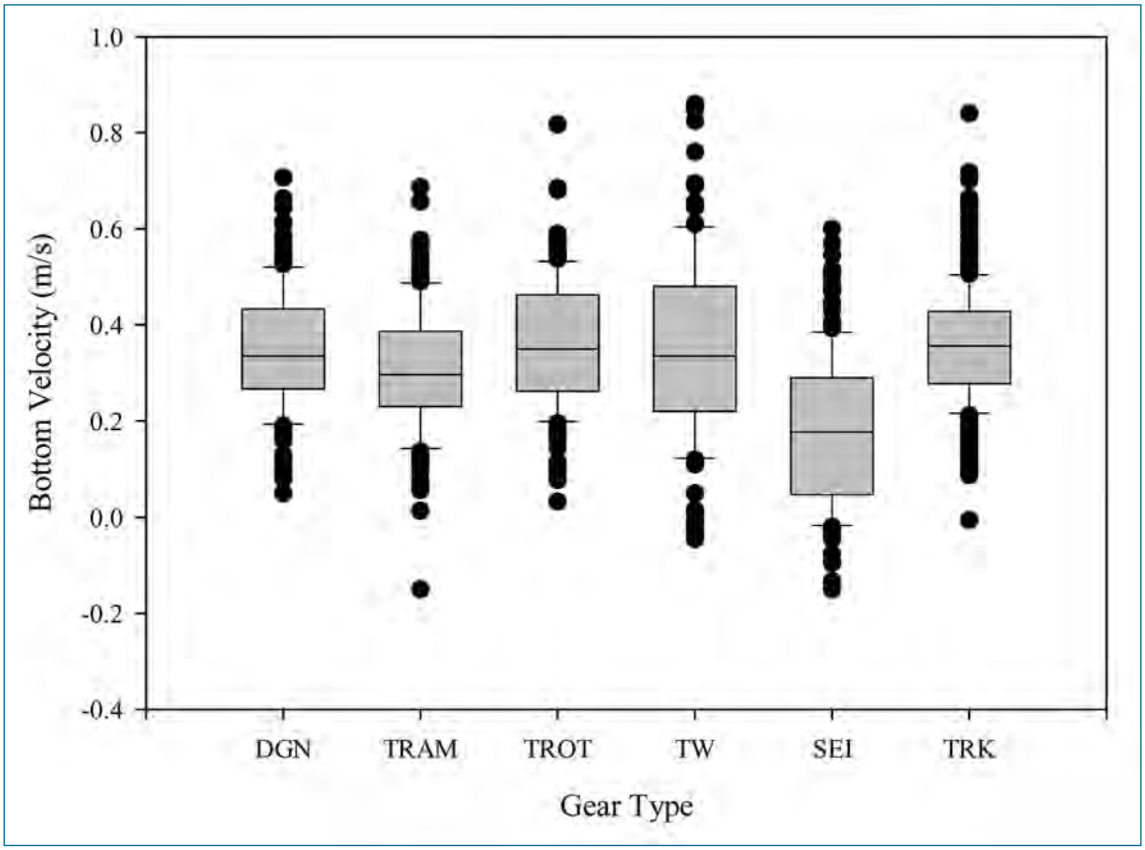


Figure 2.15. Box plots of average bottom velocity for drifted gill nets (DGN), drifted trammel nets (TRAM), trotlines (TROT), trawls (TW), seines (SEI), and telemetry (TRK). The box boundaries indicate the 25th and 75th percentiles, the line within the box denotes the median, whiskers (error bars) indicate the 10th and 90th percentiles and the dots indicate values out to the limits of the observations

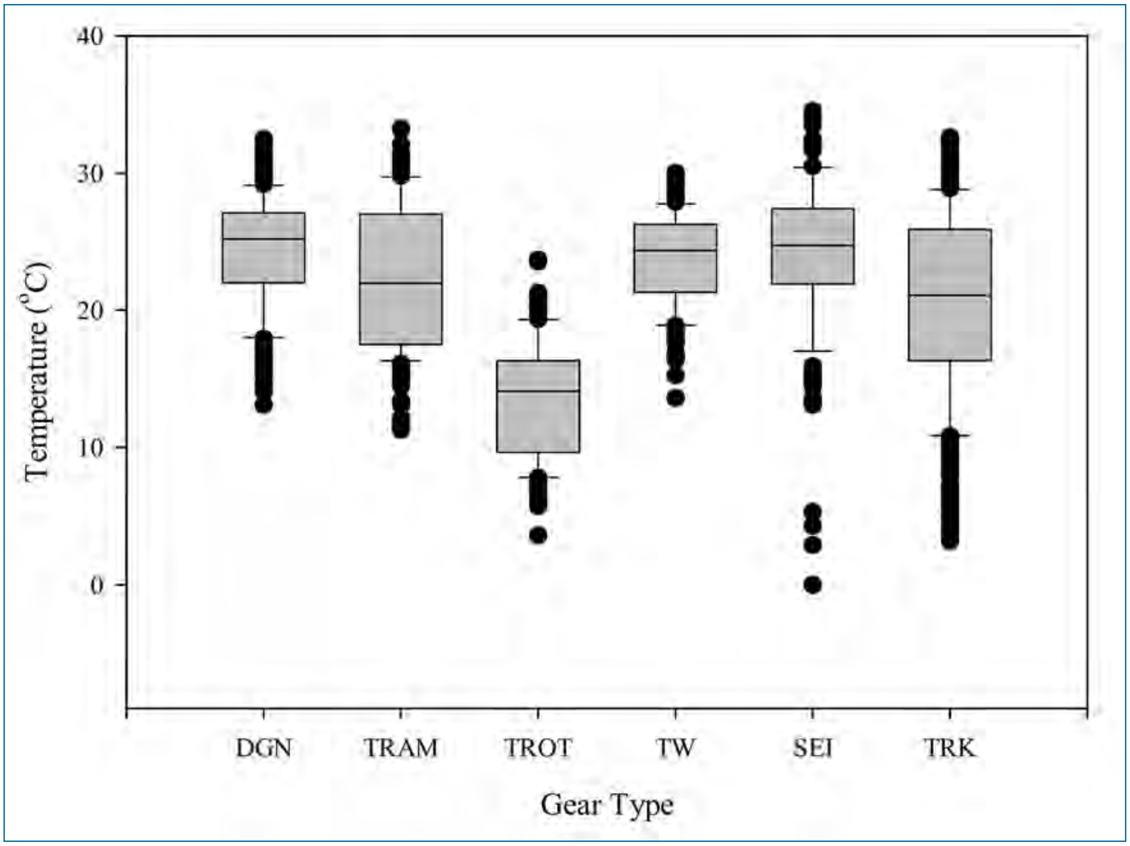


Figure 2.16. Box plots of average temperature for drifted gill nets (DGN), drifted trammel nets (TRAM), trotlines (TROT), trawls (TW), seines (SEI), and telemetry (TRK). The box boundaries indicate the 25th and 75th percentiles, the line within the box denotes the median, whiskers (error bars) indicate the 10th and 90th percentiles and the dots indicate values out to the limits of the observations

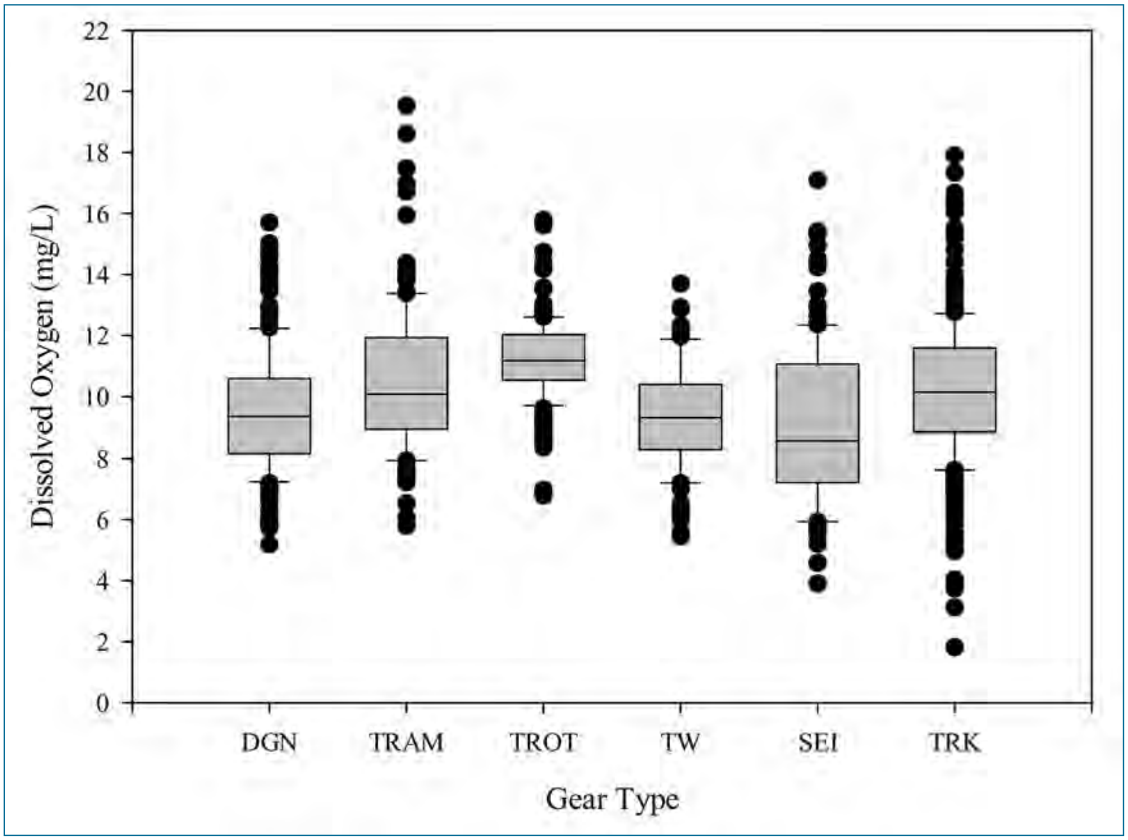


Figure 2.17. Box plots of average dissolved oxygen for drifted gill nets (DGN), drifted trammel nets (TRAM), trotlines (TROT), trawls (TW), seines (SEI), and telemetry (TRK). The box boundaries indicate the 25th and 75th percentiles, the line within the box denotes the median, whiskers (error bars) indicate the 10th and 90th percentiles and the dots indicate values out to the limits of the observations

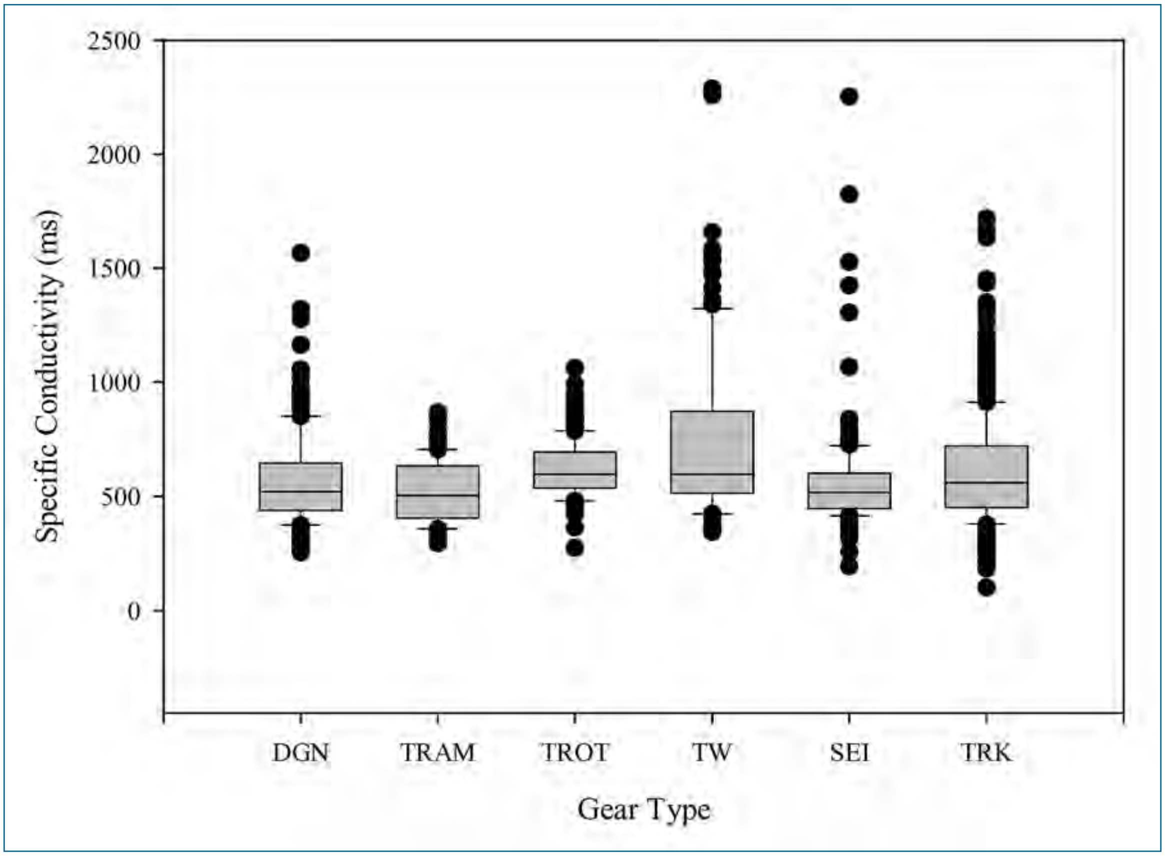


Figure 2.18. Box plots of average specific conductivity for drifted gill nets (DGN), drifted trammel nets (TRAM), trotlines (TROT), trawls (TW), seines (SEI), and telemetry (TRK). The box boundaries indicate the 25th and 75th percentiles, the line within the box denotes the median, whiskers (error bars) indicate the 10th and 90th percentiles and the dots indicate values out to the limits of the observations

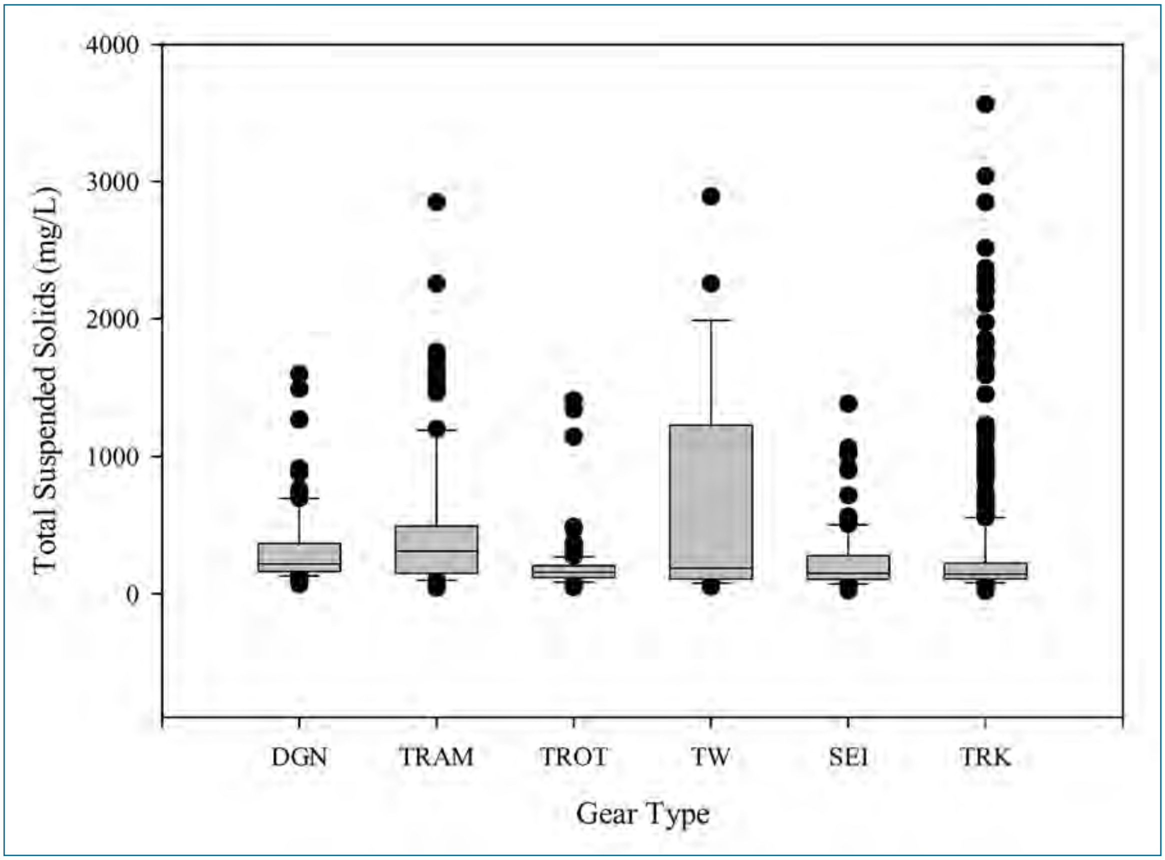


Figure 2.19. Box plots of average suspended solids for drifted gill nets (DGN), drifted trammel nets (TRAM), trotlines (TROT), trawls (TW), seines (SEI), and telemetry (TRK). The box boundaries indicate the 25th and 75th percentiles, the line within the box denotes the median, whiskers (error bars) indicate the 10th and 90th percentiles and the dots indicate values out to the limits of the observations

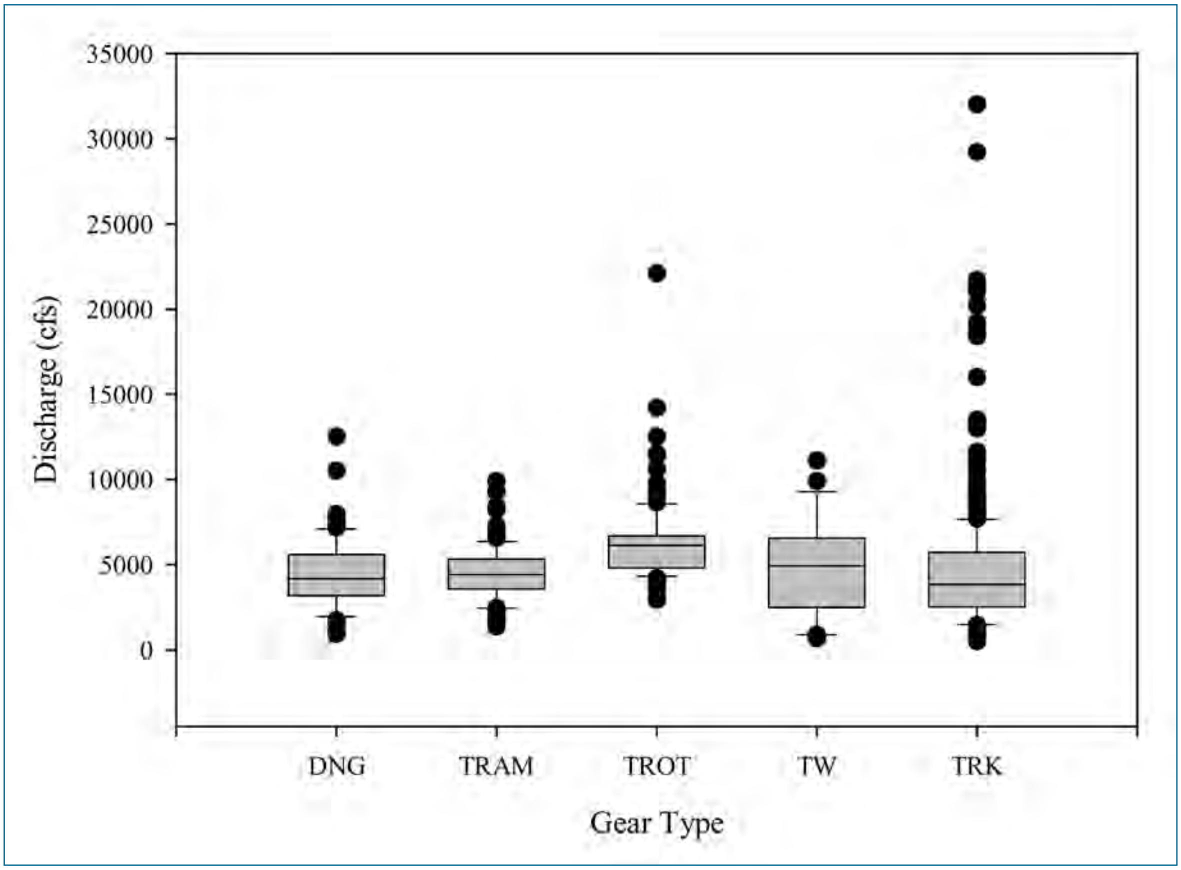


Figure 2.20. Box plots of average discharge for drifted gill nets (DGN), drifted trammel nets (TRAM), trotlines (TROT), trawls (TW), seines (SEI), and telemetry (TRK). The box boundaries indicate the 25th and 75th percentiles, the line within the box denotes the median, whiskers (error bars) indicate the 10th and 90th percentiles and the dots indicate values out to the limits of the observations

Releasing a juvenile pallid sturgeon.

CHAPTER 3

AMBIENT RIVER HABITAT CONDITIONS IN THE LOWER PLATTE RIVER

INTRODUCTION

Habitat conditions are important to the existence and viability of fish populations. In association with the study of pallid sturgeon, shovelnose sturgeon and sturgeon chub populations in the Platte River and with the support of a grant from the US Fish and Wildlife Service a monitoring program was initiated to measure several water quality parameters in the lower Platte River basin beginning in September 2000. The parameters measured corresponded directly to the water quality measurements which were made in association with radio-telemetry locations of radio tagged pallid sturgeon and shovelnose sturgeon and with collections of fish during the sturgeon and chub studies.

The objective of this portion of the study was to sample the water quality parameters; temperature, dissolved oxygen, water conductivity (including specific conductivity and salinity), and suspended solids at four locations in the lower Platte River basin. Substrate composition was an additional habitat component of the Platte River habitat that was measured within the study area.

METHODS

Starting in September 2000, we measured water temperature (ºC), dissolved oxygen (mg/L), specific conductivity (µS/cm), salinity (ppt), and total suspended solids (mg/L) at four sites in the lower Platte River basin. Starting in July 2001, turbidity was added to the list of parameters measured. Two sampling sites, near Leshara, NE (Nebraska Highway 64 Bidge) and Louisville, NE (Nebraska Highway 50 Bridge), were on the Platte River, while two other sites, near Greenwood, NE and Waterloo, NE were located on Salt Creek and the Elkhorn River, respectively. Salt Creek and the Elkhorn River are the two main tributaries of the lower Platte River and examination of past water quality records indicated that their inflows have important impacts on the chemistry of the Platte River (Hitch et al. 2003). Temperature, dissolved oxygen, specific conductivity and salinity were measured using a YSI model 85 meter. Suspended solids were determined by filtering a measured portion of a water sample following the APHA (1987) standard method. Turbidity was measured from a water sample using a Hach model 2100P turbidimeter.

All sites were sampled weekly through the year, except when ice conditions made water sampling dangerous. A sample at a location consisted of two readings at the Elkhorn River and Salt Creek sites, four readings at the Leshara site and five readings at the Louisville site. The number of samples varied with respect to the width of the river at the sampling location. Five temperature-recording units were placed at the Louisville site to monitor temperature on a continuous basis.

In the summer of 2003 (July/August), substrate samples were collected from the four water quality study sites and from sites at the US Highway 6 Bridge near Ashland, NE and the Nebraska State Highway 79 Bridge near North Bend, NE. Subsequent substrate samples were collected during October 2003 and March 2004. Samples were collected along transects across the channel using a hand-held corer that penetrated the substrate to a depth of approximately 30 cm. A random number determined the distance of each initial core location from the shore. Ten core samples were collected at an even distance for narrow sites (Salt Creek and the Elkhorn River) and 20 for Platte River sites. Water depth and mean column velocity were also measured at each core location. Cores were placed in individually labeled gallon plastic jars with any accompanying water in the corer. In the lab, samples were allowed to evaporate and then placed in pans for drying in an oven at 105 °C. Samples were then dry sieved through nested screens to separate, silt (passed through 230 sieve), fine sand (retained by 230 sieve), sand (retained by 60 sieve), coarse sand (retained by 18 sieve), and gravel (retained by 10 sieve). Each textural component was then weighed and expressed as a percentage of the total weight of the core sample.

RESULTS AND DISCUSSION

Temperature:

Average weekly temperature values for the Platte River at Leshara, the Elkhorn River at Waterloo, Salt Creek at Greenwood, and the Platte River at Louisville for the time period September 2000 through June 2004 are displayed on Figures 3.1, 3.2, 3.3 and 3.4, respectively. Water temperatures at all four sites followed basically the same pattern from year to year, peaking in July at the two Platte River sites and the Elkhorn River site at temperatures >30 °C. The Salt Creek site tended to warm faster and remain above 30 °C from June to August. In the Platte River, the highest water temperatures occurred in 2002 (Figures 3.1 and 3.4) and this coincides with the periods of lowest discharge (Figures 1.2 and 1.5). Salt Creek contrasted with the other three sites during winter, since it seldom had temperatures down to 0 °C.

Figures 3.5 to 3.9 display data from the temperature recorders installed at the Louisville site during 2000, 2001, 2002, 2003 and 2004, respectively. Note that the scales on the axes vary from one figure to the other. Unfortunately, there are gaps in the data due to lost or destroyed recorders and the data presented is the record of only one recorder. Fortunately, the times of critically high temperatures during the period of the study have been recorded. These extreme temperatures occurred during July and August 2001, 2002 and 2003. The other major value of these records is the amount of temperature fluctuation that is recorded within a day and from day to day in the lower Platte River. Diel temperature fluctuations of 10 ºC are not uncommon and have been previously reported by Fessel (1996) and Yu (1996).

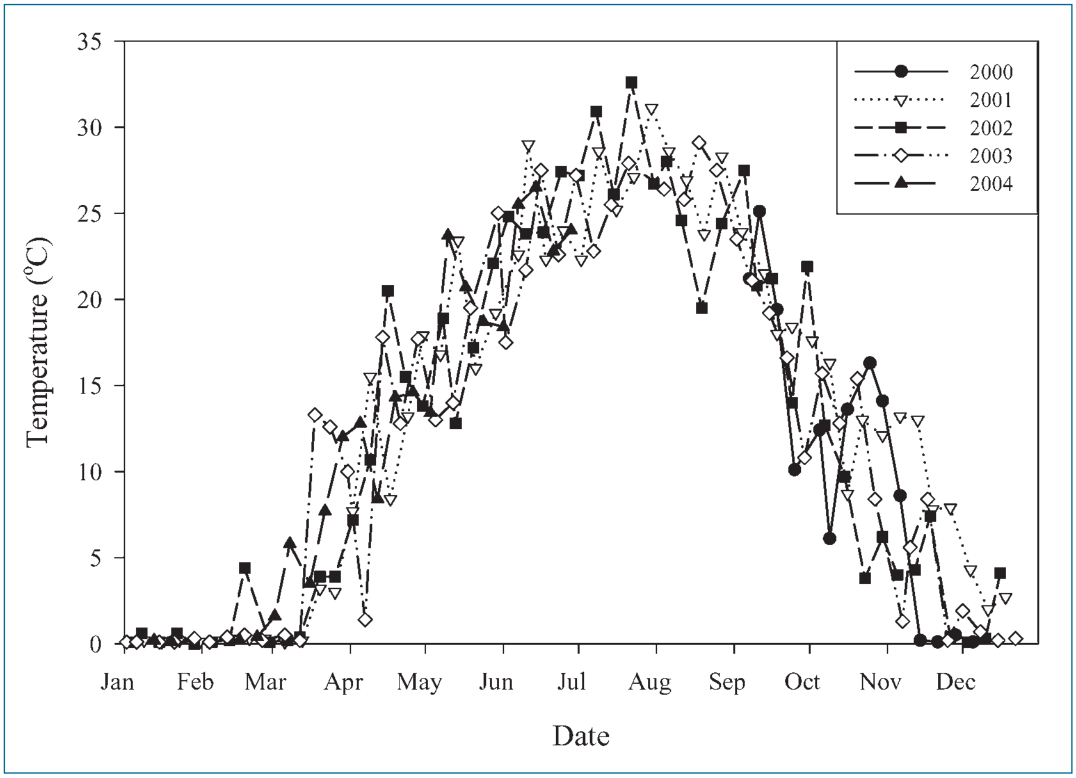


Figure 3.1. Platte River at Leshara average water temperature, September 2000 to June 2004.

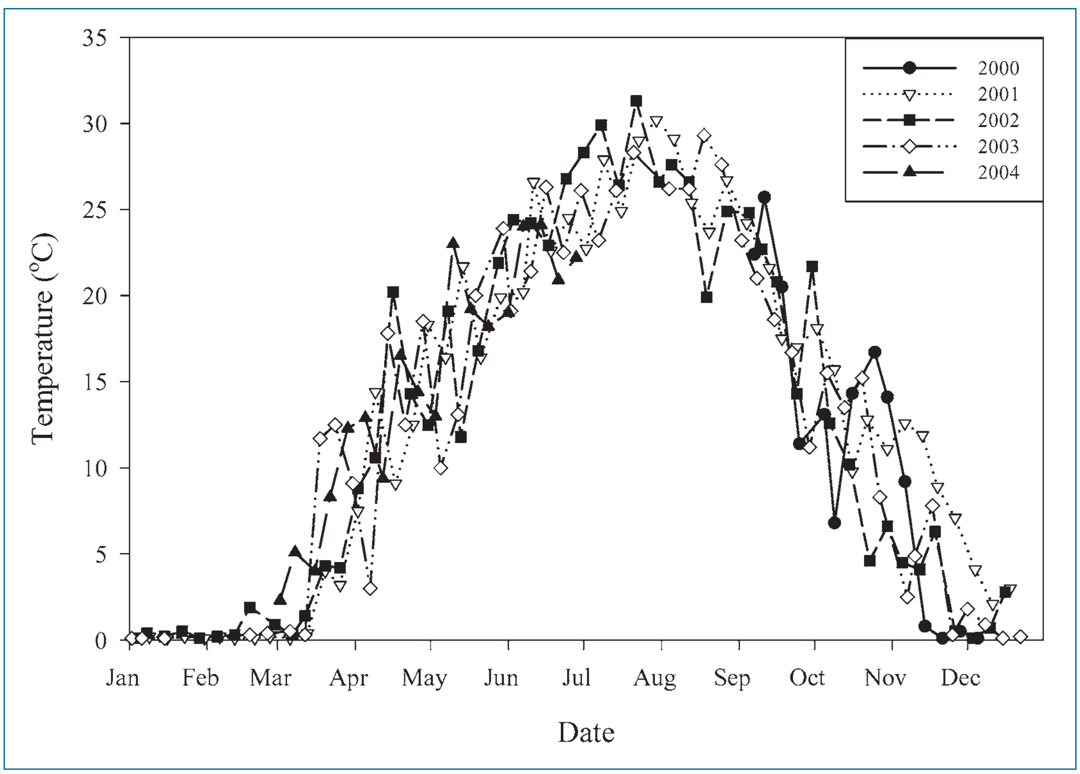


Figure 3.2. Elkhorn River at Waterloo average water temperature, September 2000 to June 2004.

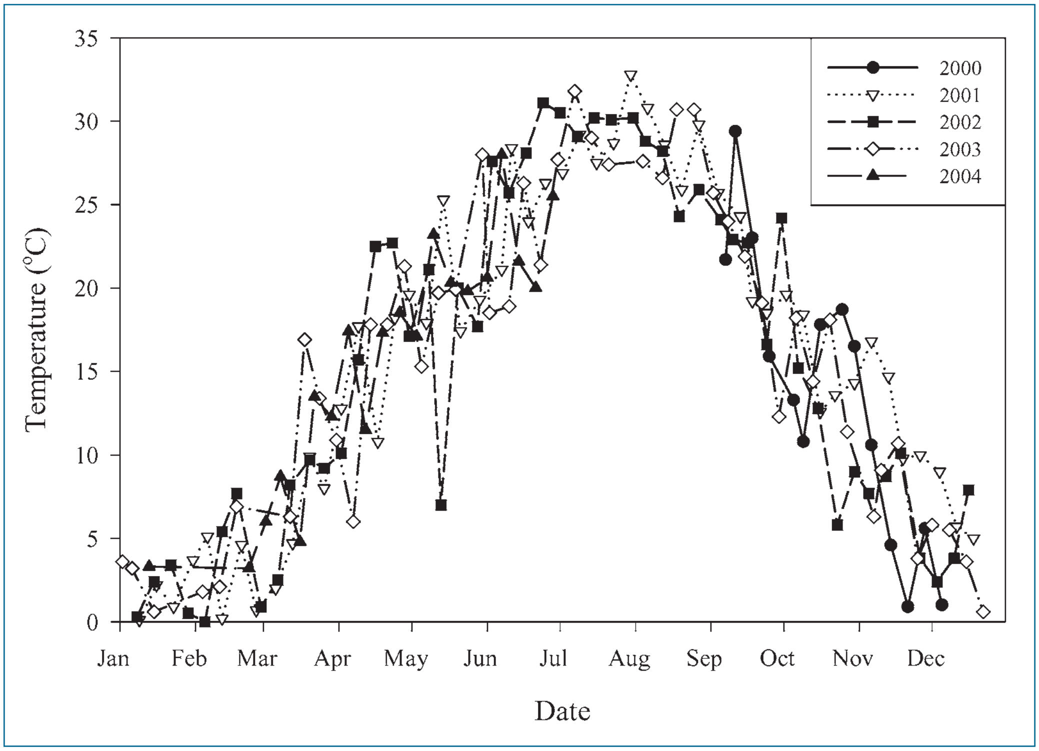


Figure 3.3. Salt Creek at Greenwood average water temperature, September 2000 to June 2004.

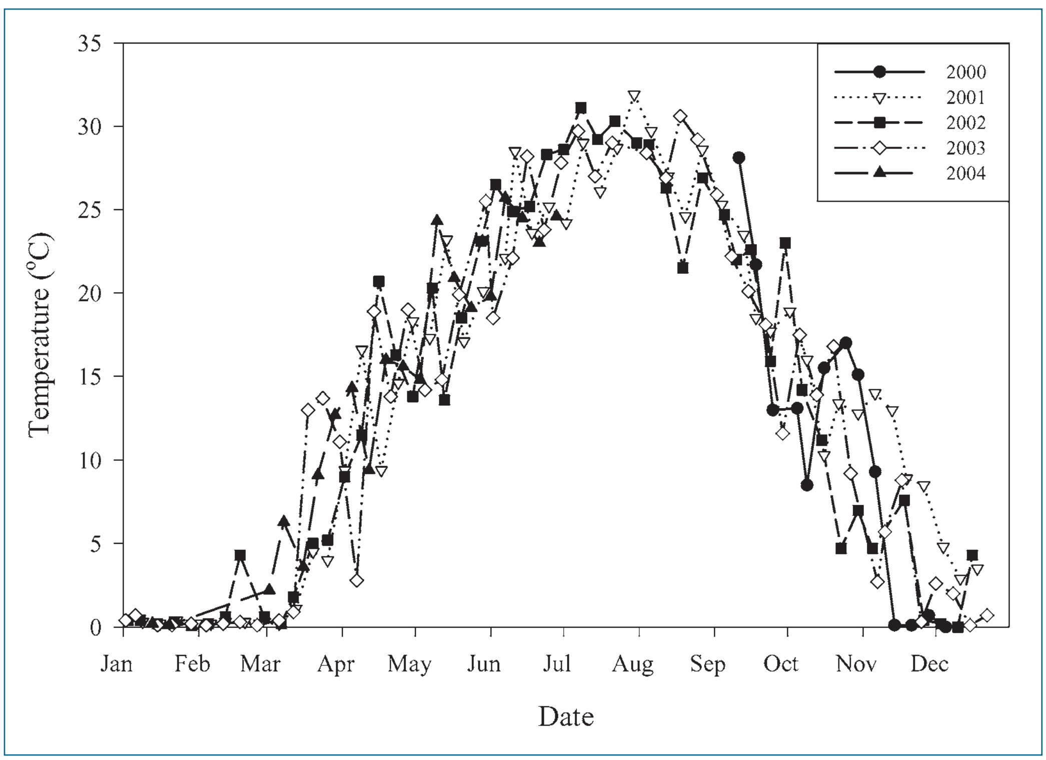


Figure 3.4. Platte River at Louisville average water temperature, September 2000 to June 2004.

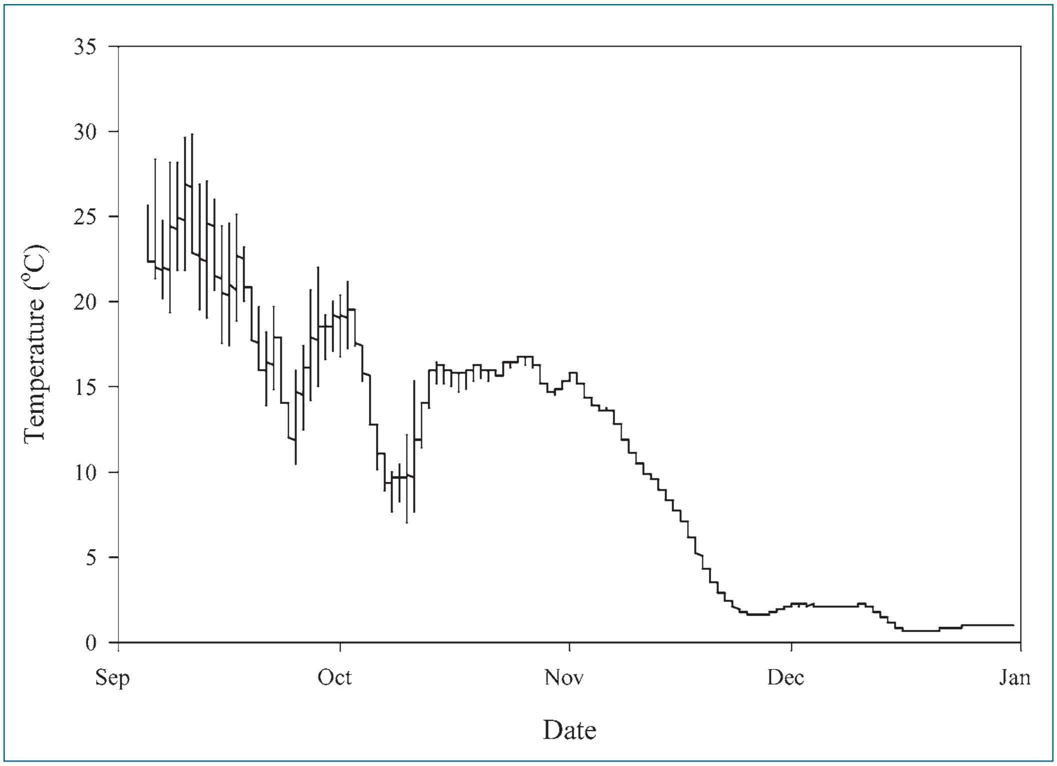


Figure 3.5. Platte River temperature probe data from September 5, 2000 to December 31, 2000 at Louisville, Nebraska.

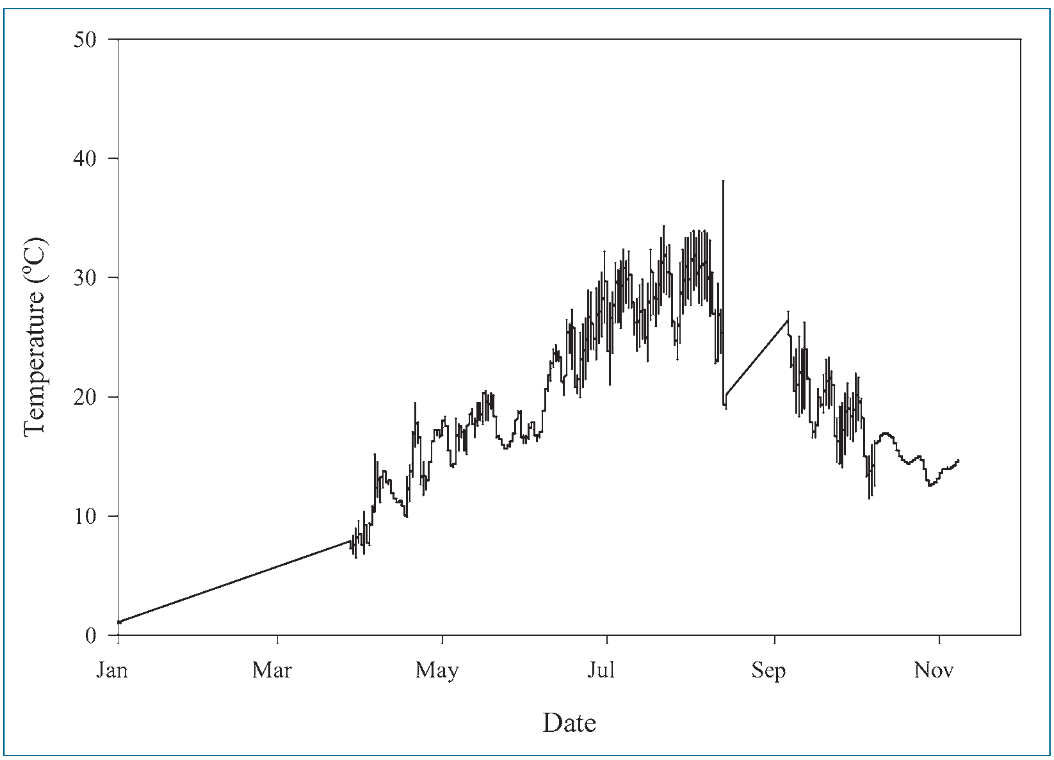


Figure 3.6. Platte River temperature probe data from January1, 2001 to November 8, 2001 at Louisville, Nebraska.

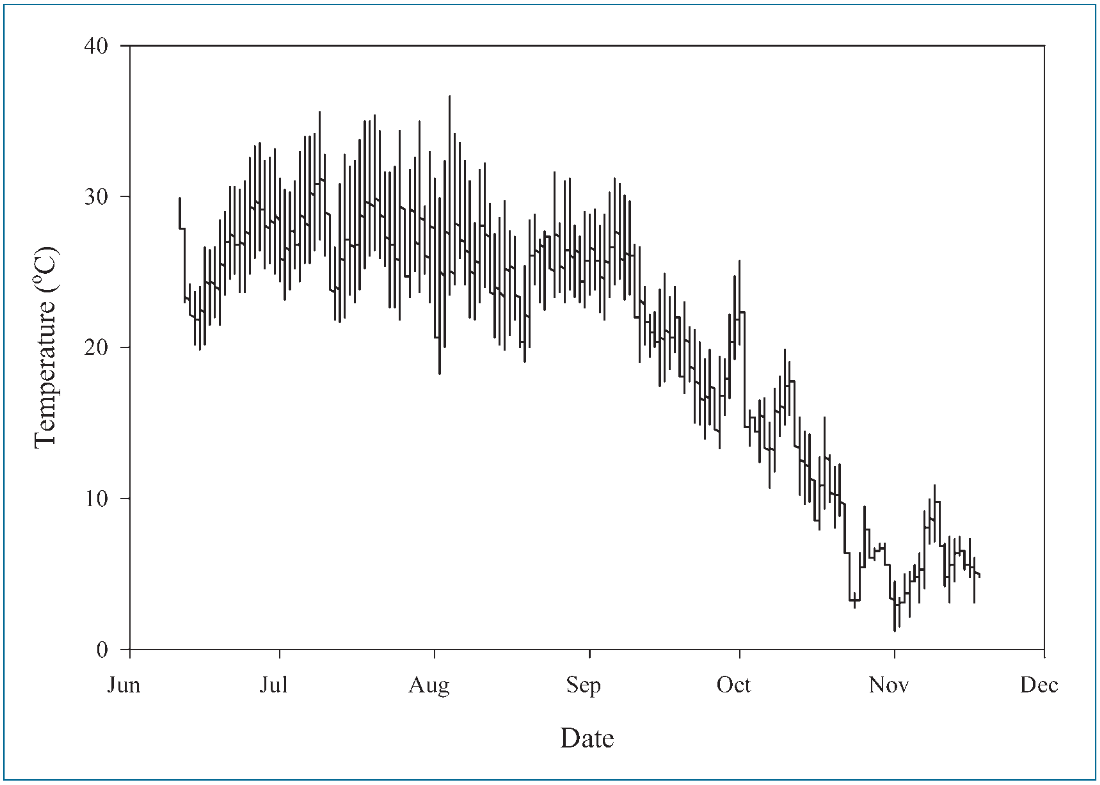


Figure 3.7. Platte River temperature probe data from June 11, 2002 to November 18, 2002 at Louisville, Nebraska.

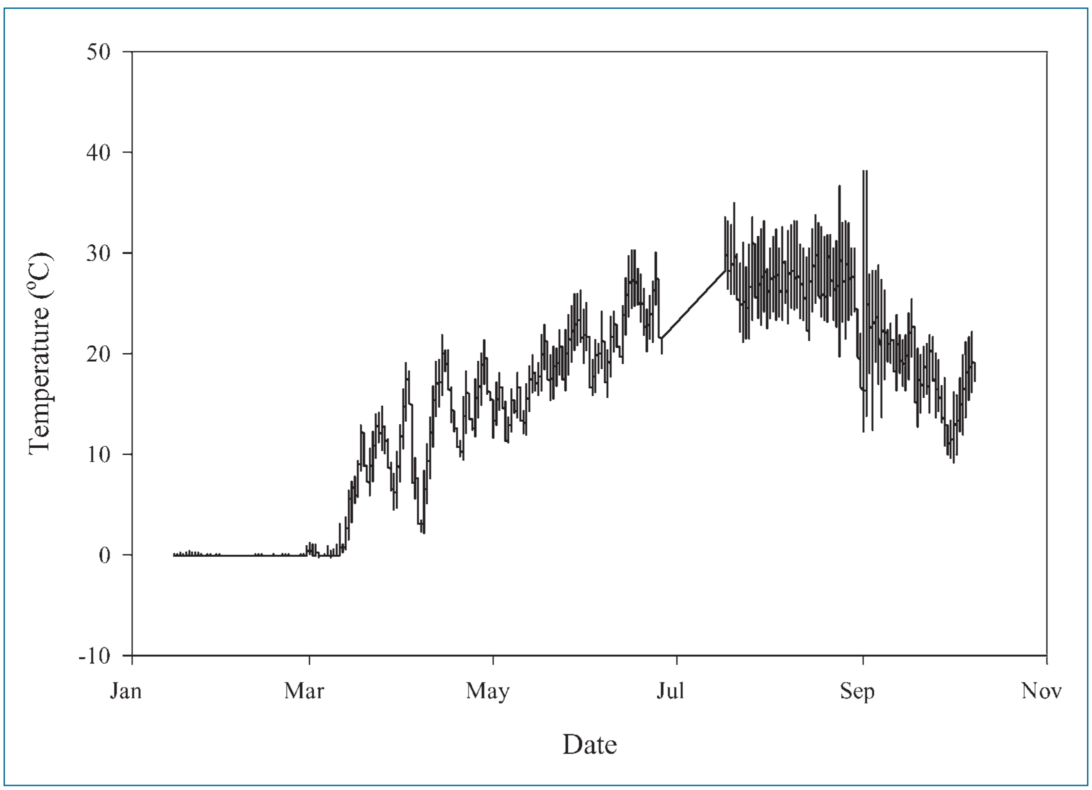


Figure 3.8. Platte River temperature probe data from January 15, 2003 to October 8, 2003 at Louisville, Nebraska.

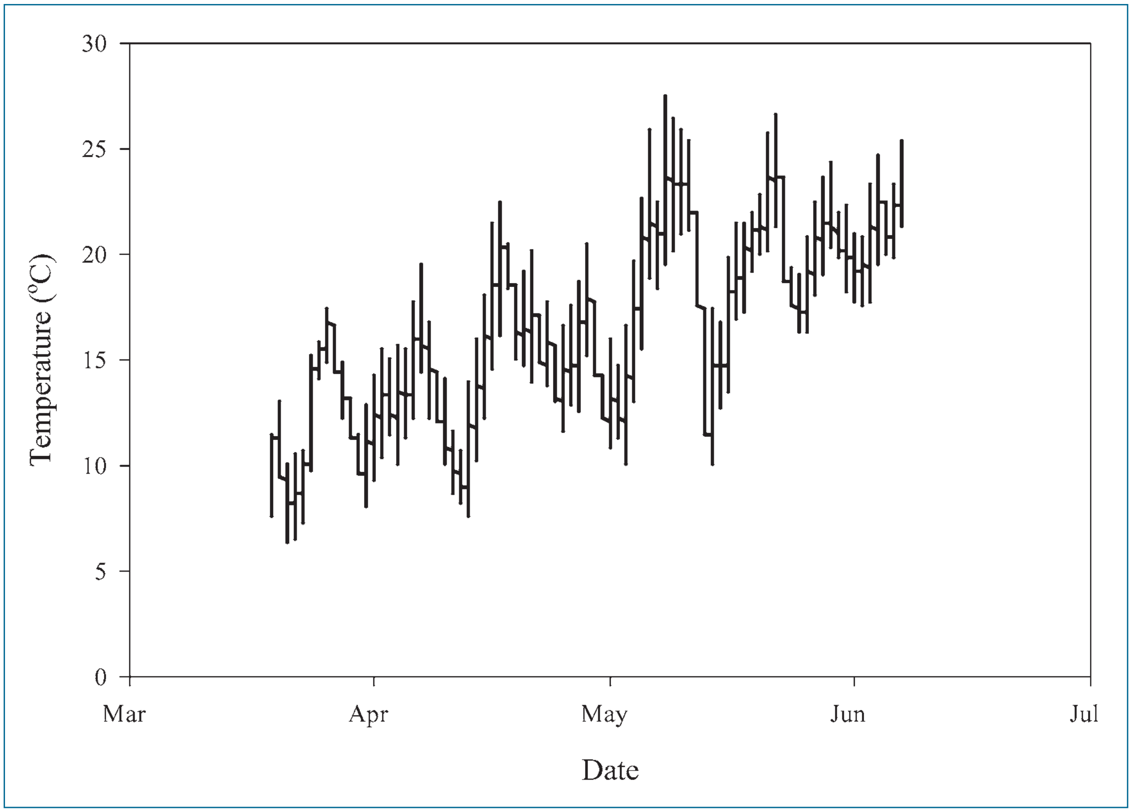


Figure 3.9. Platte River temperature probe data from March 19, 2004 to June 7, 2004 at Louisville, Nebraska.

Dissolved Oxygen:

Average weekly dissolved oxygen values for the Platte River at Leshara, the Elkhorn River at Waterloo, Salt Creek at Greenwood, and the Platte River at Louisville for the time period September 2000 through June 2004 are displayed on Figures 3.10, 3.11, 3.12 and 3.13, respectively. Dissolved oxygen concentrations do not appear to be a limiting factor in the Platte River proper, since no concentrations below 5 mg/L were measured and this is the generally recognized lower limit for aquatic life (Boyd 1979). However, the Elkhorn site had concentrations below 5 mg/L during May and July 2003 and May 2004. The Salt Creek site had the most severe dissolved oxygen conditions with concentrations below 5 mg/L in November 2000, July and August 2002, June 2003 and May 2004.

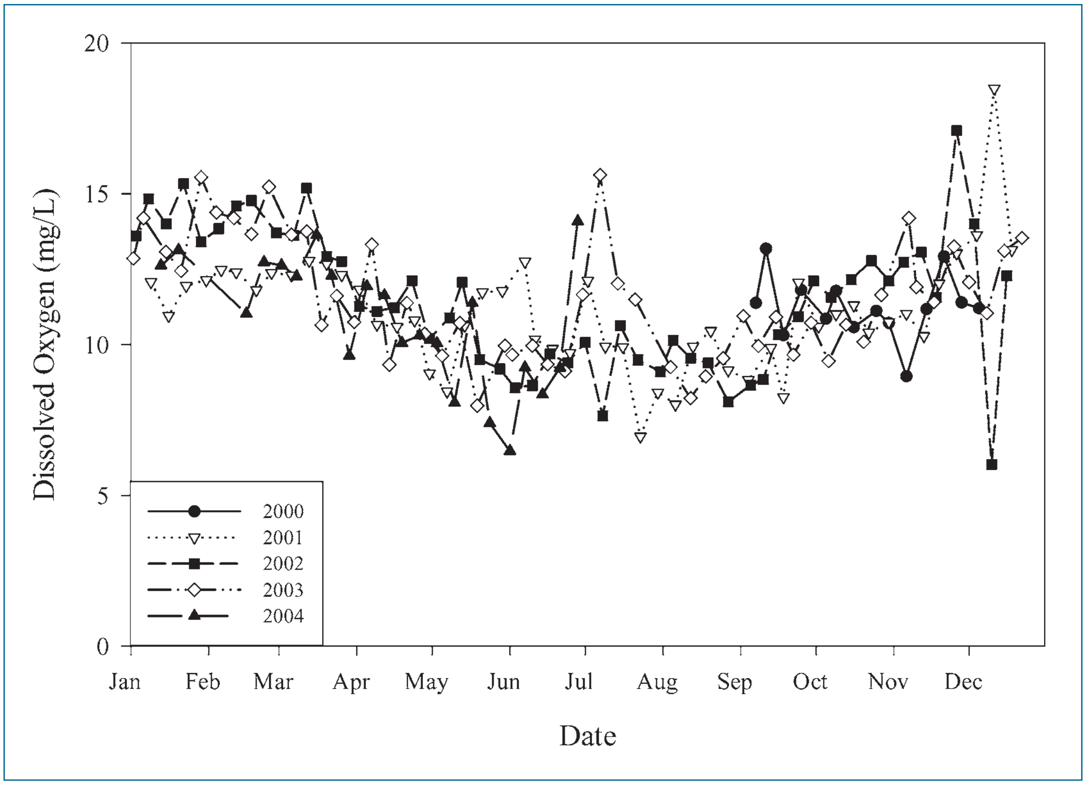


Figure 3.10. Platte River at Leshara average dissolved oxygen, September 2000 to June 2004.

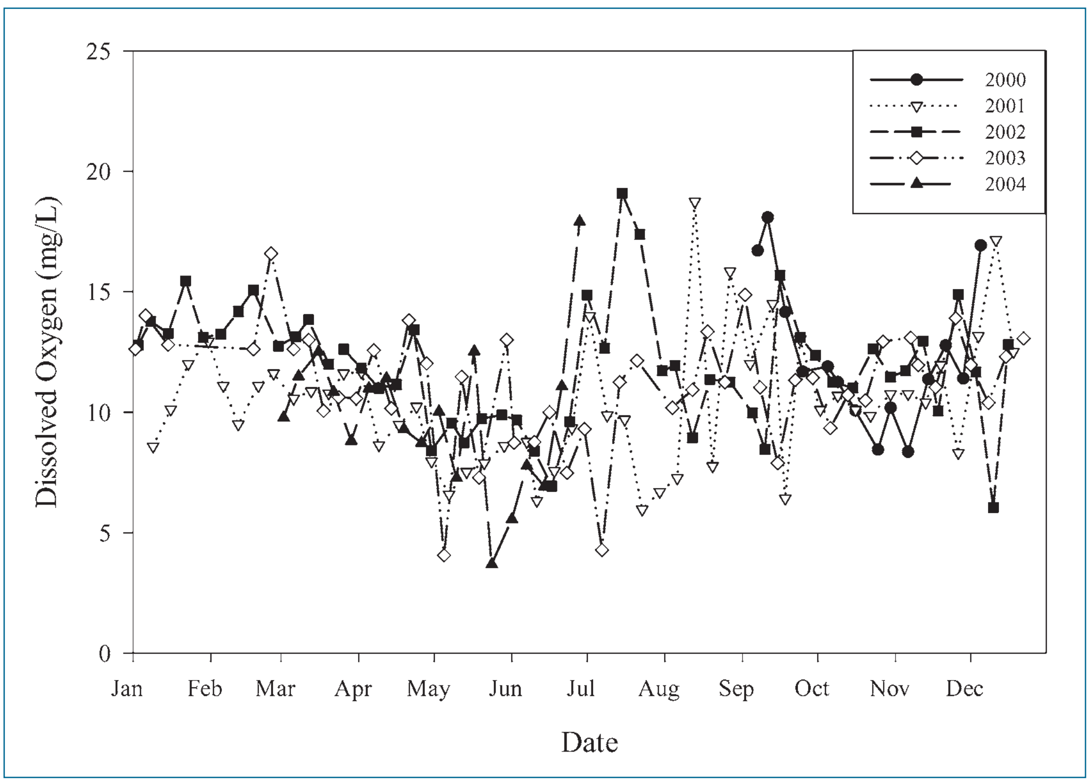


Figure 3.11. Elkhorn River at Waterloo average dissolved oxygen, September 2000 to June 2004.

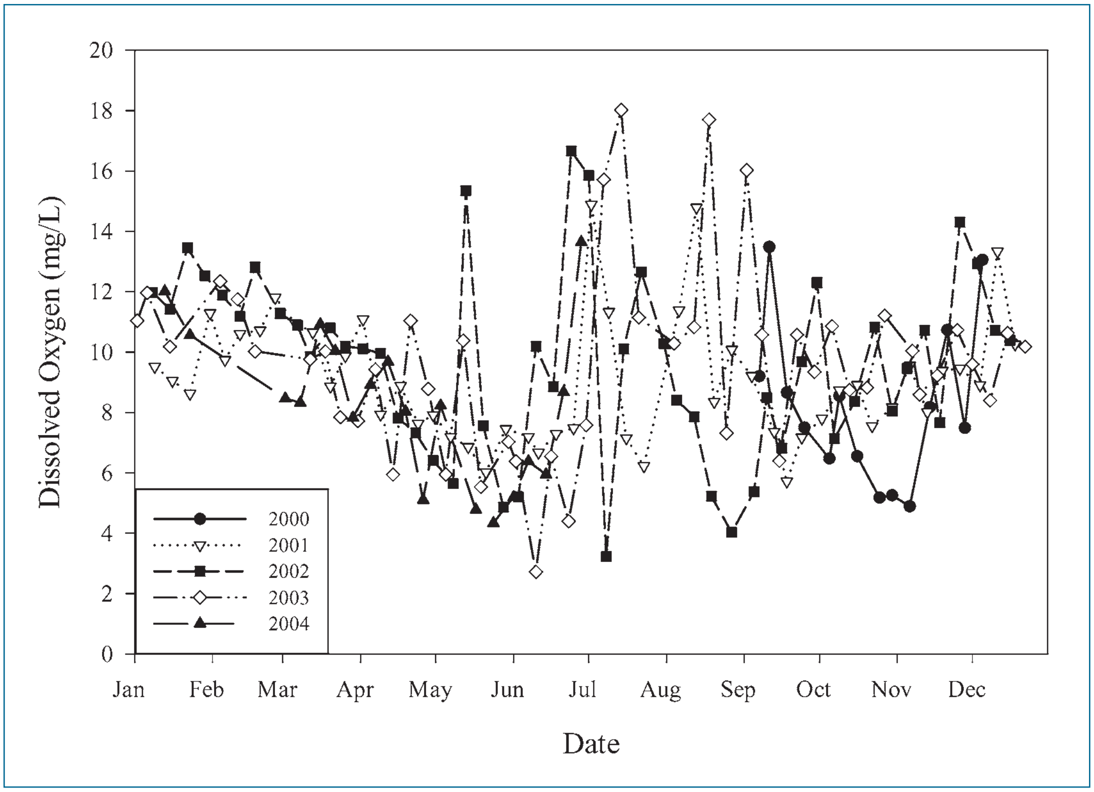


Figure 3.12. Salt Creek at Greenwood average dissolved oxygen, September 2000 to June 2004.

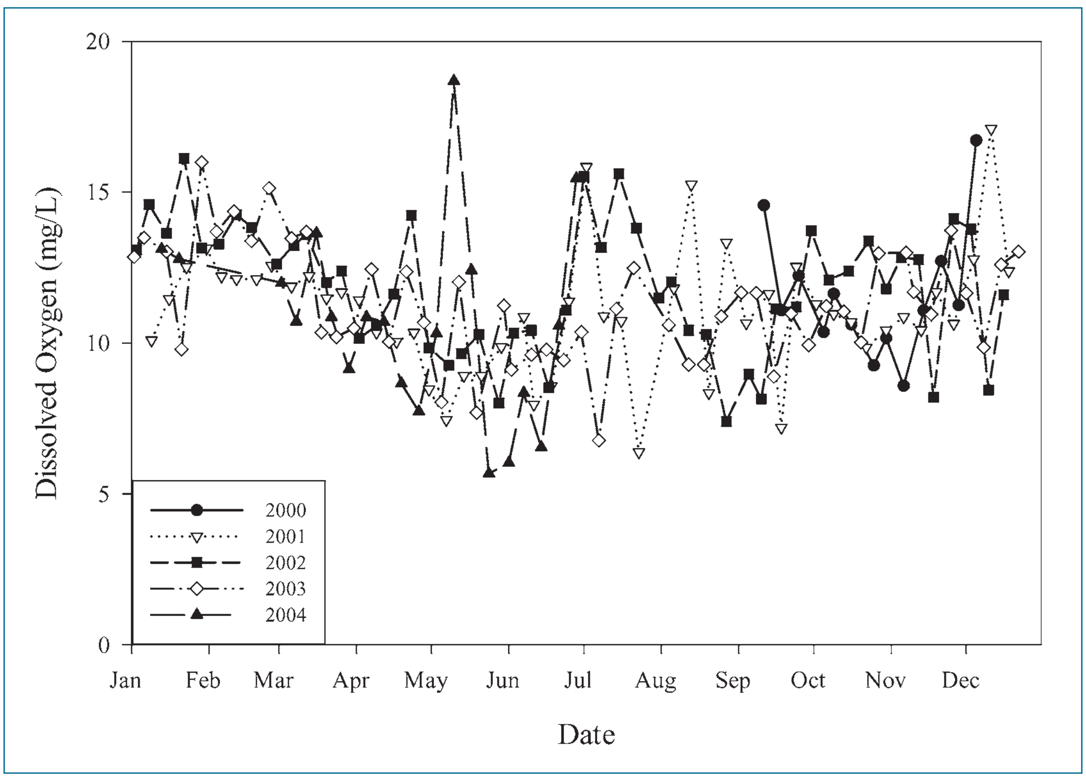


Figure 3.13. Platte River at Louisville average dissolved oxygen, September 2000 to June 2004.

Specific Conductivity:

Average weekly specific conductivity values for the Platte River at Leshara, the Elkhorn River at Waterloo, Salt Creek at Greenwood, and the Platte River at Louisville for September 2000 through June 2004 are displayed on Figures 3.14, 3.15, 3.16 and 3.17, respectively (note that the scales on the Y-axes vary at each site). Conductivity values rarely exceeded 600µS/cm at the Leshara site on the Platte River and 700µS/cm at the Elkhorn River site. In contrast, the Salt Creek site seldom had conductivity values less than 1,000 µS/cm. Since the Louisville site is downstream from the confluence of the Platte River with Salt Creek, conductivity values there reflect the mixing of the lower conductivity and higher conductivity water sources. The conductivity readings at the Leshara site (Fig. 3.14) averaged the lowest of all the sites monitored and were least influenced by changes in discharge. At the Elkhorn site (Fig. 3.15) the lowest conductivity readings coincided with high discharge events during the months of May through August (Fig. 1.3). The lowest conductivity readings at the Greenwood site on Salt Creek (Fig. 3.16) coincided with high discharge events during the period from May through June (Fig. 1.4), but other changes in conductivity seemed unrelated to discharge. Conductivity readings at the Louisville site (Fig. 3.17) were highest during the July through September period when discharge was lowest (Fig 1.5).

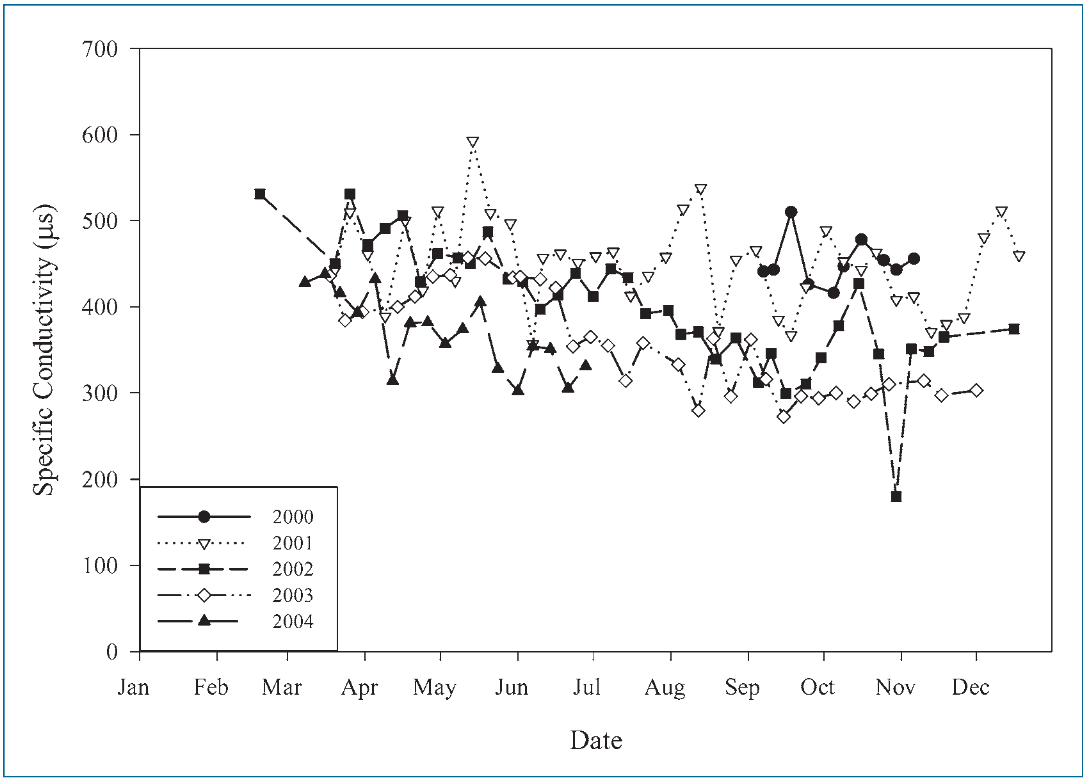


Figure 3.14. Platte River at Leshara average specific conductivity, September 2000 to June 2004.

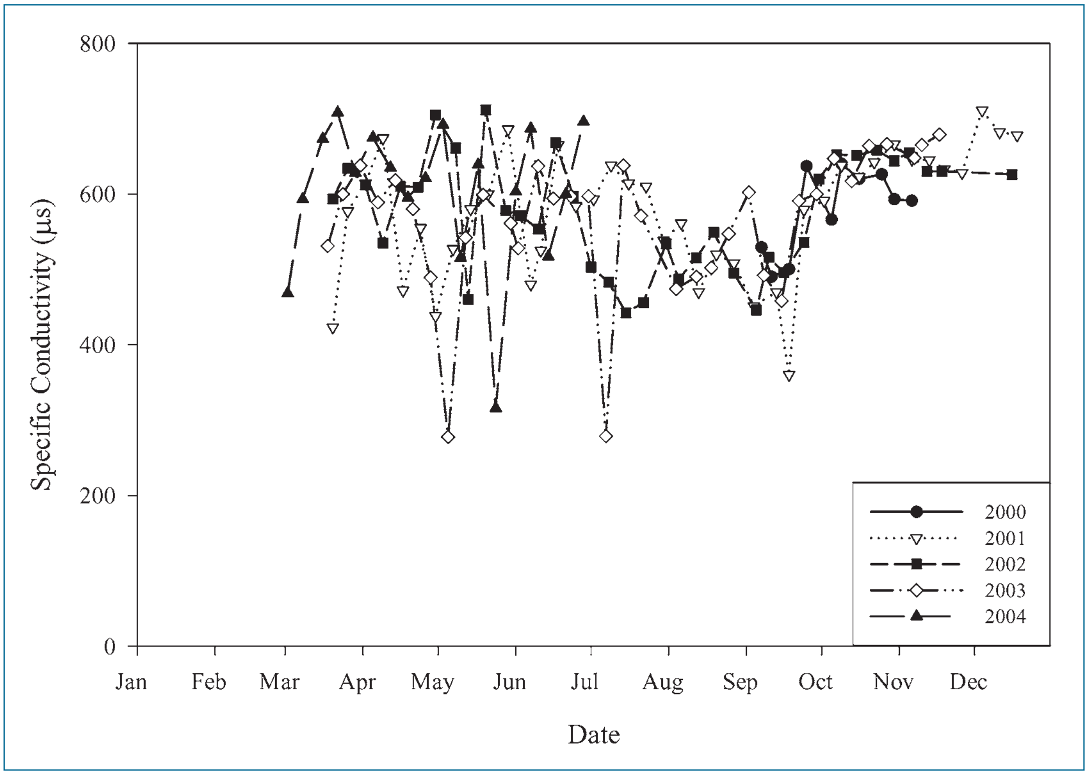


Figure 3.15. Elkhorn River at Waterloo average specific conductivity, September 2000 to June 2004.

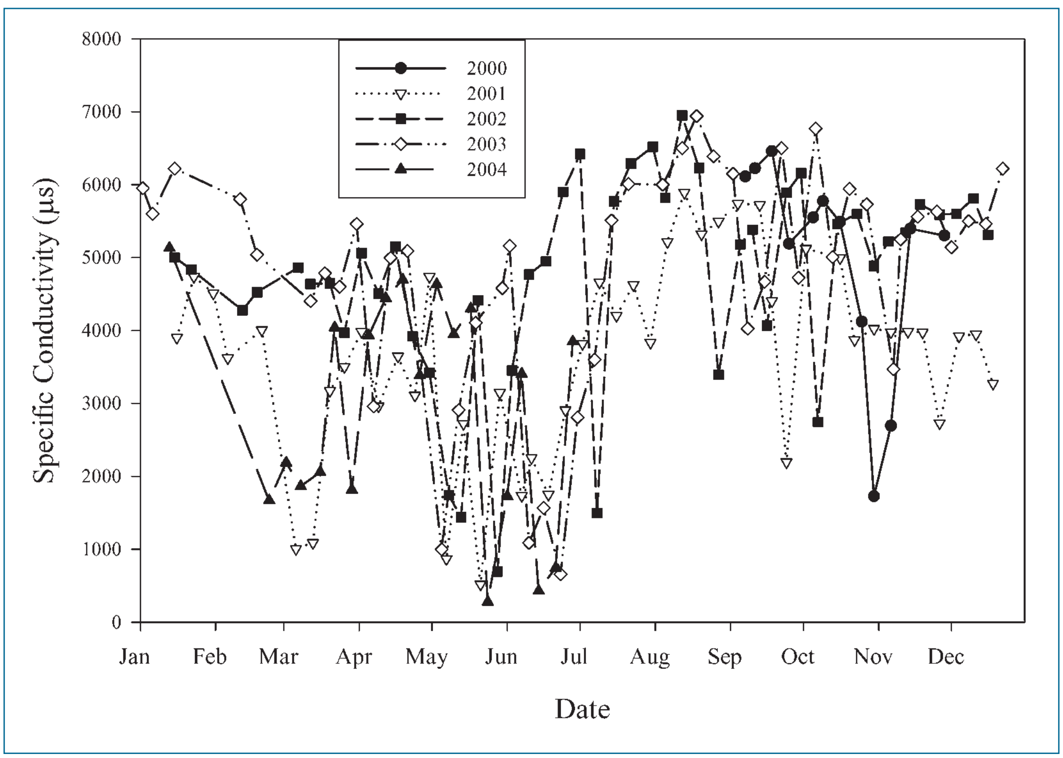


Figure 3.16. Salt Creek at Greenwood average specific conductivity, September 2000 to June 2004.

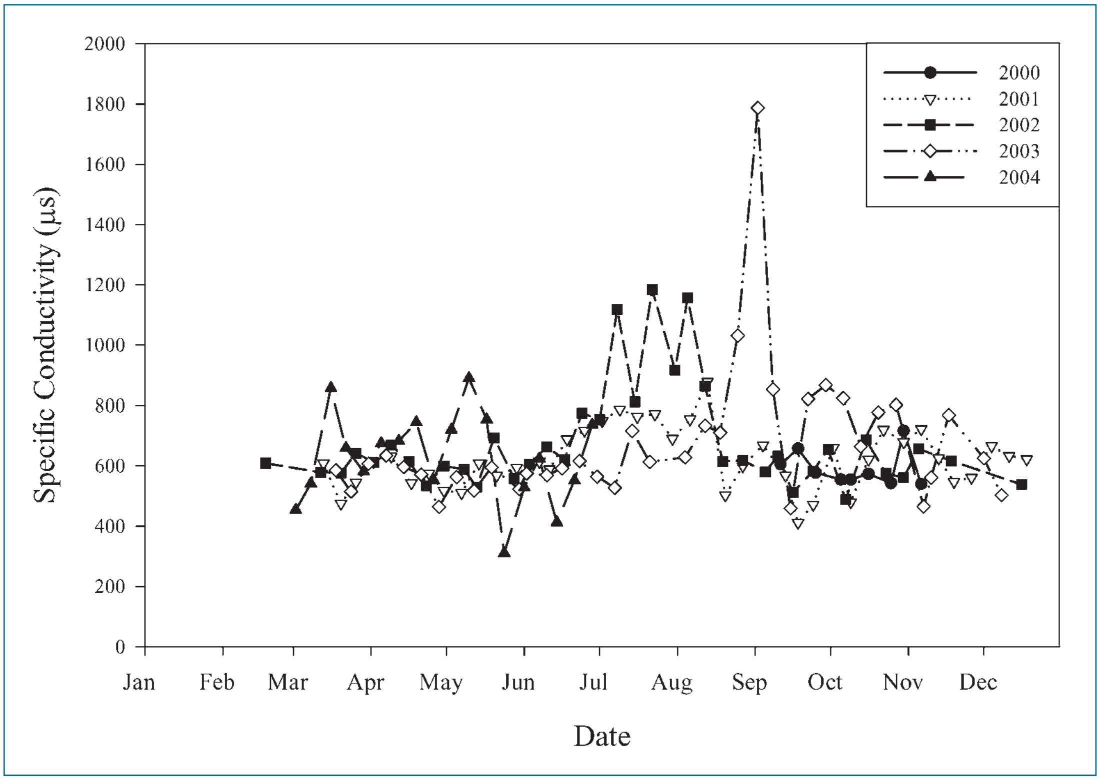


Figure 3.17. Platte River at Louisville average specific conductivity, September 2000 to June 2004.

Salinity:

Average weekly salinity values for the Platte River at Leshara, the Elkhorn River at Waterloo, Salt Creek at Greenwood, and the Platte River at Louisville for September 2000 through June 2004 are displayed on Figures 3.18, 3.19, 3.20 and 3.21, respectively (note that the scales on the Y-axes vary at each site). As expected, salinity values for the Leshara site on the Platte River were the lowest, ranging from 0.1 ppt up to 0.3 ppt with the majority of values at 0.2 ppt. The Elkhorn River site salinity ranged from 0.1 ppt to 0.4 ppt with most values at 0.3 ppt. Salinities in Salt Creek were the highest and most variable with most values above 2.0 ppt and some up to nearly 4.00 ppt. The influence of Salt Creek can be seen at the Louisville site on the Platte River where most salinity values ranged from 0.2 to 0.4 ppt, with some spikes at or above 0.6 ppt. The range in salinity readings at all sites, except the Greenwood site did not provide much insight to habitat conditions. The lowest salinity values at the Greenwood site (Fig. 3.20) coincided with highest discharges during the months of May through July (Fig. 1.4). However, the highest salinity reading at the Louisville site (Fig. 3.21) during September 2003 coincided with very low discharge (Fig. 1.5).

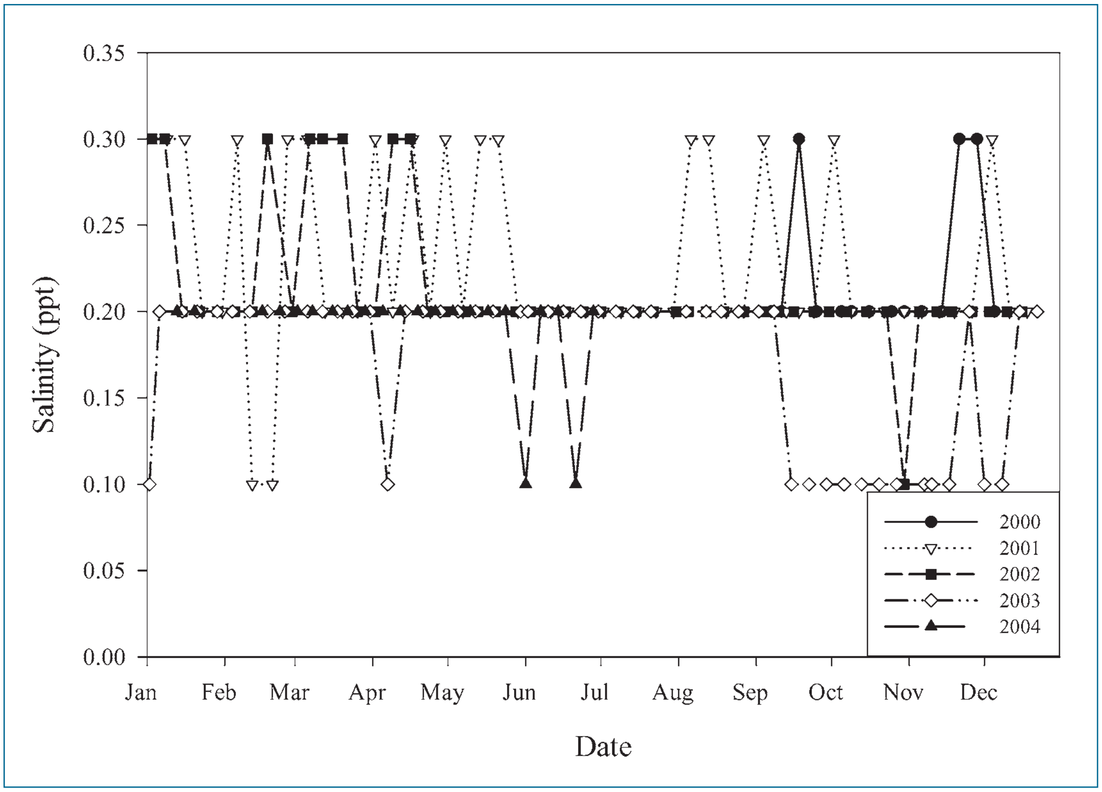


Figure 3.18. Platte River at Leshara average weekly salinity, September 2000 to June 2004.

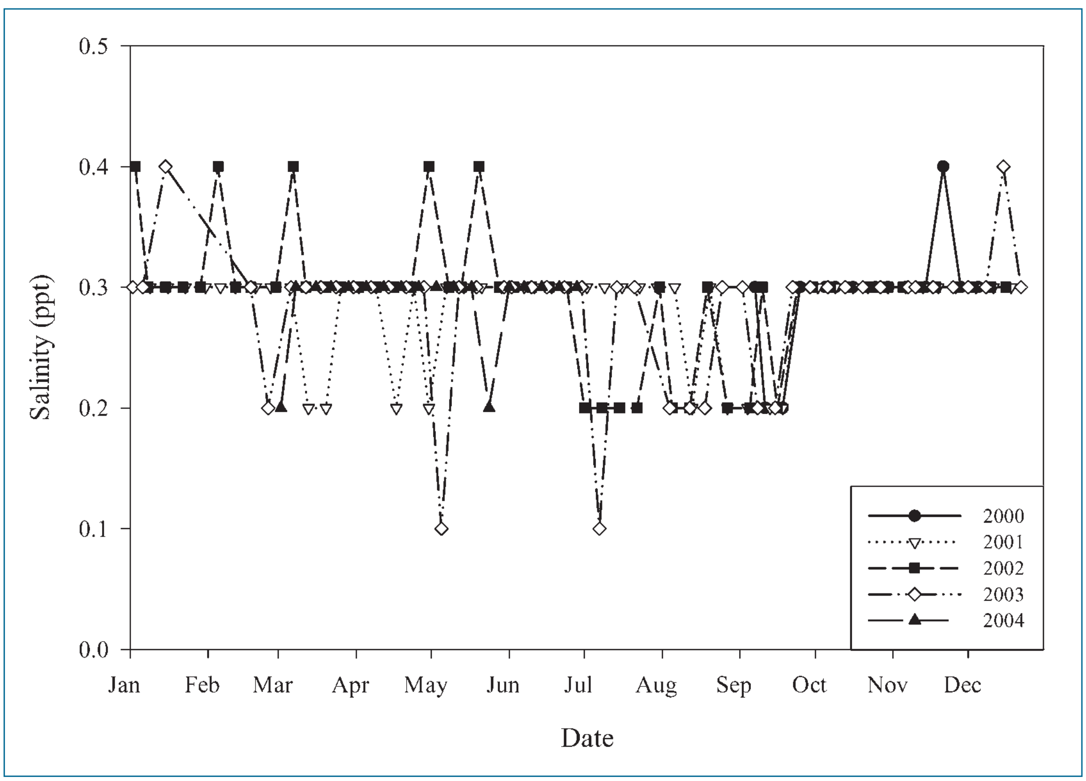


Figure 3.19. Elkhorn River at Waterloo average weekly salinity, September 2000 to June 2004.

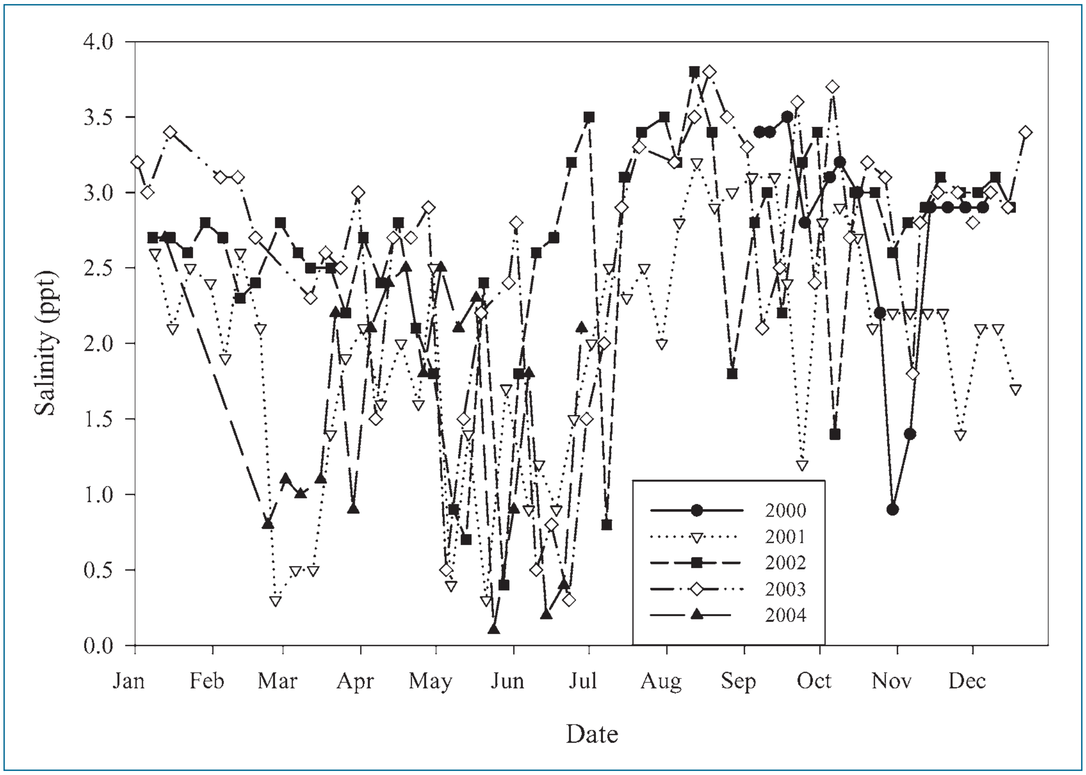


Figure 3.20. Salt Creek at Greenwood average weekly salinity, September 2000 to June 2004.

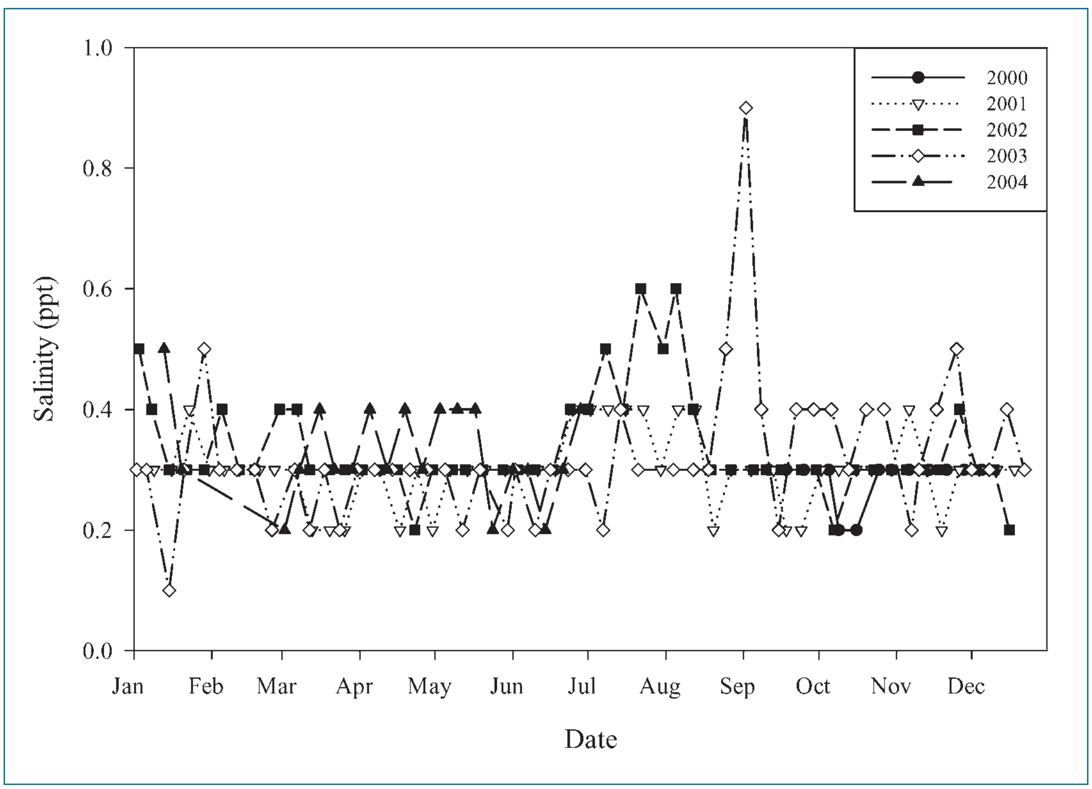


Figure 3.21. Platte River at Louisville average weekly salinity, September 2000 to June 2004.

Suspended solids:

Average weekly suspended solids values for the Platte River at Leshara, the Elkhorn River at Waterloo, Salt Creek at Greenwood, and the Platte River at Louisville for September 2000 through June 2004 are displayed on Figures 3.22, 3.23, 3.24 and 3.25, respectively (note that the scales on the Y-axes vary at each site). Suspended solids loads are related to runoff events upstream from the site at which they are measured because peaks are often related to erosion silt being transported into the river channel. Peaks in suspended solids at the Louisville site (Fig. 3.25) correspond with high discharge events (Fig. 1.5) and reflect the inputs of materials from the three other sampling sites (Figures 3.22 – 3.24), even though all three may not be contributing solids at the same rate. The peak in suspended solids during late June 2004 corresponds to the peak in suspended solids measured at the Leshara site at the same time (Fig. 3.22) combined with inputs from the Elkhorn River (Fig. 3.23) and Salt Creek (Fig. 3.24) at the same time. These readings appear to be consistent with high discharge from all three upstream sites (Figures 1.2, 1.3, 1.4).

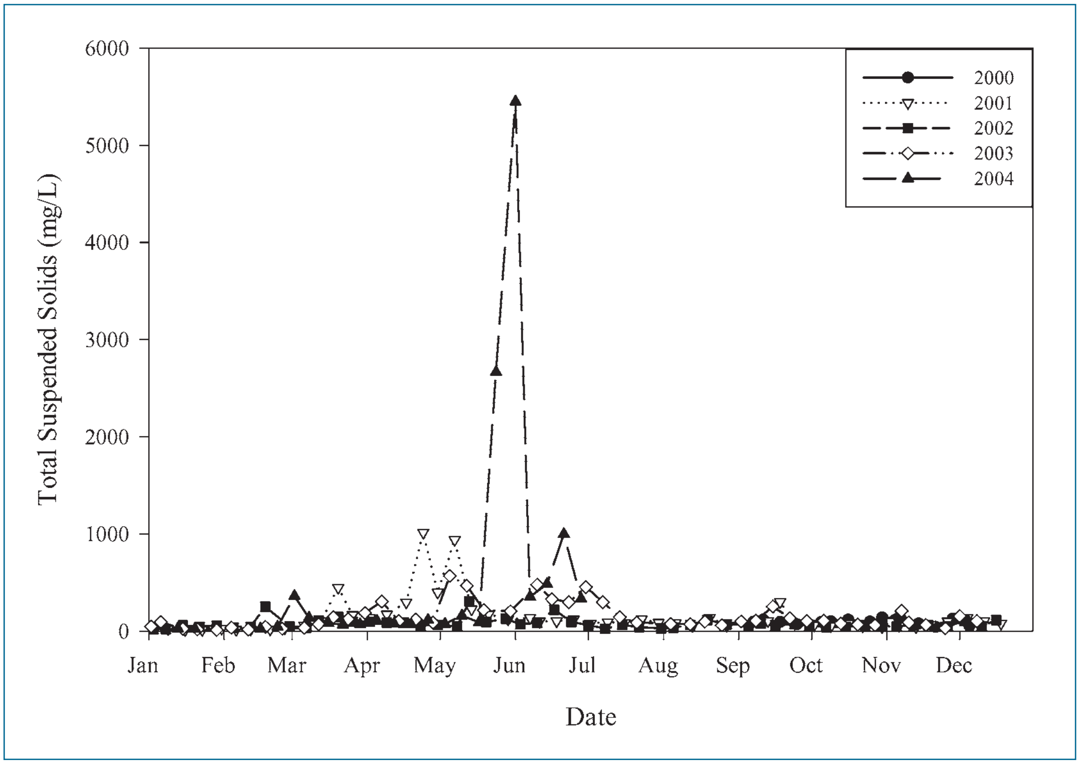


Figure 3.22. Platte River at Leshara average weekly total suspended solids, September 2000 to June 2004.

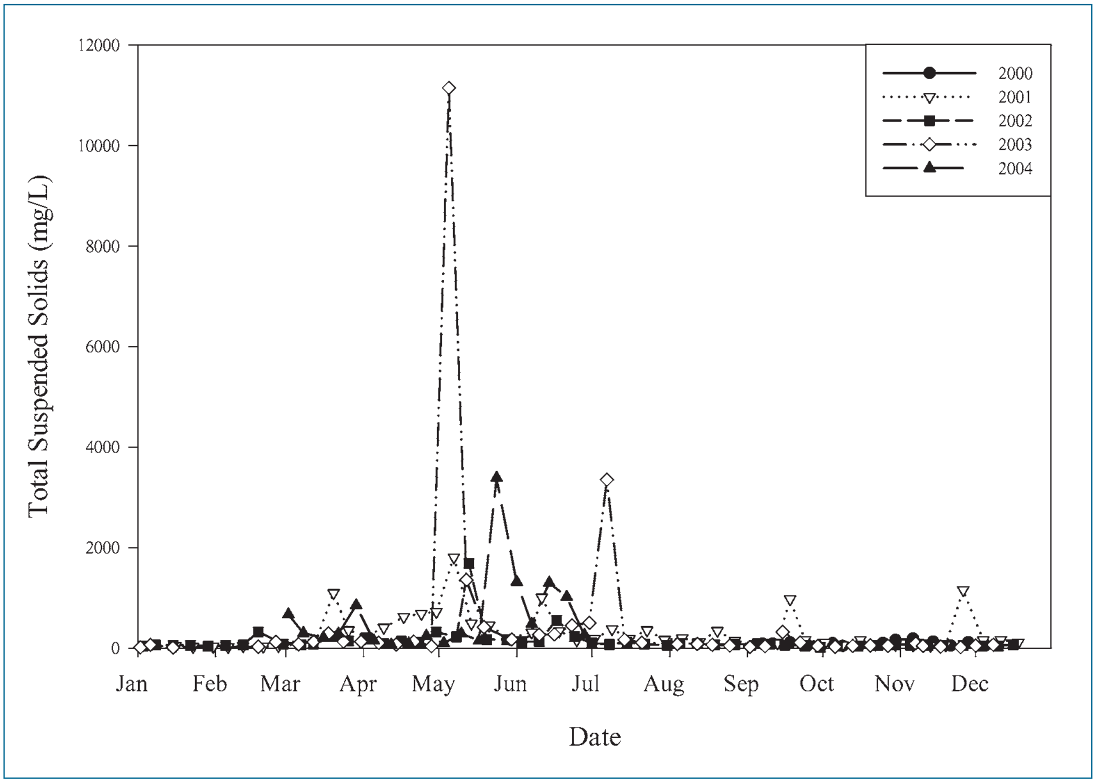


Figure 3.23. Elkhorn River at Waterloo average weekly total suspended solids, September 2000 to June 2004.

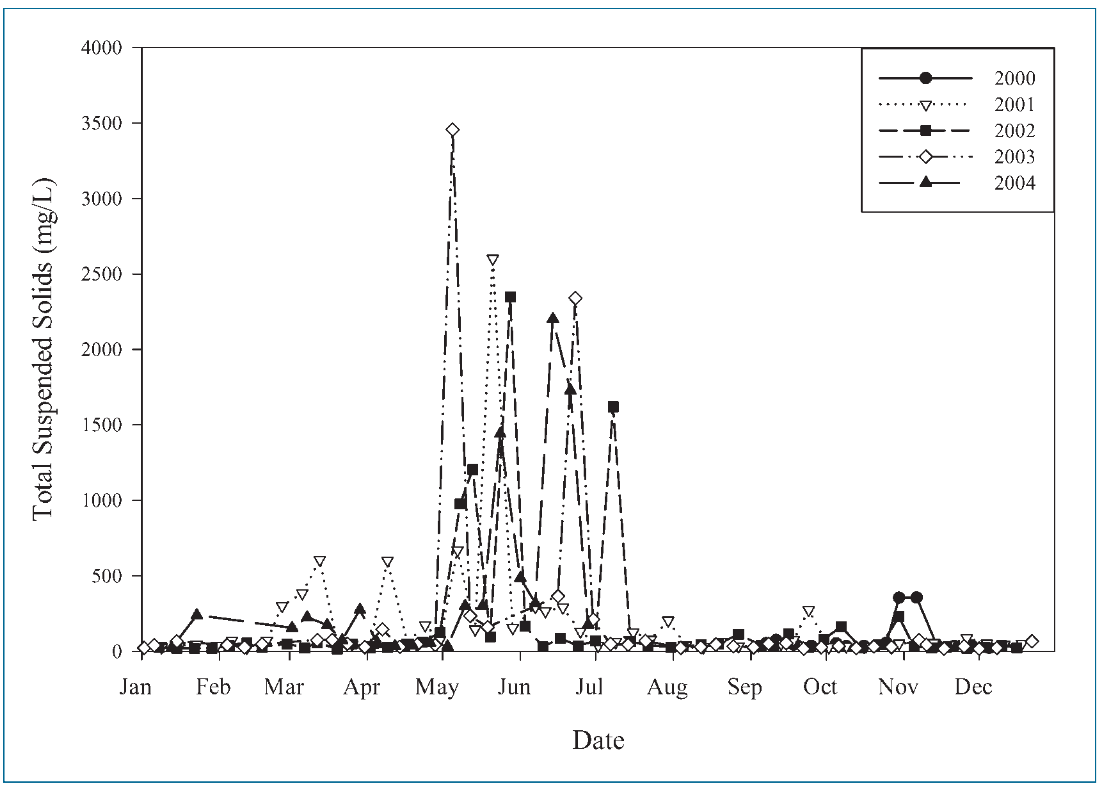


Figure 3.24. Salt Creek at Greenwood average weekly total suspended solids, September 2000 to June 2004.

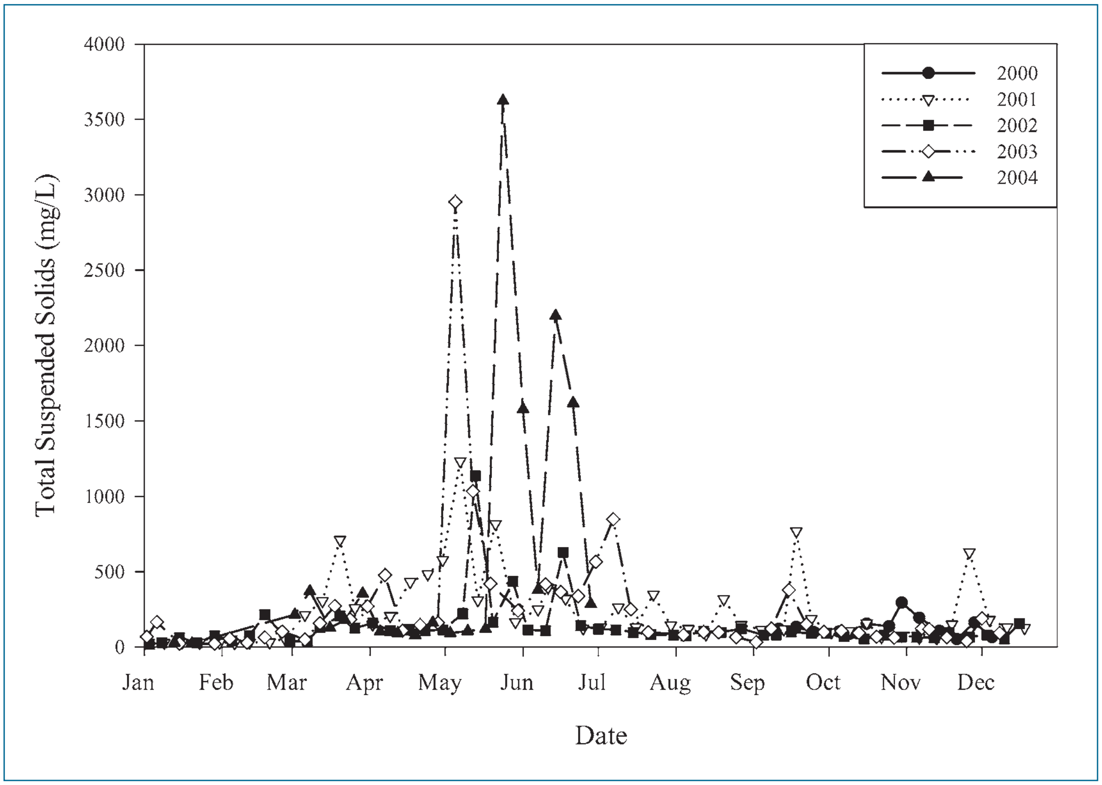


Figure 3.25. Platte River at Louisville average weekly total suspended solids, September 2000 to June 2004.

Turbidity:

Average weekly turbidity values (NTU) for the Platte River at Leshara, the Elkhorn River at Waterloo, Salt Creek at Greenwood, and the Platte River at Louisville for July 2001 through June 2004 are displayed on Figures 3.26, 3.27, 3.28 and 3.29, respectively (note that the scales on the Y-axes vary at each site). Turbidity values follow the suspended solids loads measured at each of the sites. Similarly, the peaks in turbidity coincide with peaks in discharge as discussed in the suspended solids section.

Lower Platte River exposed sandbars and a shallow sandbar complex habitat (foreground) with open water habitat surrounding it.

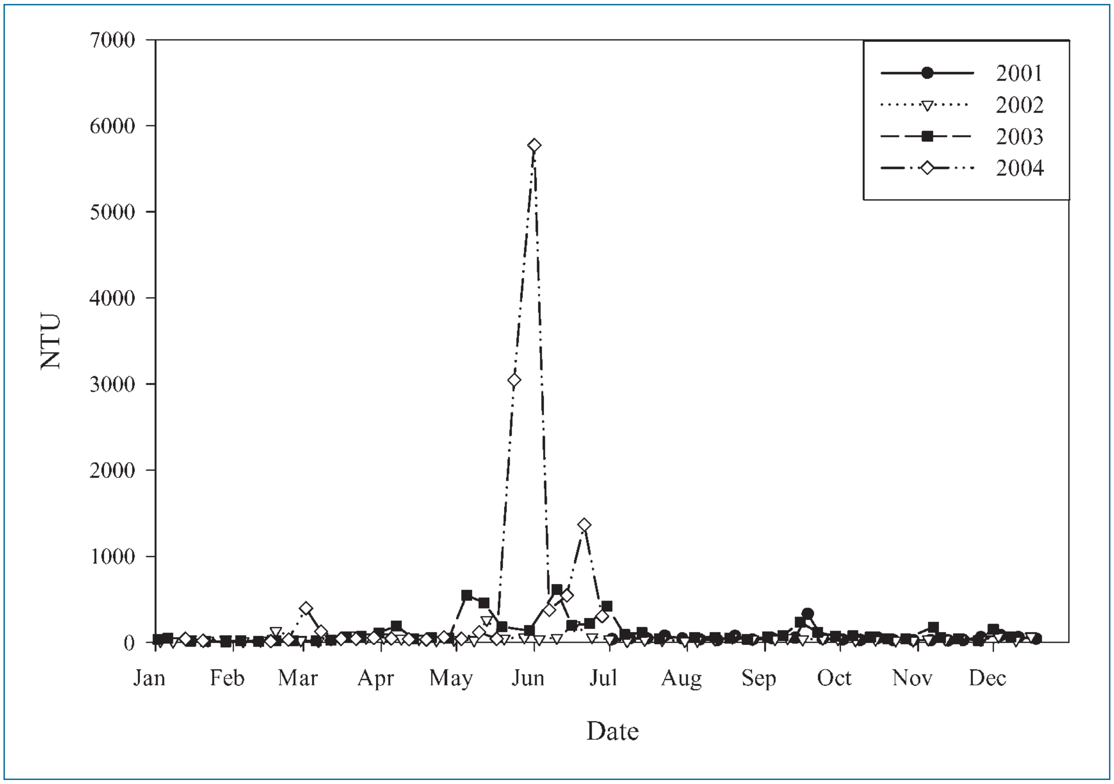


Figure 3.26. Platte River at Leshara average weekly NTU, September 2000 to June 2004.

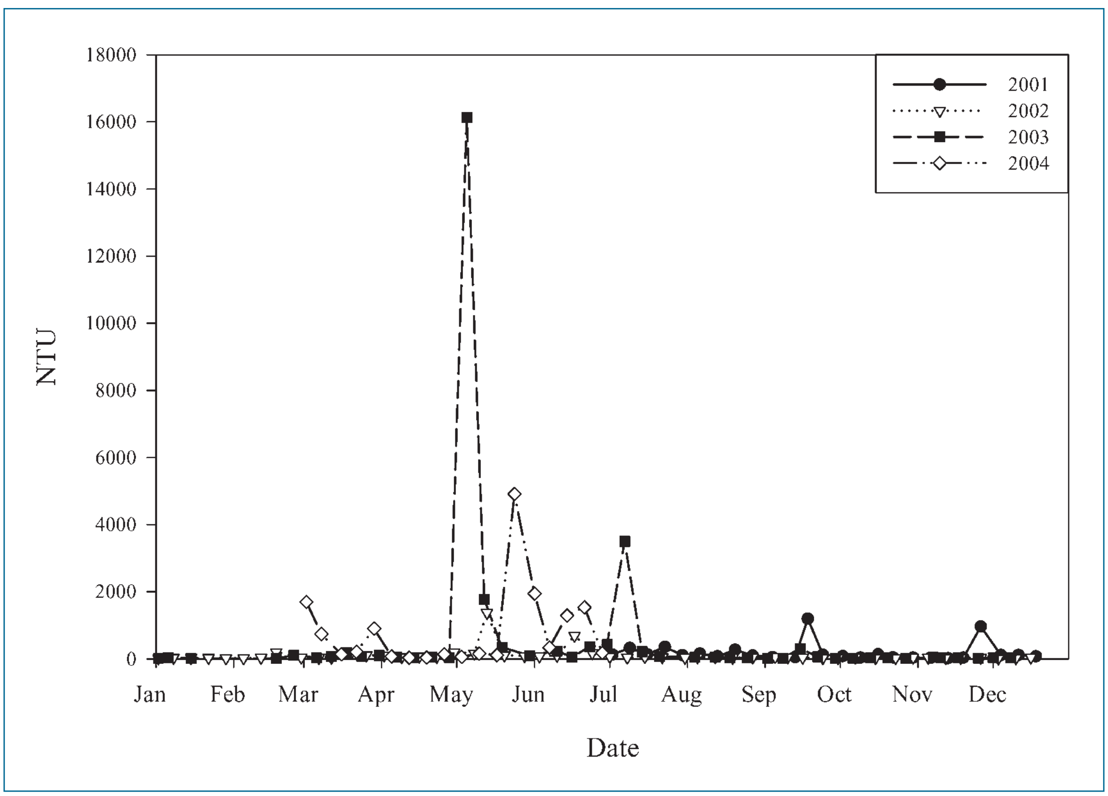


Figure 3.27. Elkhorn River at Waterloo average weekly NTU, September 2000 to June 2004.

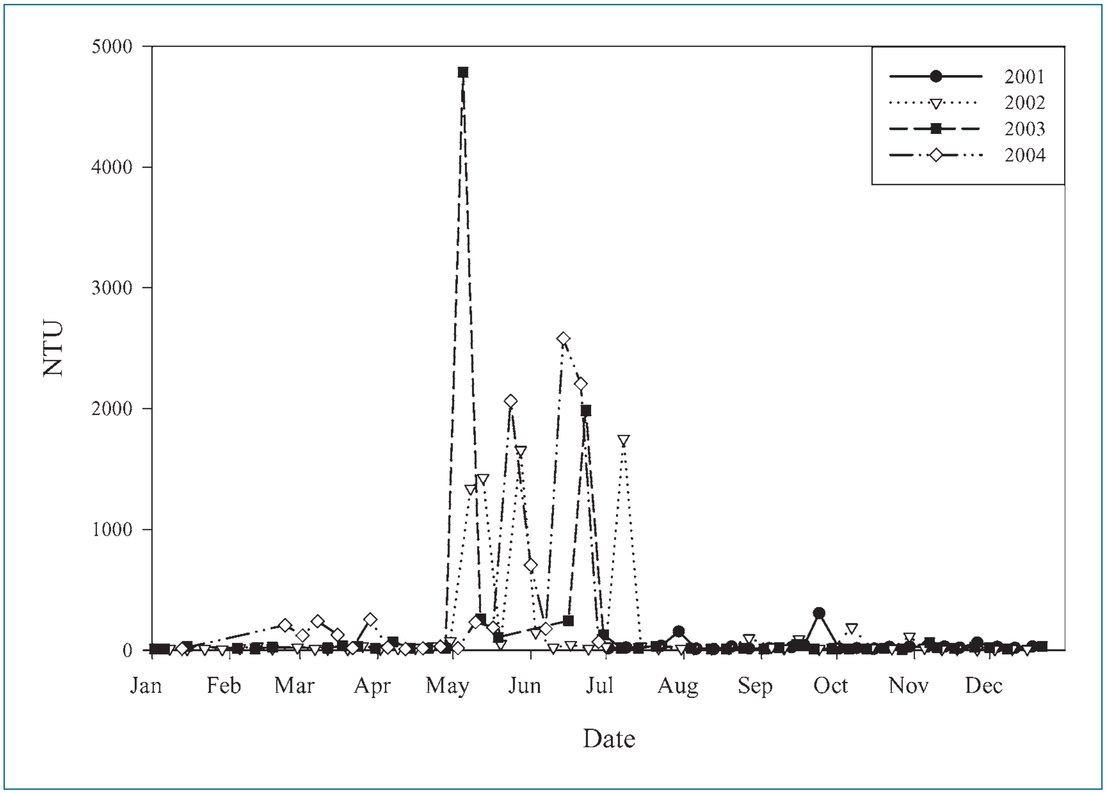


Figure 3.28. Salt Creek at Greenwood average weekly NTU, September 2000 to June 2004.

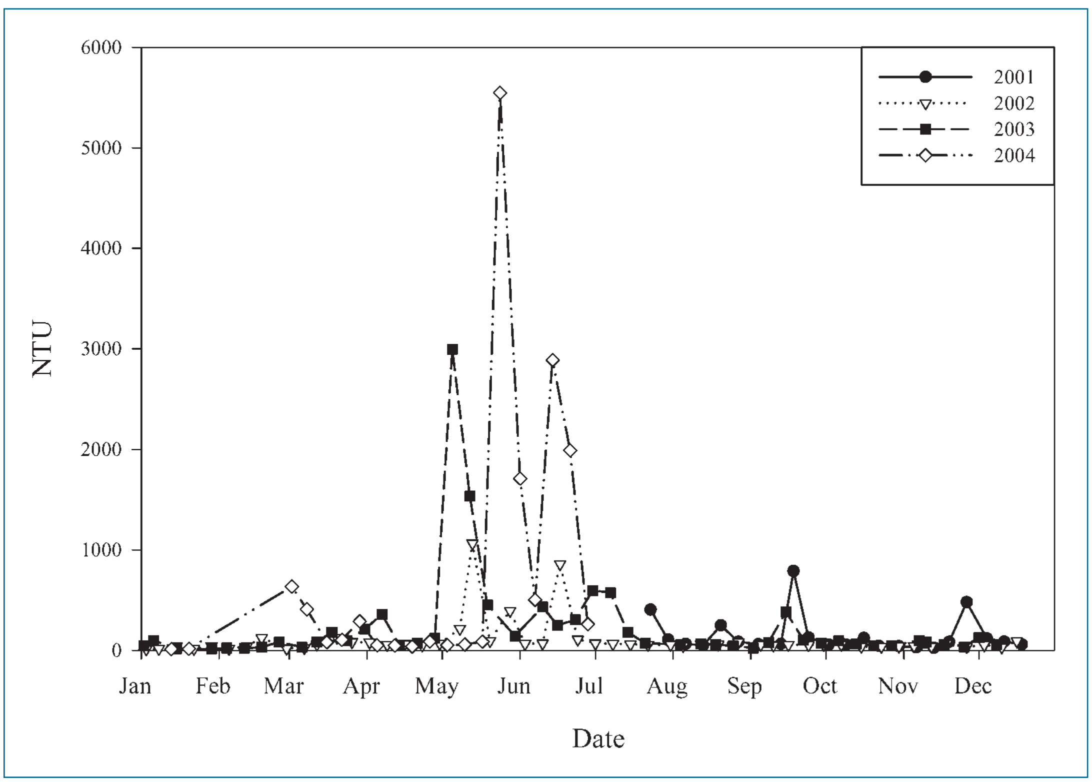


Figure 3.29. Platte River at Louisville average weekly NTU, September 2000 to June 2004.

Substrate:

Table 32 summarizes the substrate composition for all sites. Substrate composition expressed as percent of total sample weight for silt (<230), fine sand (230), sand (60), coarse sand (18) and gravel (10) along transects across the channels for the Platte River near North Bend (Nebraska highway 79), the Platte River at Leshara (Nebraska highway 64), the Elkhorn River at Waterloo, the Platte River near Ashland (US highway 6), Salt Creek at Greenwood, and the Platte River at Louisville (Nebraska highway 50) for July /August 2003, October 2003 and March 2004, are displayed as Figures 3.30 through 3.47, respectively.

The majority of Platte River substrate is sand and fine sand. The general trend at all sites was that core samples from locations with greater mean column velocities tended to have higher percentages of gravel and coarse sand. Conversely, sample locations with lower mean column velocities tended to have higher percentages of silt and fine sand.

NORTH BEND SITE ON THE PLATTE RIVER: The North Bend site (Figures 3.30, 3.31, 3.32) is the upstream most site sampled for substrate in this study and is located near the Nebraska State Highway 79 bridge. Here the river ranged from 403 to 447 m wide with depths up to 1.6 m, and was dissected by three or more bars up to 70 m wide. The substrate was dominated by sand and fine sands. Coarse sand and gravel were generally present but, in combination seldom exceeded 40% by weight in any one sample. Silt was most frequently present in shallow or exposed bar samples.

The pairwise multiple comparison procedure showed that the North Bend site had significantly higher percentages of coarse sand than the Elkhorn River site ($p<0.001$) and significantly lower percentages of sand than the Salt Creek site ($p<0.001$). Percentages of fine sand at North Bend were significantly lower than those at the Elkhorn River site ($p=0.002$) and significantly higher than those at the Salt Creek site ($p<0.001$). The North Bend site showed no significant differences in substrate composition with any of the other Platte River sites sampled.

LESHARA SITE ON THE PLATTE RIVER: The Leshara site is located near the Nebraska State Highway 64 Bridge. The river channel ranged from 503 to 580 m wide and up to 2 m deep at this site (Figures 3.33, 3.34, 3.35). The channel was dissected by one or more exposed bars up to 100 m in width. Sand and fine sand dominated most of the sample locations but, exposed bars were primarily fine sand and silt.

The pairwise multiple comparison procedure showed that substrate samples from the Leshara site on the Platte River had significantly higher percentages of coarse sand than the Elkhorn River site ($p=0.004$). The Leshara site also had significantly lower percentages of sand ($p<0.001$) and significantly higher percentages of fine sand ($p<0.001$) than the Salt Creek site. The only significant differences between the substrate composition at the Leshara site and other Platte River sites were that the percent coarse sand was lower ($p=0.004$) and the percent fine sand was higher ($p<0.001$) at the Louisville site.

ELKHORN RIVER SITE: The Elkhorn River site is located near the Nebraska State Highway 64 Bridge in the town of Waterloo, Nebraska. The river at this site ranged from 58 to 66 m wide and was up to 1.5 m deep (Figures 3.36, 3.37, 3.38). No exposed bars were found at this site. Fine sand and sand size materials dominated the substrate in the July 2003 samples and the composition shifted to sand during the October 2003 and March 2004 samples. On these dates fine sand and silt was found in higher percentage in samples from shoreline locations.

The pairwise comparison procedure showed that the Elkhorn River site had significantly lower percentages of coarse sand than the Salt Creek site ($p=0.001$) and indeed all of the sites along the Platte River as detailed below. The percentage of fine sand at the Elkhorn River site was significantly higher than that at the Salt Creek site ($p<0.001$) and all the Platte River sites, except the one at Leshara as detailed above. The percentage of sand at the Elkhorn River site was significantly lower than that at the Salt Creek site ($p<0.001$).

ASHLAND SITE ON THE PLATTE RIVER: The Ashland site is located near the US Highway 6 bridge over the Platte River. The channel ranged from 390 to 420 m wide and up to 1 m deep. In contrast to the other sites on the Platte River, there were no exposed bars that divided the river into smaller channels. However, there were exposed bars on the bank-line areas up to about 100 m wide (Figures 3.39, 3.40, 3.41). Silt was confined to exposed bar locations. Coarse sand and gravel were most abundant in the deeper, faster sections of the channel.

The pairwise comparison procedure showed that the site at the US Highway 6 Bridge on the Platte River had significantly higher percentages of coarse sand than the Elkhorn River site ($p<0.001$). This site also had significantly lower percentages of sand than the Salt Creek site ($p<0.001$). The percentage of fine sand was significantly lower than those found in the Elkhorn River site ($p=0.001$) and significantly higher than those found at the Salt Creek site ($p<0.001$). The Ashand site showed no signifiant differences in substrate composition with any of the other Platte River sites sampled.

SALT CREEK SITE: The Salt Creek site is located just north of Greenwood, Nebraska. This site ranged from 39 to 41 m wide and up to 0.7 m deep (Figures 3.42, 3.43, 3.44). The channel was divided by an exposed bar with the July and October 2003 samples. Although sand was by far the largest component of the substrate, silt commonly occurred in the samples more frequently than the other sites.

LOUISVILLE SITE ON THE PLATTE RIVER: The Louisville site is located near the Nebraska State Highway 50 bridge on the Platte River. It was the most downstream location in the Platte River that was sampled for substrate composition during this study. The channel at this site ranged from 407 to 516 m wide and up to 1.1 m deep (Figures 3.45, 3.46, 3.47). The channel at this site was divided by several small bars during the July 2003 sample but, no exposed bars were found during October 2003 or March 2004. From July 2003 to March 2004, there appeared to be a shift toward a finer substrate composition.

The pairwise comparison procedure showed that the substrate at the Louisville site on the Platte River had significantly higher percentages of gravel than the Elkhorn River site ($p<0.001$) and the Salt Creek site ($p=0.004$). Percentages of coarse sand at Louisville were significantly higher than those found at the Elkhorn River site ($p=0.001$) and at the Leshara site on the Platte River ($p=0.004$). The percentage of sand at the Louisville site was significantly lower than at the Salt Creek site ($p=0.001$). The percentage of fine sand at the Louisville site was significantly lower than the percentages at the Elkhorn River site ($p<0.001$) and the Leshara site on the Platte River ($p<0.001$) and significantly higher than at the Salt Creek site ($p=0.005$). Percentages of silt, sand and gravel at the Louisville site were not significantly different from any other site sampled on the Platte River.

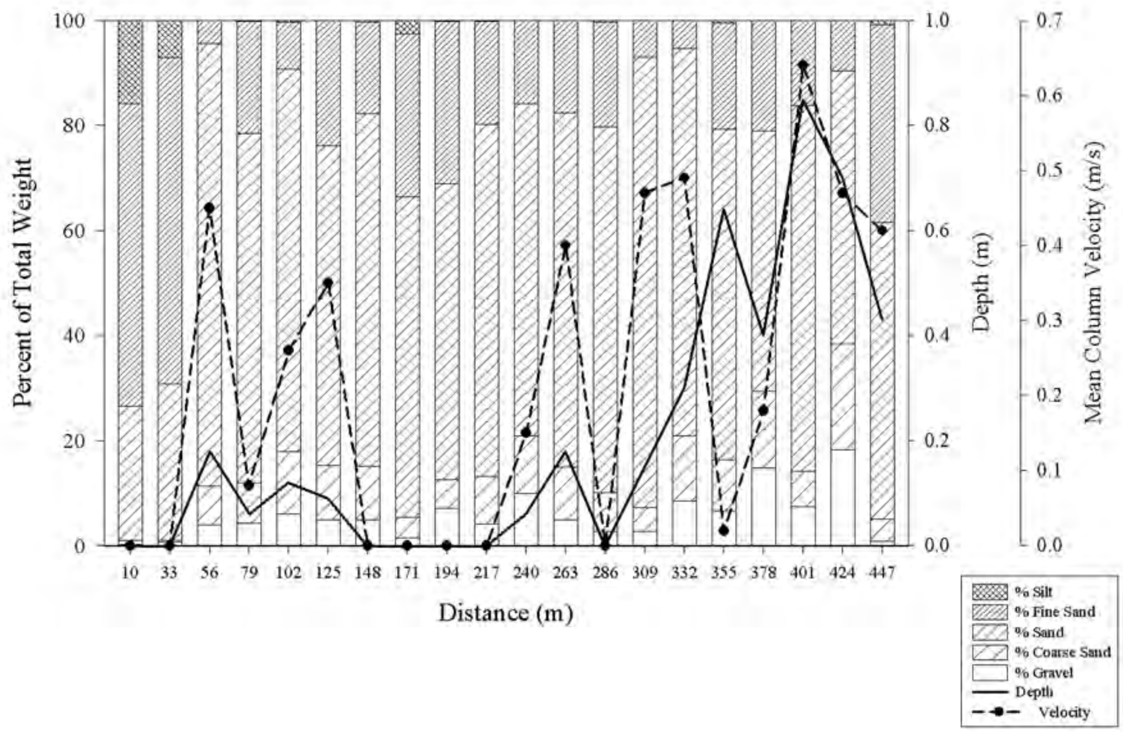


Figure 3.30. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near Nebraska State Highway 79 Bridge August 5, 2003.

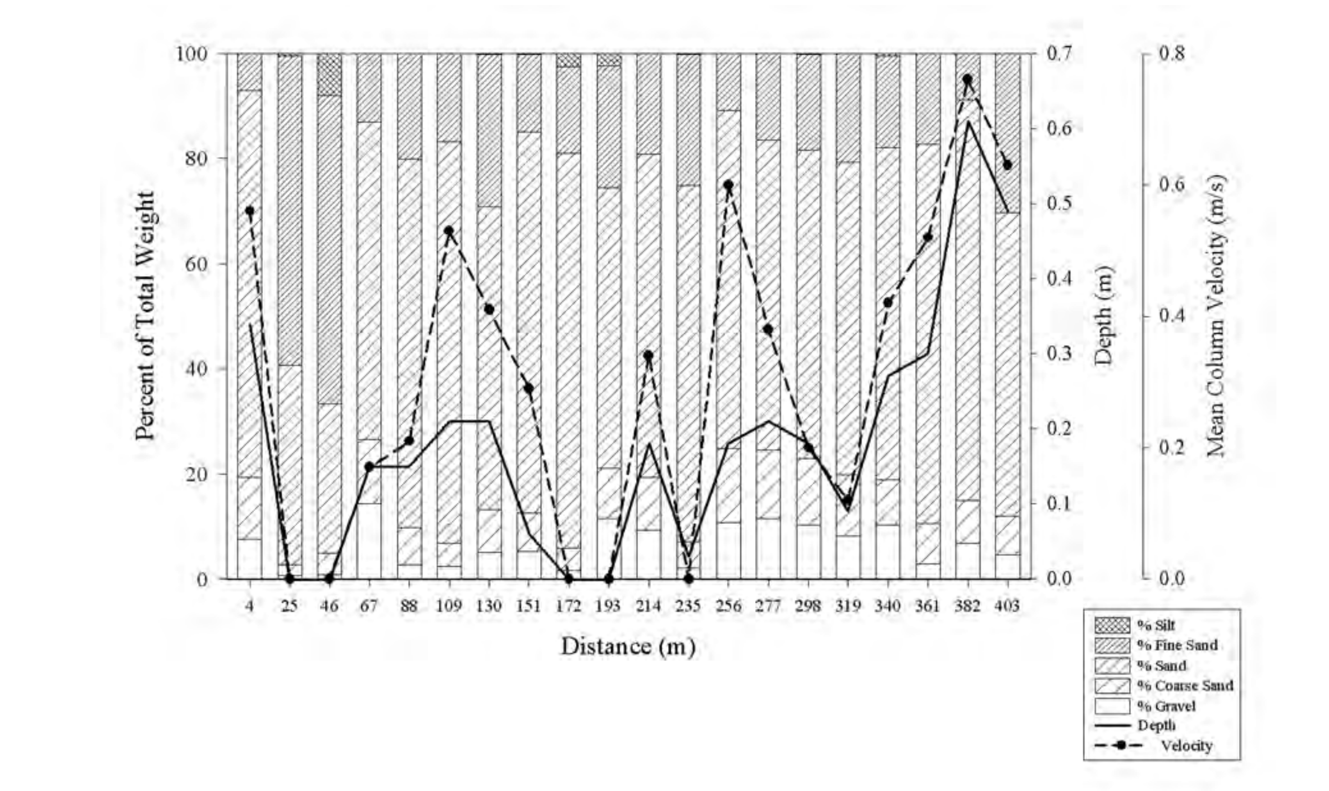


Figure 3.31. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near Nebraska State Highway 79 Bridge October 24, 2003.

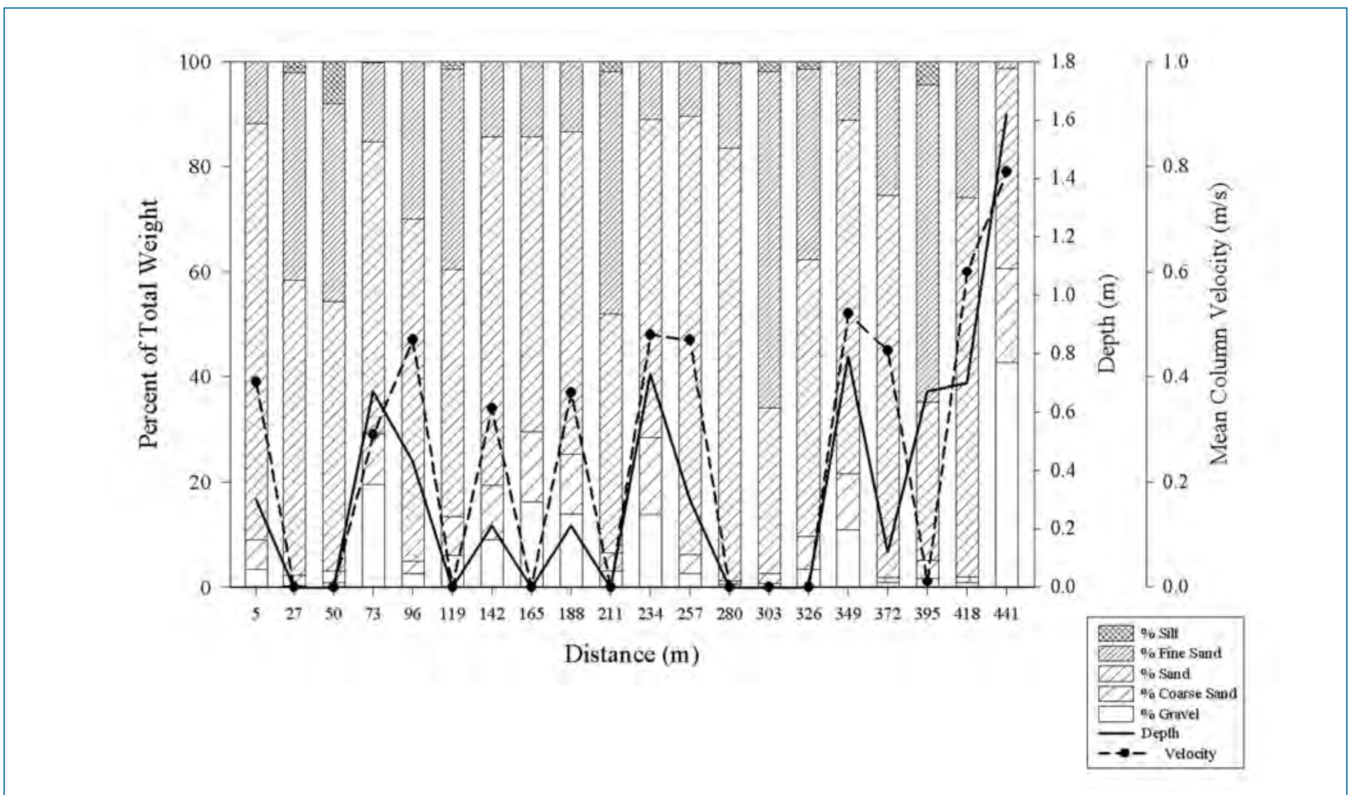


Figure 3.32. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near Nebraska State Highway 79 Bridge March 12, 2004.

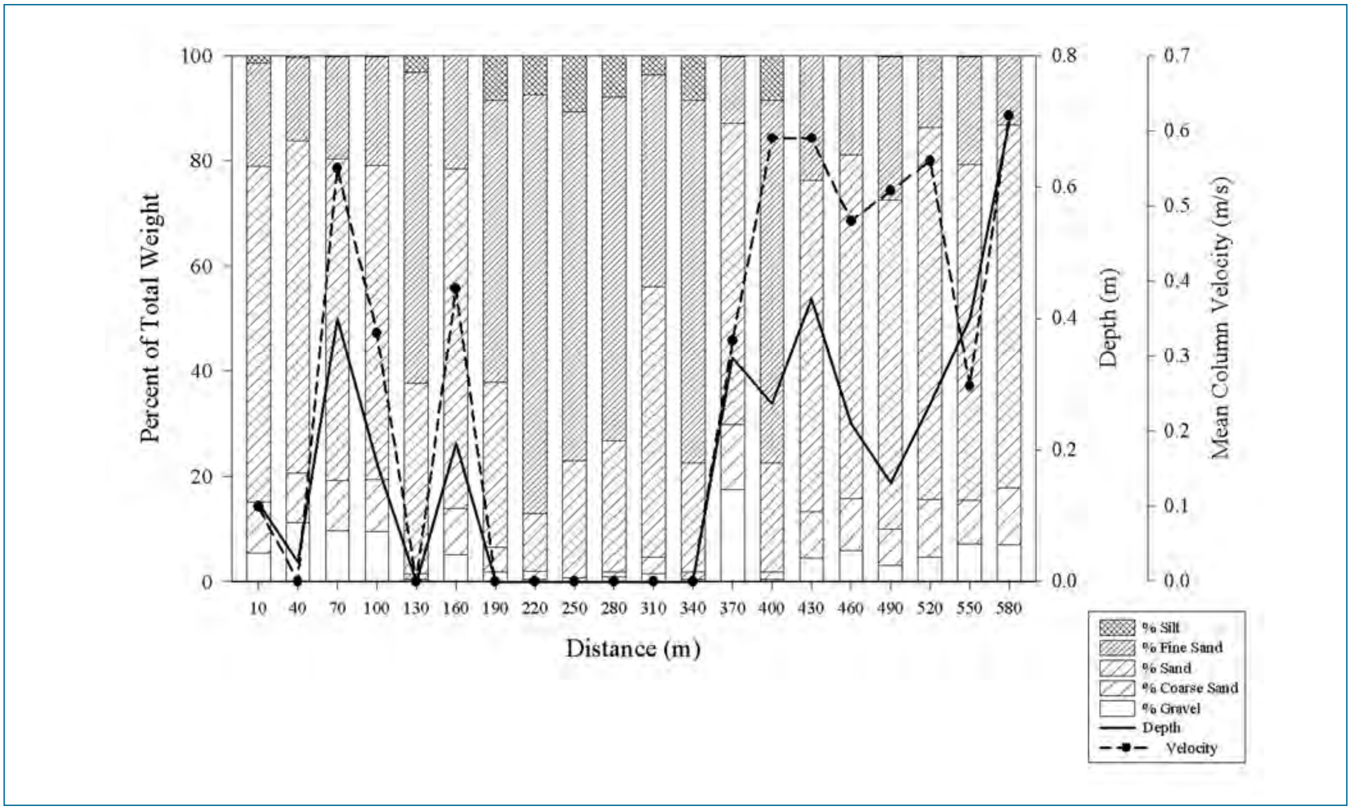


Figure 3.33. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near Nebraska State Highway 64 Bridge August 15, 2003.

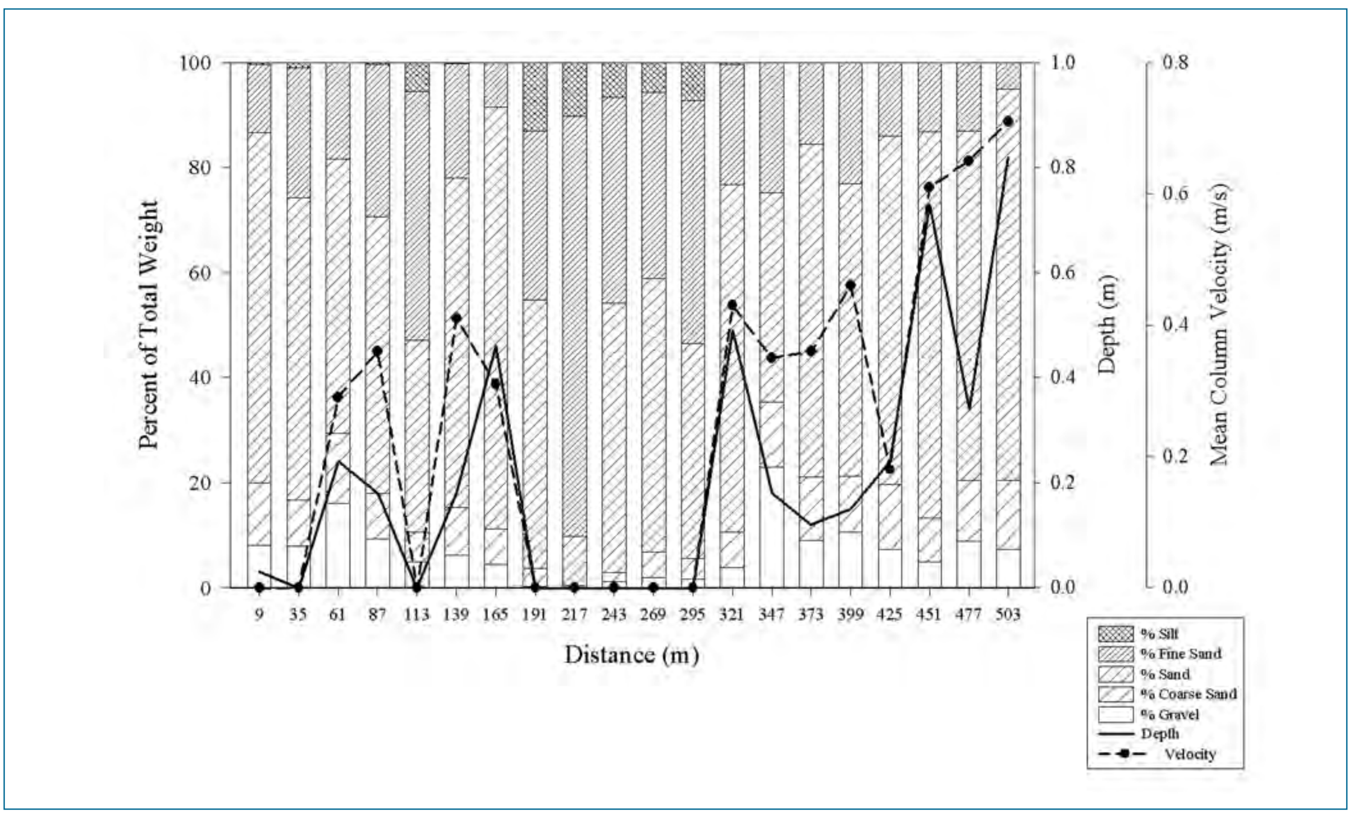


Figure 3.34. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near Nebraska State Highway 64 Bridge October 24, 2003.

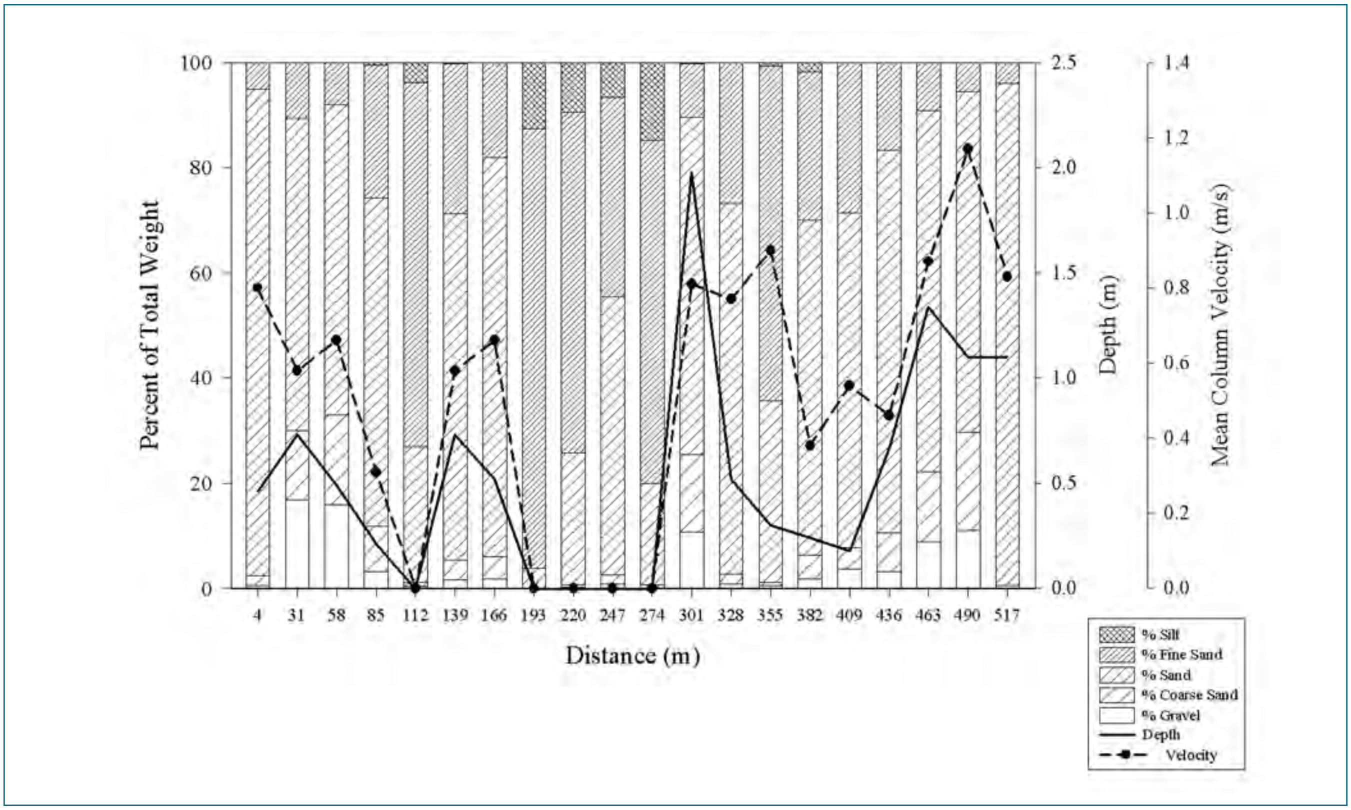


Figure 3.35. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near Nebraska State Highway 64 Bridge March 30, 2004.

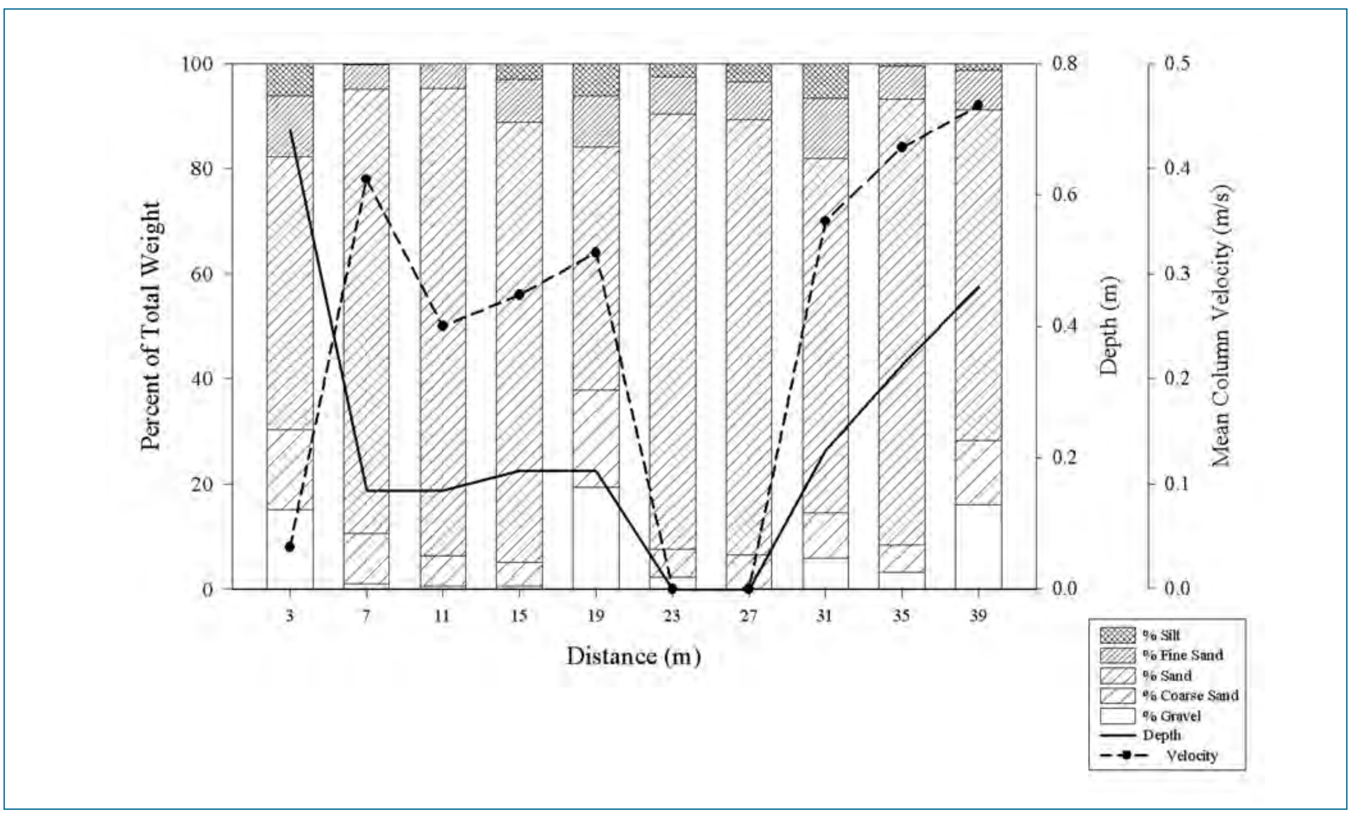


Figure 3.36. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Elkhorn River near Nebraska State Highway 64 Bridge July 23, 2003

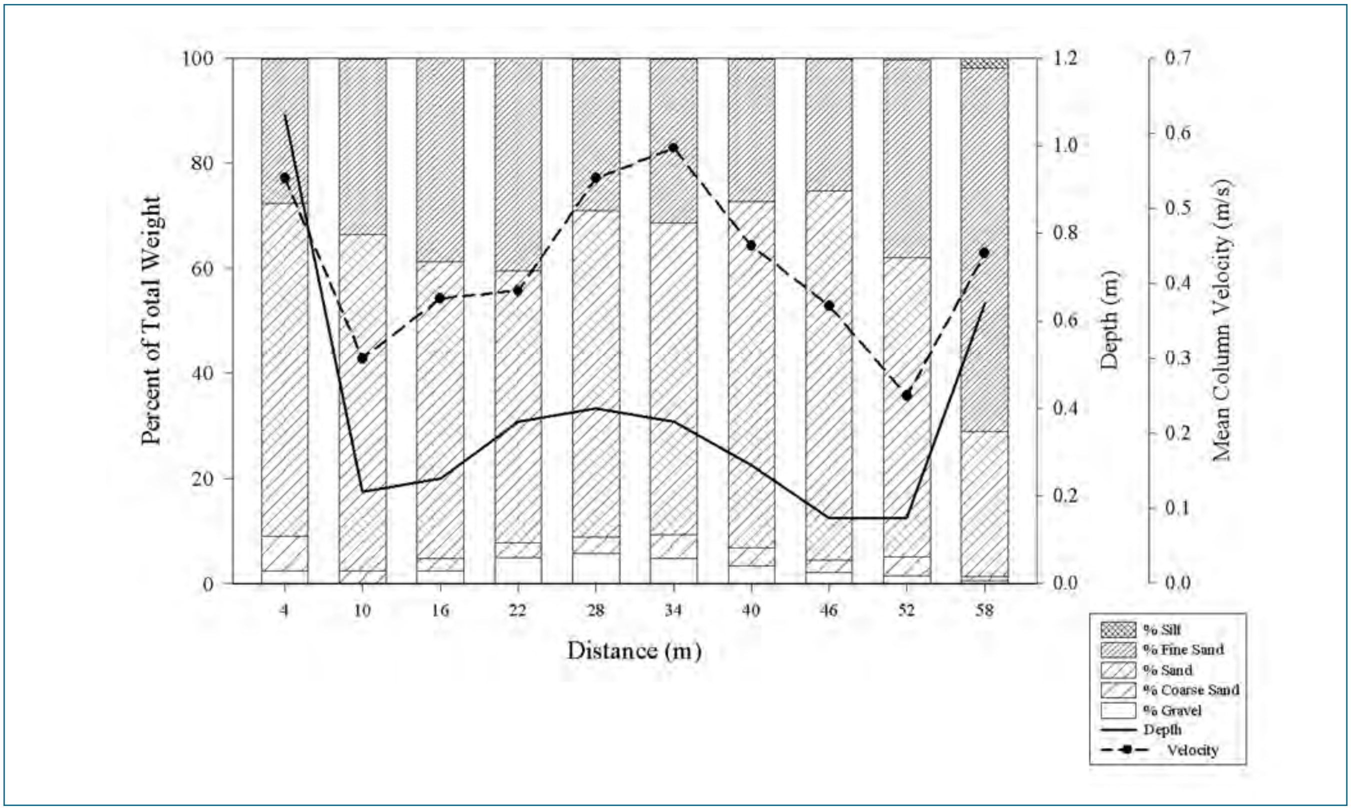


Figure 3.37. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Elkhorn River near Nebraska State Highway 64 Bridge October 8, 2003.

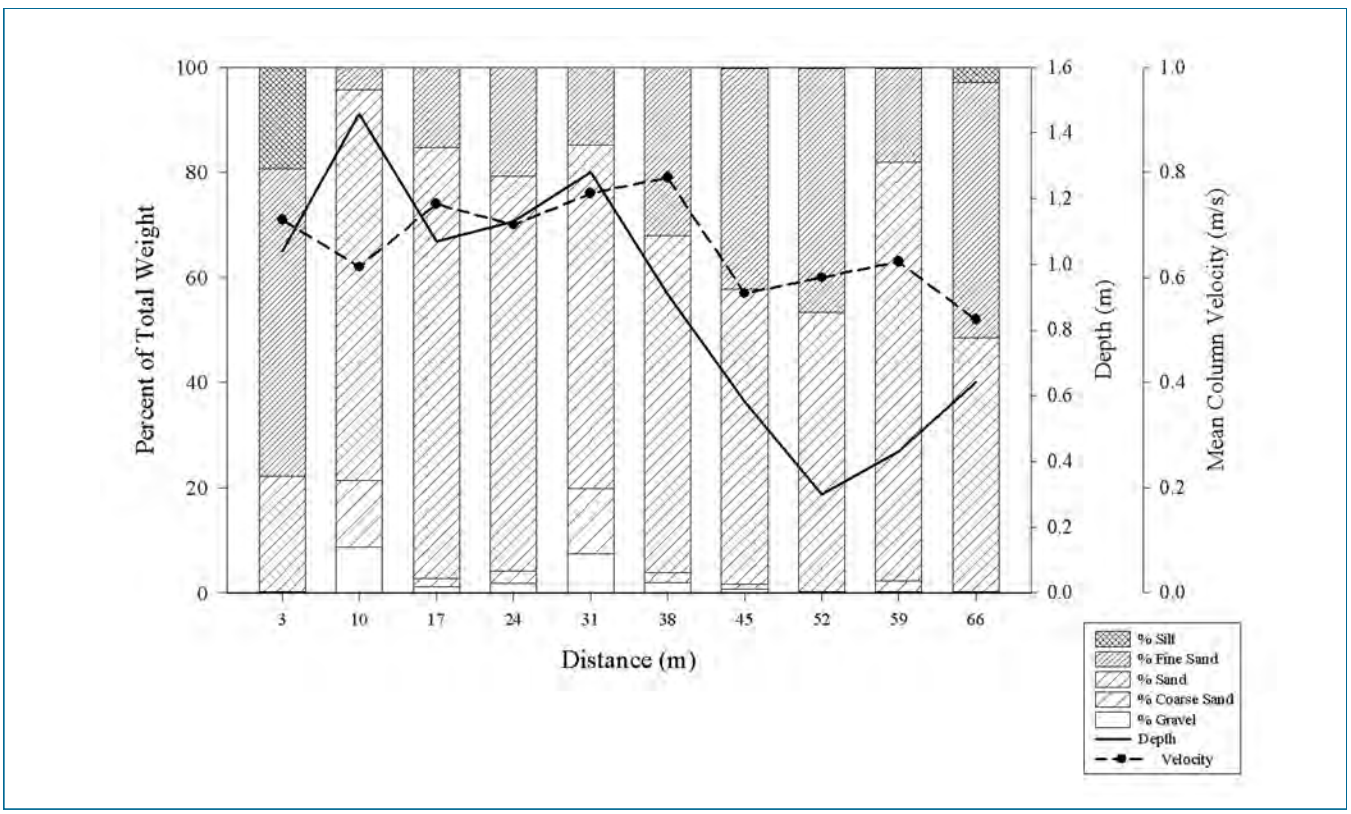


Figure 3.38. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Elkhorn River near Nebraska State Highway 64 Bridge March 31, 2004.

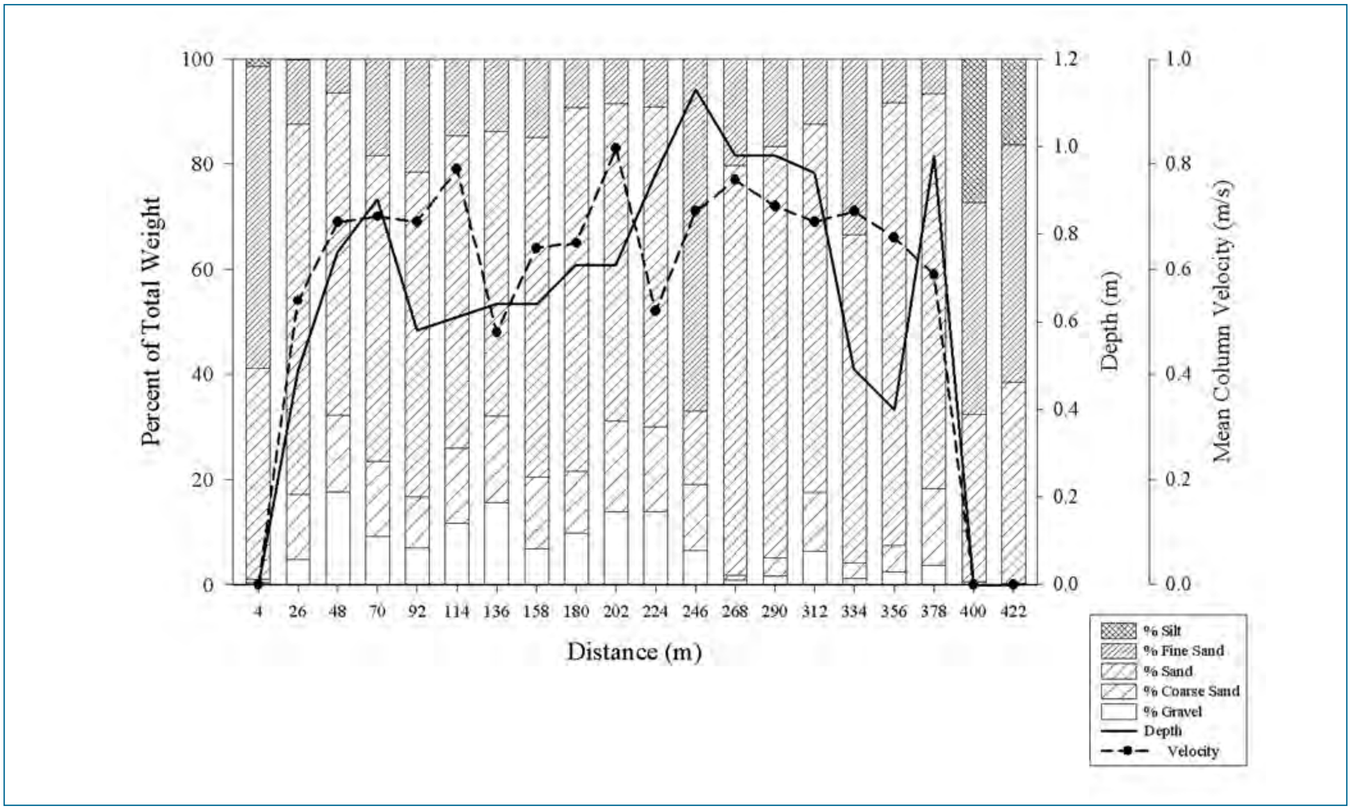


Figure 3.39. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near US Highway 6 Bridge July 31, 2003.

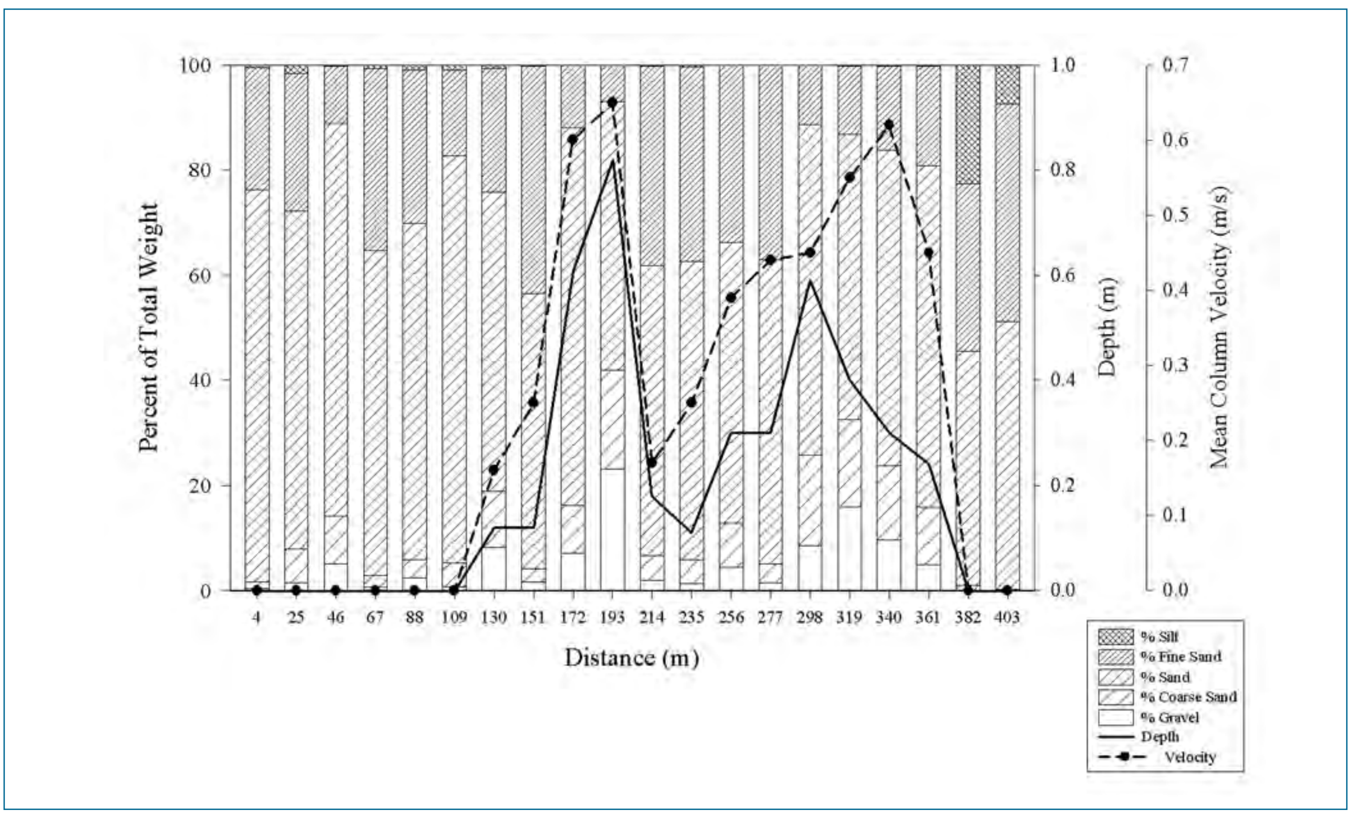


Figure 3.40. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near US Highway 6 Bridge October 10, 2003.

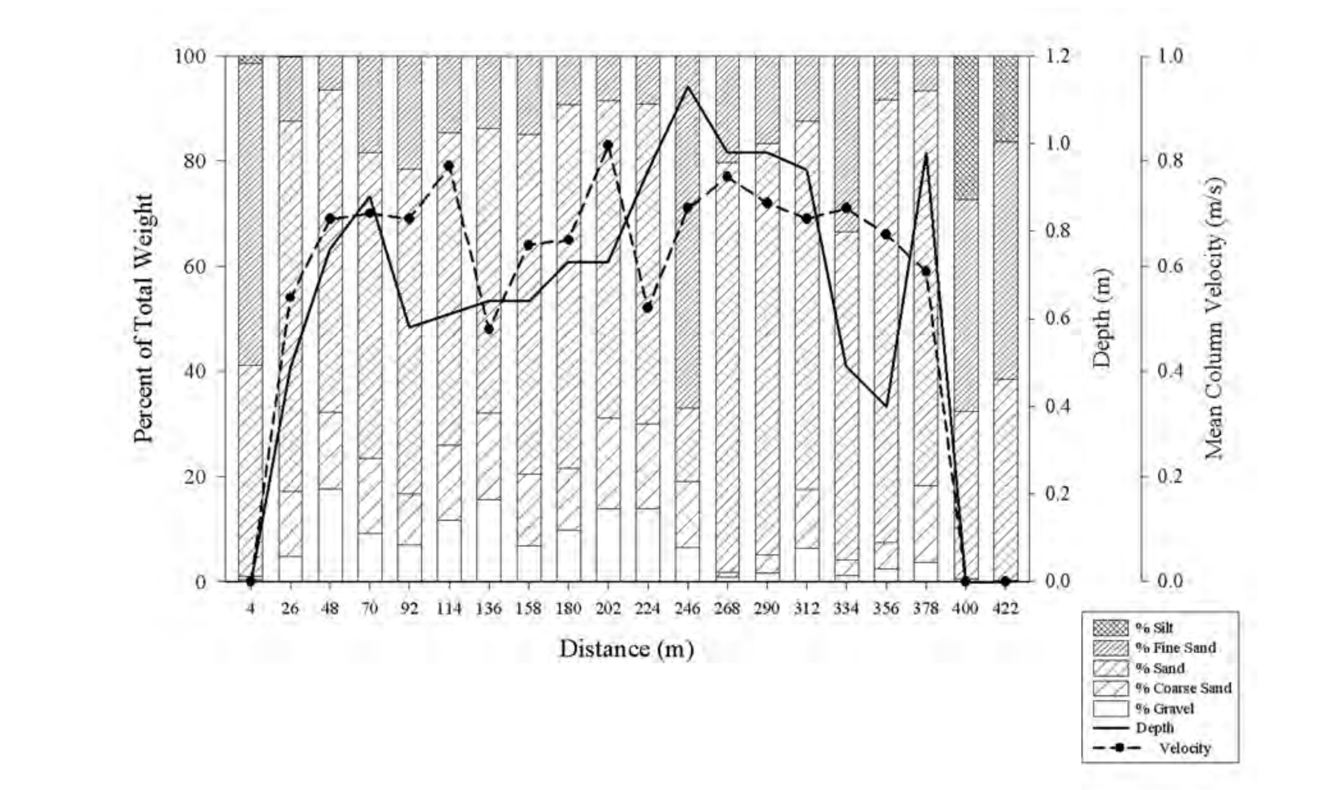


Figure 3.41. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near US Highway 6 Bridge March 19, 2004

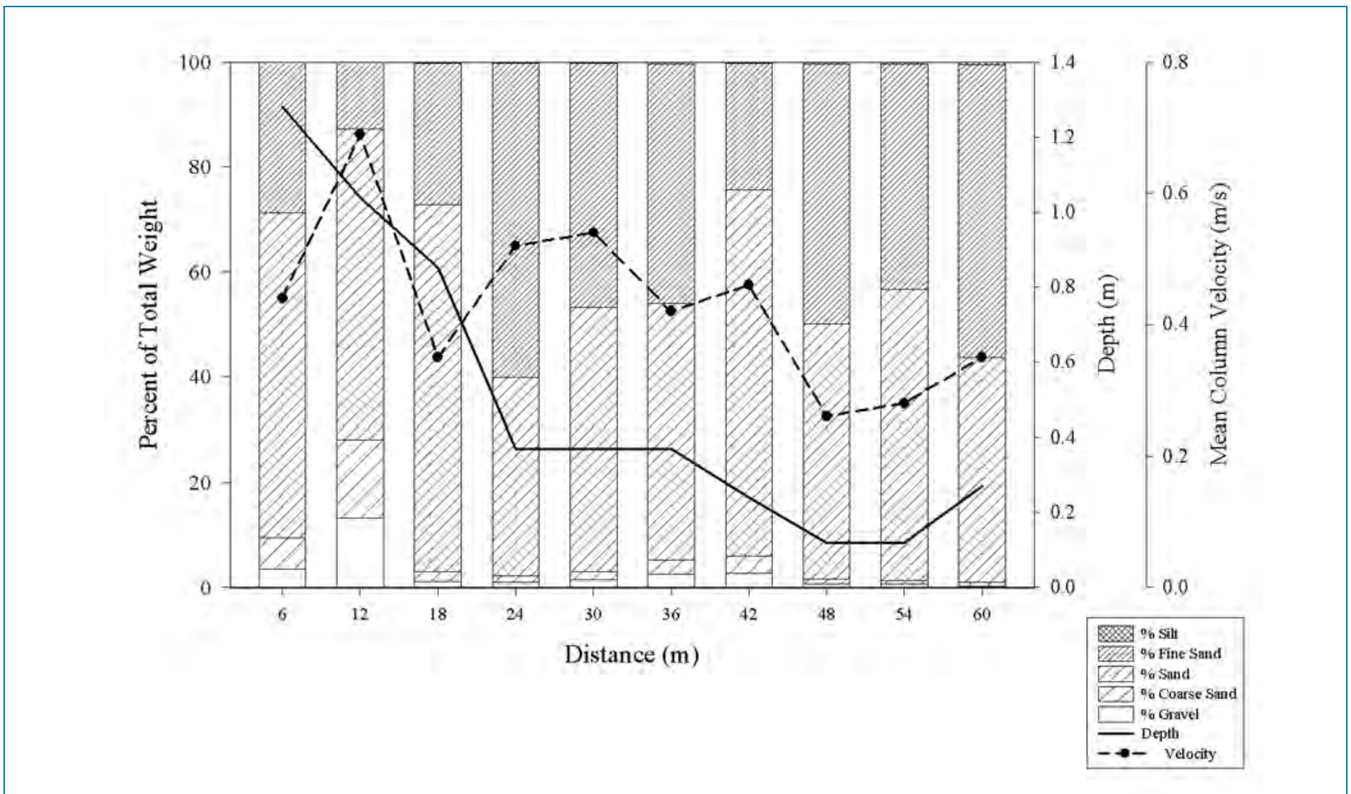


Figure 3.42. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across Salt Creek near Greenwood July 30, 2003.

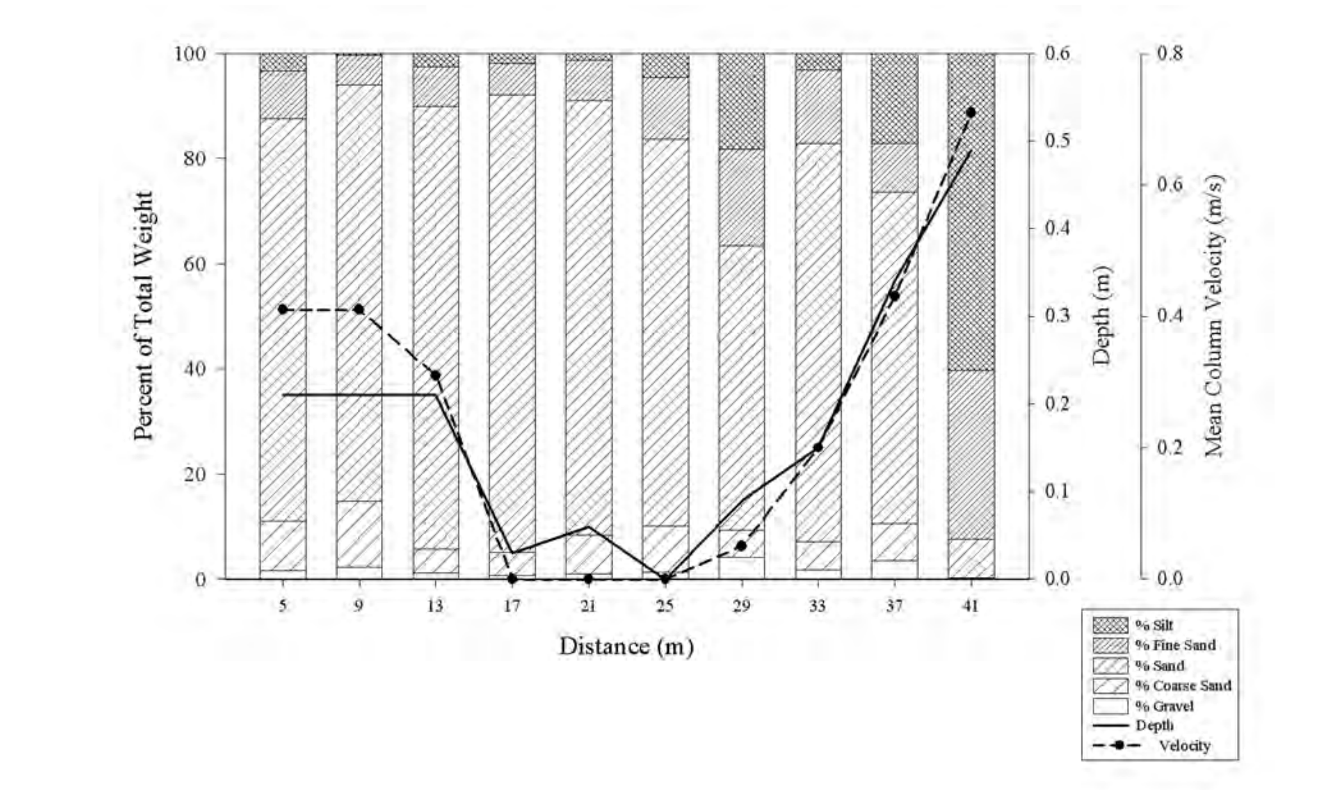


Figure 3.43. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across Salt Creek near Greenwood October 8, 2003.

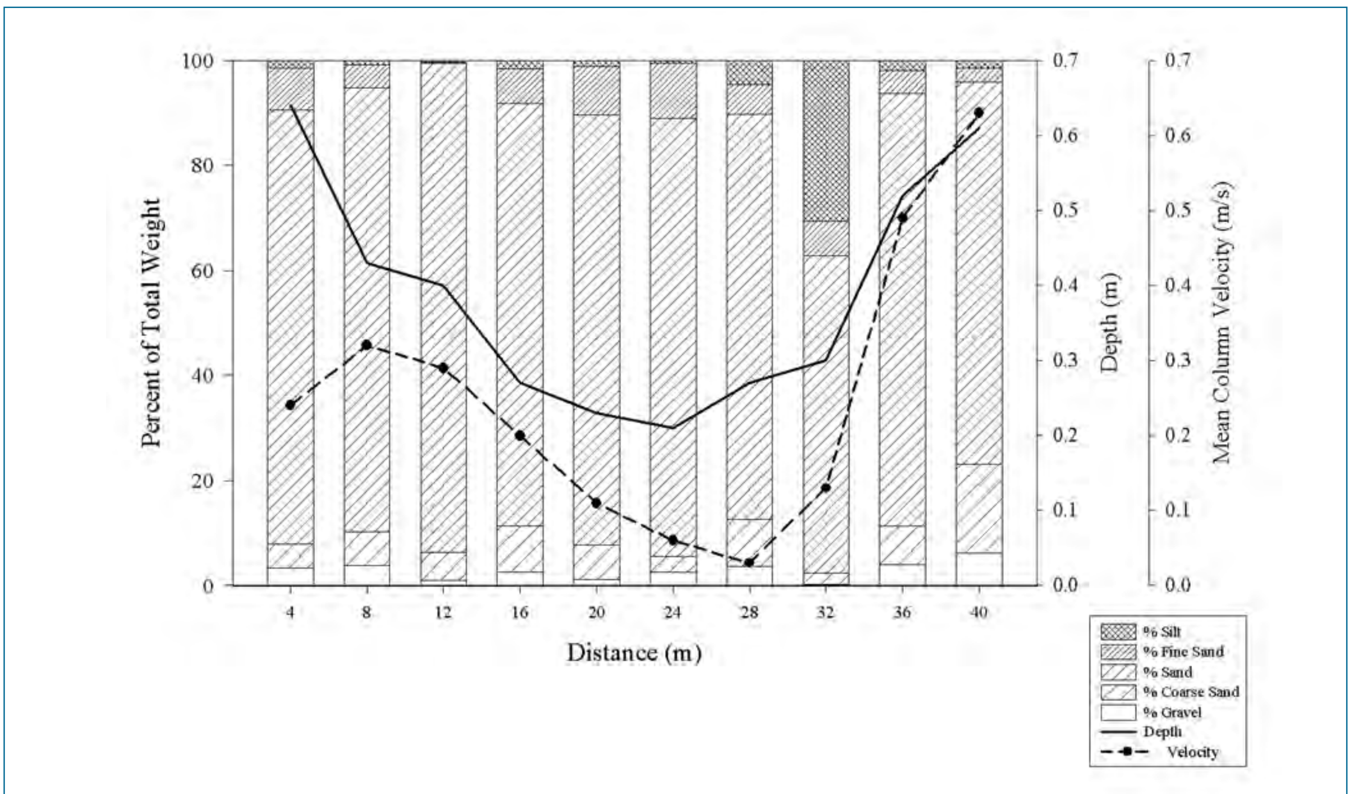


Figure 3.44. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across Salt Creek near Greenwood March 11, 2004.

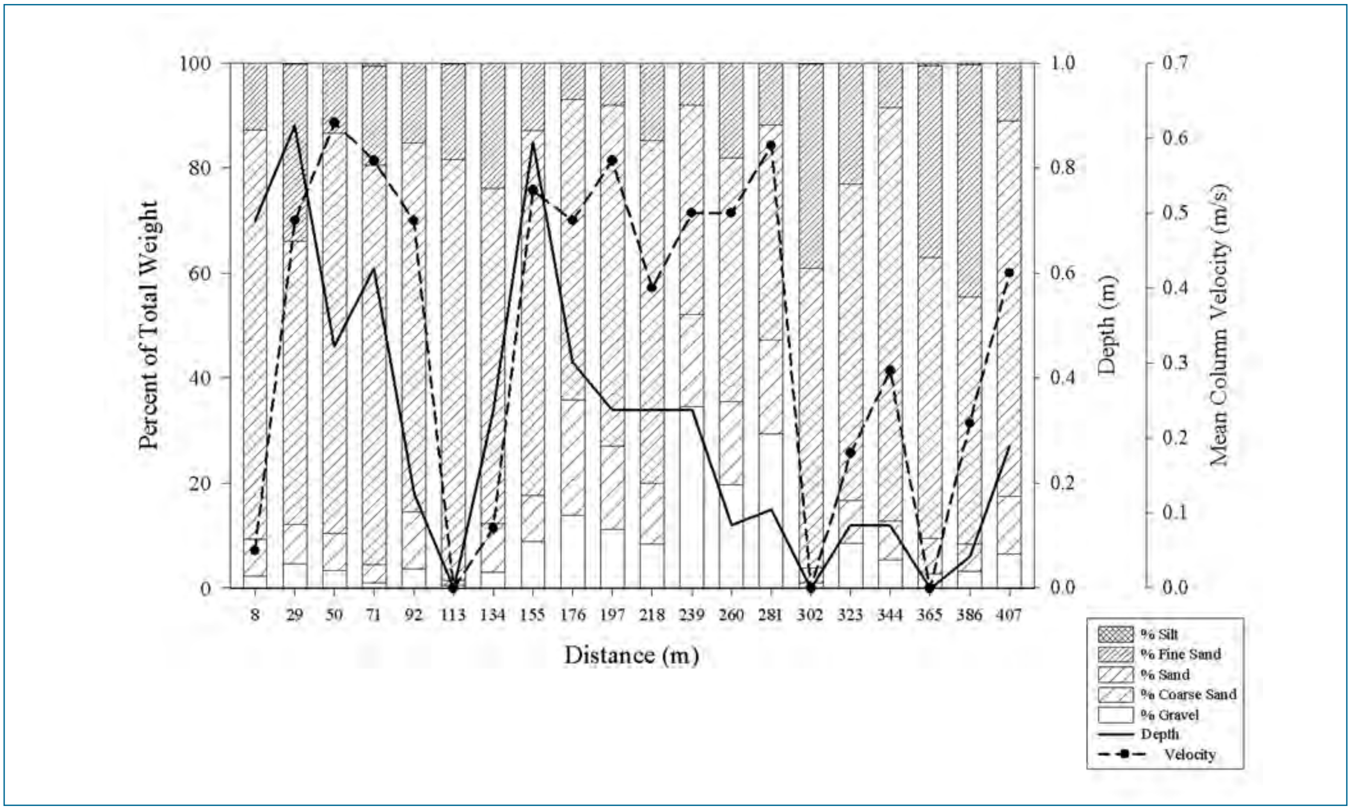


Figure 3.45. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near Nebraska State Highway 50 Bridge July 23, 2003.

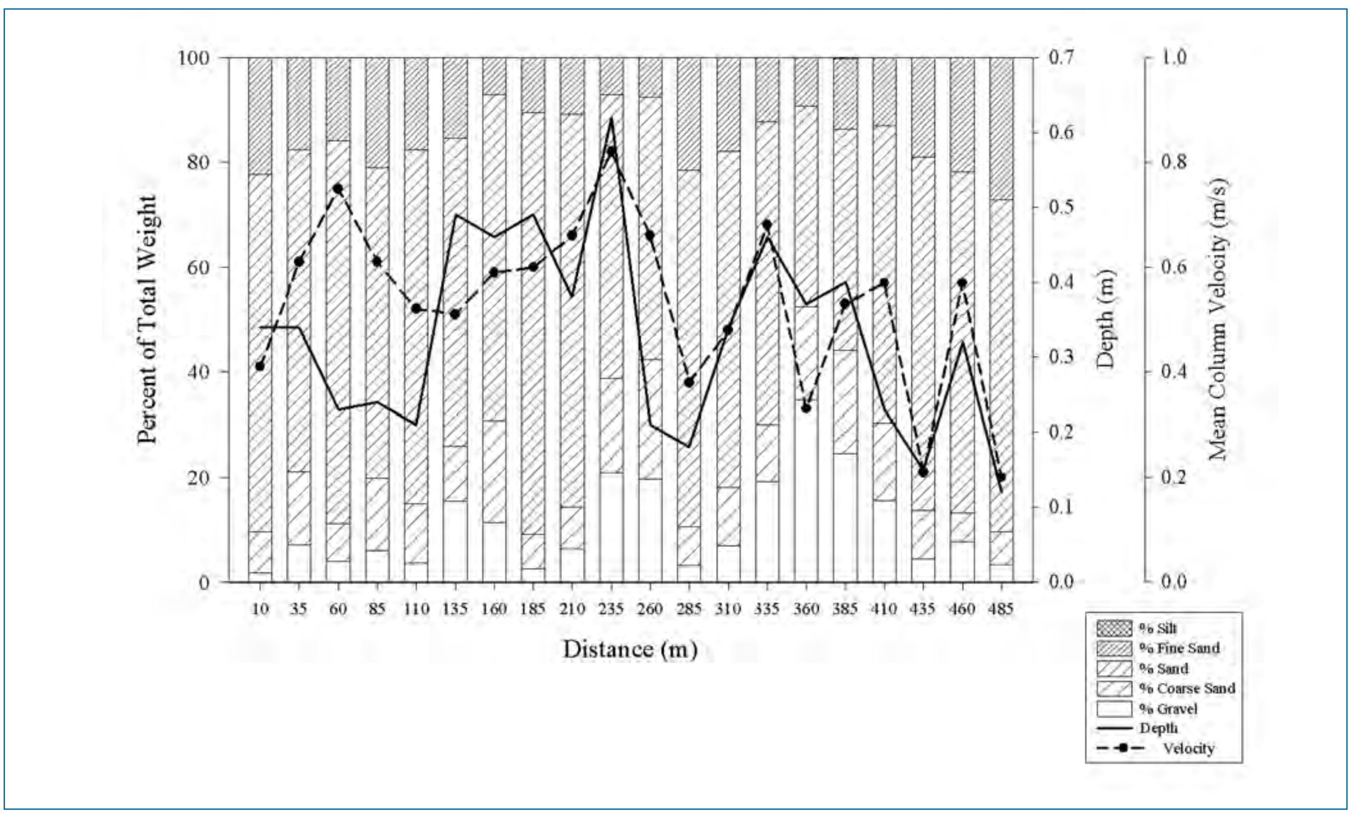


Figure 3.46. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near Nebraska State Highway 50 Bridge October 10, 2003.

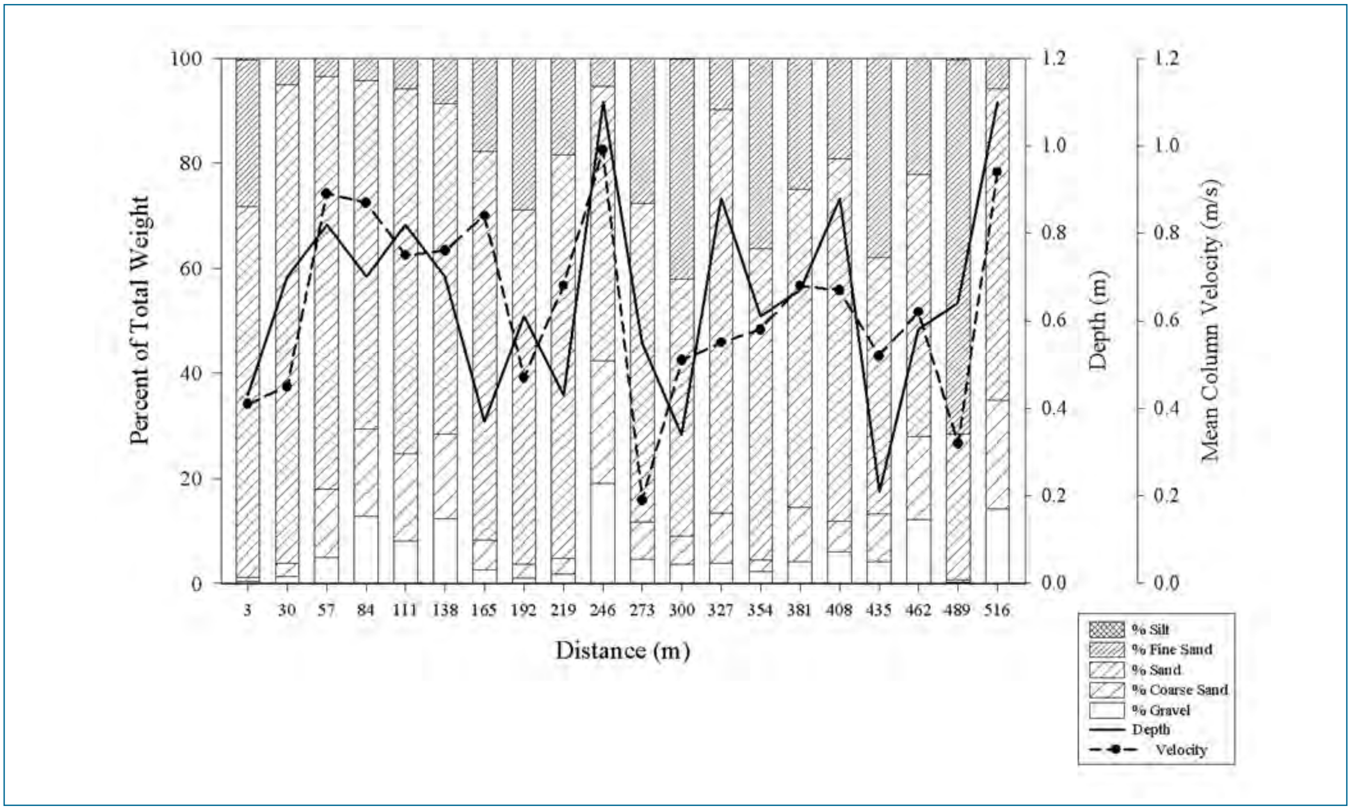


Figure 3.47. Percent substrate composition (silt, fine sand, sand, coarse sand, gravel) from core samples, depth and mean column velocities measured along a transect across the Platte River near Nebraska State Highway 50 Bridge March 17, 2004.

Table 3.1. Average percent by weight for fractions of core samples retained by number 10, 18, 60, and 230 sieves, and the fraction passing through the number 230 sieve (<230) collected from the Elkhorn River at Waterloo, Salt Creek at Greenwood, and the Platte River at North Bend, Leshara, the US Highway 6 Bridge, and Louisville, Nebraska during the summer and fall of 2003 and the spring of 2004.

Location and screen mesh size	Summer 2003	Fall 2003	Spring 2004	Mean
Elkhorn River at Waterloo, NE				
10 mesh	2.754	2.795	2.239	2.596
18 mesh	2.366	3.196	3.425	3.329
60 mesh	54.359	57.768	62.018	58.048
230 mesh	39.310	35.897	30.024	35.077
<230 mesh	0.211	0.345	2.292	0.949
Salt Creek at Greenwood, NE				
10 mesh	6.408	1.748	2.851	3.669
18 mesh	9.127	6.485	7.006	7.539
60 mesh	76.633	68.338	79.901	74.957
230 mesh	7.815	12.132	5.833	8.593
<230 mesh	3.015	11.301	4.410	6.242
Platte River at North Bend, NE				
10 mesh	5.761	6.450	7.633	6.615
18 mesh	8.345	8.447	6.439	7.744
60 mesh	62.106	62.254	58.755	61.038
230 mesh	22.355	22.105	26.070	23.510
<230 mesh	1.431	0.744	1.103	1.093
Platte River at Leshara, NE				
10 mesh	4.813	6.835	4.127	5.258
18 mesh	6.492	8.310	5.885	6.896
60 mesh	49.180	55.974	56.988	54.047
230 mesh	36.464	26.347	30.454	31.088
<230 mesh	3.050	2.532	2.544	2.709
Platte River at US Highway 6				
10 mesh	5.177	4.963	6.665	5.602
18 mesh	6.932	7.466	9.603	8.000
60 mesh	63.772	60.515	59.649	61.312
230 mesh	22.430	25.209	21.797	23.145
<230 mesh	1.689	1.848	2.287	1.941
Platte River at Louisville, NE				
10 mesh	8.598	10.929	5.943	8.490
18 mesh	9.846	12.093	9.347	10.429
60 mesh	62.533	61.533	63.578	62.548
230 mesh	18.892	15.407	21.067	18.455
<230 mesh	0.131	0.036	0.065	0.077

AMBIENT RIVER HABITAT DISCUSSION:

Other sources of information on the chemical constituents in the water of the Platte River include the annual publications of the USGS (Water Resources Data – Nebraska such as Hitch et al. (2003)). Of particular note to this study are the surface-water stations on the Platte River (Table 1.2) at North Bend (06796000), the Platte River near Leshara (06796500), the Elkhorn River at Waterloo (06800500), the Platte River near Ashland (06801000), Salt Creek at Greenwood (06803555) and the Platte River at Louisville (06805500). The stations on the Platte River near Leshara and Salt Creek at Greenwood only measure discharge. The stations on the Elkhorn River at Waterloo and the Platte River at Louisville measure discharge and, in the 2002 water year, both sites also sampled chemistry, temperature and suspended solids as part of their regular operations on a monthly basis from October through March and twice monthly April through September.

The Louisville station sampled specific conductance, water temperature and suspended sediment concentrations on a daily basis from November 1974 to September 1981. During this time period specific conductance readings varied from a low of 254µS/cm to a high of 3,450µS/cm. Our records at Louisville were well within this range. The high temperature recorded by USGS at Louisville was 36°C on 24 July 1977 (Hitch et al. 2003). Our daily temperature records are 38°C on 31 August and 1 September 2003. Suspended solids concentrations measured by USGS at Louisville ranged from 60 mg/L to 11,600 mg/L. Our highest suspended solids measurement was less than 3,800 mg/L during June 2004.

During the 2002 water year, USGS measured turbidity at the Louisville station ranging from 24 to 2,200 NTU, while our values for the same time period ranged from <50 to just over 1,000 NTU. Dissolved oxygen measurements by USGS ranged from 5.5 to 14.0 mg/L while ours ranged from 7.0 to 17.0 mg/L. The highest temperature reading recorded by USGS at Louisville during 2002 was 27.0°C on 27 July and our high was 31°C on 10 July. Specific conductance values measured by USGS at Louisville ranged from 410 to 1,990 µS/cm, while our values ranged from 400 to 1,200 µS/cm. Suspended solids concentrations measured by USGS ranged from 31 to 1,940 mg/L, while our measurements ranged from 17 to about 1,372 mg/L.

The Elkhorn River at Waterloo was sampled for a similar suite of water quality parameters during the 2002 water year. The highest water temperature measured by USGS at this station was 28°C on 10 July and our highest for this time period was 32°C on 20 July. Dissolved oxygen concentrations measured by USGS at Waterloo ranged from 1.5 to 14.3 mg/L, while our measurements ranged from 6.8 to 19.0 mg/L. Specific conductance measurements by USGS ranged from 286 to 668µS/cm, while ours ranged from 420 to 720µS/cm. Suspended solids measured by USGS ranged from 45 to 6,910 mg/L, while our measurements ranged from 16 to 1,808 mg/L for the same time period. Turbidity measurements by USGS ranged from 20 to 3,500 NTU, while our measurements ranged from 16.2 to 1,412 NTU.

Other accounts of water quality in the lower Platte River include Peters et al. (1989) who measured water temperature, dissolved oxygen, specific conductance and suspended solids while collecting data on fish and invertebrate habitat use in the reach of the lower Platte from Rogers to Fremont, Nebraska in 1986 and 1987. They measured water temperatures up to 32 °C during both years. Dissolved oxygen concentrations that they measured ranged from 2 to 14 mg/L. Specific conductance values in this reach of the Platte River ranged from 200 to 890µS/cm. However, in a related study Holland and Peters (1989) found a gradient in conductivity values from north to south across the Platte River. Typical conductivity values on the north were 315µS/cm and 550µS/cm on the south. They concluded that low conductivity water from the Loup River and Loup Power Canal were the source of low conductivity (283µS/cm) water that did not mix evenly with the higher conductivity water from the Platte River (922µS/cm) for up to 32 km downstream. A similar gradient may be established downstream from the confluence of Salt Creek with the Platte River near Ashland, but the volume of Salt Creek is considerably smaller than the Loup River. Monthly mean suspended solids concentrations were less than 500mg/L in the Rogers to Fremont reach, but reached 5,563 mg/L on 1 July 1986. Maximum concentrations exceeded 3,000mg/L in June 1986 and in May 1987.

Fessell (1996) found that only three of 19 fish species that he tested from the Platte River had mean critical thermal maxima that exceeded 38ºC. These were the plains topminnow, the plains killifish and the western mosquitofish . Species most closely related to sturgeon chub had mean critical thermal maxima of 35.2ºC for flathead chub, 35.5ºC for speckled chub, and 37.4ºC for silver chub. Recording temperature probe data indicate that maxima for flathead chub and shoal (speckled) chub may have been exceeded during July and August 2001, July and August 2002 and August and early September 2003 (Figures 3.6, 3.7, 3.8).

Yu (1996) evaluated the relationships between several chemical and physical parameters and habitat use by fishes in the lower Platte River. His analysis encompassed sites in the lower Platte River at Columbus, Rogers, North Bend, and Louisville during 1992 and 1993. In addition, he summarized habitat conditions for sampling done in the vicinity of North Bend from 1987 to 1993. Although most of the measurements for this data set are from sites upstream from the areas sampled in our 2001-2004 study, the values for maximum temperature, specific conductance, total suspended solids and dissolved oxygen fit within the ranges we found at the Platte River site near Leshara.

The substrate composition among the sites along the lower Platte River from North Bend to Louisville is quite consistent. The only significant differences indicated through the pairwise comparisons were between the Louisville site and the Leshara site for the coarse sand and fine sand fractions. However, substrate composition at the Elkhorn River site and the Salt Creek site differed significantly from the four Platte River sites on at least one substrate fraction.

The lower Platte River is a diverse complex of habitats that support species adapted to living in variable environments and several studies (Pflieger and Grace 1987, Cross and Moss 1987) have noted changes in species composition away from native species associated with stabilization of discharge and reductions in turbidity. To survive and prosper here they must be able to accommodate wide changes in temperature while they feed and reproduce in turbid conditions with fluctuating water levels. By many standards it is a harsh environment, but most of the native species have evolved under these conditions and they are apparently disadvantaged when changes in water management results in cooler, clearer water and stable discharge that favors non-native species.

The lower Platte River downstream of the Louisville gage site during low flow conditions. Note the presence of exposed sandbars, shallow sandbar complexes, as well as deeper channels near the shorelines.

CHAPTER 4

HABITAT USE, MOVEMENT AND POPULATION CHARACTERISTICS OF PALLID STURGEON IN THE LOWER PLATTE RIVER

INTRODUCTION

Pallid sturgeon are typically grey colored hunch-backed fishes with five rows of bony scutes that have been found in the lower Mississippi River and Missouri River upstream to the Great Falls in Montana. Extensive sampling in the tributaries of the Missouri River basin has found populations of pallid sturgeon only in the Yellowstone, Kansas and Platte Rivers (USFWS 1993) and Cross and Collins (1995) state that it only enters the Kansas River during floods. However, tributary mouths have been characterized as an important habitat feature by several studies (Hurley1998, Sheehan et al. 1998). The earliest records of pallid sturgeon in Nebraska were from the Missouri River during the 1950's and the earliest record from the Platte River was from Sarpy County in 1979 (Darrell Feit; personal communication) but as Keenlyne (1989) pointed out, many fishery reports failed to distinguish between pallid and shovelnose sturgeon until the 1970's. Starting in January 2000, the NGPC began compiling pallid sturgeon catches in Nebraska (Darrell Feit; personal communication) including records from 1979, 1990, 1993, 1995 and 1997. This listing includes documented Heritage Data base reports from anglers and each report was subjectively evaluated for accuracy. Figures 4.1 and 4.2 indicate the locations of pallid sturgeon captured by anglers that were confirmed by Darrell Feit from the NGPC from the Platte River and the Elkhorn River prior to and during this study.

Historically, pallid sturgeon were more abundant in the main stem and major tributaries of the Missouri and Mississippi Rivers than they are currently. Forbes and Richardson (1905) estimated that pallid sturgeon comprised 1 in 5 river sturgeon collected in the lower Missouri River. Keenlyne (1989) reported that "correspondence and notes of researchers suggest that pallid sturgeon were still fairly common in many parts of the Mississippi and Missouri river systems as late as 1967". In 1990 the pallid sturgeon was listed as an endangered species by the US Fish and Wildlife Service (Federal Register 55 [September 6, 1990]: 36641-36647). Overfishing and modification of rivers for navigation, power production and agricultural water use are hypothesized to be responsible for the decline of pallid sturgeon (Kallemeyn 1983, USFWS 1993).

Since 1997 pallid sturgeon have been stocked in the Missouri River and Platte River to attempt to augment their recovery from endangered status (Krentz et al. 2005). In 1997, 401 pallid sturgeon were stocked into the Platte River at the Nebraska highway 50 Bridge. These fish were hatched in 1997 at the Blind Pony Fish Hatchery in Missouri and were tagged with external Floy tags at the base of their pectoral fins. In 1998, 84 age 6 pallid sturgeon, spawned at the Blind Pony Fish Hatchery in Missouri in 1992 were tagged with passive integrated transponder (PIT) tags and coded wire tags and released into the Platte River at Two Rivers State Recreation Area (RM 40). Ten of these fish were also implanted with radio transmitters. In 1999, 15 age 7 pallid sturgeon were PIT tagged, coded wire tagged and implanted with radio transmitters and released into the Platte River at Two Rivers State Recreation Area. These fish were monitored for movement and habitat use from April 1998 to May 2000 (Snook 2001), but none of these fish were collected during this study. From 1994 through 2004, 68,815 pallid sturgeon have been stocked into the section of the Missouri River which comprises Recovery Priority Management Area 4 that extends from Gavins Point Dam downstream to the mouth of the Missouri River. Of these, 20,622 were stocked in the Missouri River between Bellevue, NE (RM 601.4) and St. Helena, NE (RM 799) during the years 2002-2004 (Krentz et al. 2005).

The objective for this study was to study the juvenile and adult pallid sturgeon population in the lower Platte River, Nebraska. Efforts focused on three main areas of investigation.

- **First,** determine the habitat conditions that pallid sturgeon use and document the species which are associated with them in these habitats.
- **Second,** determine the movement patterns of pallid sturgeon into, within and out of the Platte River.
- **Third,** determine the characteristics of the pallid sturgeon population in the Platte River. This included an analysis of their age and growth, length weight relationship and morphometrics.

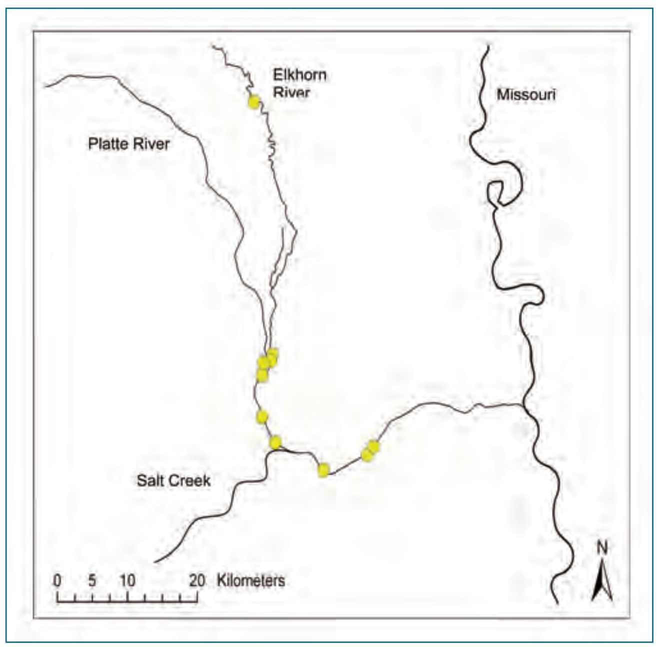


Figure 4.1. Locations of confirmed pallid sturgeon captures within the Platte River basin by anglers prior to this study (1979 – 2000).

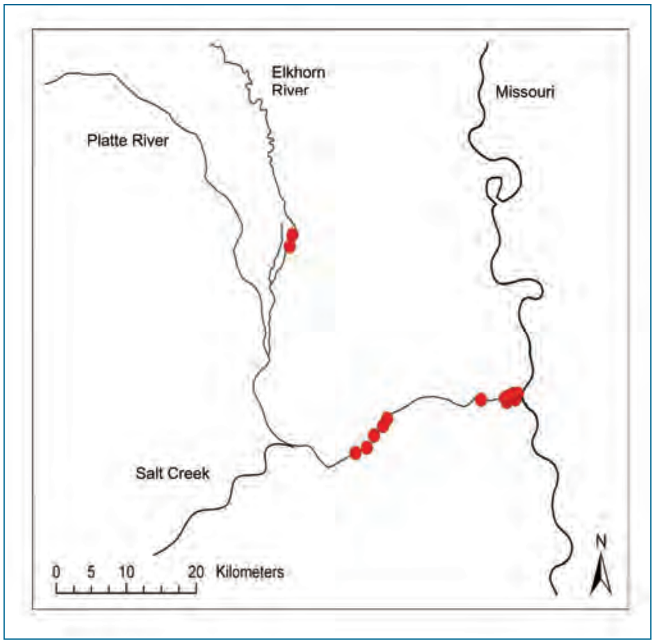


Figure 4.2. Locations of confirmed pallid sturgeon captures within the Platte River basin during this study (2001 – 2004).

METHODS

Sampling efforts for juvenile and adult pallid sturgeon used a variety of gears to sample as wide a range of habitats as possible in the lower Platte River. The gears used for pallid sturgeon were primarily, drifted gill nets, drifted trammel nets, trotlines, and trawls, but stationary gill nets, seines and minnow traps were also used. Detailed descriptions of the deployment and use of these gears is described in Chapter 2 of this report.

When a Pallid sturgeon was captured, it was weighed, measured (fork length) and measured for morphometric analysis (Sheehan et al. 1999). All pallid sturgeon were tagged with a PIT tag if scanning showed that they did not already have one. Individuals that were large enough (>300 g) were implanted with a uniquely tuned radio transmitter tag, released in the vicinity of their capture and monitored from surface boats and aircraft on a regular basis. These methods are detailed in Chapter 2 of this report.

RESULTS AND DISCUSSION

A total of 15 pallid sturgeon were captured, 13 during this study and two fish, captured by the University of Nebraska Statewide stream fisheries inventory crew during their sampling of the lower Platte River. One specimen, captured on a trotline on 2 April 2004 was identified as a pallid sturgeon, but then it was lost before it could be measured. Habitat data were collected on the 13 fish from this study. The same habitat data were not collected on the 590 mm pallid sturgeon captured on 23 July 2004 by the Statewide inventory crew because they used different measurement methodologies. This fish was not scanned for a PIT tag. However, the 363 mm, 150 gram pallid sturgeon caught on September 25, 2004 was scanned for a PIT tag and the habitat where it was caught was measured according to the pallid sturgeon study protocol. This fish was tagged with PIT tag number 4311506852 and released. Pallid sturgeon were caught in drifted gill nets (1), drifted trammel nets (4), and with trotlines (10). Most of the captures occurred in the spring of the year with the most fish being captured in April (9) and May (4). Table 4.1 provides the time and capture locations of all pallid sturgeon captured during this study and includes two pallid sturgeon captured by the statewide stream fisheries inventory project on 23 July 2004 and 25 September 2004. The specimens identified as “wild” showed no evidence of any type of tag, but it is possible that a PIT tag may have been lost.

Radio implanted pallid sturgeon:

Pallid sturgeon 621, a female (880 mm, 2.45 kg), was captured on a trot line, implanted, tagged with PIT tag 115551734A, and released near Louisville, Nebraska at RM 16.2 on May 3, 2001 (Figure 4.3). Three days later (May 6, 2001) this fish was located 0.95 km downstream of the release site. Some local movement was observed, however the pallid remained within 0.25 km of this location from 6 May through 24 May. Between 3 May and 29 May, this fish moved at an average rate of 150 m/d, while from 29 May to June 9, 2001 it moved at an average downstream rate of 1,940 m/d. This pallid sturgeon resided in the Platte River a minimum of 37 days, entering the Missouri River on 9 June 2001. This fish was considered to be a wild fish as it showed no identification tags or markings upon capture.

Pallid sturgeon 721 (1,030 mm, 4.1 kg. sex unknown), was captured on 23 May 2002 in a drifted gill net 800 m upstream from the capture site of pallid sturgeon 621 (Figure 4.4). This fish was implanted, tagged with PIT tag 422D7E243F, and released at Louisville at RM 16.2 and located 14.8 km downstream of the release site five days later. This pallid sturgeon resided in the Platte River at least 8 days, entering the Missouri River on 30 May 2002. This fish moved downstream at an average rate of 3,250 m/d. This fish was likely a wild fish as it showed no identification tags or markings upon capture. General inspection during surgical implantation was unable to determine the sex of this fish. Because of the rapid downstream movement, it may have already spawned, but we were unable to confirm this.

Pallid sturgeon 542 (788 mm, 1.8 kg, sex unknown), was captured on a trotline, implanted, tagged with PIT tag 43114E287B, and released 3 April 2003 upstream of the mouth of the Platte River at RM 3.70 (Figure 4.5). This fish remained within 1 km of the release site until 23 April; however, by 27 April the fish had entered the Missouri River. In comparison with pallid sturgeon tracked during 2001 and 2002, fish 542 entered the Missouri River considerably earlier in the year. Early movement out of the Platte River was possibly influenced by increased spring 2003 water temperatures. During the second week in April of 2003 river temperatures exceeded 20°C. Temperatures in the Platte River during 2001 and 2002 did not exceed 20°C until the second week of May. This fish was likely a wild fish as it had no identification tags or markings upon capture.

Pallid sturgeon 291 (891 mm, 2.7 kg, sex unknown) was captured on April 8, 2004 on a trotline approximately 0.6 RM

Table 4.1. Capture information for pallid sturgeon caught by this study and by the Nebraska Stream Fisheries Inventory (*) in the Platte River between 3 May 2001 and 25 September 2004.

Date Captured	Location	North GPS	West GPS	Method	Pit Tag #	Status
5/3/2001	0.5 miles downstream from Hwy 50	41.01268	96.15036	Trotline	115551734A	Wild
5/23/2002	0.5 mi upstream from Hwy 50	41.01027	96.1677	Gill net	422D7E243F	Wild
4/3/2003	1 mile upstream from Hwy 75	41.06188	95.95645	Trotline	43114E287B	Wild
4/2/2004	4 miles upstream from Hwy 75	41.0527	95.98572	Trotline	unknown	unknown
4/7/2004	near Schilling WMA	41.05292	95.88122	Trotline	444411282B	Stocked
4/8/2004	near Schilling WMA	41.05778	95.88575	Trotline	4262274C51	Stocked
4/8/2004	near Schilling WMA	41.0568	95.88419	Trotline	4311594D2B	Wild
4/13/2004	near Schilling WMA	41.05703	95.88486	Trotline	424E754E2A	Stocked
4/14/2004	near Schilling WMA	41.05743	95.89998	Trotline	431156624B	Wild
4/15/2004	1.25 miles downstream from Hwy 75	41.05693	95.90102	Trotline	4442685D64	Stocked
4/15/2004	1.25 miles downstream from Hwy 75	41.05693	95.90102	Trotline	43115B1A46	Wild
5/13/2004	near Cedar Creek, NE	41.05377	96.1018	Trammel net	44435F0919	Stocked
5/13/2004	near Cedar Creek, NE	41.05168	96.1082	Trammel net	44233E4D32	Stocked
7/23/2004*	2 miles upstream from Hwy 50	40.99528	96.2121	Trammel net	unknown	unknown
9/25/2004*	4 miles upstream from Hwy 75	41.05972	95.96324	Trammel net	4311506852	Wild

upstream from the mouth of the Platte River. It was implanted, tagged with PIT tag 4311594D2B, and released at that location (Figure 4.6). This fish was tracked on four different occasions before it entered the Missouri River. This fish was likely a wild fish as it showed no identification tags or markings upon capture.

Pallid sturgeon 910 (494 mm, 408g, sex unknown) was captured on 8 April 2004 on a trotline 0.6 RM upstream of the mouth of the Platte River and released at the site where it was captured. This pallid sturgeon (PIT tag number: 4262274C51) was hatched at Garrison National Fish Hatchery on 26 June 2001 and stocked at Boonville, MO (RM 195.1) on 3 April 2002. It was 200mm long when it was tagged. When we caught this fish on a trotline on 8 April 2004 near the mouth of the Platte River it had been at large for 736 days and had traveled a minimum of 399.9 miles. During that time it had grown 294mm in length. Since this fish was age 5 when it was captured its sex could not be determined. This fish was not located again after it was released.

Pallid sturgeon 260 (695 mm, 1.0 kg, sex unknown) was captured on 13 April 2004 on a trotline 0.72 RM upstream of the mouth of the Platte River and was released at this point (Figure 4.7). This pallid sturgeon was a recapture (PIT tag number: 424E754E2A) that had been stocked in the Missouri River at Boonville, Missouri (RM 195.1) on 25 April 2002. This fish had been at large for 719 days and had traveled a minimum of 400 miles before we caught it. It had been hatched on June 14, 1999 at the Gavins Point Fish Hatchery and it was 580mm long and weighed 860 grams when it was tagged. During its time at large this fish had grown 115mm in length and gained about 140 grams in weight. Since this fish was age 5 when captured it was an immature fish and its sex could not be determined. This fish was tracked one time before it entered the Missouri River two days after it was released.

Pallid sturgeon 931 (497 mm, 0.4 kg, sex unknown) was captured on 14 April 2004 on a trotline 0.8 RM upstream from the mouth of the Platte River, implanted, tagged with PIT tag 431156624B, and released at this point. This fish was not located after it was released. This fish had no PIT tags or other markings upon capture and was considered to be a wild fish.

Pallid sturgeon 231 (913 mm, 2.8 kg, sex unknown) was captured on 15 April 2004 on a trotline 0.9 RM upstream from the mouth of the Platte River (Figure 4.8). It was implanted, tagged with PIT tag 43115B1A46, and released at this point. This fish was located once and followed to the Missouri River on the same day that it was released. This fish had no PIT tags or other markings upon capture and was considered to be a wild fish.

All the pallid sturgeon implanted during April 2004 apparently moved out of the Platte River by 15 April 2004 during the time when a back-flushing operation at the Metropolitan Utilities District (MUD) water treatment plant released a white material into the river.

Recaptures of PIT tagged fish:

The pallid sturgeon recovery effort within RPMA 4 includes the stocking of hatchery reared individuals into the Missouri River and Platte River. During this study six PIT tagged pallid sturgeon were captured and their tag numbers were traced to specific hatchery sources, stocking locations and dates using the US Fish and Wildlife Service database. Two of these individuals were large enough to implant with radio transmitters and they are described in the previous section, but four were too small to implant with radio transmitters. These "recaptures" are described individually here.

The pallid sturgeon with PIT tag number 444411282B was hatched at Gavins Point National Fish Hatchery on 22 June 2002 and stocked at Bellevue, NE (RM 601.4) on 4 September 2003. It was 304 mm in length and weighed 118 grams when it was tagged. When this fish was caught on 7 April 2004 on a trotline at the mouth of the Platte River it was 333mm long and weighed 112g. This fish had been at large for 216 days and was caught about 7 miles from its point of stocking. During that time it had grown 29mm in length and lost 6g in weight.

The pallid sturgeon with PIT tag number: 4442685D64 was hatched at Gavins Point National Fish Hatchery on 22 June 2002 and stocked at Bellevue, NE (RM 601.4) on 4 September 2003. It was 251mm long and weighed 63g when it was tagged. When this fish was caught on 15 April 2004 on a trotline in the Platte River (RM 1.3) it was 284mm long and weighed 100g. This fish had been at large for 224 days and had traveled a minimum of 8.2 miles from where it was stocked before it was caught During that time it had grown 33mm in length and gained 37g in weight.

The pallid sturgeon with PIT tag number 44233E4D32 was hatched at Gavins Point National Fish National Hatchery on 22 June 2002 and stocked at Bellevue, NE (RM 601.4) on 4 September 2003. It was 287mm long and weighed 101g when it was tagged. When this fish was caught on 13 May 2004 in a trammel net run in the Platte River near Cedar Creek (RM 12.5) it was 329mm long and weighed 120grams. This fish had been at large for 252 days and had traveled a minimum of 19.4 miles before it was caught. During that time it had grown 42mm in length and gained 19g in weight.

The pallid sturgeon with PIT tag number 44435F0919 was hatched at Gavins Point National Fish Hatchery on 22 June 2002 and stocked at Bellevue, NE (RM 601.4) on 4 September 2003. It was 299mm long and weighed 105g when it was tagged. When this fish was caught on 13 May 2004 in a trammel net run in the Platte River near Cedar Creek (RM 12) it was 334mm long and weighed 119grams. This fish had been at large for 252 days and had traveled a minimum of 19.4 miles before it was caught. During that time it had grown 35mm in length and gained 15g in weight.

Habitat at capture locations:

In general, pallid sturgeon were most frequently captured in the deepest and swiftest runs of the river (Table 4.2). The depth averaged almost 1.6 m and the mean column current velocities approached 0.8 m/s. Within these areas of swift, deep water, pallid sturgeon were using bottom velocities similar to those found throughout the river. These values were above the average depths and velocities sampled by any gear type which suggests that shallow, slow moving water is not commonly selected habitat for pallid sturgeon in the lower Platte River. While these depths are not considered deep for the Missouri River, over 90% of the lower Platte River is less that 60 cm deep with an average depth of 26 cm (Peters et al. 1989). While pallid sturgeon captures were not observed in as close proximity to sandbar ledges or underwater dunes as shovelnose sturgeon, the deep runs where we captured most of the pallid sturgeon typically had a wide range of instream habitats (shallow and exposed sandbars) within 50 to 100 m of the capture locations. The overall catch rate improved substantially in 2004 (12 of the 15 fish captured) when the deepest, swiftest flow areas were targeted during sampling.

Our capture of pallid sturgeon began after the water temperature reached approximately 10 °C and stopped after it reached 17 °C (Table 4.3). Pallid sturgeon were captured in water with relatively high dissolved oxygen, high conductivity readings and a range of turbidities. These water quality variables may reflect the spring time water conditions when pallid sturgeon are moving in the Platte River or may be actively selected by the fish. At this time it is not possible to differentiate from the data gathered.

Habitat Analysis (DRIFTED GILL NETS AND TRAMMEL NETS):

Pallid sturgeon were captured in 5 of the 536 nets. Drifted gill nets and trammel nets captured pallid sturgeon at an average depth of 1.04 m, an average mean column velocity of 0.63 m/s, and an average bottom velocity of 0.37 m/s over a substrate composed primarily of sand (Table 4.2). Water temperature averaged 17.8ºC, dissolved oxygen averaged 10.1 mg/L, specific conductivity averaged 589 uS/cm and suspended solids averaged 235.5 mg/L (Table 4.3).

For statistical comparisons of pallid sturgeon habitat use, the distribution of the data within the habitat variables was not normal for any of the variables measured so the data were rank transformed. Differences between the mean habitat for

Table 4.2. Habitat data collected in association with pallid sturgeon captures (*) denotes specimens caught by the Nebraska Stream Fishery Inventory study.

Collection Method	PIT tag number	Date captured	Average Depth (m)	Average Mean Velocity (m/s)	Average Bottom Velocity (m/s)
Trotline	115551734A	5/3/2001	1.46	1.02	0.54
Trotline	43114E287B	4/3/2003	1.52	0.63	0.21
Trotline	unknown	4/2/2004	1.74	0.85	0.38
Trotline	444411282B	4/7/2004	1.63	0.99	0.37
Trotline	4262274C51	4/8/2004	2.22	1.21	0.38
Trotline	4311594D2B	4/8/2004	1.68	1.08	0.17
Trotline	424E754E2A	4/13/2004	2.42	0.37	0.29
Trotline	431156624B	4/14/2004	1.79	0.71	0.35
Trotline	4442685D64	4/15/2004	1.71	0.85	0.34
Trotline	43115B1A46	4/15/2004	1.71	0.85	0.34
Gill net	422D7E243F	5/23/2002	0.39	0.50	0.23
Trammel net	44435F0919	5/13/2004	1.51	0.74	0.46
Trammel net	44233E4D32	5/13/2004	1.92	0.76	0.17
Trammel net	unknown	7/23/2004*			
Trammel net	4311506852	9/25/2004*	0.36	0.52	0.40
		Average	1.58	0.79	0.33

Table 4.3. Water quality data measured in association with pallid sturgeon captures (*) denotes specimens caught by the Nebraska Stream Fishery Inventory study.

PIT tag number	Date captured	Water Temp (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)
115551734A	5/3/2001	17.2	8.9	745.5	336	
43114E287B	4/3/2003	17.2	11.1	542.5	110.5	92.8
unknown	4/2/2004	12.9	10.7	576.5	153	89.9
444411282B	4/7/2004	15.5	12.1	635.5	158.5	75.1
4262274C51	4/8/2004	15.8	11.8	574.0	129	64.8
4311594D2B	4/8/2004	16.3	12.6	634.0	129	64.8
424E754E2A	4/13/2004	9.9	15.8	636.5		
431156624B	4/14/2004	12.3	12.5	626.5	168.5	50.4
4442685D64	4/15/2004	14.4	11.7	648.5	115.5	45.8
43115B1A46	4/15/2004	14.4	11.7	648.5	115.5	45.8
422D7E243F	5/23/2002	16.6	11.9	617.0		
44435F0919	5/13/2004	13.3	9.5	548.0	164	299
44233E4D32	5/13/2004	13.4	12.0	561.0	307	292
Unknown*	7/23/2004	24.9	7.0	541.0		110
4311506852*	9/25/2004	20.8	10.0	678.0		1040
	Average	15.0	11.6	619.4	171.5	196.4

nets catching pallid sturgeon and in nets not containing pallid sturgeon using Mann-Whitney t-test on ranks were not observed for the variables of depth ($p = 0.98$), mean column velocity ($p = 0.56$), bottom velocity ($p = 0.90$), dissolved oxygen ($p = 0.44$), specific conductivity ($p = 0.74$), total suspended solids ($p = 0.94$) or daily mean discharge ($p = 0.95$). The only variable to show a difference in use was temperature ($p = 0.02$). The pairwise comparisons showed that nets where fish were caught had lower median temperatures (median = 13.4 °C) than either all nets (median = 24.6 °C) or nets without pallid sturgeon (median = 24.6 °C). There was no statistical difference between depths measured in all nets and nets without pallid sturgeon. The results of these analyses must be interpreted cautiously due to the low sample size for pallid sturgeon.

Habitat Analysis (TROTLINES):

Trotlines proved to be our most effective gear for catching pallid sturgeon with 10 of the 15 fish captured coming from trotline sets. The majority of the pallid sturgeon caught on trotlines were captured in the lower 10 km of the river, early in the year, on trotlines set in deep swift waters. The trotlines captured all sizes of both wild and stocked pallid sturgeon. In the spring of 2004, we specifically targeted the deepest and swiftest waters in the mouth of the Platte River and captured 9 pallid sturgeon as a result.

Pallid sturgeon were captured in 9 of the 223 trotlines set in the Platte River. Trotlines captured pallid sturgeon at an average depth of 1.8 m, an average mean column velocity of 0.86 m/s and an average bottom velocity of 0.34 m/s over a substrate composed primarily of sand (Table 4.2). Water temperature averaged 14.6ºC, dissolved oxygen averaged 11.9 mg/l, specific conductivity averaged 496.8 uS/cm and suspended solids averaged 145.7 mg/L (Table 4.3). The data for the habitat variables for depth, temperature, dissolved oxygen, specific conductivity, total suspended solids, and discharge were not normally distributed, so the data were rank transformed for statistical comparisons of pallid sturgeon habitat use. Mean column and bottom velocity data were normally distributed, and therefore, not transformed. Differences between the mean habitat for trotlines which caught pallid sturgeons and trotlines not containing pallid sturgeons using Mann-Whitney t-test on ranks (or t-test on non-transformed data) were observed for depth ($p = 0.02$), but not for the other variables (mean column velocity $p = 0.12$, bottom velocity $p = 0.84$, temperature $p = 0.66$, dissolved oxygen $p = 0.35$, specific conductivity $p = 0.85$, total suspended solids $p = 0.82$ or daily mean discharge $p = 0.26$). The pairwise comparisons for depth showed that trotlines where fish were caught were deeper (median = 1.7 m) than either all nets (median = 1.3 m) or nets without pallid sturgeon (median = 1.3 m). The results of this analysis must be interpreted cautiously due to the low sample size for pallid sturgeon.

Water depth seems to be the most widely measured variable recorded for catches of pallid sturgeon in published reports. Clancey (1990) caught pallid sturgeon from the tail race of Fort Peck reservoir on the Missouri river at depths ranging from 1.2 to 3.7m. Watson and Stewart (1991) caught them from the Missouri and Yellowstone Rivers at depths between 0.6 and 14.5m, while Constant et al. (1997) caught them at an average depth of 15.2m from a constructed channel of the Atchafalaya River in Louisiana. In the lower Mississippi River pallid sturgeon are typically caught on trotlines in water 50 to 75 feet deep. By comparison, pallid sturgeon in the Platte River are captured in water depths at the lower end of those measured by other studies.

Velocity measurements associated with pallid sturgeon captures are relatively uncommon. Clancey(1990) measured mean column velocities ranging from 0.46 to 0.96m/s where pallid sturgeon were caught in the Fort Peck reservoir tail race. This range matches well with velocities where pallid sturgeon were caught in the Platte River. Other studies use descriptors ranging from swift to slow to describe the habitats of capture. This may be due to the difficulty of getting accurate measurements of velocity in areas that are deep and often swift.

Specific assessments of other habitat variables at the times when pallid sturgeon were collected are sparse and are generally expressed in descriptive terms. Sandy substrates and turbid water are the two most frequently mentioned characteristics. The values measured in association with Platte River collections agree with these conditions. Based on our experience catching pallid sturgeon, we think that water velocity is a primary factor in determining what habitat that they use once sufficient water depth and turbidity are factored into the matrix of conditions. The pallid sturgeon's selection for sandy substrates is probably related to their turbidity selection. Chemical and physical requirements for pallid sturgeon have not been sufficiently elucidated to assess where the conditions we encountered in the Platte River fit into a quality environment for this species.

Habitat use (Radio Telemetry):

The data gathered from random daily measurements around radio tagged pallid sturgeon provide a picture similar to the capture data (Tables 4.4 to 4.7). The fish were found in deep, swift water although the average depth observed was slightly shallower than that where the pallid sturgeon were captured(1.27 m as compared to 1.6 m). The habitats used by pallid sturgeon fit in the deep water, swift current velocity spatial niche (Hardy and Associates 1992). Pallid sturgeon were generally found over sand substrate and were observed within 10m of a sandbar ledge 15% of the time and among underwater dunes 76% of the time.

Pallid sturgeon are fish of large turbid rivers (Cross and Collins 1995, Bailey and Allum 1962, Lee et al.1980). Bramblett and White (2001) found them most regularly in river reaches with frequent islands and sand bars. This fits well with our observations. Hurley (1998) found them at the mouths of tributaries and Snook et al. (2002) found them at the downstream end of sand bars where currents converge. Depth of water used by telemetry located pallid sturgeon range from less than 1 m (Bramblett and White 2001, Snook et al. 2002) to 12 m (Hurley 1998). Depth use in the Platte River is undoubtedly truncated by availability of deeper water, but we found that pallid sturgeon used deeper water at rates higher than expected by chance. Bottom velocity use ranged from 0 to 0.97m/s (Bramblett and White 2001 and

Table 4.4. Habitat variables measured in association with pallid sturgeon during random daily telemetry contacts.

Fish	Date	Average depth (m)	Average mean velocity (m/s)	Average bottom velocity (m/s)	Average % Silt	Average % sand	Average % gravel	Presence of ledges	Presence of dunes	Daily mean discharge (CFS)
621	5/4/2001	1.83	1.14	0.59	0	100	0			16000
621	5/6/2001	1.49	0.76	0.54	0	100	0			31500
621	5/9/2001	1.24	0.62	0.35	0	100	0			23700
621	5/14/2001	1.40	0.76	0.54	0	100	0			13300
621	5/15/2001	0.90	0.84	0.52	26	74	0			11700
621	5/22/2001	1.00	0.75	0.57	0	100	0			12500
621	5/24/2001	1.81	0.96	0.61	0	100	0			8460
621	6/1/2001	0.96	0.78	0.59	0	100	0			11600
621	6/5/2001	0.98	0.88	0.68	0	100	0			8100
621	6/7/2001	0.73	0.76	0.46	0	100	0			8129
721	5/29/2002	1.19	0.82	0.51	0	100	0	No	Yes	7480
542	4/4/2003	1.35	0.78	0.44	0	100	0	Yes	No	7200
542	4/5/2003	1.18								7520
542	4/7/2003	0.78	0.70	0.57	0	100	0	No	No	6020
542	4/8/2003	1.20	0.99	0.48	0	100	0	No	No	5810
542	4/9/2003	1.07	0.77	0.46	0	100	0	No	Yes	6810
542	4/10/2003	0.89	0.79	0.45	0	100	0	No	Yes	6720
542	4/13/2003	0.91	0.65	0.22	0	100	0	No	Yes	7220
542	4/14/2003	1.96	1.11		0	100	0		Yes	7600
542	4/15/2003	0.62	0.40	0.26	0	100	0	Yes	Yes	9300
542	4/17/2003	1.18	0.71	0.41				No	Yes	7230
542	4/21/2003	0.62	0.58	0.30				No	Yes	6600
542	4/22/2003	1.11	0.75	0.06				Yes	Yes	6610
542	4/23/2003	0.79	0.65	0.14	0	100	0	No	Yes	6340
542	4/24/2003	1.35	1.02	0.53	0	100	0	No	No	6190
542	4/25/2003	0.84	0.71	0.42	0	100	0	No	Yes	5960
542	4/26/2003	1.51	0.86	0.48	0	100	0	No	Yes	5810

Table 4.4 (continued)

Fish	Date	Average depth (m)	Average mean velocity (m/s)	Average bottom velocity (m/s)	Average % Silt	Average % sand	Average % gravel	Presence of ledges	Presence of dunes	Daily mean discharge (CFS)
291	4/12/2004	1.11	0.61	0.40	0	100	0	No	Yes	4360
291	4/13/2004	1.47	0.78	0.30	0	100	0	No	Yes	4460
260	4/14/2004	1.13	0.52	0.21	0	100	0	No	No	4890
291	4/14/2004	1.16	0.95	0.53	0	100	0	No	No	4890
231	4/15/2004	1.74	0.73	0.44	0	100	0	No	Yes	4620

Table 4.5. Individual and combined average habitat variables measured in association with pallid sturgeon during daily random telemetry contacts.

Fish	Average depth (m)	Average mean velocity (m/s)	Average bottom velocity (m/s)	Average % Silt	Average % sand	Average % gravel	Daily mean discharge (CFS)
231	1.74	0.73	0.44	0	100	0	4620
260	1.13	0.52	0.21	0	100	0	4890
291	1.25	0.78	0.41	0	100	0	4570
542	1.08	0.76	0.37	0	100	0	6809
621	1.23	0.82	0.55	2.6	97.4	0	14499
721	1.19	0.82	0.51	0	100	0	7480
Average	1.27	0.74	0.41	0.4	99.6	0	7145

Trotline sampling of sturgeon in the Platte River.

Table 4.6. Water quality variables measured in association with pallid sturgeon during random daily telemetry contacts.

Fish	Date	Water Temp (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	Total Suspended Solids (mg/L)
621	5/4/2001	14.8	8.74	510	876
621	5/6/2001	18.2	7.54	444	1208
621	5/9/2001	19.1	8.12	504	1228
621	5/14/2001	24.0	8.41	534	466
621	5/15/2001	24.9	8.75	549	432
621	5/17/2001	24.7	8.19	610	838
621	5/22/2001	15.8	12.22	528	574
621	5/24/2001	13.2	9.65	670	270
621	6/1/2001	16.1	8.80	514	503
621	6/5/2001	16.8	9.82	675	198
621	6/7/2001	18.5	7.80	621	445
721	5/29/2002	22.0	6.71	523	1172
542	4/4/2003	9.1	9.85	641	231
542	4/5/2003	7.9	10.34	582	236
542	4/7/2003	3.5	12.20	655	213
542	4/8/2003	6.5	11.46	510	305
542	4/9/2003	7.7	11.58	500	244
542	4/10/2003	9.8	10.70	559	236
542	4/13/2003	17.6	10.50	616	
542	4/14/2003	20.9	14.51	552	167
542	4/15/2003	20.2	10.67	548	156
542	4/16/2003	19.1	15.90	565	152
542	4/17/2003	13.2	11.54	701	168
542	4/21/2003	14.2	10.93	644	238
542	4/22/2003	15.1	12.28	474	226
542	4/23/2003	15.0	11.07	573	159
542	4/24/2003	12.7	11.81	712	192
542	4/25/2003	12.9	10.32	620	76
542	4/26/2003	16.1	11.05	645	74
291	4/12/2004	10.1	18.41	640	
291	4/13/2004	9.4	12.21	589	101
260	4/14/2004	14.3	12.48	655	114
291	4/14/2004	14.3	12.48	655	114
231	4/15/2004	15.0	12.47	584	86

Table 4.7. Individual and combined average water quality variables measured in association with pallid sturgeon during daily random telemetry contacts.

Fish	Water Temp (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	Total Suspended Solids (mg/L)
231	15.0	12.47	584	86
260	14.3	12.48	655	114
291	11.3	14.37	628	108
542	13.0	11.57	594	192
621	18.7	8.91	560	640
721	22.0	6.71	523	1172
Average	15.7	11.09	591	385

Snook et al. 2002). Our observations of bottom velocity fit comfortably with these previous observations.

Pallid sturgeon tolerate temperatures from 0 to 33ºC, but no specific thermal tolerances have been published. Our permits required us to limit our sampling for pallid sturgeon to times when water temperatures were below 17ºC, but water temperatures of up to 24.9ºC were measured when a specimen was caught on 23 July 2004 and also during a telemetry survey on 15 May 2001. Bailey and Cross (1954) and Erickson (1992) state that pallid sturgeon avoid areas that are not turbid. Average total suspended solids during our study ranged from 86 to 1,172 mg/L which agrees with these general statements. Very little is known about pallid sturgeon tolerances for most water chemistry parameters, but the Missouri River and its western tributaries are generally high in dissolved solids and maintain acceptable dissolved oxygen concentrations (Galat et al. 2005a). The Platte River where pallid sturgeon were found seems to fit those standards. However, as noted local water quality problems may arise when back flushing of water treatment facilities occurs.

ASSOCIATED SPECIES:

Six species of fish were captured in the same gear along with pallid sturgeon during this study. Shovelnose sturgeon were captured on 12 of the 14 occasions when pallid sturgeon were captured. Shovelnose sturgeon were captured on 8 of the 9 trotline sets, in 1 of the 1gill nets and in 3 of the 4 trammel nets which captured pallid sturgeon. Only trammel nets caught additional fish species with pallid sturgeon. Goldeye and blue sucker were caught in 2 of 4 nets that also caught pallid sturgeon. Shortnose gar, grass carp and river carpsucker were caught in 1 of 4 nets that also caught pallid sturgeon.

MOVEMENT:

Of the 15 pallid sturgeon, only eight were large enough to be implanted with a radio transmitter. Two of these fish that we radio tagged were previously PIT tagged, indicating to us that they were hatchery reared fish. Radio tagged pallid sturgeon were located seven times from the air and 42 times from the airboat (Table 4.8). Figures 4.3-4.8 summarize the movements of the pallid sturgeon which we were able to locate via telemetry after they were implanted with transmitters and released. The female (Fish 621) was carrying eggs when it was captured on 3 May 2001 (Figure 4.3). Since this fish remained near Louisville (RM 15.5) for nearly a month before rapidly moving downstream it is tempting to assume that it was in the Platte River to spawn. Unfortunately, we have no direct confirmation of spawning by this fish. However, larval sturgeon were captured in samples collected on 23 May 2001 at RM 27.9. This was just prior to the time when fish 621 started moving downstream. Fish 721 (Figure 4.5) may have been a spent female, because no eggs were detected when it was implanted with the transmitter at RM 15.5 on 23 May 2002. This fish moved downstream between each telemetry location and exited the Platte River on 30 May 2002. It is also tempting to interpret this fish's movements as post-spawning because a larval sturgeon was captured at RM 27.9 on 21 May 2002. Again there is no direct confirmation of this hypothesis. Fish 542 (Figure 4.6) was the only other pallid sturgeon which was detected in the Platte River for more than a couple of days. It was captured on 3 April 2003 and was last detected in the Platte River on 27 April 2003. During most of that time it remained near the location it was captured at about RM 3.0 before moving to the mouth of the Platte River. No sturgeon larvae were captured during the time when this fish was detected in the Platte River.

Of the seven pallid sturgeon that were not implanted with radio transmitters, four already carried either PIT tags, one escaped before it could be handled, one was captured by a crew that did not have authorization to implant a telemetry tag, and one showed no evidence of being tagged, but was too small to implant. The pallid sturgeon captured by the Nebraska stream inventory crew in a trammel net at River Mile 20 on 23 July 2004 was not scanned for tags. This fish was 590mm in length and was released at the same location as it was caught. The final small pallid sturgeon that was caught on 25 September 2004 carried no tags when it was caught in a trammel net at RM 4.5, and was presumed to be a wild fish. This fish was 363mm in length and weighed 150g. It was PIT tagged (4311506852) and released at the same location as it was caught.

Table 4.8. Number of pallid sturgeon locations in the Platte River, Nebraska by survey method and year from 2000 to 2004.

Common Name	Survey Method	2000	2001	2002	2003	2004	Total Number of Locations
Pallid Sturgeon	Boat	2	11	7	17	5	42
Pallid Sturgeon	Plane	-	3	1	2	1	7
	Total	2	14	8	19	6	49

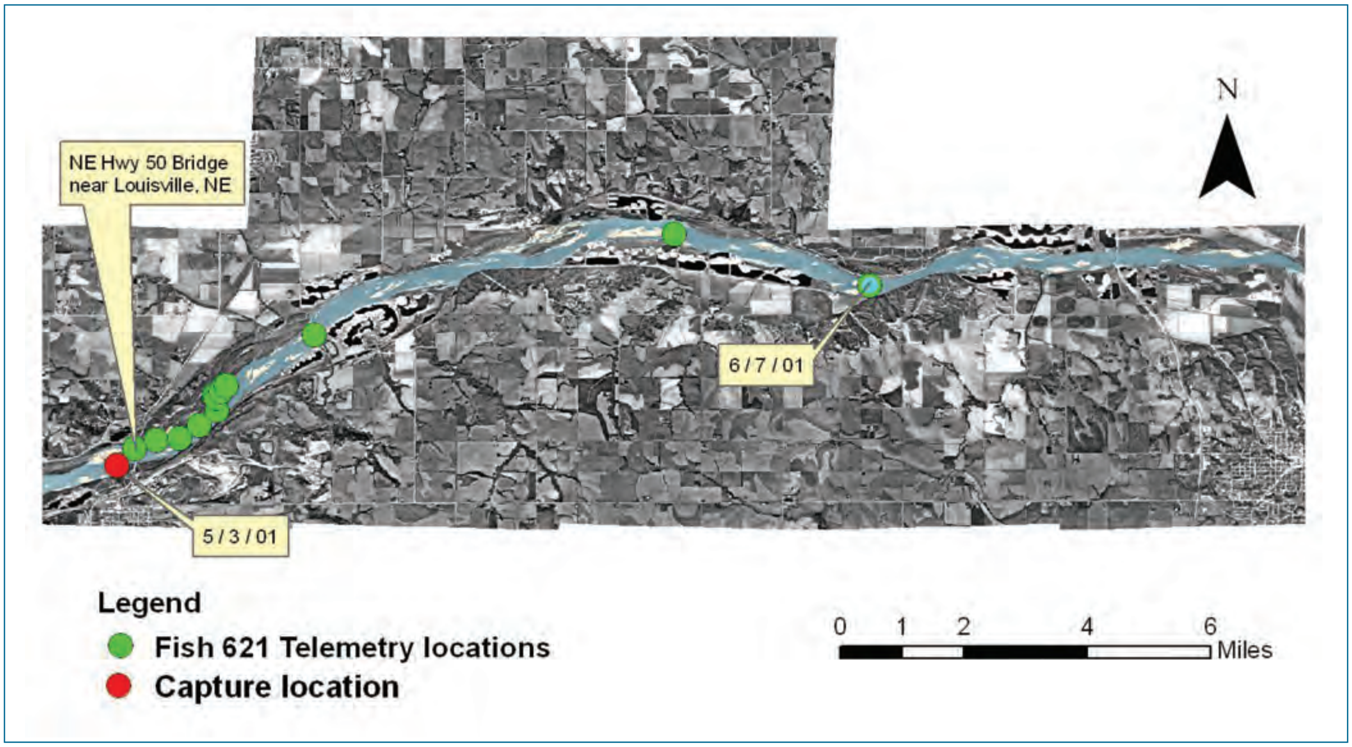


Figure 4.3. Capture and telemetry locations of pallid sturgeon #621 during May and June of 2001.

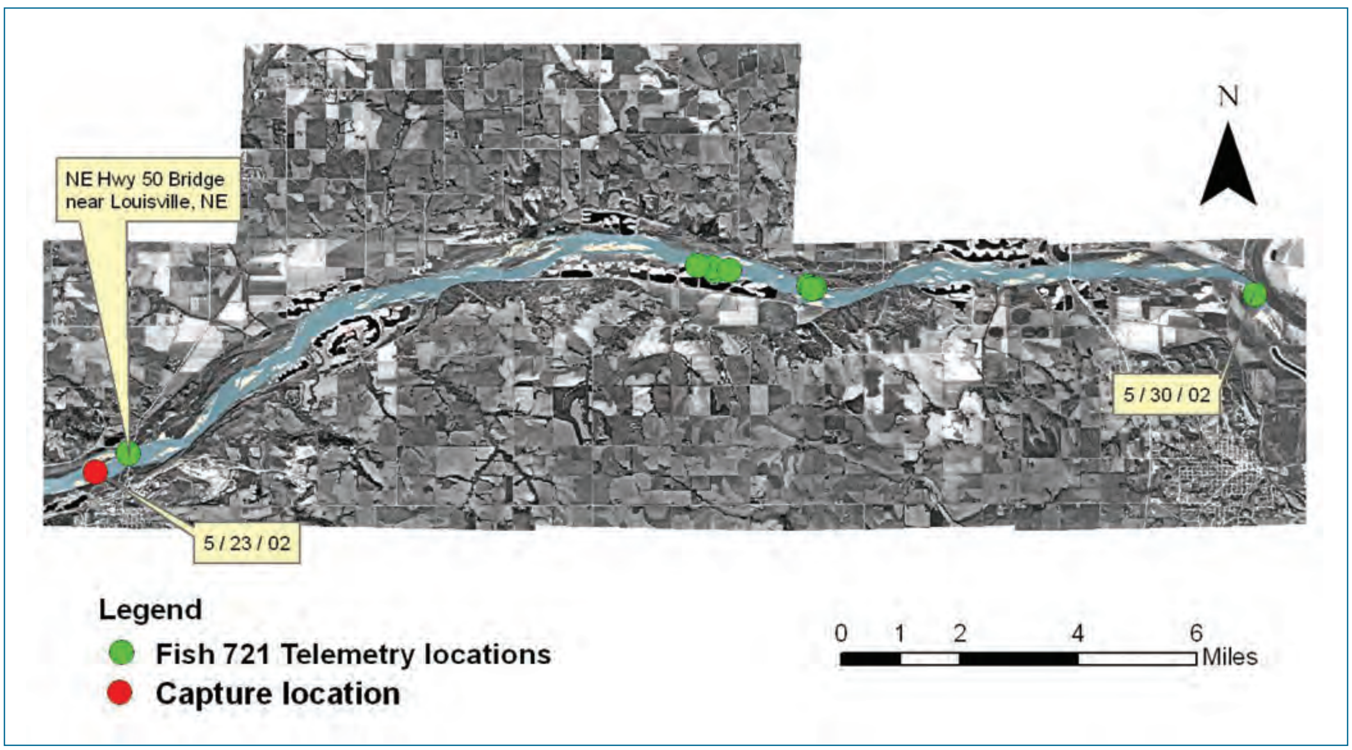


Figure 4.4. Capture and telemetry locations of pallid sturgeon #721 during May of 2002.

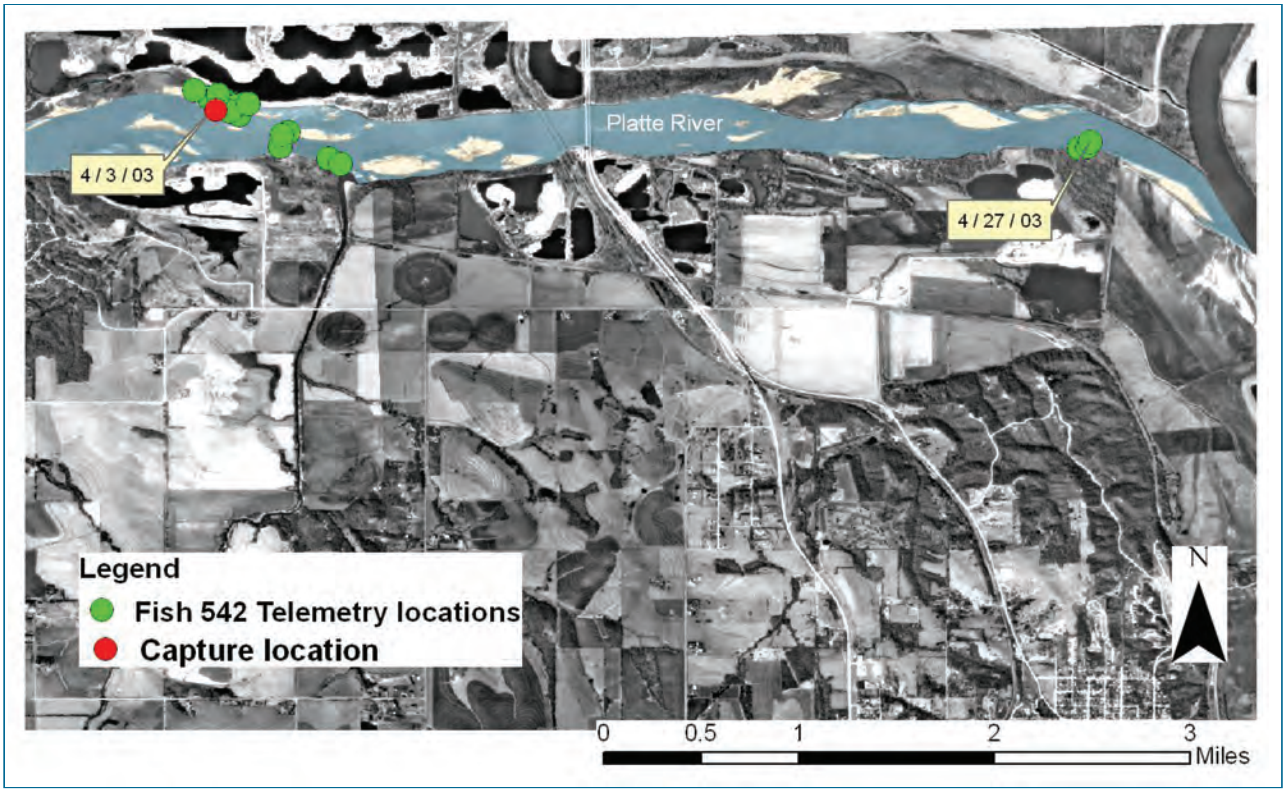


Figure 4.5. Capture and telemetry locations of pallid sturgeon #542 during April of 2003.

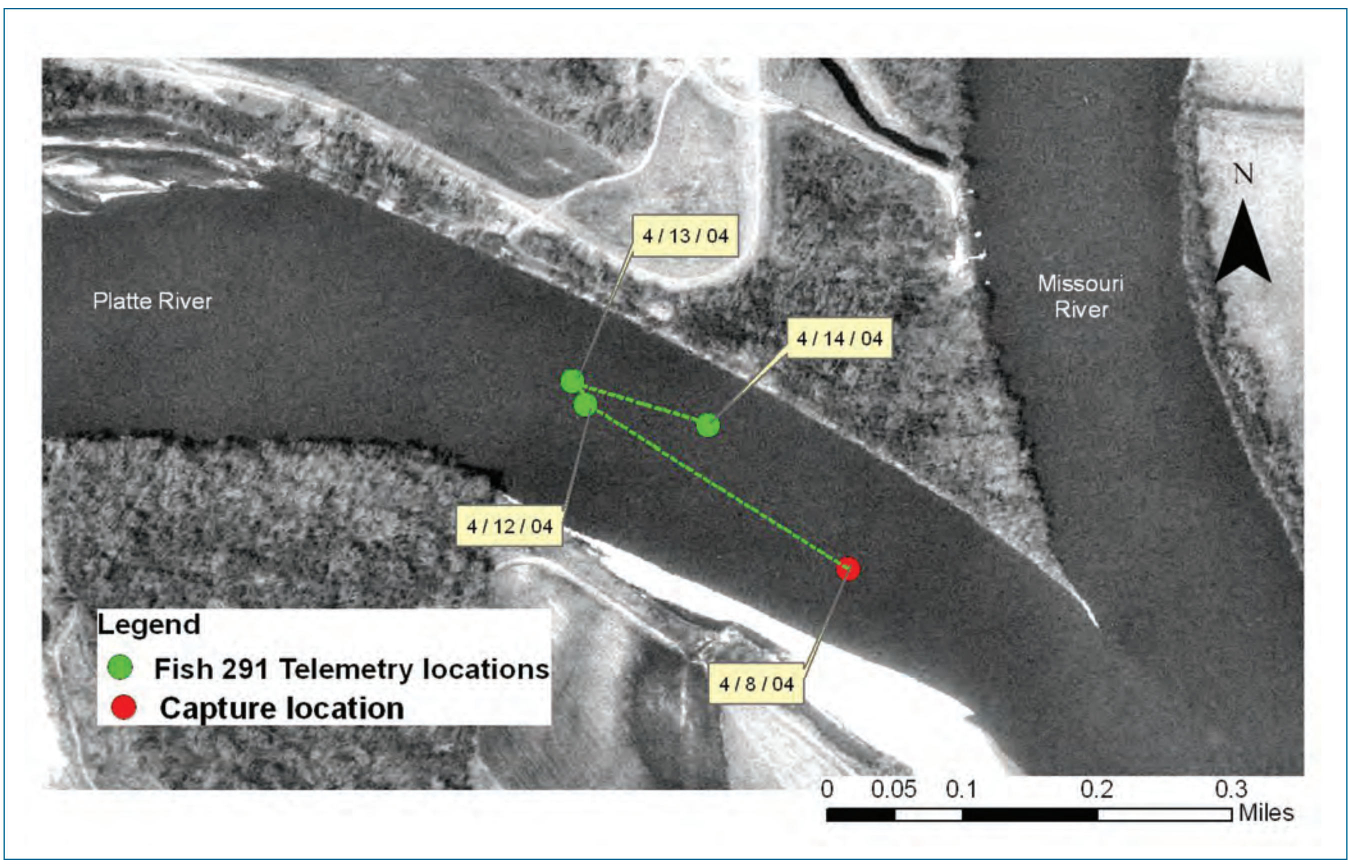


Figure 4.6. Capture and telemetry locations of pallid sturgeon #291 during April of 2004.

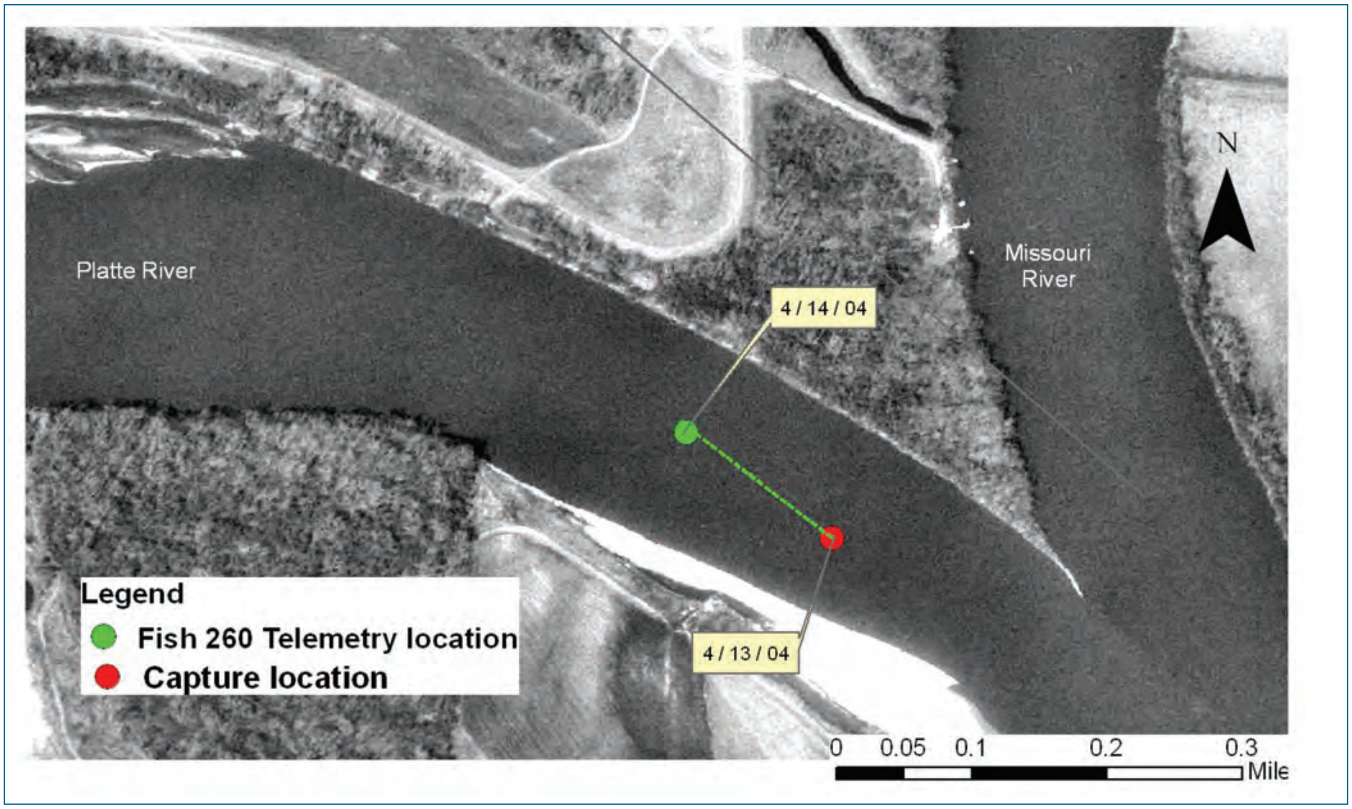


Figure 4.7. Capture and telemetry locations of pallid sturgeon #260 during April of 2004.

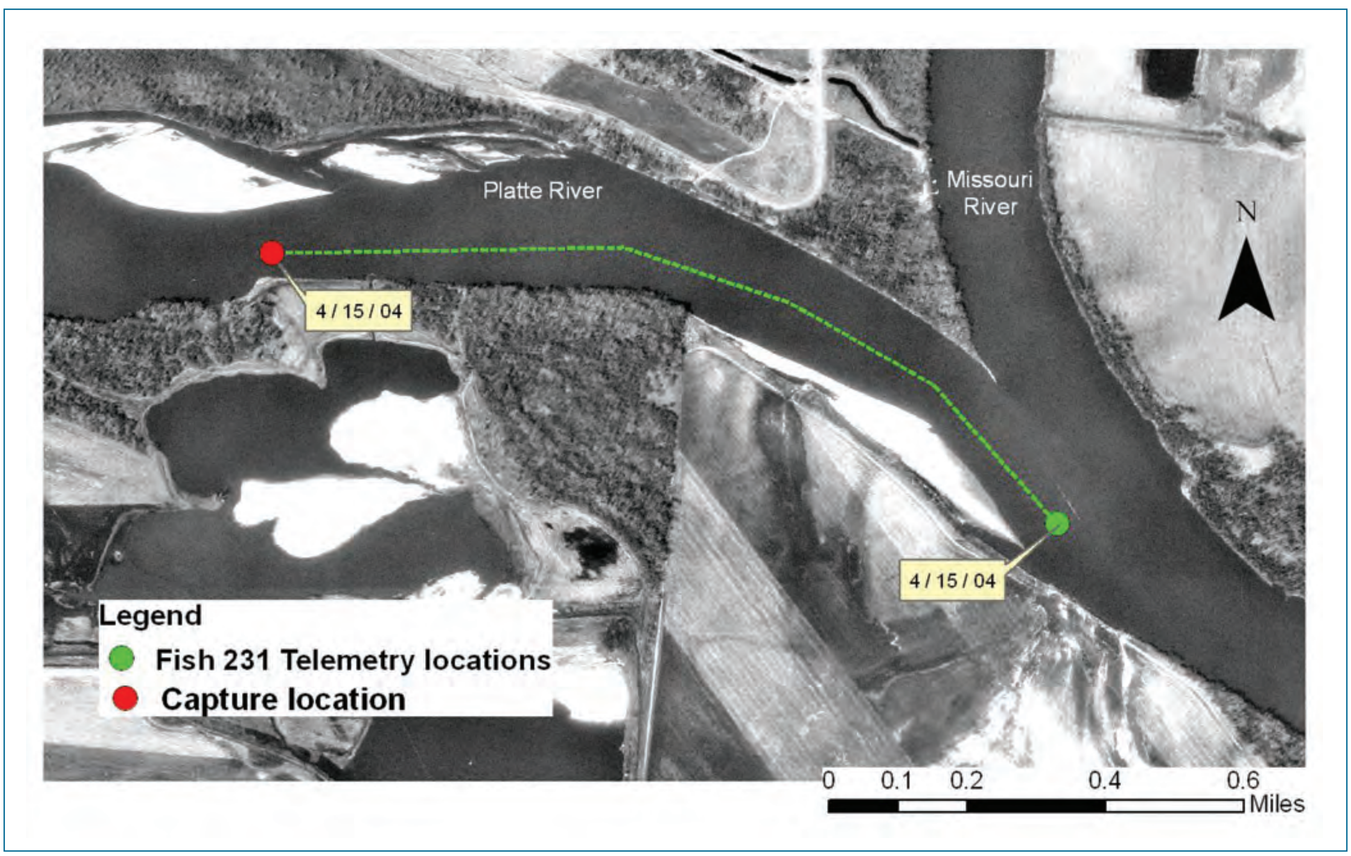


Figure 4.8. Capture and telemetry locations of pallid sturgeon #231 during April of 2004.

PALLID STURGEON MOVEMENT DISCUSSION:

Pallid sturgeon that use the Platte River appear to be mobile animals. Up to the year 2004 evidence pointed toward a conclusion that they may only be using the Platte River during the spring and early summer. This would agree with observations by Bramblett and White (2001) who found that pallid sturgeon moved upstream into the Yellowstone River from the Missouri River in the spring and downstream again later in the year. However, in 2004 one juvenile size pallid sturgeon was captured in the Platte River in July and another during September. Snook (2001) noted that two of the pallid sturgeon he was tracking during 1999 moved upstream during late September. Hofpar (1997) recorded similar movements in shovelnose sturgeon in the Platte River during the fall of 1996. Our small sample size limits our ability to make definitive statements about the number of pallid sturgeon that use the Platte River, but the fact that we caught pallid sturgeon during spring, summer and fall months of the year indicates to us that the lower Platte River is an important part of RPMA 4 (USFWS 1993), which includes all of the Missouri River downstream from Gavins Point Dam to its confluence with the Mississippi River (approximately 800 river miles).

The pallid sturgeon that carried PIT tags gave us some insights to the distances that this species travels. Four of the tagged fish had only traveled a short distance from Bellevue, NE (7-20 miles) but two of the fish we captured had traveled over 400 miles upstream from Boonville, MO to reach the Platte River. The distances moved and survival duration for pallid sturgeon provides support for two conclusions. First, pallid sturgeon stocked into the Missouri River are surviving and growing and that they do travel up tributary rivers. Second, the capture of six pallid sturgeon that were stocked into the Missouri River suggests that conditions in the Platte River are attractive to stocked pallid sturgeon. We captured 6 hatchery reared pallid sturgeon during 2004 while Krentz et al. (2005) recorded a total of 91 recaptures from all of RPMA 4. That works out to 1 recapture / 2.1 miles of river in the Platte River and 1 recapture / 8.8 miles of river in the Missouri River.

Bramblett and White (2001) reported that movement rates in the Yellowstone and Missouri rivers were highest in the spring (March 20–June 20) and lowest during the winter (21 December–19 March) for both shovelnose and pallid sturgeon. In addition, they speculated that long-range spring and summer movements by both species were associated with spawning activities. Although the pallid sturgeon in the Platte River were not tracked outside of spring months, our data support this theory. Following synchronized long-distance upstream movements by shovelnose tracked in 2001 and 2002, these radio-tagged fish were relatively sedentary between 18 May and 13 June 2001 and 14- 28 May 2002. Collection of day-old larval Scaphirhynchus at RM 27.8 on 23 May 2001 and 21 May 2002 coincided with these dates. Water temperatures during sedentary periods ranged from 17.2 to 21.6°C (2001) and from 15.2 to 25.1ºC (2002); encompassing reported temperatures for Scaphirhynchus reproduction (Moos 1978). Given this combination of evidence, reproduction by Scaphirhynchus sturgeon in the Platte River likely takes place between mid-May and early June.

Pallid sturgeon activity in the Platte River may also be attributable to reproduction. During spring months pallid sturgeon moved downstream in coordinated patterns, exhibited spring sedentary phases similar to shovelnose sturgeon, and one pallid sturgeon (fish 621) carried late-stage eggs. Although pallid sturgeon reproduction in the Platte River cannot be confirmed, additional efforts should continue to substantiate this speculation.

None of the implanted pallid sturgeon was detected moving out of the Platte River in one year and then returning into the Platte River the next year. However, this is not unexpected if they had spawned during the year when we caught them we would not expect them to return for as long as10 years to reproduce again (Keenlyne and Jenkins 1993). During the 5-year study no confirmed pallid sturgeon eggs or larval fish were sampled in the Platte River. However, as noted above Scaphirhynchus larvae were sampled.

AGE AND GROWTH:

We were not able to determine the age of pallid sturgeon captured during this study because our Endangered Species permit did not allow that. However, there were six PIT tagged pallid sturgeon caught during this study for which we have information about their age and the size at which they were released (Table 4.9). From this information we can reconstruct some growth histories and make some inferences about the growth of pallid sturgeon in the lower Platte River and adjoining portions of the Missouri River. The four fish that were at large only from age 1 to age 2 were really in the wild for about seven months through the autumn, winter and early spring and their average growth of 34.75mm reflects this short interval. Fish 910 was at large for two years, from age 1 to age 3 and grew 294mm in length. Fish 260 was released at age 3 and recaptured at age 5 during which time it grew 115mm. Fogle (1963) found that pallid sturgeon growth was rapid at first, but slowed to about 70 mm per year by age 5. This pattern seems to be holding for the PIT tagged fish we captured in the Platte River.

Although we have no specific documentation of age for the fish in which we found no PIT tags, if we use the value of 70mm/year (Fogle 1963) as an upper limit we can predict their ages. Based on these assumptions, fish 621 would be approximately age 7 or 8, fish 721 age 10 or 11, fish 542 age 6 or 7, fish 291 age 7 or 8, fish 231 age 8 or 9. The smaller untagged fish captured on 25 September 2004 is estimated to be age 2 and the 590mm fish caught on 23 July 2004 is estimated to be age 3.

Pallid sturgeon are long lived fishes. As a result of this and the fact that most of their skeletons are cartilaginous, determination of growth rates has been challenging (Morrow et al. 1998). Helms (1973), working in the Mississippi River and Fogle (1963) working in the Missouri River, found large variations in length at age for shovelnose sturgeon.

Table 4.9. Age and length of PIT tagged pallid sturgeon at time of release and capture during the study in the Platte River, Nebraska, 2000-2004.

PIT tag number (telemetry tag number)	Age		Length	
	Release	Capture	Release	Capture
444411282B	1	2	304	333
4442685D64	1	2	251	284
44233E4D32	1	2	287	329
44435F0919	1	2	299	334
4262274C51 (910)	1	3	200	494
424E754E2A (260)	3	5	580	695

Determining the age of pallid sturgeon has been limited by endangered species regulations designed to protect the species from undue stress. Hurley (1998) used hatchery reared pallid sturgeon to document the age determination by use of pectoral fin rays and found that most readings were 3 years off.

LENGTH / WEIGHT:

During the 5 years of sampling we weighed and measured 14 pallid sturgeon. The mean condition factor (K(FL)) for these sturgeon was 0.349 and the fish ranged from 284 mm to 1,030 mm fork length. The relationship between length and K(FL) exhibited a non-significant relationship ($t = 1.020$; $p = 0.328$) with a positive slope. However, the power of this test was low. The only other set of data available on lengths and weights of pallid sturgeon was for 74 hatchery reared pallid sturgeon from the Gavins Point National Fish Hatchery in Yankton, South Dakota. These fish ranged in size from 423 to 734 mm and had a mean K(FL) of 0.410. The relationship of K(FL) to fork length showed a significant, positive linear relationship ($t = 4.932$; $p < 0.001$). As expected, the condition factor of fish in the wild was lower than those from a hatchery, but because of the small sample size no statistical comparisons were made.

Indexes of condition for fish fall into two main types, the Fulton condition factors (K) and relative weight (Wr) (Anderson and Neumann 1996). The value of K is computed by multiplying the weight of a fish in grams (W) by 100,000 and dividing this product by the length of the fish in millimeters cubed (L^3). Relative weight values compare the weight of an individual fish of a given length to a standard weight for fish of that same length as calculated from a regression equation developed for that species. Carlander (1969) summarized K values for many species including pallid sturgeon. However, the values he listed were calculated using total lengths (K(TL)) rather than the fork length measurements we typically use to measure pallid sturgeon today. More recently, Quist et al. (1999) developed standard weight equations for shovelnose sturgeon that has allowed use of this method of assessing condition to be used for the management and evaluation of shovelnose sturgeon population health. However, at this time, there are no published standard weight equations for evaluation of pallid sturgeon condition. Shuman et al. (2006) developed proportional stock density and relative stock density criteria for pallid sturgeon, but did not develop standard weight equations. So, as yet there are no standard criteria by which the well-being of pallid sturgeon captured in the Platte River can be judged.

MORPHOMETRICS:

Of the 15 pallid sturgeon caught between 3 May 2001 and 25 September 2004, 13 were measured for calculation of the mCI (see Chapter 2). One specimen not measured was the pallid sturgeon that escaped before it could be measured and the other was captured by the statewide stream inventory crew on 23 July 2004. In general, the mCI did a reasonable job distinguishing the 13 pallid sturgeon that were measured from shovelnose, but there was some overlap. No fish identified in the field as a pallid sturgeon exhibited mCI values over -0.19 (Figure 4.9), but some fish that were identified as being shovelnose sturgeon exhibited mCI values as low as -0.73. All of the fish that exhibited a mCI higher than a value of -1.0 were less than 334 mm fork length and four of these were hatchery reared fish with either elastomere or PIT tags. On the other hand, the fish we classified as shovelnose sturgeon that exhibited mCI values between -0.2 and -0.73 included a mixture of sizes, but many were over 500 mm fork length. It is possible that some of these fish may be hybrids, but we have not received confirmation of any hybrids from tissue samples submitted for analysis.

Difficulties in distinguishing between pallid sturgeon and shovelnose sturgeon have led several studies to propose morphological and meristic tools as field aids. Compounding the difficulties in accurate species identification is the suspicion that the two species are hybridizing. Hybridization has led to a number of intergrades with individuals lacking definite characteristics of one species or the other. Carlson et al. (1985) and Sheehan et al. (1999), have proposed indexes that have been the basis for many field identifications. Unfortunately, several studies, including Kuhajda et al.

(2005) have found inconsistencies in identification of specimens because of the difficulties in consistently performing certain field measurements such as barbel lengths. On the other hand, Murphy et al. (2005) found that in the lower Mississippi River basin, using morphometric ratios may be useful in areas where hybridization rates are low. Based on the information that we have, we do not think that any of the pallid sturgeon we caught were hybrids.

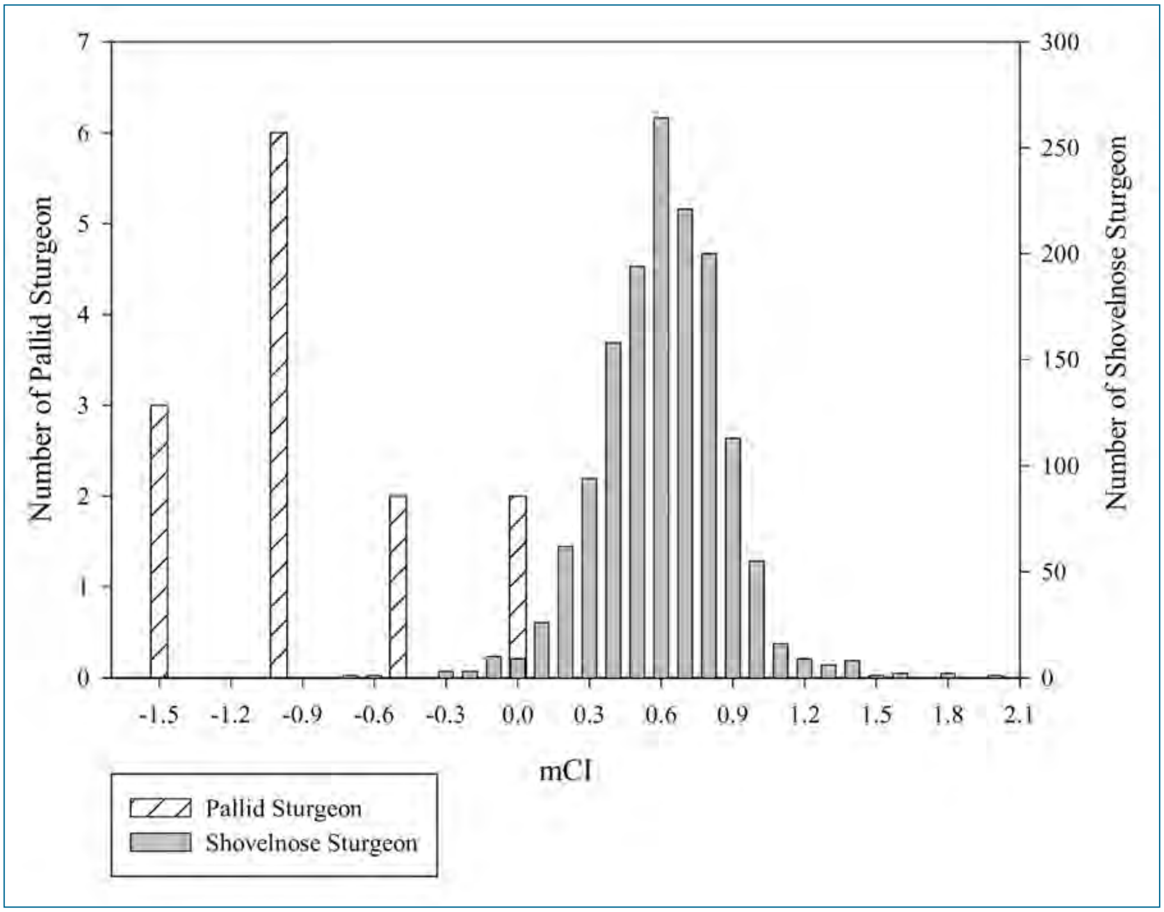


Figure 4.9. Comparison of mCI values calculated from measurements on pallid and shovelnose sturgeon from the Platte River.

Morphometric measurement of a pallid sturgeon.

CHAPTER 5

HABITAT USE, MOVEMENT AND POPULATION CHARACTERISTICS OF SHOVELNOSE STURGEON IN THE LOWER PLATTE RIVER

INTRODUCTION

Shovelnose sturgeon are tan, elongate, somewhat hunchback fish with five rows of bony plates extending the length of their bodies. Their mouth is ventral and both the upper and lower lips have four lobes. They have four barbels on the lower side of their snout (Lee et al. 1980). Shovelnose sturgeon are bottom dwelling fish of turbid rivers and are found throughout the Mississippi and Missouri River systems. Shovelnose sturgeon are more common and widespread in the Platte River than pallid sturgeon. While we do not consider shovelnose sturgeon to be surrogates for pallid sturgeon, shovelnose sturgeon are the nearest relative to pallid sturgeon and share many traits. This makes an understanding of shovelnose sturgeon habitat use, movement and population characteristics helpful to the overall management of the Platte River for both species.

Hofpar (1997) and Swigle (2003) studied habitat use and movement by shovelnose sturgeon and Shuman (2003) studied their population characteristics. The theses by Swigle (2003), Shuman (2003) and the publication by Shuman et al. (2007) comprise a major portion of the analysis presented in this chapter.

The objective is to present current information on the juvenile and adult shovelnose sturgeon population in the lower Platte River, NE. These efforts focused on three main areas of investigation.

- **First,** to determine the habitat conditions that shovelnose sturgeon use and document the species which are associated with them in these habitats.
- **Second,** to determine the movement patterns of shovelnose sturgeon into, within and out of the Platte River.
- **Third,** to determine the characteristics of the shovelnose sturgeon population in the Platte River. This included an analysis of their age and growth, length weight relationships, morphometric characteristics and population density.

METHODS

Sampling efforts for juvenile and adult shovelnose sturgeon used a variety of gears to sample a range of habitats in the lower Platte River. The gears used for shovelnose sturgeon were primarily, drifted gill nets, drifted trammel nets, trotlines and trawls, but stationary gill nets, seines and minnow traps were also used. Details on deployment and use of these gears are described in Chapter 2 of this report.

Distribution:

GPS locations were recorded for each sample collected. These locations were used to describe the distribution of shovelnose sturgeon within the lower Platte River. The number and catch per unit area of shovelnose sturgeon captured in the drifted nets was tabulated to examine local distributional patterns.

Habitat Use:

Habitat use for each species was described by comparing samples with shovelnose sturgeon to samples without shovelnose sturgeon for each sampling gear. Where normality and equality of variance of the data existed, the means were compared with a t-test. Where normality and equality of variance did not exist, data were rank transformed and compared with a Mann-Whitney Rank Sum Test. For telemetry data, each random observation was considered to be independent even when gathered on the same fish on different days. To describe the habitat use data for telemetry observations the median, 25% and 75% values are reported for each parameter.

Additionally, depth and mean column velocity was analyzed using a bivariate table with four categories of depth and four categories of mean column velocity. First, utilization of the habitat was determined by tabulating the number of captures for each cell in the table, and then calculating the percent frequency of each cell in the table. Selection of the depth and velocity combinations was determined by dividing the percent frequency of occurrence in each cell with the percent frequency of the sampling effort for that cell (see sampling chapter for data on percent frequency of the sampling effort). For the telemetry data, observations of habitat use were compared to the general habitat availability collected during past research by NGPC. The habitat selection was normalized by dividing each cell value by the sum of all cell values. These values were standardized to a scale of 0 to 1 by dividing each cell value by the largest cell value (Bovee and Milhous 1978, Peters et al. 1989). In cases where undefined numbers would result in division by zero, the value was replaced with a zero.

Associated Species:

Associated species are those species captured in samples with shovelnose sturgeon. We considered that those species which were captured more frequently with the shovelnose sturgeon to be more highly associated than those which were less frequently captured with shovelnose sturgeon.

Movement:

GPS locations were recorded for each sample collected. All shovelnose sturgeon were scanned for a PIT tag to determine if they had been captured in the past. If they were untagged, the fish was given a unique numbered PIT tag. Selected individuals that were large enough (>300 g) were implanted with a uniquely tuned radio transmitter tag, released in the vicinity of their capture and monitored from boats and aircraft on a regular basis. These methods are detailed in Chapter 2 of this report.

We recorded the tag number, location and date of telemetry contacts for each shovelnose sturgeon. We tallied the number of telemetry contacts for each shovelnose sturgeon for each survey platform in each year. To determine the distance moved for an individual fish, we measured the minimum linear distance along the river channel from ortho-rectified aerial images of the river. The distance moved was divided by the number of days between contacts to calculate daily movement rate. For individual shovelnose sturgeon with more than 2 observations within a month, we calculated average monthly movement. The overall average monthly movement was the average of all individual monthly movement rates. For recaptured fish, we determined their minimum distance traveled and calculated their time at large.

Age and Growth:

Shovelnose sturgeon were measured for fork length and pectoral fin rays were removed from a subset of the shovelnose sturgeon for determination of age following protocols outlined by Devries and Frie (1996) for determination of age and growth.

Length-Weight:

We used the length categories and relative weight equation proposed by Quist et al. (1999) to determine the structure of the shovelnose sturgeon population in the lower Platte River. Length-weight relationships were developed by plotting the $\log_{10}$ length against $\log_{10}$ weight for all specimens. Linear regression was used to calculate the intercepts and slopes of the relationships (Anderson and Neuman 1996).

Population Density:

Population estimates for shovelnose sturgeon were calculated from drifted gill and trammel net catches using a simple area-density expansion (Everhart and Youngs 1981). The length of net drift was multiplied by the average width of the net drift to determine the area sampled. The number of shovelnose sturgeon in the net was then divided by the area sampled by the net to determine the density of shovelnose sturgeon in the drift (n/m^2). A probability of capture coefficient was developed using the average number of net drifts that were required to capture a radio tagged shovelnose sturgeon at a location. The average density of shovelnose sturgeon was divided by the sampling efficiency factor and then multiplied by the surface area of the lower Platte River at mean discharge to obtain an estimate of the total population in the river. Upper and lower bounds were estimated using the 25% and 75% percentile catch values.

RESULTS AND DISCUSSION

Distribution:

Shovelnose sturgeon were captured or tracked in the lower Platte River from the confluence of the Platte River with the Missouri River (RM 0) upstream to the confluence of the Loup River (RM 103). Radio telemetry tracking indicated that some fish moved between the Platte River and the Missouri River while other shovelnose sturgeon stayed in the Platte River all year. Historical records show that shovelnose sturgeon were found as far west as Casper, WY (Evermann and Cox 1896, Baxter and Stone 1995), but in recent years shovelnose sturgeon have not been captured west of Grand Island, NE (NGPC: collection permit records).

When viewing the plots of percent frequency of occurrence of fish caught per net (Figure 5.1), the fish had a clumped distribution in the river with most nets capturing few fish and a few nets capturing many fish. This pattern may result from the nets passing through groups of fish in locally suitable habitat or the aggregations of shovelnose sturgeon may be associated with spawning or other unknown reasons. Additionally, the data clearly show that trammel nets caught more shovelnose sturgeon per drift than gill nets.

Habitat Use:

Drifted Gill Nets: Shovelnose sturgeon were captured in 177 of the 323 drifted gillnets. Drifted gill nets were generally run through areas that were expected to have sturgeon. Mean column velocity and bottom velocity was lower where drifted gill nets caught shovelnose sturgeon than where they did not catch shovelnose sturgeon (Table 5.1). Most other parameters were similar between nets with fish and nets without fish. Sand substrate was the most frequent substrate where shovelnose sturgeon were captured (Table 5.2). The selectivity analysis for the combination of depth and mean column velocity suggests that the shovelnose sturgeon select moderately deep and moderately swift currents (Tables 5.3 to 5.5).

Drifted Trammel Nets: Shovelnose sturgeon were captured in 160 of 213 drifted trammel nets. Drifted trammel nets were a more effective capture method than drifted gill nets (Figure 5.1), probably because of the ability of the nets to snag the sharp scutes of the sturgeon. The trammel nets also appear to do less physical damage to the shovelnose sturgeon than the gill nets making the drifted trammel nets a better gear for sampling shovelnose sturgeon in the lower Platte River.

There were no differences in habitat conditions between areas where shovelnose sturgeon were collected and where they were not collected when sampling with trammel nets(Table 5.6). Sand was the most frequent substrate where shovelnose sturgeon were captured (Table 5.7). The selectivity analysis for the combination of depth and mean column velocity suggests that the shovelnose sturgeon select moderately deep and moderately swift currents (Tables 5.8 to 5.10).

The lack of difference between most habitat variables and shovelnose sturgeon occurrence may be the result of drifting trammel nets in shovelnose sturgeon habitat and therefore there is little difference between nets catching shovelnose sturgeon and those nets not catching shovelnose sturgeon. Overall, trammel net data supports the use of moderate depth with moderately swift currents by shovelnose sturgeon.

When comparing the discharge between nets that captured shovelnose sturgeon and nets that did not, pairwise comparisons showed that fish were caught at lower daily discharges (median = 3,970 cfs) than nets without shovelnose sturgeon (median = 4,500 cfs). This suggests a number of possibilities. First, the efficiency of the drifted nets may decrease as discharge increases. Second, the sturgeon are more spread out at higher discharges making the chance of encounter with the net decrease. Or possibly, the shovelnose sturgeon are in different habitats than we sampled at higher discharge.

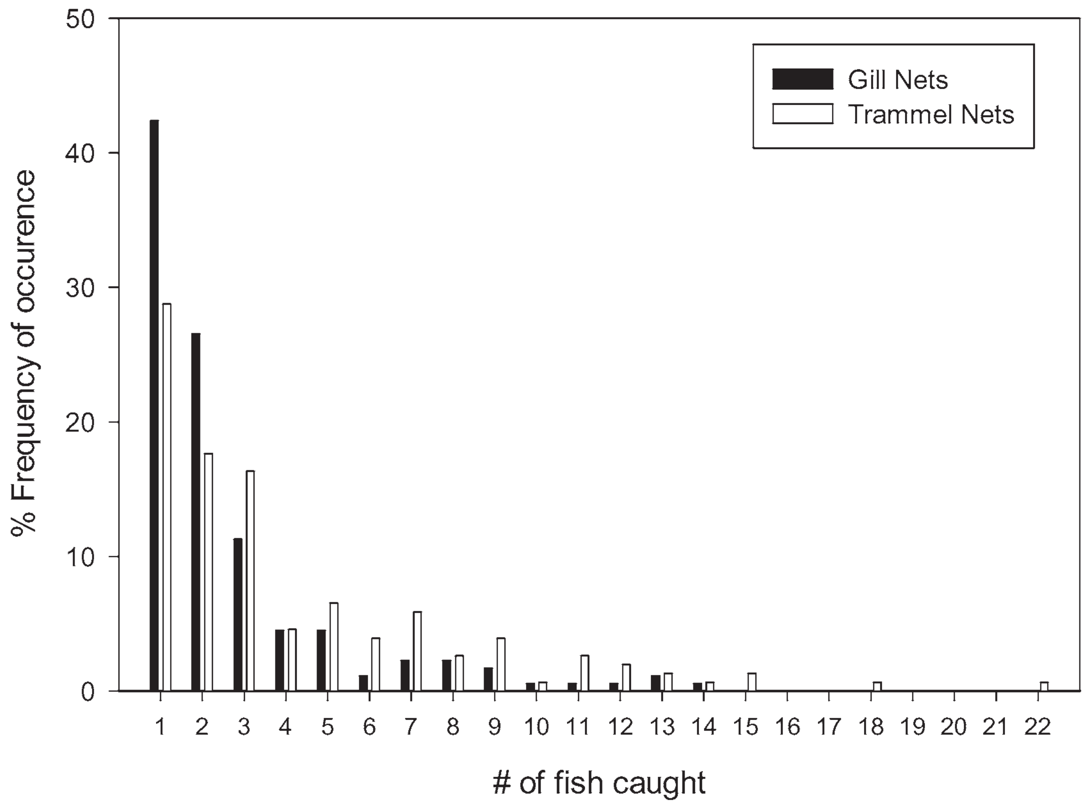


Figure 5.1. Distribution of percent frequency of occurrence of shovelnose sturgeon captured in drifted nets.

*Table 5.1. Comparisons of samples with shovelnose sturgeon to samples without for the drifted gillnet sampling in the lower Platte River, Nebraska. * Indicates where normality and equal variance of the data existed and means were compared using a t-test. (MCV= mean column velocity (m/sec), BV = bottom velocity (m/sec), Temp = temperature (ºC), DO = dissolved oxygen (mg/L), Sp Cond = specific conductivity (µS/cm), TSS = total suspended solids (mg/L)*

Parameter	Fish/no fish	Number	Missing	Median	25%	75%	p value
Depth	fish	177	19	0.60	0.50	0.76	0.52
	No fish	146	33	0.64	0.51	0.77	
MCV	fish	177	20	0.52	0.46	0.61	0.006*
	No fish	146	33	0.58	0.49	0.68	
BV	fish	177	20	0.32	0.26	0.41	0.054
	No fish	146	33	0.35	0.28	0.46	
Temp	fish	177	16	25.2	22.6	27.4	0.41
	No fish	146	6	25.2	21.7	26.9	
DO	fish	177	17	9.3	8.0	10.8	0.77
	No fish	146	9	9.5	8.3	10.5	
Specific Conductivity	fish	177	21	535	435	684	0.26
	No fish	146	10	509	442	613	
TSS	fish	177	115	254	160	396	0.78
	No fish	146	95	211	175	307	

Table 5.2. Comparison of samples with shovelnose sturgeon to samples without for substrate in the drifted gillnet sampling in the lower Platte River, Nebraska.

	Number	Missing	% sand	% gravel	% silt	% rock
Substrate fish	177	15	96.9	1.5	1.5	0.0
Substrate none	146	16	98.5	0.4	1.2	0.0

Table 5.3. Shovelnose sturgeon number captured for the categories of depth and velocity for the drifted gillnet sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	1	2	0	0	3
	0.30-0.60	6	62	9	0	77
	0.60-0.90	0	31	31	0	62
	>0.90	1	4	10	0	15
	Total	8	99	50	0	157

Table 5.4. Shovelnose sturgeon percent use for the categories of depth and velocity for the drifted gillnet in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.6	1.3	0.0	0.0	1.9
	0.30-0.60	3.8	39.5	5.7	0.0	49.0
	0.60-0.90	0.0	19.7	19.7	0.0	39.5
	>0.90	0.6	2.5	6.4	0.0	9.6
	Total	5.1	63.1	31.8	0.0	100.0

Table 5.5. Shovelnose sturgeon normalized selected habitats for the categories of depth and velocity for the drifted gillnet sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	1.00	0.50	0.00	0.00
	0.30-0.60	1.00	0.65	0.37	0.00
	0.60-0.90	0.00	0.65	0.62	0.00
	>0.90	1.00	0.57	0.43	0.00

Trotlines: Shovelnose sturgeon were captured in 139 of the 224 trotlines set in the Platte River. Trotlines were an effective capture method during the colder water periods of the year. The trotline data differs from the entanglement nets in that the shovelnose sturgeon were caught a greater depths on trotlines (median = 1.4 m). There were no differences in habitat conditions between areas where shovelnose sturgeon were collected and where they were not collected when sampling with trotlines (Table 5.11). Sand substrate was again the most frequent substrate where shovelnose sturgeon were captured (Table 5.12). The selectivity analysis for the combination of depth and mean column velocity suggests that the shovelnose sturgeon's habitat is in deep and moderately swift currents (Tables 5.13 to 5.15).

The lack of difference between most habitat variables and shovelnose sturgeon occurrence may be the result of setting the trotlines in shovelnose sturgeon habitat and therefore there is little difference between trotlines catching shovelnose sturgeon and those trotlines not catching shovelnose sturgeon. Overall, trotlines extend the depth use range for shovelnose sturgeon into some of the deepest waters available in the river at least during the colder water periods when trotlines were used to capture fish.

*Table 5.6. Comparisons of samples with shovelnose sturgeon to samples without for the drifted trammel net sampling in the lower Platte River, Nebraska. * Indicates where normality and equal variance of the data existed and means were compared using a t-test. (MCV= mean column velocity (m/sec), BV = bottom velocity (m/sec), Temp = temperature (ºC), DO = dissolved oxygen (mg/L), Sp Cond = specific conductivity (µS/cm), TSS = total suspended solids (mg/L)*

Parameter	Fish/no fish	Number	Missing	Median	25%	75%	p value
Depth	fish	160	25	0.65	0.52	0.90	0.273
	No fish	53	7	0.59	0.46	0.96	
MCV	fish	160	25	0.54	0.45	0.62	0.544
	No fish	53	7	0.52	0.42	0.63	
BV	fish	160	25	0.30	0.23	0.38	0.602
	No fish	53	7	0.29	0.23	0.41	
Temp	fish	160	22	22.1	17.8	26.3	0.717
	No fish	53	7	20.9	17.3	27.3	
DO	fish	160	24	10.1	9.0	11.9	0.466
	No fish	53	8	10.0	8.7	12.0	
Sp Cond	fish	160	25	499	405	637	0.781
	No fish	53	10	525	411	614	
TSS	fish	152	42	279	142	494	0.391
	No fish	53	23	332	214	404	
Turbidity	fish	160	48	200	74	396	0.34
	No fish	53	23	237	124	353	

Table 5.7. Comparison of samples with shovelnose sturgeon to samples without for substrate in the drifted trammel net sampling in the lower Platte River, Nebraska.

	Number	Missing	% sand	% gravel	% silt	% rock
Substrate fish	160	29	95.8	3.1	1.1	0.0
Substrate none	53	9	96.6	3.4	0.0	0.0

Table 5.8. Shovelnose sturgeon number captured for the categories of depth and velocity for the drifted trammel net sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0	5	0	0	5
	0.30-0.60	3	44	9	0	56
	0.60-0.90	0	27	13	0	40
	>0.90	0	11	21	2	34
	Total	3	87	43	2	135

Table 5.9. Shovelnose sturgeon percent use for the categories of depth and velocity for the drifted trammel net sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.0	3.7	0.0	0.0	3.7
	0.30-0.60	2.2	32.6	6.7	0.0	41.5
	0.60-0.90	0.0	20.0	9.6	0.0	29.6
	>0.90	0.0	8.1	15.6	1.5	25.2
	Total	2.2	64.4	31.9	1.5	100.0

Table 5.10. Shovelnose sturgeon normalized selected habitats for the categories of depth and velocity for the drifted trammel net sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.00	0.96	0.00	0.00
	0.30-0.60	0.69	0.86	0.74	0.00
	0.60-0.90	0.00	0.87	1.00	0.00
	>0.90	0.00	0.85	0.87	0.77

*Table 5.11. Comparisons of samples with shovelnose sturgeon to samples without for the trotline sampling in the lower Platte River, Nebraska. * Indicates where normality and equal variance of the data existed and means were compared using a t-test. (MCV= mean column velocity (m/sec), BV = bottom velocity (m/sec), Temp = temperature (ºC), DO = dissolved oxygen (mg/L), Sp Cond = specific conductivity (μS/cm), TSS = total suspended solids (mg/L)*

Parameter	Fish/no fish	Number	Missing	Median	25%	75%	p value
Depth	fish	139	23	1.40	1.12	1.77	0.023*
	No fish	85	10	1.26	0.97	1.53	
MCV	fish	139	22	0.73	0.62	0.83	0.484
	No fish	85	13	0.70	0.56	0.90	
BV	fish	139	45	0.36	0.27	0.46	0.488*
	No fish	85	23	0.35	0.26	0.47	
Temp	fish	139	5	14.2	11.8	16.2	0.748
	No fish	85	4	13.9	8.5	16.6	
DO	fish	139	7	11.0	10.5	12.0	0.265
	No fish	85	10	11.5	10.6	12.2	
Sp Cond	fish	139	9	595	549	661	0.421
	No fish	85	5	607	531	725	
TSS	fish	139	38	159	121	214	0.087
	No fish	85	26	147	113	179	
Turbidity	fish	139	51	77	56	116	0.106
	No fish	85	32	65	50	98	

Table 5.12. Comparison of samples with shovelnose sturgeon to samples without for substrate in the trotline sampling in the lower Platte River, Nebraska.

	Number	Missing	% sand	% gravel	% silt	% rock
Substrate fish	139	14	99.2	0.2	0.2	0.4
Substrate none	85	6	97.5	0.3	1.5	0.6

Table 5.13. Shovelnose sturgeon number captured for the categories of depth and velocity for the trotline sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0	0	0	0	0
	0.30-0.60	0	0	0	0	0
	0.60-0.90	0	7	6	1	14
	>0.90	1	16	70	15	102
	Total	1	23	76	16	116

Table 5.14. Shovelnose sturgeon percent use for the categories of depth and velocity for the trotline sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.0	0.0	0.0	0.0	0.0
	0.30-0.60	0.0	0.0	0.0	0.0	0.0
	0.60-0.90	0.0	6.0	5.2	0.9	12.1
	>0.90	0.9	13.8	60.3	12.9	87.9
	Total	0.9	19.8	65.5	13.8	100.0

Table 5.15. Shovelnose sturgeon normalized selected habitats for the categories of depth and velocity for the trotline sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.00	0.00	0.00	0.00
	0.30-0.60	0.00	0.00	0.00	0.00
	0.60-0.90	0.00	0.42	0.10	0.05
	>0.90	0.39	0.61	1.00	0.69

Trawls: Shovelnose sturgeon were captured in 27 of the 157 trawls run in the Platte River. Trawl runs captured shovelnose sturgeon in water with slower bottom velocities than those run that did not capture sturgeon (Table 5.16). Tests for all other habitat variables measured showed no differences between runs that captured sturgeon and runs that did not. Shovelnose sturgeon were collected over gravel more frequently in trawl samples than in any other gear type, but still were captured over sand substrates 87.8% of the time (Table 5.17). The selectivity analysis for the combination of depth and mean column velocity supports the description of the shovelnose sturgeon's habitat in deep and moderately swift currents (Tables 5.18 to 5.20). This lack of difference between the habitat variables and shovelnose sturgeon occurrence within trawls may be the result of running the trawls in shovelnose sturgeon habitat.

Radio Telemetry: Shovelnose sturgeon were located 799 times during airboat surveys and 520 times during airplane surveys (Table 5.21). Shovelnose sturgeon were located during each month of the year. The analysis of habitat use included observations on 29 individual shovelnose sturgeon. On average, 29 surveys of habitat use were performed on each shovelnose sturgeon (range = 3 - 88).

*Table 5.16. Comparisons of samples with shovelnose sturgeon to samples without for the trawl sampling in the lower Platte River, Nebraska. * Indicates where normality and equal variance of the data existed and means were compared using a t-test. (MCV= mean column velocity (m/sec), BV = bottom velocity (m/sec), Temp = temperature (ºC), DO = dissolved oxygen (mg/L), Sp Cond = specific conductivity (µS/cm), TSS = total suspended solids (mg/L)*

Parameter	Fish/no fish	Number	Missing	Median	25%	75%	p value
Depth	fish	27	0	1.23	1.04	1.62	0.345
	No fish	130	2	1.13	0.79	1.63	
MCV	fish	27	1	0.68	0.52	0.81	0.641*
	No fish	130	18	0.67	0.53	0.85	
BV	fish	27	1	0.27	0.17	0.37	0.015
	No fish	130	21	0.35	0.23	0.48	
Temp	fish	27	2	24.0	22.7	25.2	0.393
	No fish	130	8	24.8	21.2	26.4	
DO	fish	27	2	9.3	8.2	11.2	0.973*
	No fish	130	8	9.3	8.3	10.4	
Sp Cond	fish	27	2	585	537	705	0.823
	No fish	130	8	607	469	937	
TSS	fish	27	10	672	133	1090	0.321
	No fish	130	42	177	107	1224	

Table 5.17. Comparison of samples with shovelnose sturgeon to samples without for substrate in the trawl sampling in the lower Platte River, Nebraska.

	Number	Missing	% sand	% gravel	% silt	% rock
Substrate fish	28	1	87.8	8.5	1.9	1.9
Substrate none	129	9	93.8	4.5	0.4	1.2

Table 5.18. Shovelnose sturgeon number captured for the categories of depth and velocity for the trawl sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0	0	0	0	0
	0.30-0.60	0	0	0	0	0
	0.60-0.90	0	6	0	0	6
	>0.90	1	2	15	2	20
	Total	1	8	15	2	26

Table 5.19. Shovelnose sturgeon percent use for the categories of depth and velocity for the trawl sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.0	0.0	0.0	0.0	0.0
	0.30-0.60	0.0	0.0	0.0	0.0	0.0
	0.60-0.90	0.0	23.1	0.0	0.0	23.1
	>0.90	3.8	7.7	57.7	7.7	76.9
	Total	3.8	30.8	57.7	7.7	100.0

Table 5.20. Shovelnose sturgeon normalized selected habitats for the categories of depth and velocity for the trawl sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.00	0.00	0.00	0.00
	0.30-0.60	0.00	0.00	0.00	0.00
	0.60-0.90	0.00	0.67	0.00	0.00
	>0.90	1.00	0.27	0.58	0.19

The monthly average of physical habitat conditions measured at shovelnose sturgeon locations are presented in Table 5.22. Average depths used by shovelnose sturgeon were shallower than the yearly average during the months of May, July, August, September, October and November and deeper during March, April and June. This may be related to the annual fluctuation in Platte River discharge (Table 1.4). Average mean column velocity used by shovelnose sturgeon was also lowest during the months of July, August and September. Average monthly bottom velocity used by shovelnose sturgeon varied little from the annual average of 0.35 m/s, but was lowest during August.

Table 5.23 presents the monthly average water chemistry variables measured at shovelnose sturgeon locations. As expected, average temperatures recorded at shovelnose sturgeon locations were highest during the months of June, July and August and lowest during the months from November to March. Dissolved oxygen levels below 5 mg/L (the general lower limit for healthy fish populations (Boyd 1979)) were recorded during the months of May, June and August at shovelnose sturgeon locations. Specific conductivity readings and suspended solids concentrations in the vicinity of shovelnose sturgeon showed no distinguishable pattern.

According to the telemetry data, shovelnose sturgeon used deeper waters (median = 0.77 m) with moderately swift mean column velocities (median = 0.58 m/s) and slightly lower bottom velocities (median = 0.36 m/s) (Table 5.24). This pattern shows a general good agreement with conditions where sturgeon were captured by the gear types discussed earlier.

Shovelnose sturgeon were located in the river at a range of discharge levels with the median at 4,120 cfs. Substrate containing sand was used extensively by shovelnose sturgeon. Shovelnose sturgeon were observed over sand substrate during 96% of all observations(Table 5.25). Use of substrate containing gravel accounted for 3.5% of all observations. Shovelnose sturgeon rarely (<1%) used silt substrate.

Shovelnose sturgeon used a wide range of habitat conditions in the Platte River. Tables 5.26 – 5.28 show that shovelnose sturgeon used all but the slowest shallowest habitat conditions during our telemetry studies. However, they did show a selection for water over 0.3 m deep with mean column velocities over 0.3 m/s and the velocities used by shovelnose sturgeon tended to increase as the depths increased. These results fit into the spatial niches with intermediate to deep water with moderate to swift velocity (Hardy and Associates 1992).

At the focal location of each tracked sturgeon, we also recorded the presence or absence of structural features including the presence of sandbar ledges, underwater dunes and cover (mostly woody debris). Areas adjacent to or below shallow sunken sandbars, where secondary flows converged with the main channel, frequently held radio-tagged sturgeon. A distinctive ledge, where water depth sharply increased, was usually associated with the areas near shallow sunken sandbars. Shovelnose sturgeon were located within 10 m of a ledge in 38.2% of the observations and when located within this habitat, the shovelnose sturgeon were positioned in deeper water below the sandbar ledge. Shovelnose sturgeon frequently used underwater dunes being located in this channel structure in 51% of the observations. Overall, shovelnose sturgeon were located near structure in 71.1 % of observations. The use of instream cover was rare for shovelnose sturgeon as they were located near cover in less than 1 % of the observations.

The velocity use observations are in concordance with those found by other studies of shovelnose sturgeon, but studies in larger rivers have found that shovelnose sturgeon may use water depths which are greater than those available in the Platte River (Hurley et al. 1987, Curtis et al. 1997, Bramblett and White 2001). Substrate use by shovelnose sturgeon is often noted as being sandy (Quist et al. 1999) and the Platte River observations fit that description well. The other conditions we measured (ie. temperature, turbidity, etc.) are typical of tributaries of the Missouri River which support shovelnose sturgeon populations (Galat et al. 2005a). However, alterations in discharge levels and patterns in the Platte River could result in habitat deterioration for the shovelnose sturgeon similar to those documented by Cross and Moss (1987).

Associated Species:

As summarized in Chapter 2 each type of sampling gear assessed the shovelnose sturgeon population in a different way. For example, the drifted nets covered a wide range of habitat on each drift. Even when the majority of the drift was in the deeper, swifter channel habitat, the nets passed through shallow and slow waters near sandbars when the nets were deployed and retrieved. As a result, they caught the most species with shovelnose sturgeon, even though in the field, it seemed clear

Table 5.21. Number of radio-tagged shovelnose sturgeon locations by survey method and year.

Survey Method	2000	2001	2002	2003	2004	Total Number of Locations
Boat	79	188	268	164	100	799
Plane	50	182	128	72	88	520
Total	129	370	396	236	188	1319

Table 5.22. Physical habitat values during radio telemetry tracking for shovelnose sturgeon by month and year.

Species	Date	Avg Depth (m)	Min Depth (m)	Max Depth (m)	Avg MCV (m/s)	Min MCV (m/s)	Max MCV (m/s)	Avg BV (m/s)	Min BV (m/s)	Max BV (m/s)
Shovelnose Sturgeon	03/2002	1.13	0.64	2.55	0.60	0.24	0.76	0.35	0.14	0.54
Shovelnose Sturgeon	03/2004	1.02	0.54	2.53	0.65	0.48	0.92	0.36	0.29	0.57
Shovelnose Sturgeon	04/2002	1.11	0.56	2.26	0.67	0.42	1.04	0.38	0.22	0.56
Shovelnose Sturgeon	04/2003	1.00	0.55	1.66	0.67	0.37	1.00	0.40	0.24	0.54
Shovelnose Sturgeon	04/2004	1.20	0.54	2.32	0.68	0.40	1.02	0.37	0.19	0.64
Shovelnose Sturgeon	05/2001	0.93	0.47	1.58	0.69	0.14	1.12	0.42	0.16	0.70
Shovelnose Sturgeon	05/2002	0.95	0.37	2.48	0.69	0.20	1.11	0.38	0.11	0.65
Shovelnose Sturgeon	05/2003	0.61	0.28	1.37	0.56	0.29	0.99	0.37	0.23	0.52
Shovelnose Sturgeon	05/2004	0.78	0.39	1.32	0.63	0.26	1.22	0.43	0.18	0.84
Shovelnose Sturgeon	06/2001	1.15	0.45	3.09	0.66	0.40	1.08	0.42	0.21	0.72
Shovelnose Sturgeon	06/2002	0.90	0.23	1.72	0.62	0.34	1.03	0.34	0.14	0.57
Shovelnose Sturgeon	06/2003	0.74	0.29	1.74	0.50	0.07	0.81	0.30	-0.01	0.54
Shovelnose Sturgeon	06/2004	1.01	0.36	2.23	0.61	0.38	1.13	0.38	0.27	0.49
Shovelnose Sturgeon	07/2000	0.76	0.24	2.03	0.51	0.38	0.66	0.34	0.14	0.49
Shovelnose Sturgeon	07/2001	0.74	0.37	2.39	0.59	0.32	0.99	0.39	0.17	0.64
Shovelnose Sturgeon	07/2002	0.72	0.27	1.29	0.54	0.28	0.93	0.34	0.18	0.54
Shovelnose Sturgeon	07/2003	0.58	0.29	1.71	0.51	0.29	1.12	0.31	0.15	0.48
Shovelnose Sturgeon	08/2000	0.81	0.33	1.29	0.59	0.33	0.82	0.33	0.15	0.54
Shovelnose Sturgeon	08/2001	0.76	0.37	1.39	0.52	0.23	0.83	0.30	0.10	0.52
Shovelnose Sturgeon	08/2002	0.68	0.33	1.40	0.47	0.25	0.99	0.31	0.15	0.65
Shovelnose Sturgeon	08/2003	0.76	0.39	1.52	0.62	0.39	1.12	0.35	0.20	0.66
Shovelnose Sturgeon	09/2000	0.85	0.35	1.69	0.58	0.33	0.87	0.37	0.19	0.47
Shovelnose Sturgeon	09/2001	0.81	0.38	1.57	0.60	0.34	1.09	0.40	0.24	0.61
Shovelnose Sturgeon	09/2002	0.72	0.43	1.36	0.53	0.28	0.83	0.32	0.18	0.42
Shovelnose Sturgeon	09/2003	0.73	0.29	1.62	0.61	0.12	0.77	0.40	0.11	0.60
Shovelnose Sturgeon	10/2000	0.95	0.32	2.49	0.62	0.29	0.87	0.31	0.09	0.45
Shovelnose Sturgeon	10/2001	1.01	0.51	1.66	0.63	0.43	0.92	0.36	0.13	0.51
Shovelnose Sturgeon	10/2002	0.77	0.28	1.30	0.50	0.31	0.68	0.28	0.14	0.46
Shovelnose Sturgeon	10/2003	0.61	0.30	0.84	0.62	0.36	0.76	0.45	0.27	0.65
Shovelnose Sturgeon	11/2001	0.98	0.44	1.66	0.61	0.39	0.86	0.30	0.19	0.43
Shovelnose Sturgeon	11/2002	0.74	0.48	1.63	0.46	0.34	0.57	0.32	0.17	0.47
Shovelnose Sturgeon	11/2003	0.52	0.29	0.76	0.38	0.30	0.47	0.29	0.20	0.38
Shovelnose Sturgeon	12/2001	0.95	0.59	1.23	0.62	0.41	0.82	0.31	0.22	0.45
	Averages	0.85	0.39	1.75	0.59	0.31	0.92	0.35	0.17	0.56

Table 5.23. Average water chemistry values at the time of radio telemetry tracking of shovelnose sturgeon.

Species	Date	Avg Temp (˚C)	Min Temp (˚C)	Max Temp (˚C)	Avg DO (mg/L)	Min DO (mg/L)	Max DO (mg/L)	Avg Sp. Cond (µS/cm)	Min Sp. Cond (µS/cm)	Max Sp. Cond (µS/cm)	Avg TSS (mg/L)	Min TSS (mg/L)	Max TSS (mg/L)
Shovelnose Sturgeon	03/2002	5.94	3.20	10.80	11.96	10.55	13.03	680	541	1084	132	39	240
Shovelnose Sturgeon	03/2004	9.08	6.90	11.40	12.95	10.47	17.90	532	435	691	98	56	117
Shovelnose Sturgeon	04/2002	15.50	7.90	21.40	13.02	9.92	16.63	645	381	789	130	98	171
Shovelnose Sturgeon	04/2003	15.14	7.90	20.30	11.41	10.01	13.09	580	365	968	201	119	340
Shovelnose Sturgeon	04/2004	16.00	9.50	20.40	11.97	8.48	16.68	590	407	786	108	71	179
Shovelnose Sturgeon	05/2001	18.30	13.50	25.00	11.31	7.79	15.50	568	372	698	255	67	740
Shovelnose Sturgeon	05/2002	18.73	12.10	27.30	10.05	3.12	17.33	549	422	948	407	87	2356
Shovelnose Sturgeon	05/2003	18.20	13.30	24.60	9.78	8.69	11.68	468	405	494	582	147	1122
Shovelnose Sturgeon	05/2004	20.49	16.80	24.00	8.64	7.31	11.92	553	331	1015	503	101	2368
Shovelnose Sturgeon	06/2001	22.63	15.80	29.40	10.17	6.92	13.43	579	292	910	217	49	867
Shovelnose Sturgeon	06/2002	25.06	21.10	29.80	8.79	3.74	14.82	622	326	1148	591	50	3564
Shovelnose Sturgeon	06/2003	23.21	19.60	28.20	9.86	4.03	13.55	492	183	727	530	138	2108
Shovelnose Sturgeon	06/2004	22.74	17.50	26.70	8.45	7.26	10.77	468	280	963	1282	316	2848
Shovelnose Sturgeon	07/2000	26.50	25.20	28.50	8.75	7.07	10.90	596	471	727	195	119	232
Shovelnose Sturgeon	07/2001	27.04	23.20	32.60	8.66	5.26	11.64	641	405	1089	218	46	922
Shovelnose Sturgeon	07/2002	28.97	25.20	31.90	10.39	5.13	14.41	708	347	1327	95	20	154
Shovelnose Sturgeon	07/2003	26.98	22.90	30.60	8.62	6.22	10.09	534	344	963	180	34	422
Shovelnose Sturgeon	08/2000	26.85	22.10	30.80	9.80	6.31	12.15	930	371	1717	133	77	350
Shovelnose Sturgeon	08/2001	27.50	24.00	32.10	9.82	6.80	15.23	714	411	1077	134	87	223
Shovelnose Sturgeon	08/2002	25.83	21.00	29.50	9.43	1.82	12.51	632	280	1435	394	71	2516
Shovelnose Sturgeon	08/2003	27.91	23.20	31.30	10.09	7.03	15.41	620	322	1211	85	43	123
Shovelnose Sturgeon	09/2000	20.12	16.00	25.50	11.05	8.96	12.31	781	420	1672	144	111	172
Shovelnose Sturgeon	09/2001	21.55	16.30	27.40	10.44	8.24	13.99	695	422	1150	145	96	253
Shovelnose Sturgeon	09/2002	21.45	16.10	27.40	9.30	6.45	12.30	575	316	1011	113	83	164
Shovelnose Sturgeon	09/2003	18.02	12.70	24.10	10.16	7.88	13.52	550	222	1320	167	43	358
Shovelnose Sturgeon	10/2000	16.28	11.60	19.00	11.24	9.45	13.54	584	415	974	159	90	250
Shovelnose Sturgeon	10/2001	13.19	10.30	20.10	10.39	8.24	12.51	600	369	843	117	83	203
Shovelnose Sturgeon	10/2002	11.00	4.00	17.70	12.38	9.31	13.90	647	101	1161	-	-	-
Shovelnose Sturgeon	10/2003	13.59	8.60	20.20	11.56	7.13	12.92	451	211	845	97	63	122
Shovelnose Sturgeon	11/2001	14.67	13.60	15.60	10.50	9.64	11.83	673	492	1163	82	59	112
Shovelnose Sturgeon	11/2002	6.29	5.10	8.00	11.78	10.76	12.84	701	480	965	-	-	-
Shovelnose Sturgeon	11/2003	6.05	3.70	8.40	12.33	11.24	13.42	555	448	663	110	110	110
Shovelnose Sturgeon	12/2001	9.22	9.10	9.50	11.33	11.21	11.56	658	443	1101	228	170	266
	Averages	18.79	14.52	23.32	10.50	7.65	13.43	611	364	1019	253	88	773

Table 5.24. Habitat characteristics at tracked shovelnose sturgeon locations.

Parameter	Number	Missing	Median	25%	75%
Depth	608	8	0.77	0.57	1.07
MCV	608	10	0.58	0.47	0.70
BV	608	17	0.36	0.28	0.43
Temp	608	23	21.1	16.3	25.9
DO	608	31	10.2	8.8	11.6
Sp Cond	608	28	560	452	722
TSS	608	100	143	107	224
Turbidity	608	446	91	52	345

Table 5.25. Substrate texture at tracked shovelnose sturgeon locations.

	Number	Missing	% sand	% gravel	% silt	% rock
Substrate fish	608	12	96.1	3.5	0.4	0.0

Table 5.26. Shovelnose sturgeon number captured for the categories of depth and velocity for the telemetry sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0	7	2	0	9
	0.30-0.60	9	131	25	0	165
	0.60-0.90	11	107	79	2	199
	>0.90	3	49	136	37	225
	Total	23	294	242	39	598

Table 5.27. Shovelnose sturgeon percent use for the categories of depth and velocity for the telemetry sampling data.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.0	1.2	0.3	0.0	1.5
	0.30-0.60	1.5	21.9	4.2	0.0	27.6
	0.60-0.90	1.8	17.9	13.2	0.3	33.3
	>0.90	0.5	8.2	22.7	6.2	37.6
	Total	3.8	49.2	40.5	6.5	100.0

Table 5.28. Shovelnose sturgeon normalized selected habitats for the categories of depth and velocity for the telemetry sampling data.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.00	0.01	0.03	0.00
	0.30-0.60	0.11	0.22	0.06	0.00
	0.60-0.90	0.34	0.40	0.21	0.12
	>0.90	0.27	1.00	0.53	0.63

that different species were being captured in different habitats during a run. Trotlines were selective in capturing only fish species that consume nightcrawlers and this limited the number of species observed with sturgeon caught by this method. Trawls were specifically used to target smaller fishes than the other gears, but still captured shovelnose sturgeon.

Drifted gill nets captured 23 species of fish in addition to shovelnose sturgeon (Table 5.29). The most frequently captured species on drifted gill nets that also captured shovelnose sturgeon were goldeye, shortnose gar, quillback and river carpsucker. Drifted trammel nets captured 24 species of fish in addition to shovelnose sturgeon (Table 5.30). The most frequently captured species on drifted trammel nets that also captured shovelnose sturgeon were goldeye, quillback, river carpsucker, and shortnose gar. The consistent pattern between drifted gill and trammel nets suggests that goldeye, quillback, shortnose gar and river carpsucker have some overlap in their habitats in the lower Platte River.

Trotlines captured three species of fish in addition to shovelnose sturgeon (Table 5.31). The most frequently captured species on trotlines that also captured shovelnose sturgeon was pallid sturgeon. Trawls captured 28 species of fish in addition to shovelnose sturgeon (Table 5.32). The most frequently captured species in trawls that also captured shovelnose sturgeon were shoal chubs, channel catfish, sand shiner and river shiner.

Seining in proximity to the locations of radio-tagged shovelnose sturgeon captured 9 species of fish in 39 seine hauls (Table 5.33). Shoal chubs were the most common species and red shiners were only the fourth most common species. Chubs in general made up 42% of the catch in the 3/8th inch seines near sturgeon, where chubs made up only 14 % of the catch in all other ⅜th inch seines.

Overall, of the larger species, goldeye, quillback, river carpsucker, shortnose gar and channel catfish show some association with shovelnose sturgeon. While for the smaller species, the shoal chubs and silver chubs and sand shiners and river shiners appear to associate with shovelnose sturgeon habitats.

Movement:

Thirty-three shovelnose sturgeon (569-693 mm fork length; 750-1,250 g) were implanted with radio transmitters between 2000 and 2004. Data regarding 5 of the radio -tagged fish was removed from the analysis because the transmitters carried by these individuals became stationary shortly after the fish's release. Recovery of 4 of the 5 transmitters confirmed suspicions that these fish had either died or expelled the transmitter following their release. Additionally, only fish that were located at least twice during a month on different days were included in the analyses. The remaining 28 fish included in analysis of shovelnose movement were located 403 times from the air and 555 times from the airboat.

Table 5.29. Frequency of occurrence for fish species caught during drifted gill net runs with shovelnose sturgeon.

Common Name	Frequency of occurrence
Goldeye	50
Shortnose Gar	42
Quillback	38
River Carpsucker	24
Channel Catfish	18
Longnose Gar	13
Gizzard Shad	13
Common Carp	10
Blue Sucker	9
Freshwater Drum	7
Mooneye	7
Bigmouth Buffalo	5
Smallmouth Buffalo	5
Shorthead Redhorse	4
Sauger	4
Walleye	3
Paddlefish	1
Black Crappie	1
Bighead Carp	1
Pallid Sturgeon	1
Flathead Catfish	1
Striped Bass Hybrid (wiper)	1
Grass Carp	1

Table 5.30. Frequency of occurrence for fish species caught during drifted trammel net runs with shovelnose sturgeon.

Common Name	Frequency of occurrence
Goldeye	70
Quillback	62
River Carpsucker	45
Shortnose Gar	43
Channel Catfish	38
Common Carp	32
Blue Sucker	25
Sauger	16
Longnose Gar	13
Bighead Carp	12
Grass Carp	12
Smallmouth Buffalo	11
Freshwater Drum	9
Flathead Catfish	7
Gizzard Shad	7
Shorthead Redhorse	5
Paddlefish	4
Pallid Sturgeon	3
Walleye	3
White Crappie	2
Bigmouth Buffalo	2
Blue Catfish	1
Saugeye	1
Black Crappie	1

Table 5.31. Frequency of occurrence for fish species caught during trotline samples that also captured shovelnose sturgeon

Common Name	Frequency of occurrence
Pallid Sturgeon	8
Common Carp	2
Channel Catfish	1

Table 5.32. Frequency of occurrence for fish species caught during trawl runs with shovelnose sturgeon.

Common Name	Frequency of occurrence
Channel Catfish	15
Shoal Chub	11
Sand Shiner	11
Silver Chub	8
River Shiner	7
Red Shiner	5
Emerald Shiner	4
River Carpsucker	3
Freshwater Drum	3
Plains Minnow	2
Johnny Darter	2
Green Sunfish	1
Western Silvery Minnow	1
Flathead Chub	1
Fathead Minnow	1
Saugeye	1
Common Carp	1
Suckermouth Minnow	1
Blue Catfish	1
Quillback	1

Table 5.33. Number of fish by species caught in 3/8th inch seines near radio-tagged shovelnose sturgeon in 39 different seine hauls.

Common Name	July	August	Total
Shoal Chub	4	36	40
Sand Shiner	26	5	31
River Shiner	5	17	22
Red Shiner	7	9	16
Plains Minnow	1	14	15
Silver Chub	8	6	14
Emerald Shiner	3	2	5
River Carpsucker	2	0	2
Common Carp	0	1	1
Total	56	90	146

Rate of movement by shovelnose sturgeon ranged from 0.07 to 14,014 m/d. However, 70% of all movement rates were less than 350 m/d. Most movement by study fish occurred during the spring (Figure 5.2), although not all fish moved at the same rate each month (Table 5.34). Shovelnose sturgeon typically moved upstream during April and May. Downstream movement consistently occurred in June. The maximum total upstream movements in April and May of each year showed that fish 161 moved upstream 139.2 km in 2001, fish 281 moved upstream 72.2 km in 2002, fish 241 moved upstream 85.7 km in 2003 and fish 601 moved upstream 42.2 km. On average, each radio-tagged shovelnose moved upstream 7.2 km during April and 19.4 km upstream in May. Long distance downstream movements were observed in June. Fish 101 moved downstream 81.2 km in June 2001, fish 241 moved downstream 47.4 km in June

2002, fish 341 moved downstream 85 km in June 2003 and fish 140 moved downstream 36.7 km in June 2004. On average, each shovelnose sturgeon moved 13.7 km downstream during the month of June. The greatest distance between two contact locations in the lower Platte River during any year of the study was 141 km.

Five shovelnose sturgeon tracked during this study moved into the Missouri River. Three of these fish migrated out of the Platte River between 1 November and 4 December 2000 and returned to the Platte River the following spring. Two additional radio-tagged shovelnose sturgeon moved into the Missouri River during September of 2002. Contact with these shovelnose sturgeon was not reestablished prior to 15 November 2002, the estimated expiration data of the transmitters. Besides the 5 shovelnose sturgeon that moved out of the Platte River during the fall of 2000 and 2002, shovelnose sturgeon were generally sedentary from October through March of each year of the study. From October through March, 90% of movement rates by shovelnose sturgeon did not exceed 350 m/d.

Recaptures:

During the regular sampling and at times when radio transmitters were about to expire because their batteries were nearing the end of their expected life, we recaptured some of the previously PIT-tagged individual sturgeon. The results provide some interesting insights, but in general, not as much detail as was afforded by telemetry. Table 5.35 summarizes the recaptures of PIT-tagged shovelnose sturgeon during the project. Most of these fish were at large for a day or less and were captured in the same area as they were released. In addition, a shovelnose sturgeon (PIT tag number: AVID020286127) was tagged by Rob Hofpar during his study of shovelnose sturgeon on the lower Platte River during 1996. This specimen was at large for over 5 years and it was recaptured at the mouth of the Elkhorn River where it was initially tagged.

Shovelnose sturgeon time at large between captures ranged from less than a day to almost 3 years for specimens initially tagged during our study. Seven individuals were at large for over a year, five from 1 month to a year and 14 for less than a month. Of particular note was one shovelnose sturgeon (PIT tag number: 042035277) that was first captured on 11 August 2000 and at that time it was implanted with a radio tag with the frequency 49.201 mHz. This fish was tracked with this transmitter until 12 September 2001. At that time the fish was recaptured and re-implanted with another radio transmitter with the frequency 49.401 mHz. It was then tracked until the signal was last located on 12 November 2002. On 10 April 2004 during an ichthyology class field trip, we recaptured this fish about 1 km downstream from Nebraska State Highway 50 near Louisville, NE with the expired radio transmitter still in place.

The distances moved and survival duration for shovelnose sturgeon provide support for two contentions. First, shovelnose sturgeon may move upstream one year and then remain in nearly the same location during another year. Whether this is related to spawning is not currently known, but the time of movement overlaps the time when larval sturgeon were found in samples. Second, the use of radio-transmitters in the fish may provide a valid description of habitats used by untagged sturgeon. The recaptures of fish implanted with transmitters that appear relatively healthy

Table 5.34. Average movement rate (m/day) of shovelnose sturgeon with at least 2 observations within the month. Positive values denote upstream movement and negative values denote downstream movement.

Fish	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
21	-11	-20	-200	804	375	-379	-378	190	215	491	-91	-30	81
81	3	1	-48	204	-	-83	58	-154	-16	152	-41	-5	6
101	0	-17	-8	329	795	-2,187	-27	-159	-76	11	-32	-44	-118
121	-	-	-	1,702	2,434	-605	-2,078	16	-26	736	-371	-	226
140	-	-	-	104	793	-1,648	-	-	-	-	-	-	-250
161	-2	-6	-498	1,945	2,080	-2,451	-1,743	-68	198	116	-44	-75	-46
181	-	-	-	-	-	-	-621	-45	-	-	-	-	-333
191	-	-	-	-75	-38	-	-	-	-	-	-	-	-56
201	-39	-26	-97	219	328	871	-191	-422	-135	-125	8	46	37
241	-	13	-	-50	1,691	-1,550	-7	569	568	5	227	-65	140
250	-	-	-	67	-508	442	-	-	-	-	-	-	0
261	-	-	-	-	-	-240	-	-	-	-	-	-	-240
271	-	-	-	34	-310	-163	-	-	-	-	-	-	-146
281	-	-193	-	-44	1,188	517	-341	-2,620	-1,195	-4	58	-43	-268
301	-	-54	-	-38	724	-708	-39	144	405	75	-44	-19	45
341	-	-	-	-	-	-3,456	-101	-27	-	-	-	-	-1,194
381	-	-106	-11	269	1,034	-1,216	478	-899	-132	14	-129	129	-52
501	-	-	-	771	9	29	608	115	-	-116	-1,030	-	55
521	-	23	-12	-24	-158	-172	-216	-5	-187	478	104	73	-9
581	-	-	-	51	-983	-4	-86	51	14	28	34	-	-112
601	-	-	-	683	1,026	-1,351	-	-	-	-	-	-	119
602	-130	-7	243	66	-767	-526	1,327	122	-1,135	-1	-	-	-81
641	-	-	-	-	3,025	1,380	-3,953	102	-	40	-	-	119
661	-	-168	-45	34	444	-	-	-	-	10	14	-212	11
761	-	-	-	-	769	607	-285	-76	-571	-439	-	-	1
821	-	-	-	-	230	-	-642	-	276	-	-	-	-45
841	-	-	-	-	613	-	-	-	-	-	-	-	613
882	-	-	379	4	-	-	-	-	-	-	-	-	191
Average	-30	-47	-30	336	643	-586	-434	-176	-120	86	-96	-22	-39

Table 5.35. Location and date of initial release and location and date of subsequent recapture(s) of shovelnose sturgeon PIT tagged in the lower Platte River, NE.

PIT Tag Number	1st Date caught	1st Location (RM)	2nd date caught	2nd Location (RM)	3rd date caught	3rd Location(RM)
Avid 020286127	6/19/1996	Elkhorn R(32.8)	8/3/2001	Elkhorn R. (32.8)		
Avid 041828111	7/18/2000	Louisville (16.3)	9/26/2001	Louisville(16.3)		
422E237C2F	8/10/2000	Louisville (16.3)	9/19/2001	Louisville(16.3)		
421F340C09	5/3/2001	.5 mi. downstream from Hwy 50(15.8)	3/30/2004	Schilling(0.5)		
4234402F61	6/22/2001	Louisville(16.3)	8/9/2001	Louisville(16.3)		
42352B6C39	6/22/2001	Louisville(16.3)	8/9/2001	Louisville(16.3)		
423523704C	6/22/2001	Louisville(16.3)	5/30/2002	Louisville(16.3)		
422E1E3D41	7/19/2001	Louisville(16.3)	3/26/2003	1 mi downstream from Hwy 50(15.3)		
422E0E5B79	9/12/2001	Louisville(16.3)	4/10/2004	Louisville(16.3)		
4179367444	4/5/2002	2 mi downstream from Hwy 50(14.3)	5/27/2003	Fremont(57.0)		
422E0E5432	5/23/2002	Louisville(16.3)	6/25/2002	Schilling(0.5)		
4311516F4B	6/3/2002	Elkhorn R.(32.8)	6/15/2004	Downstream from Elkhorn R.(32.5)		
423A5C3D3D	7/16/2002	Elkhorn R.(32.8)	7/18/2002	Elkhorn R.(32.8)		
423A6D5D28	9/14/2002	Louisville(16.3)	9/19/2002	Louisville(16.3)		
4237766935	9/14/2002	Louisville(16.3)	9/19/2002	Louisville(16.3)		
423A6E3349	9/14/2002	Louisville(16.3)	9/19/2002	Louisville(16.3)		
43111F3757	6/24/2003	Leshara(48.8)	7/14/2003	Louisville(16.3)		
4311697E3A	3/24/2004	Cedar Creek(13.0)	6/3/2004	Schramm(22)		
4315423B15	3/30/2004	Schilling(0.5)	4/13/2004	Schilling(0.5)		
4310777B37	4/2/2004	Omaha well field(6.0)	4/7/2004	Omaha well field(6.0)		
43116A317B	4/2/2004	Omaha well field(6.0)	4/22/2004	Omaha well field(6.0)		
4311560E6D	4/2/2004	Omaha well field(6.0)	6/8/2004	Upstream from Elkhorn R.(33.0)	6/29/2004	Guard Camp(28.8)
43110F4325	4/6/2004	Omaha well field(6.0)	4/27/2004	Cedar Creek(13.0)		
43110B2749	4/8/2004	Downstream from rookery (10.0)	4/27/2004	Rookery(10.5)		
4311581F0C	4/8/2004	Schilling(0.5)	5/3/2004	Cedar Creek(13.0)		
4312790607	5/27/2004	Louisville(16.3)	4/22/2004	Omaha well field		
4311513E6F	6/8/2004	Upstream from Elkhorn R.(33.0)	6/15/2004	Downstream from Elkhorn R.(32.5)		

and the subsequent survival after re-implantation suggest that the sturgeon are physically able to deal with the stresses of transmitter implantation and return to normal conditions.

Population Characteristics:

During this study, we collected 1,338 shovelnose sturgeon from the lower Platte River. These were captured from drifted gill nets (n = 420), drifted trammel nets (n = 534), trotlines (n = 340) and benthic trawls (n = 44). Data from these specimens were used in the study of stock characteristics of shovelnose sturgeon in the lower Platte River (Shuman et al. 2007) and that information is summarized in this section.

These shovelnose sturgeon ranged in length from 329 to 797 mm fork length with 1,164 (87%) of the individuals between 500 and 649 mm and 323 (24.1%) of them in the 575 to 599 mm length category.

Age and Growth:

Fin rays were collected from 21 shovelnose sturgeon in 2001 and 44 shovelnose sturgeon in 2002. Ages determined from these specimens ranged from 5 to 14 years (Figure 5.3). The three readers who examined these fin rays agreed on the age of only one fish, but two of the three agreed on the ages of 24 fish. Most (75 %) of the fish where the readers agreed ranged between age 7 and age 9 and these individuals were between 469 and 663 mm fork length. No individuals were determined to be younger than age 5.

Quist et al. (1999) proposed relative stock density (RSD) length categories for stock (250-379 mm), preferred (380-509 mm), quality (510-639 mm), memorable (640-809 mm) and trophy (> 810 mm) sizes of shovelnose sturgeon. Using these categories the shovelnose sturgeon we captured fit primarily into the preferred and memorable classes (Table 5.36). Incremental RSD preferred - memorable values were 83 and 78 in reaches upstream and downstream from the mouth of the Elkhorn River. In areas sampled from near Louisville downstream to the mouth of the Platte RSD preferred – memorable values were 86 and 89. However, the RSD quality – preferred values increased in upstream reaches while the RSD memorable – trophy values declined in upstream reaches (Shuman et al. 2007). This indicates that larger size shovelnose sturgeon were more frequently captured in the downstream reaches of the Platte River.

Because shovelnose sturgeon are long lived species and most of their skeletons are cartilaginous, determination of growth rates has been challenging (Morrow et al. 1998). Helms (1973) working in the Mississippi River and Fogle (1963) working in the Missouri River, found large variations in length at age for shovelnose sturgeon. Fogle (1963) found that shovelnose sturgeon growth was rapid at first, but slowed to about 70 mm per year by age 5. Growth of shovelnose sturgeon from the Platte River (Shuman et al. 2007) is intermediate to that reported from the Missouri River (Fogle 1963) and the Mississippi River (Helms 1974).

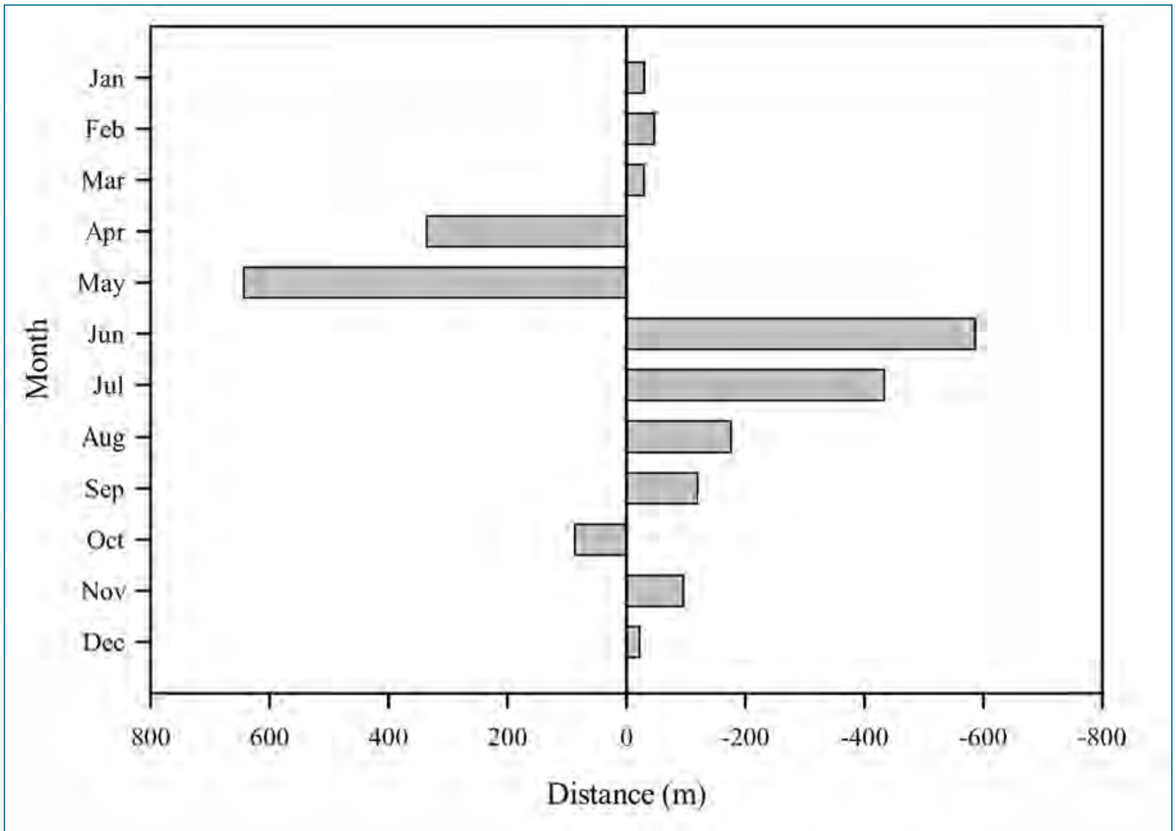


Figure 5.2. Average monthly movement rate (m/d) for shovelnose sturgeon. Positive values denote upstream movement and negative values denote downstream movement.

Length / Weight:

Indexes of condition for shovelnose sturgeon fall into two main types, the Fulton condition factors (K) and relative weight (Wr) by Anderson and Neumann (1996). Most of the condition values surveyed by Carlander (1969) are listed K(TL) which means that they were calculated using total lengths rather than the fork length measurements we typically use today. The development of a standard weight equations for shovelnose sturgeon (Quist et al. 1999) has allowed use of the relative weight method of assessing condition to be used for management and evaluation of shovelnose sturgeon populations in the Platte River. Shuman et al. (2007) calculated the fork length, weight relationship to be: log10 weight = -5.611+3.060*$\log_{10}$ fork length (Figure 5.4). The mean Wr value for shovelnose sturgeon from the lower Platte River was 86 and there was no significant difference between years. As fish increased in size their average Wr values generally decreased.

Based on the recommendations developed by Quist et al. (1999) the shovelnose sturgeon populations in the Platte River appear to be healthy.

Population Density:

Over the four years 1,129 shovelnose sturgeon were captured in drifted gill net (n=323) and trammel net runs (n=213). After applying the capture coefficient (0.308) our median population estimate was 9.6 shovelnose sturgeon/ha with confidence limits from 9.2 to 27/ha. Based on these density values we estimate the shovelnose sturgeon population of the lower Platte River is between 23,000 and 69,000.

Population estimates for large river fishes are difficult to attain because the species are generally mobile and obtaining a large enough sample to meet the assumptions of most population estimators is challenging. Shovelnose sturgeon move long distances most years and even though the lower Platte River has been intensively netted and fished for 5 years or more, we seldom catch tagged individuals. Several studies have attempted to use mark and recapture to estimate the populations of shovelnose sturgeon in the Missouri River, South Dakota (Schmulbach 1974), the Mississippi River, Iowa (Helms 1972) and the Chippewa and Red Cedar Rivers, Wisconsin (Christiansen 1975). Table 5.37 compares shovelnose sturgeon populations on the basis of number per mile of river. All the other studies used mark and recapture approaches. We used data from our standard population surveying techniques to estimate sturgeon populations in the Platte River and our results fit well within the range of population densities calculated by other researchers.

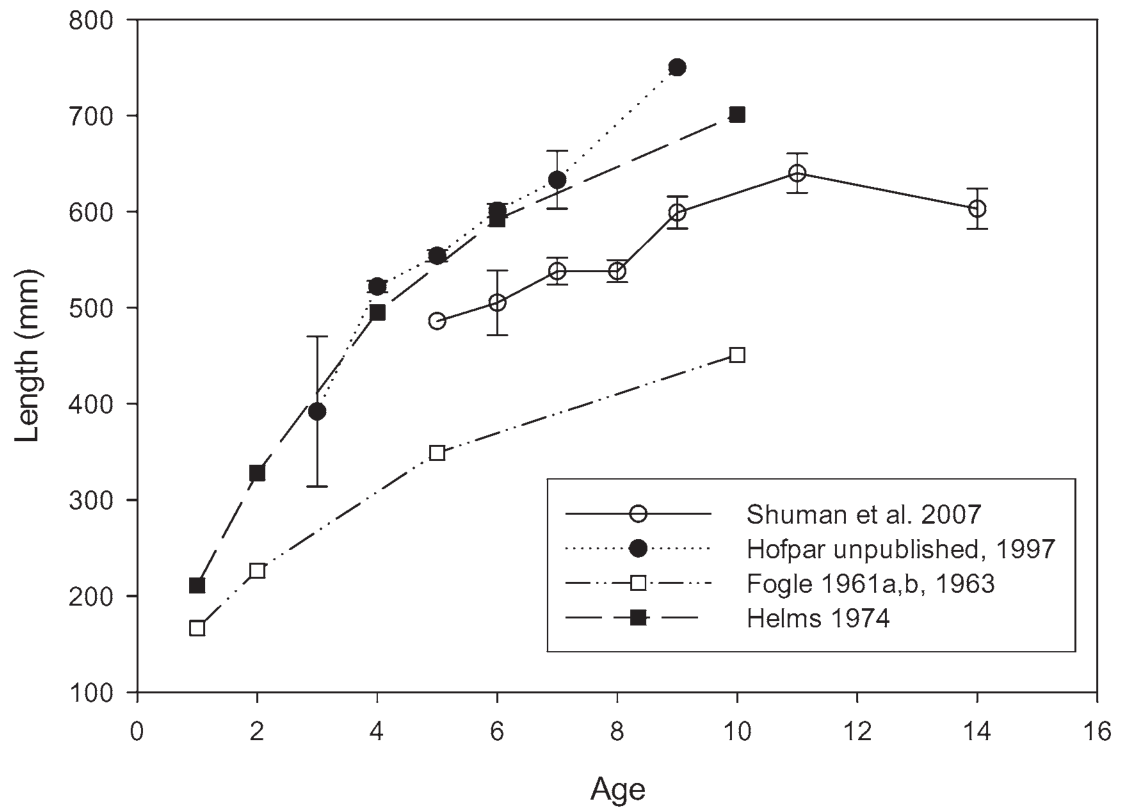


Figure 5.3. Age at length relationship for shovelnose sturgeon from the lower Platte River (Shuman, Hofpar) and for Missouri River (Fogle) and Mississippi River (Helms)

Table 5.36. Incremental relative stock density (RSD) indices by year and reach for shovelnose sturgeon captured from the lower Platte River, NE

	Stock - Quality 250 – 379 mm	Quality – Preferred 380 – 509 mm	Preferred - Memorable 509 – 639 mm	Memorable - Trophy 640 – 809 mm
2000	1	4	92	3
2001	< 1	6	88	5
2002	0	9	84	7
2003	< 1	13	82	5
2004	< 1	19	77	4
Years Overall	**1**	**12**	**82**	**5**
Reach 1	0	4	86	10
Reach 2	0	7	89	4
Reach 3	< 1	11	83	6
Reach 4	1	19	78	2

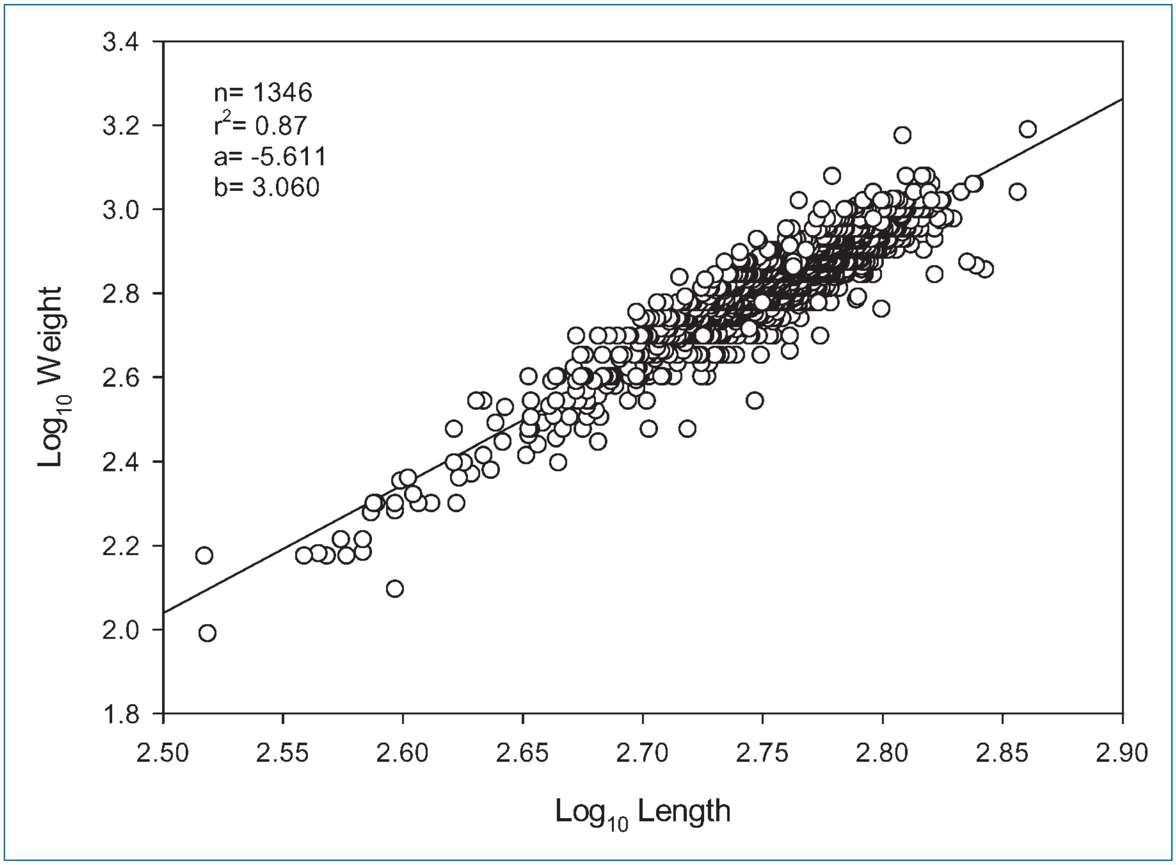
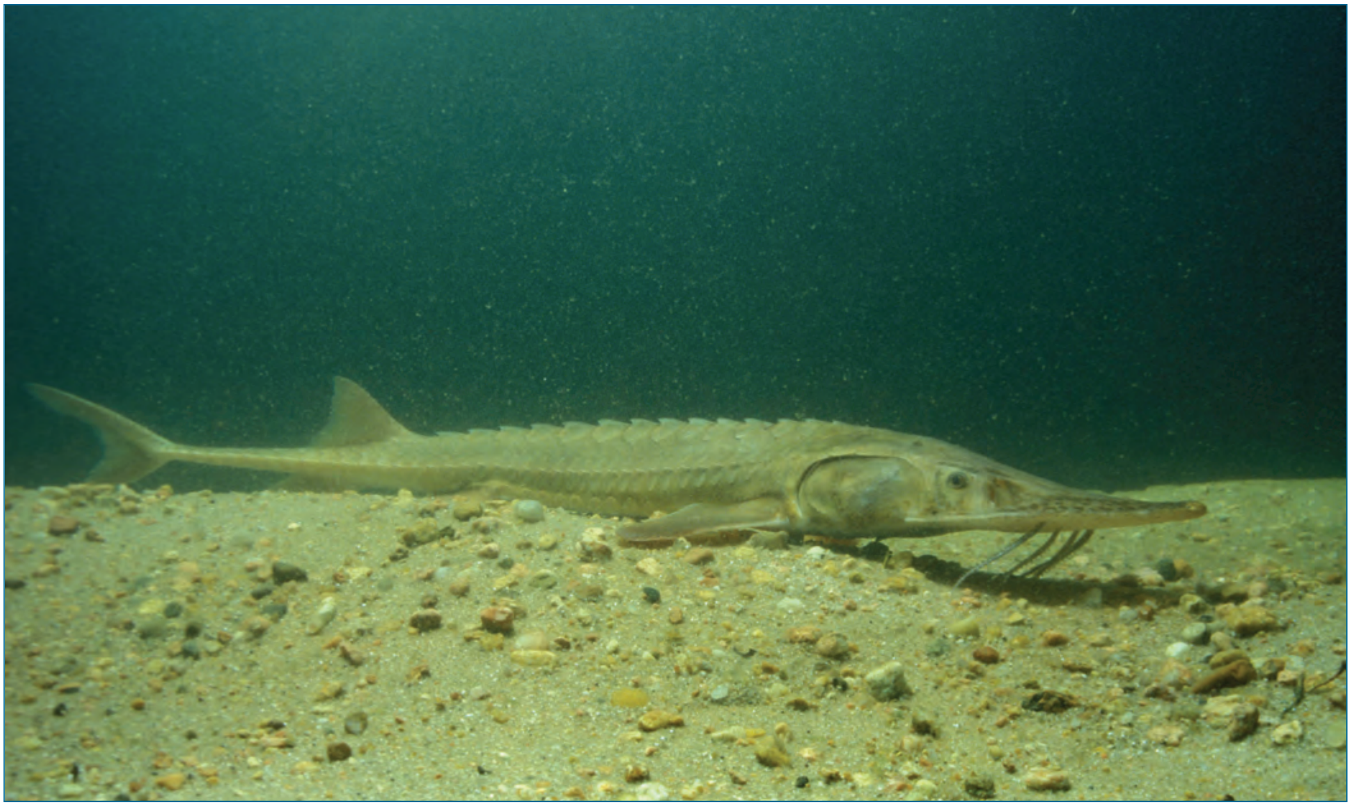


Figure 5.4. Length weight relationship for shovelnose sturgeon from the lower Platte River, NE.

Table 5.37. Comparison of population densities of shovelnose sturgeon among the Missouri River, South Dakota; the Mississippi River, Iowa; the Chippewa and Cedar rivers, Wisconsin and the lower Platte River, Nebraska.

River, State (Reference)	Number per km
Unchannelized Missouri River, South Dakota (Schmulbach 1974)	2500
Mississippi River, Iowa (Helms 1974)	1,030
Chippewa and Cedar River, Wisconsin (Christiansen 1975)	100
lower Platte River, Nebraska	142 - 426



Shovelnose Sturgeon

CHAPTER 6

FOOD HABITS OF SHOVELNOSE STURGEON IN THE LOWER PLATTE RIVER

INTRODUCTION

One of the most direct links between a species and its association with other species is via the food resources that it consumes. During the period 2001 to 2002, shovelnose sturgeon stomachs were sampled to find the composition of their diet (Shuman 2003, Shuman and Peters 2007). Studies of shovelnose sturgeon food habits indicate that shovelnose sturgeon consume a diversity of prey, but primarily consume insects of the orders Diptera, Trichoptera and Ephemeroptera (Hoopes 1959, Held 1969, Modde and Schmulbach 1977, Carlson et al. 1985, Hofpar 1997). For the most part these studies have limited their taxonomic resolution to the family level and only Modde and Schmulbach (1977) evaluated any relation of what was consumed to what was available as a food resource.

One of the limitations of diet analysis is in many cases the study animals must be sacrificed to obtain reliable information. Pulsed gastric lavage (PGL) was developed by Foster (1977) and has been used successfully on many species. Hofpar (1997) used gastric lavage on shovelnose sturgeon in the Platte River and Brosse et al. (2002) used it on Siberian sturgeon. Both of these studies found no problems with the use of PGL. However, there have been several reports of water being forced into the air bladder of sturgeon during the lavage process (Sprague et al. 1993). This potentially serious problem has resulted in a restriction being placed on the use of this technique on endangered species like pallid sturgeon.

The objectives were first to determine the diet composition of shovelnose sturgeon in the Platte River and second to test the safety of PGL for pallid sturgeon by running a series of controlled survival tests on wild caught shovelnose strugeon.

METHODS

Sturgeon were sampled from the Platte River by drifting 30.5 m long by 1.8m deep gill nets with alternating panels of 2.5 cm and 5.1 cm bar mesh netting through areas of appropriate habitat as indicated by previous studies of habitat use (Hofpar 1997, Snook 2001). Sturgeon captured were first measured for fork length and morphological index characters, weighed and tagged with a PIT tag, prior to gastric lavage.

PGL was accomplished by inserting a flexible, 6mm diameter plastic tube through the sturgeon's mouth, into the anterior portion of the digestive tract and pulsing water from a pressurized sprayer tank into the stomach. During this procedure, the abdomen of the fish was gently massaged. Materials washed from the stomach were caught in a 595 µm mesh sieve and transferred to labeled jars, fixed with 10% formalin, and transported to the lab for identification and enumeration.

To evaluate abundance of macroinvertebrate taxa in the Platte River, the organisms drifting in the area were collected using 0.5 mm mesh nets set to collect larval fish (see Chapter 8 for details). These samples were considered to be representative of the invertebrate taxa which would be most available to sturgeon and other fish species when they settle to the substrate in areas of slow current and eddies where the fish feed.

To study the effects of PGL on shovelnose sturgeon 72 fish were captured and handled in the field just as they were for food habits studies. The only exception was that they were not subjected to PGL in the field. A total of nine experimental runs of eight fish each were performed. Each batch of eight fish was transported to UNL where they were randomly assigned to two holding tanks (four to each tank) for a 4-6 day acclimation period. After acclimation, PGL was performed on six fish while two randomly chosen control fish were handled in the same way and for the same duration as the PGL fish but their stomachs was not lavaged. All fish were returned to their tank, where they were held for a 15-day observation period.

During the acclimation and observation period temperature, dissolved oxygen, conductivity, and salinity were monitored daily with a hand held meter, and nitrite and ammonia concentrations were monitored using specific test kits. Fish were not fed during the acclimation or observation periods. Sodium chloride (1 mg/L) was added to the tanks for batches 7,8 and 9 to reduce handling stress on these fish. In addition, fish in batch 7 were treated with 55 mg/kg oxytetracycline hydrochloride because of a Columnaris infection.

Logistic regression was used to test whether survival of control fish was greater than survival of experimental fish. Analysis of variance was used to test for differences in temperature, dissolved oxygen, nitrite, ammonia, conductivity and salinity among batches. If significance was detected, Tukey's multiple comparison test was performed to identify specific differences. All tests were performed using SAS software.

RESULTS

During 2001 and 2002, 211 shovelnose sturgeon ranging from 450 to 718 mm fork length were sampled using gastric lavage. These contents were comprised primarily of aquatic insects belonging to 36 genera, in 16 families from 6 orders; two families of fish and a few terrestrial insects (Tables 6.1, 6.2). In many cases the invertebrates were still alive when they were flushed from the stomachs of the sturgeon. Of particular note was that very little detritus or inorganic matter was found in the stomachs of sturgeon.

The order Diptera was the most abundant order of the food items in the diets of shovelnose sturgeon, averaging 1,977 and 1,187 per stomach in 2001 and 2002, respectively. The family Chironomidae was the most diverse Dipteran family with 19 genera identified from sturgeon stomachs. The second most abundant and diverse order of insects in sturgeon stomachs was Ephemeroptera, which averaged 27 and 70 per stomach during 2001 and 2002, respectively. Most of the remainder of the sturgeon's diet was comprised of Trichopterans. Two other orders of insects (Odonata and Plecoptera), two families of fishes (Sciaenidae and Cyprinidae) and a few terrestrial insects were also found in sturgeon stomachs (Table 6.2).

To test the survival of shovelnose sturgeon subjected to PGL, nine tests each containing eight fish were conducted. These 72 shovelnose sturgeon were captured in 56 gill net drifts (N=56 sturgeon) and four trammel net drifts (N=16 sturgeon).

No significant difference (p=0.7094) was detected between survival of PGL and control fish for all nine tests. Survival was 100% during tests 1, 2, 3, 4, 7, 8 and 9 (Table 6.3). Mortality during test 5 consisted of two PGL fish and no control fish for a mortality rate of 44%. During test 6 five of the six PGL fish and both control fish expired, for mortality rates of 83% and 100%, respectively.

Water temperatures during the tests ranged from 16.7 to 28.1°C with an overall mean of 20°C. There was a significant difference of temperature among the nine tests (p=0.0001), but the variation of temperature within a test remained relatively constant (Shuman 2003). However, there seemed to be no direct relationship between temperature during a test and mortality of the fish in the test, since tests 5 and 6, when mortality occurred were near the center of the temperature range. Dissolved oxygen concentrations during the tests ranged from 6.9 to 9.5 mg/L with an overall mean of 8.1mg/L. A significant difference among tests was detected for dissolved oxygen concentrations (p=0.0016). However, no relationship between dissolved oxygen concentrations during a test and mortality was detected, since the concentrations for tests 5 and 6 were near the center of the range of values. Conductivity levels among tests were significantly different, but most of the difference was due to the addition of sodium chloride to the water during tests 7, 8 and 9. There was no detectable relationship between conductivity level and mortality of sturgeon during the tests. Ammonia concentrations were significantly different among tests (p=0.0003), but there were no detectable relationships between ammonia concentrations and sturgeon mortality during the tests. Nitrite concentrations afford the only potential cause and effect relationship between a chemical factor and mortality of test sturgeon. Concentrations of nitrite were significantly higher during tests 5 and 6 than during all other tests (p<0.0001). Nitrite levels during tests 5 and 6 were above 5 mg/L for eight and seven days, respectively. This corresponded to the only times when sturgeon died during the nine test runs.

Pulsed gastric lavage (PGL) of sturgeon to determine their diet.

Table 6.1. List of taxa found in shovelnose sturgeon stomach contents and drift in the Platte River.

	FAMILY	GENUS or SPECIES	STOMACH CONTENTS	DRIFT
Diptera			**x**	**x**
	Ceratopogonidae:		x	x
	Chaoboridae	*Chaoborus sp.*	x	
	Simuliidae	*Simulium sp.*	x	x
	Tabanidae		x	x
	Tipulidae		x	x
	Chironomidae		x	x
	Chironominae		x	x
		Chernovskiia sp.	x	x
		Chironomus sp.	x	x
		Cryptochironomus sp.	x	x
		Cyphomella spp./ Paracladopelma sp.	x	x
		Dicrotendipes sp..	x	
		Glyptotendipes spp.		x
		Harnischia sp.	x	
		Lauterborniella sp.	x	
		Parachironomus sp.		x
		Paracladopelma sp.	x	
		Paratendipes sp.	x	
		Polypedilum sp.	x	x
		Robackia sp.	x	x
		Saetheria sp..	x	x
		Stenochironomus sp.		x
		Tribelos sp.	x	x
		Cladotanytarsus sp.	x	
		Paratanytarsus sp.	x	
		Rheotanytarsus sp.	x	
		Sublettea sp.	x	
		Tanytarsus sp.	x	x
	Tanypodinae:	*Ablabesmyia sp.*	x	x
	Orthocladiinae			
		Orthocladius/Cricotopus sp.		x
		Nanocladius spp.		x

DISCUSSION

Our analysis of shovelnose sturgeon food habits agrees, in general with findings by Modde and Schmulbach (1977) and Hofpar (1997) who considered them to be opportunistic benthivores. However, the predominance of chironomids in the diet seems to indicate that they are selecting for these larvae.

Recent advances in gastric lavage reported here from Shuman (2003), and Shuman et al. (2007) and colonic flushing (George et al. 2005) show that they hold great promise to understanding the food habits of pallid sturgeon in the lower Platte River. Although we were unable to sample stomach contents of pallid sturgeon, the information gained by a study of pallid sturgeon food habits may clarify whether pallid sturgeon choose habitats based on habitat characteristics or the presence of favorable food items. George et al. (2005) found that pallid sturgeon from the Mississippi River consumed shoal chub and this species is common in the lower Platte River.

Shuman (2003) and Shuman and Peters (2007) found that there was no significant difference between survival of lavaged shovelnose sturgeon and non-lavaged shovelnose sturgeon in the laboratory. These results combined with other studies on pallid sturgeon formed the basis for the U.S. Fish and Wildlife Service’s recommendation to allow PGL on pallid sturgeon in the field as of 2006. Unfortunately, approval to PGL pallid sturgeon stomachs came too late for us to use this technique during 2006.

(Table 6.1. continued)

	FAMILY	GENUS or SPECIES	STOMACH CONTENTS	DRIFT
Ephemeroptera			**x**	**x**
	Baetidae		x	x
	Caenidae		x	x
		Amercaenis ridens	x	x
		Brachycercus sp.	x	
		Caenis sp.	x	x
		Cercobrachys sp.	x	x
	Ephemeridae	*Hexagenia sp.*		x
	Heptageniidae	*Heptagenia sp*	x	x
	Polymitarcyidae		x	x
		Ephoron sp.	x	x
		Totorpus sp.	x	x
	Pseudironidae	*Pseudiron sp.*	x	
Odonata			**x**	
	Gomphidae		x	
		Gomphus sp.	x	
		Progomphus sp.	x	
Plecoptera			**x**	**x**
	Perlidae	*Acroneuria sp.*	x	x
	Perlodidae	*Isoperla sp.*	x	x
Trichoptera			**x**	**x**
	Hydropsychidae		x	x
		Cheumatopsyche sp.	x	x
		Hydropsyche sp.	x	x
		Potomyia flava	x	x
				x
	Leptoceridae	*Nectopsyche sp.*		x
Hemiptera				**x**
	Corixidae			x
Gastropoda				x
Cladocera		*Daphnia sp.*		x
Fish			**x**	**x**
	Scianenidae	*Aplodinotus grunniens*	x	
	Cyprinidae		x	
Terrestrial insects			x	x

Table 6.2. Number, frequency of occurrence, and percent composition by number of food items by year found in shovelnose sturgeon stomach rations during 2001 and 2002.

	2001 n= 169			2002 n= 42		
	Number	Occurrence	Composition	Number	Occurrence	Composition
Chironomidae	**334182**	**95.9%**	**96.0%**	**49844**	**100.0%**	**89.0%**
Chernovskiia sp.	93111	85.2%	26.8%	9001	88.1%	16.0%
Saetheria sp.	41986	66.1%	12.1%	12369	59.5%	22.0%
Paracladopelma sp.	141390	88.2%	40.7%	9171	81.0%	16.3%
Robackia sp.	30838	71.6%	8.9%	12529	95.2%	22.3%
Polypedilum sp.	3315	30.2%	1.0%	1191	57.1%	2.1%
Paratendipes sp.	12485	50.5%	3.6%	3284	40.5%	5.8%
Paratanytarsus sp.	396	6.7%	0.1%	0	0.0%	0.0%
Cryptochironomus sp.	5022	43.2%	1.4%	945	42.9%	1.7%
Tanytarsus sp.	871	15.4%	0.3%	97	19.0%	0.2%
Chironomus sp.	1132	16.0%	0.3%	215	19.0%	0.4%
Cyphomella/ Paracladopelma sp.	2514	26.9%	0.7%	975	38.1%	1.7%
Lauterbornella sp.	322	5.9%	0.1%	0	0.0%	0.0%
Rheotanytarsus sp.	11	0.6%	0.0%	0	0.0%	0.0%
Harnishia sp.	29	0.6%	0.0%	0	0.0%	0.0%
Sublettea sp.	158	1.8%	0.0%	0	0.0%	0.0%
Cladotanytarsus sp.	150	1.8%	0.0%	0	0.0%	0.0%
Tribelos sp.	1	0.8%	0.0%	0	0.0%	0.0%
Dicrotendipes sp.	50	1.2%	0.0%	8	2.4%	0.0%
Tanypodinae	**401**	**7.7%**	**0.1%**	**59**	**6.8%**	**0.1%**
Ablabesmia sp.	401	7.7%	0.1%	59	6.8%	0.1%
Ephemeroptera	**4542**	**82.2%**	**1.3%**	**2977**	**85.7%**	**5.3%**
Isonychia sp.	2197	72.8%	0.6%	1419	66.7%	2.5%
Cercobrachus sp.	1969	71.6%	0.6%	1420	78.6%	2.5%
Brachycerus sp.	73	18.9%	0.0%	45	28.6%	0.1%
Amercaenis ridens	20	6.7%	0.0%	2	6.8%	0.0%
Caenis sp.	2	1.2%	0.0%	0	0.0%	0.0%
Baetidae	209	27.8%	0.1%	74	35.7%	0.1%
Heptageniidae	15	6.5%	0.0%	6	7.1%	0.0%
Ephoron sp.	27	6.1%	0.0%	1	2.4%	0.0%
Tortopus sp.	4	1.8%	0.0%	0	0.0%	0.0%
Pseudiron sp.	2	1.2%	0.0%	10	7.1%	0.0%
Trichoptera	**2140**	**57.4%**	**0.6%**	**200**	**42.9%**	**0.4%**
Potomyia flava	1682	66.5%	0.5%	189	47.6%	0.3%
Hydropsyche sp.	64	19.5%	0.0%	2	6.8%	0.0%
Cheumatopsyche sp.	104	33.1%	0.0%	9	16.3%	0.0%
Plecoptera	**2**	**1.2%**	**0.0%**	**0**	**0.0%**	**0.0%**
Perlidae sp.	1	0.6%	0.0%	0	0.0%	0.0%
Isoperla sp.	1	0.6%	0.0%	0	0.0%	0.0%

(Table 6.2. continued)

Diptera	**84**	**3.0%**	**0.0%**	**12**	**6.8%**	**0.0%**
Ceratopogoninae	78	1.8%	0.0%	11	2.4%	0.0%
Chaoborous sp.	1	0.6%	0.0%	0	0.0%	0.0%
Tibanidae	1	0.6%	0.0%	0	0.0%	0.0%
Tipulidae	4	2.4%	0.0%	0	0.0%	0.0%
Simulium sp.	0	0.0%	0.0%	1	2.4%	0.0%
Odonata	**11**	**5.3%**	**0.0%**	**2**	**6.8%**	**0.0%**
Gomphus sp.	10	5.3%	0.0%	2	6.8%	0.0%
Progomphus sp.	1	0.6%	0.0%	0	0.0%	0.0%
Terrestrial	**11**	**5.3%**	**0.0%**	**2**	**6.8%**	**0.0%**
Larval fish	**5**	**2.4%**	**0.0%**	**0**	**0.0%**	**0.0%**
Cyprinidae sp.	3	1.8%	0.0%	0	0.0%	0.0%
Aplodinotus grunniens	2	1.2%	0.0%	0	0.0%	0.0%

Table 6.3. Number of deaths and percent survival of shovelnose sturgeon subjected to pulsed gastric lavage during nine laboratory experiments with eight individuals per experiment.

	Control Deaths	Treatment Deaths	Control Percent surviving	Treatment Percent Surviving
Batch 1	0	0	100	100
Batch 2	0	0	100	100
Batch 3	0	0	100	100
Batch 4	0	0	100	100
Batch 5	0	2	100	67
Batch 6	2	5	0	17
Batch 7	0	0	100	100
Batch 8	0	0	100	100
Batch 9	0	0	100	100

CHAPTER 7

HABITAT USE AND POPULATION CHARACTERISTICS BY CHUB SPECIES (STURGEON CHUB, SHOAL CHUB, SILVER CHUB AND FLATHEAD CHUB) IN THE LOWER PLATTE RIVER

INTRODUCTION

Chubs of the genus Macrhybopsis and the genus Platygobio belong to the minnow family (Cyprinidae) and they tend to be species which inhabit turbid rivers like the Missouri River and its tributaries (Cross 1967, Pflieger 1997). They tend to be bottom dwelling species and they share habitats similar to those used by pallid sturgeon and shovelnose sturgeon. In addition, several studies have documented that sturgeon chub (Gerrity et al. 2006) and shoal chub (George et al. 2005) are common in the diets of pallid sturgeon. Peters et al. (1989) and Peters and Holland (1994) presented univariate habitat suitability criteria (depth and velocity) for speckled (shoal) chub, silver chub and flathead chub. An unpublished report (Peters and Holland) developed a spatial niche approach to habitat analysis in the Platte River that was used by Hardy and Associates (1992) in their habitat analysis of the central Platte River.

When this study began the sturgeon chub was being considered for listing as an endangered species and one of our primary objectives was to document habitat use, habitat selection and species associated with sturgeon chub in the lower Platte River. In addition, since sturgeon chub are rare, this study was expanded to include all chub species in the lower Platte River. Kopf (2003) studied the habitat use by chubs, including sturgeon chub, in the lower Platte River and her study comprises a major portion of the results presented in this chapter.

Our objectives were to

1. Determine the distribution and the habitats used by the chub species in the lower Platte River.

2. Determine the population characteristics of the chub populations in the lower Platte River in terms of the age and growth, length-weight relationships, population density, reproductive status and their species associations.

METHODS

Chubs were captured primarily by the use of trawls and seines (for a description of sampling methodology and effort see Chapter 2). All specimens were fixed in 10% formalin and returned to the laboratory for further study. In the laboratory, specimens were identified, measured, weighed and examined to determine their sex and spawning condition.

Distribution:

GPS locations were recorded for each sample collected. This was used to describe the distribution of each species within the lower Platte River.

Habitat Use:

Habitat use for each species was described by comparing samples with the species to samples without the species for each sampling gear. Where normality and equal variance of the data existed, the means were compared with a t-test. Where normality or equal variance did not exist, data were rank transformed, and compared with a Mann-Whitney Rank Sum Test.

Additionally, depth and mean column velocity was analyzed using a bivariate table with four categories of depth and four categories of mean column velocity. First, utilization of the habitat was determined by tabulating the number of captures for each cell in the table, and then calculating the percent frequency of each cell in the table. Selection of the depth and velocity combinations was determined by dividing the percent frequency of occurrence in each cell with the percent frequency of the sampling effort for that cell (see sampling chapter for data on percent frequency of the sampling effort). The habitat selection was normalized by dividing each cell value by the sum of all cell values. These values were standardized to a scale of 0 to 1 by dividing each cell value by the largest cell value (Bovee and Milhous 1978, Peters et al. 1989). In cases where undefined numbers would result in division by zero, the value was replaced with a zero.

Age and Growth:

Length-frequency distributions were developed using total length measurements. When the total number of specimens captured allowed, length frequency histograms were used to identify cohorts (year classes) of individuals (DeVries and Frie 1996).

Length-Weight:

Length-weight relationships were developed by plotting the $\log_{10}$ length against $\log_{10}$ weight for all specimens. Linear regression was used to calculate the intercepts and slopes of the relationships. When there were insufficient numbers of specimens to develop a length-weight relationship, we used a Fulton condition index, where K = weight * 100,000 / length^3 (Anderson and Neuman 1996).

Population Density:

Population density estimates were based on measures of catch per unit area (CPUA) (Yu 1996). CPUA was calculated by multiplying the length of a trawl run by the width of the trawl mouth to estimate the area sampled. Next, area sampled was divided into the number of individuals of each species caught in a sample to obtain an estimate of catch per unit area. CPUA was standardized to a number of fish per 100 m2. Overall population density was the average standardized CPUA for the entire lower Platte River in each year, while site population density was the average standardized CPUA for a given region of the river.

Reproductive Status:

Individuals large enough to be considered adults were dissected to examine their gonads and determine their gender and reproductive status. Gonads were then weighed and the gonadosomatic index (GSI) was calculated. GSI equals the gonad weight (X100) divided by the total weight of the fish (Strange 1996). Plots of GSI values by sampling date were then used to identify spawning times for each species. These data along with larval fish sampling provided insight about chub spawning times.

Associated Species:

Associated species are those species captured in samples with species of concern. We considered that those species which were captured more frequently with the species of concern to be more highly associated than those which were less frequently captured with the species of concern.

RESULTS AND DISCUSSION

Sturgeon Chub Distribution:

Sturgeon Chub sampled in the lower Platte River

A total of five sturgeon chub was captured at two locations during the 2000 to 2004 study period (Figure 7.1). Three of these specimens were captured at Louisville on 20 August 2000, one was captured at Louisville on 30 May 2002 and one was captured at Schilling on 26 June 2002. Since we only found sturgeon chub in the lowest reaches of the Platte River it seems that we are seeing a trend similar to those documented by Cross and Moss (1987) and Pflieger and Grace (1987).

Sturgeon chub are endemic to the Missouri River and its tributaries which flow in from the west and along with the Mississippi River downstream from the Missouri River (Bailey and Allum 1962, Lee et al. 1980, Pflieger 1997, Etnier and Starnes 1993). During recent years, sturgeon chubs have been collected widely during surveys in the Missouri River main stem (Galat et al. 2005b) and several of its tributaries (Werdon 1992). Because of their apparently greater abundance than previously thought, the sturgeon chub did not receive Federal endangered species or threatened species status, even though their overall distribution has been constricted (Werdon 1993). However, sturgeon chub are considered a threatened species in Nebraska. The first documented collection of sturgeon chubs in Nebraska was from Bazile Creek and the Platte River near Grand Island (Evermann and Cox 1896). Johnson (1942) considered sturgeon chub to be abundant in the Republican River and he indicated that sturgeon chub were found in the Platte River downstream from Gothenburg and in the Elkhorn River downstream from Winslow. Collections, since 1980, have only found sturgeon chub in the lower Platte River and the Missouri River (Schainost and Koneya 1999), and there are no recent records from the Republican River.

Habitat Use:

Water depths where sturgeon chubs were caught ranged from 1.04 to 1.4 m and averaged 1.3 m. Bottom velocities where sturgeon chubs were caught ranged from 0.21 to 0.46 m/s and averaged 0.30 m/s. Four of the five sturgeon chub were found at sites where substrates were composed of 90% sand and 10% gravel. The other sturgeon chub was found where the substrate was composed of 75% sand and 25% gravel.

The conditions where sturgeon chubs were collected during this study were deeper water and in slower velocities

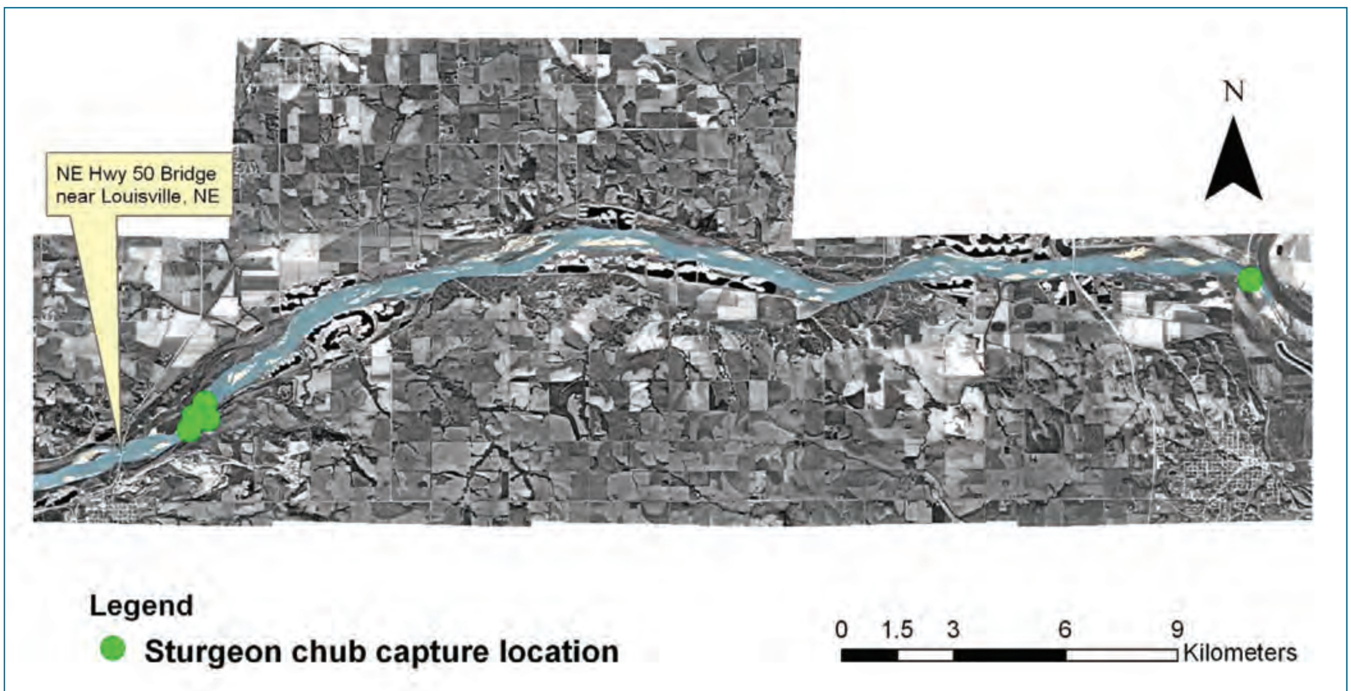


Figure 7.1. Map of locations where sturgeon chub were captured from 2000 to 2004 in the lower Platte River, Nebraska

than that where Peters et al. (1989) collected a sturgeon chub in 1987. The sandy conditions were similar between our study and Peters et al. (1989). Other studies (Werdon 1992, Herzog and Ostendorf 2002) found sturgeon chubs in areas that have water velocities over 0.4 m/s in depths less than 2 m deep. The typical substrates in areas where these studies found sturgeon chubs were gravel and rubble. Overall, sturgeon chub appear to fit into the deep water (>0.6 m) moderate (0.3-0.6 m/s) to swift water (>0.6 m/s) spatial niches proposed for the shallow water fish community by Peters and Holland and used by Hardy and Associates (1992).

One of the primary habitat characteristics noted for sturgeon chub is their apparent dependence on turbid water (Stewart 1981, Werdon 1992). Turbidity at sites where sturgeon chub sampled during this project ranged from 70 to 130 NTU which was typical for the lower Platte River during the study period from 2000 to 2004, but these values are considerably lower than the 500 JTU values reported by Werdon (1992) from the Powder River, WY.

Only two sturgeon chub were captured in the trawls in the lower Platte River during this study. Both individuals were captured in 2002. Although, this species is of high interest, given the small sample size it is hard to conclude much about the habitat use or selection of Platte River sturgeon chub. The first sturgeon chub was found 30 May 2002 at the Louisville site with a length of 92.9 mm over 90% sand 10% gravel substrate at 1.4 m and a bottom velocity of 0.46 m/s. The second was captured 26 June 2002 at the Plattsmouth site with a length of 52.2 mm over 75% sand 25% gravel substrate at 1.1 m and a bottom velocity of 0.21 m/s. Findings were consistent with other sturgeon chub collections throughout the Missouri River basin cited as using fast velocities over gravel substrate (Werdon 1992).

Age and Growth:

Sturgeon chub live up to four years and attain lengths up to 96mm in Wyoming (Stewart 1981) but seldom attain lengths of over 75mm in Missouri where they seldom live past age 2 (Pfleiger 1997). Even though we attempted to focus our collection efforts to sample sturgeon chub, we were able to capture only five during this study (Table 7.1). One additional specimen used in the age and growth analysis for the lower Platte River was captured in 1987 near Fremont, NE (Peters et al. 1989). These fish ranged in size from 52.5 to 92.4 mm total length. There were not enough data to compile a meaningful histogram. Werdon (1992) found up to three age classes and Stewart (1981) found that age 0 sturgeon chub in the Powder River, WY ranged from 38 to 48 mm in length. Age 1 individuals ranged from 55.3 to 80 mm, age 2 individuals ranged from 68.6 to 92.7 mm and age 3 individuals ranged from 81.3 to 91.4 mm. However, Everett (1999) found that age 3 individuals ranged from 73-86 mm. Based on these results, the smallest individual was likely age 1, while the rest of the specimens were either age 2 or age 3. This is supported by our observations that the 4 largest individuals were all sexually mature (3 females and 1 male) and the 52.5 mm specimen was apparently immature. However in some localities (Stewart 1981), sturgeon chub may be similar to shoal chub in their life history with most of the individuals living only through two summer seasons and expiring after spawning at age one.

Length-Weight:

The small number of sturgeon chubs did not allow calculation of a meaningful length-weight regression. Condition factors for the three fish identified as female ranged from 0.70 to 0.77 and averaged 0.74 while the condition factor value for the male fish was 0.54. From data presented by Stewart (1981), we calculated condition factors for sturgeon chubs and they ranged from 0.29 to 0.87 with a mean of 0.59. Our values fall within this range.

Population Density:

No estimate of density was attempted for sturgeon chubs because the number captured during this study was too small.

Reproductive Status:

One sturgeon chub (64.4 mm, captured on 20 August 2000) contained identifiable eggs and had a GSI value of 6.6.

Table 7.1. Length, body weight, gonad weight, sex, Fulton's condition factor (K), and gonadosomatic index (GSI) for sturgeon chub collected in the Platte River, Nebraska, 2000-2002. (= fish too small to determine values)*

Date	Location	Length (mm)	Body weight (grams)	Gonad Weight (grams)	Sex	Fulton's K	GSI
8/20/2000	Louisville RM 15.5	64.4	2.065	0.137	Female	0.77	6.6
8/20/2000	Louisville RM 15.5	78.5	3.387	0.041	Female	0.70	1.2
8/20/2000	Louisville RM 15.5	80.9	3.936	0.056	Female	0.74	1.4
5/30/2002	Louisville RM 15.5	92.4	4.908	0.037	Male	0.54	0.8
6/26/2002	Schilling RM 0.5	52.5	0.785	*	*	0.62	*

In contrast, two larger females captured on that same date had no identifiable eggs and GSI values of 1.2 and 1.4, suggesting that they had already spawned. Stewart (1981) collected no gravid females from the Powder River, WY after 26 July. One identifiable male was captured on 30 May 2002 and it had a GSI of 0.8, but there was no evidence of breeding tubercles on this specimen. Cross (1967) stated that male sturgeon chub collected in late June had well developed breeding tubercles. Most studies of sturgeon chub spawning indicate that reproduction takes place from May to late June at water temperatures between 18 and 23ºC (Werdon 1992). These temperatures are typically attained in the Platte River during late May and early June.

Associated Species:

We collected seven species, silver chub, shoal chub, plains minnow, red shiner, sand shiner, channel catfish and sauger in the same trawl hauls as sturgeon chub (Table 7.2). Collection records from the University of Michigan Museum of Zoology show that Schultz and DeLacy collected 12 species, plains minnow, brassy minnow, red shiner, sand shiner, river shiner, bigmouth shiner, plains killifish, plains topminnow, longnose dace, creek chub and green sunfish along with three sturgeon chub from the Platte River near Gothenburg, NE on 8 September 1931. Gould (1997) found literature references to 48 species that had been found associated with sturgeon chub. Several studies have mentioned strong associations with either flathead chub, (Stewart 1981, Werdon 1992) or speckled chub (Gelwicks et al. 1996, Werdon 1992, Peters et al. 1989). Associations with longnose dace seem surprising, since Werdon (1992) and Stewart (1981) both state that longnose dace apparently replace sturgeon chubs in clear water conditions.

Shoal Chub Distribution:

Shoal chub, previously known as speckled chub, are quite widespread in eastern Nebraska. Since 1970 they have been collected from the main stem of the Platte River as far west as Kearney and up the Loup and Elkhorn River systems. There are no records of shoal chub being collected from the Republican River system or the Big Blue River system since 1970. Yu (1996) reported speckled chubs from Clarks to North Bend on the Platte River in 1992 and 1993.

Habitat use:

Trawls: Shoal chubs were captured in 75 of the 157 trawls run in the Platte River. Water depth, water temperature, dissolved oxygen concentrations and specific conductivity were higher where shoal chubs were collected than where they were not. Total suspended solids and turbidity values were lower where shoal chubs were collected than where they were not collected (Table 7.3). All of these differences are concordant with a relationship among the parameters and differences in discharge. Shoal chubs were captured more frequently ($p < 0.01$) at lower discharge rates (median = 2,790 cfs), than observed in trawls that caught no shoal chubs (median = 5,650 cfs). The results of these analyses suggest that shoal chubs are more densely distributed or are more easily captured at lower water level conditions than at higher water level conditions.

Table 7.2. Species captured in trawl runs that also captured sturgeon chubs in the lower Platte River, Nebraska, 2000 – 2004.

SPECIES	RM 15.5 09/19/2000	RM 15.5 09/19/2000	RM 15.5 05/30/2002	RM 0.5 06/26/2002
Sturgeon chub	1	2	1	1
Shoal chub	11	7	0	1
Silver chub	4	4	0	0
Plains minnow	3	7	0	0
Red shiner	1	0	0	0
Sand shiner	0	1	0	0
Channel catfish	1	5	0	2
Sauger	0	1	0	0

Sand was the most frequent substrate texture found in areas sampled which contained shoal chubs and those samples which did not contain them (Table 7.4). Gravel texture substrate was the second most frequent substrate type in trawl samples which contained shoal chubs and those that did not. Silt texture substrate was only noted in areas of trawl samples that contained shoal chubs and rock substrate was only noted in areas of trawl samples that did not contain shoal chubs.

Shoal chub were most frequently captured by trawls at depths greater than 0.6 m and at mean column water velocities greater than 0.3 m/s (Table 7.5, Table 7.6). The highest normalized selected values show the influence of small sample size on this measure of selection (Table 7.7). From these tables and our analysis of trawl selectivity (Chapter 2) we conclude that shoal chub show a selection for water greater than 0.6 m deep with mean column water velocities that increase from 0.3 to 0.6 m/s to velocities up to 0.9 m/s at depths greater than 0.9 m.

Percent frequency of occurrence of the number of shoal chubs (Figure 7.2) suggests that fish are not randomly distributed in the river with most trawls capturing a small number of fish (< 10) and a few nets capturing many fish (maximum = 608). This means that in most areas of the river no or few shoal chubs would be captured by a trawl, but in some areas large numbers of shoal chubs would be caught in a single sample. Possibly this is related to the trawl passing through favorable habitats for the shoal chub or that shoal chub aggregate for other reasons.

Seines: A total of 258 shoal chub was captured in 252 seine hauls. Shoal chub did not use any habitat variable in a proportion different from which it was sampled (Table 7.8). Shoal chubs were captured by seines in moderate current at moderate water depths.

Table 7.9 shows that there was a higher frequency of occurrence of sand and gravel substrates in seine samples that contained shoal chub and a higher frequency of occurrence of silt and rock substrate in seine samples that did not contain shoal chub. This may indicates a selection of sand and gravel substrates, but not for silt substrates. This is similar to the conclusions of Peters and Holland (1994) except for silt which they found to be suitable if combined with cover.

Shoal chub were most frequently caught by seines (Table 7.10, Table 7.11, Table 7.12) at depths less than 0.6 m and at mean column velocities less than 0.6 m/s. Seines caught shoal chubs in water deeper than 0.9 m with water velocities over 0.6 m/s, but the small number of samples in these habitat categories make these data difficult to interpret.

Peters and Holland (1994) considered shoal (speckled) chubs to be indicators of habitats with moderate to swift current flow in shallow water sections of the Platte River. Our collections of shoal chubs with seines corroborate those findings, but our trawl data expand the habitat into deeper and swifter conditions. Using the spatial niche classification (Hardy and Associates 1992) shoal chubs would fit into the moderate to swift velocity (0.3 - >0.6 m/s) / shallow (< 0.3 m) to deep (>0.6 m) conditions with a preference toward the deeper and swifter classes. This agrees with studies in other systems that have found water depth to be less important than current velocity in their habitat selection (Pflieger 1997). Since shoal chub probably spend most of their time close to the substrate it is likely that mean column velocities in deep water have little influence on the actual current which they experience.

*Table 7.3. Comparisons of samples with and without shoal chubs for the trawl sampling in the lower Platte River, Nebraska. * Denotes where normality and equal variance of the data existed and the data were compared with a t-test. (MCV= mean column velocity (m/sec), BV = bottom velocity (m/sec), Temp = temperature (ºC), DO = dissolved oxygen (mg/L), Sp Cond = specific conductivity (S/cm), TSS = total suspended solids (mg/L)*

Parameter	Fish/no fish	Number	Missing	Median	25%	75%	p value
Depth	fish	75	1	1.03	0.74	1.24	<0.001
	No fish	82	1	1.45	1.07	1.94	
MCV	fish	75	7	0.63	0.52	0.85	0.265*
	No fish	82	12	0.73	0.57	0.86	
BV	fish	75	8	0.33	0.23	0.44	0.505
	No fish	82	14	0.34	0.21	0.56	
Temp	fish	75	3	25.4	22.0	26.8	0.032
	No fish	82	7	23.9	21.2	25.8	
DO	fish	75	3	9.9	8.9	11.3	<0.001*
	No fish	82	7	8.8	7.9	9.6	
Sp Cond	fish	75	3	805	517	1163	<0.001
	No fish	82	7	567	490	659	
TSS	fish	75	18	124	88	180	<0.001
	No fish	82	34	768	372	1368	
Turbidity	fish	75	18	65	45	126	<0.001
	No fish	82	34	1044	337	1919	

Table 7.4. Comparison of percent frequencies of samples with and without shoal chub, by substrate texture, during trawl sampling in the lower Platte River, Nebraska.

	Size	Missing	% sand	% gravel	% silt	% rock
Substrate fish	75	1	93.1	6.2	0.7	0.0
Substrate none	82	7	91.0	4.4	0.0	3.0

Table 7.5. Number of shoal chub captured in combined depth and velocity categories during trawl sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0	0	0	0	0
	0.30-0.60	1	8	0	0	9
	0.60-0.90	0	16	7	1	24
	>0.90	1	4	18	12	35
	Total	2	28	25	13	68

Table 7.6. Percent use by shoal chub captured in combined depth and velocity categories during trawl sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.0	0.0	0.0	0.0	0.0
	0.30-0.60	1.5	11.8	0.0	0.0	13.2
	0.60-0.90	0.0	23.5	10.3	1.5	35.3
	>0.90	1.5	5.9	26.5	17.6	51.5
	Total	2.9	41.2	36.8	19.1	100.0

Table 7.7. Normalized selected habitats for shoal chub captured in combined depth and velocity categories during trawl sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.00	0.00	0.00	0.00
	0.30-0.60	1.00	0.80	0.00	0.00
	0.60-0.90	0.00	0.89	0.47	1.00
	>0.90	0.50	0.27	0.35	0.57

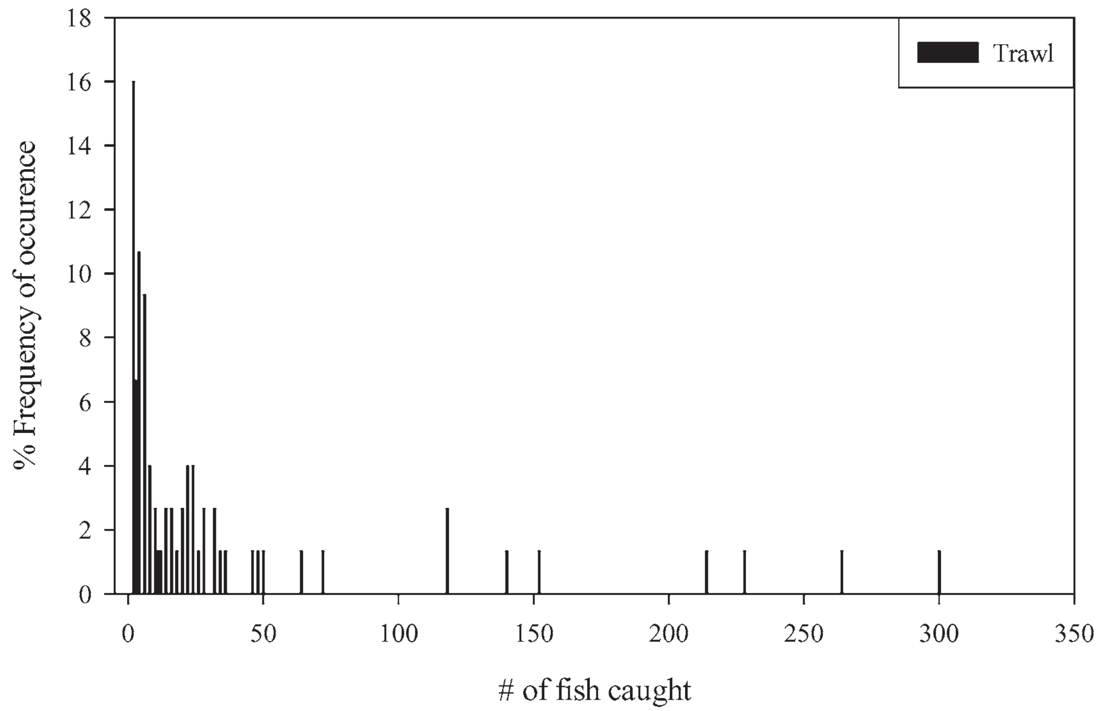


Figure 7.2 Percent frequency of the occurrence of shoal chubs in trawl samples in the lower Platte River, Nebraska.

*Table 7.8. Comparisons of samples with and without shoal chubs for the seine sampling in the lower Platte River, Nebraska . * Denotes where normality and equal variance of the data existed and the data were compared with a t-test. (MCV= mean column velocity (m/sec), BV = bottom velocity (m/sec), Temp = temperature (^{o}C), DO = dissolved oxygen (mg/L), Sp Cond = specific conductivity (S/cm), TSS = total suspended solids (mg/L)*

Parameter	Fish/no fish	Number	Missing	Median	25%	75%	p value
Depth	fish	52	9	0.38	0.31	0.53	0.251
	No fish	200	31	0.49	0.29	0.67	
MCV	fish	52	11	0.34	0.20	0.48	0.055*
	No fish	200	50	0.25	0.09	0.42	
Temp	fish	52	10	24.7	19.5	27.2	0.213
	No fish	200	47	23.6	17.7	26.1	
DO	fish	52	10	9.1	7.3	11.6	0.293
	No fish	200	47	8.6	7.3	10.9	
Sp Cond	fish	52	11	508	445	653	0.347
	No fish	200	51	505	439	572	
TSS	fish	52	31	133	97	245	0.454
	No fish	200	116	155	114	277	

Age and growth:

Shoal chub are small fish that seldom live past age 2 and most specimens die after age 1 (Cross 1967, Pflieger 1997). Shoal chub were by far the most abundant of the chub species encountered in the lower Platte River during this study. Most of the shoal chub caught during this study were between 30 and 40 mm total length and none were larger than 70 mm (Kopf 2003). From an analysis of length frequency distributions Kopf (2003) determined that shoal chub live for about 2 years and in that time they may attain a size of up to 73.3 mm total length. During their first year of life, they grow to about 35 or 40 mm total length and these fish then overwinter to form the main breeding stock for the coming year. Cross (1967), Becker (1983) and Pfleiger (1997) reported similar ages and lengths.

Table 7.9. Comparison of percent frequencies of samples with and without shoal chub, by substrate texture, during seine sampling in the lower Platte River, Nebraska.

	Size	Missing	% sand	% gravel	% silt	% rock
Substrate fish	52	13	84.5	4.6	10.9	0.0
Substrate none	200	39	74.8	0.5	24.5	0.8

Table 7.10. Number of shoal chub captured in combined depth and velocity categories during seine sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	5	3	0	0	8
	0.30-0.60	12	13	1	0	26
	0.60-0.90	1	4	0	0	5
	>0.90	0	1	1	0	2
	Total	18	21	2	0	41

Table 7.11. Percent use by shoal chub captured in combined depth and velocity categories during seine sampling in the lower Platte River, Nebraska .

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	12.2	7.3	0.0	0.0	19.5
	0.30-0.60	29.3	31.7	2.4	0.0	63.4
	0.60-0.90	2.4	9.8	0.0	0.0	12.2
	>0.90	0.0	2.4	2.4	0.0	4.9
	Total	43.9	51.2	4.9	0.0	100.0

Table 7.12. Normalized selected habitats for shoal chub captured in combined depth and velocity categories during trawl sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.42	0.63	0.00	0.00
	0.30-0.60	0.90	1.00	0.73	0.00
	0.60-0.90	0.09	0.65	0.00	0.00
	>0.90	0.00	0.58	0.97	0.00

Length-Weight:

Length-weight regressions for shoal chubs were calculated by Kopf (2003). The regression for males was Log_{10} W = -5.494 + (3.190 (Log_{10} Total Length)) and for females it was Log_{10} W = -5.742 + (3.342 (Log_{10} Total Length)). Fulton condition factors (K(TL)) averaged 0.662 for males and 0.668 for females, and showed no significant differences due to size of fish or month through the sampling season (May to September). Swingle (1965) reported a condition factor of 0.39 to 0.83 for speckled chub in Alabama, and a length weight regression of Log_{10} W = -4.61 + (2.77 (Log_{10} Total Length)). It appears that shoal chub in the lower Platte River have similar body shapes as speckled chubs in Alabama.

Population Density:

The density of shoal chubs ranged from 0.973 to 12.579 /100m^2 during 2001 and 2002, respectively. Their density generally increased in samples collected downstream from the Elkhorn River (Table 7.13). These densities are generally higher than those reported by Yu (1996) who found the density of shoal chubs to be less than 1/100m^2 at study sites from Clarks to North Bend, Nebraska. The only exception was his value of 6.5/100m^2 at Columbus, Nebraska in 1992. However, Yu (1996) used electrofishing grids which sampled

Table 7.13. Comparison of shoal chub densities for locations along the Platte River from Clarks, NE to the confluence with the Missouri River. Data adapted from Yu (1996) and Kopf (2003).

Location (River Mile)	1992 (Yu 1996)	1993 (Yu 1996)	2001 / 2002 (Kopf 2003)
Clarks (134-135)	0.125	0.125	-
Columbus (100-101)	6.500	0.250	-
Rogers (80-81)	0.375	0	-
North Bend (69-70)	0.625	0.625	-
Leshara (48-49)	-	-	2.831
Elkhorn (32-33)	-	-	1.680
Louisville (15-16)	0	0	9.217
Schilling WMA(0-1)	-	-	9.770

Table 7.14. Frequency of occurrence by species associated with shoal chub from trawl and seine samples collected in the lower Platte River, Nebraska.

Species common name	Frequency of occurrence from trawls	Frequency of occurrence from seines	Frequency of occurrence total
Channel catfish	52	9	61
River shiner	41	9	50
Sand shiner	41	7	48
Silver chub	27	11	38
Red shiner	23	9	32
River carpsucker	11	6	17
Freshwater drum	10	3	13
Shovelnose sturgeon	11	1	12
Emerald shiner	5	5	10
Plains minnow	3	4	7
Quillback	4	1	5
Flathead chub	2	2	4
Fathead minnow	2	1	3
Flathead catfish	3	0	3
Suckermouth minnow	3	0	3
Bigmouth shiner	2	0	2
Blue catfish	2	0	2
Bluegill	2	0	2
Johnny darter	2	0	2
Sauger	2	0	2
White perch	2	0	2
Blue sucker	1	0	1
Western silvery minnow	1	0	1
Green sunfish	1	0	1

water < 1meter deep in contrast to the trawls which sample deeper water more effectively. Yu (1996) did not find any shoal chubs in the Louisville area where Kopf (2003) reported high densities of this species.

Reproductive Status:

All of the 26 female shoal chubs that contained well developed eggs were larger than 45 mm and all of the females in the 65 and 70 mm size categories contained eggs. GSI for female shoal chubs averaged 2.178 and the highest value was 14.588. All individuals that exhibited GSI values over 5.00 occurred between 23 May and 1 August during 2002. This agrees with information from larval fish collections reported in Chapter 8 of this study and with those found by Becker (1983) in Wisconsin.

Associated Species:

Shoal chubs were collected in association with 24 species of fish, 24 species from trawls and 13 species from seines (Table 7.14). Channel catfish were collected most frequently (61 times), river shiner (50 times), sand shiner (48 times), silver chubs (38 times) and red shiner (32 times). Becker (1983) collected 11 species of fish with speckled chubs in Wisconsin with the five most common species being, in order of abundance, spotfin shiner, bullhead minnow, emerald shiner and western sand darter.

Silver Chub Distribution:

Silver chubs were captured in 37 of the 140 trawl runs and in 61 of the seine hauls in the lower Platte River. Nebraska Game and Parks Commission records indicate that silver chub have been collected from the Platte River as far west as Kearney, the lower reaches of the Loup River, the Elkhorn River and the Niobrara River since 1970. Prior to 1970, records indicate that they were also collected in the upper Republican River and from sites farther up the Elkhorn River. Peters and Holland (1994) collected silver chub from as far west in the Platte River as Clarks, NE.

Habitat use:

Trawls: Differences between conditions where silver chubs were collected and where they were not collected were not significant for the habitat variables of mean column velocity, bottom velocities, temperature, total suspended solids and turbidity (Table 7.15). Silver chubs were collected at sites which were shallower than those where they were not collected. Dissolved oxygen concentrations at sites where silver chubs

*Table 7.15. Comparisons of samples with silver chubs to samples without for the trawl sampling in the lower Platte River, Nebraska. * Denotes where normality and equal variance of the data existed, the means were compared with a t-test. (MCV= mean column velocity (m/sec), BV = bottom velocity (m/sec), Temp = temperature (ºC), DO = dissolved oxygen (mg/L), Sp Cond = specific conductivity (S/cm), TSS = total suspended solids (mg/L)*

Parameter	Fish/no fish	Number	Missing	Median	25%	75%	p value
Depth	fish	41	0	0.85	0.64	1.38	0.005
	No fish	116	2	1.24	0.90	1.69	
MCV	fish	41	4	0.53	0.44	0.73	0.095*
	No fish	116	15	0.72	0.55	0.85	
BV	fish	41	5	0.31	0.21	0.39	0.14
	No fish	116	17	0.36	0.22	0.51	
Temp	fish	41	1	24.8	22.3	25.7	0.766
	No fish	116	9	24.3	21.2	26.5	
DO	fish	41	1	9.8	8.7	11.3	0.033*
	No fish	116	9	9.3	8.1	10.2	
Sp Cond	fish	41	1	699	558	1260	0.007
	No fish	116	9	584	485	788	
TSS	fish	41	6	124	82	1284	0.062
	No fish	116	46	284	131	1078	
Turbidity	fish	41	6	65	45	1644	0.063
	No fish	116	46	235	70	1640	

Table 7.16. Comparison of percent frequencies of samples with and without silver chub, by substrate texture, during seine sampling in the lower Platte River, Nebraska.

	Size	Missing	% sand	% gravel	% silt	% rock
Substrate fish	41	1	94.9	5.1	0.0	0.0
Substrate none	116	8	91.4	5.8	0.0	2.8

Table 7.17. Number of silver chub captured in combined depth and velocity categories during trawl sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0	0	0	0	0
	0.30-0.60	1	7	0	0	8
	0.60-0.90	0	10	2	0	12
	>0.90	0	2	11	4	17
	Total	1	19	13	4	37

Table 7.18. Percent use by silver chub captured in combined depth and velocity categories during trawl sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	0.0	0.0	0.0	0.0	0.0
	0.30-0.60	2.7	18.9	0.0	0.0	21.6
	0.60-0.90	0.0	27.0	5.4	0.0	32.4
	>0.90	0.0	5.4	29.7	10.8	45.9
	Total	2.7	51.4	35.1	10.8	100.0

Table 7.19. Normalized selected habitats for silver chub captured in combined depth and velocity categories during trawl sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.00	0.00	0.00	0.00
	0.30-0.60	1.00	0.70	0.00	0.00
	0.60-0.90	0.00	0.56	0.13	0.00
	>0.90	0.00	0.13	0.21	0.19

were collected were higher than those where they were not collected. Specific conductivities at sites where silver chubs were collected were higher than those at sites where they were not collected.

Percent frequencies of substrate textures in trawl sample areas where silver chub were collected were nearly identical to those from samples where they were not collected (Table 7.16). Rock substrates were found only in areas where silver chub were not collected.

Most silver chub were captured by trawls in habitats more than 0.6 m deep with water velocities less than 0.90 m/s (Tables 7.17, 7.18, 7.19). The high selection values for the habitats in slow to moderate current velocities (<0.60 m/s) and in depths >0.6 m are concordant with the conclusions of other studies (Peters and Holland 1994).

In the plots of percent frequency of occurrence of the number of silver chub caught per net a median around 2 fish is observed (Figure 7.3). This suggests that fish frequently occur in small groups in the river, with a few trawls capturing many fish (maximum = 40).

Seines: As shown in Table 7.20 locations where silver chubs were collected in seines did not differ from those where they were not collected for depth, mean column velocity, dissolved oxygen concentration or specific conductivity. However, water temperature was higher and total suspended solids loads were lower at locations where silver chub were collected.

Silver chub were collected using seines at a slightly higher percent of frequency (Table 7.21) over sand and at slightly lower frequencies over gravel, silt and rock than locations that had no silver chub.

Silver chub were captured with seines most frequently from areas that were less than 0.9 m deep with water velocities less than 0.6 m/s (Tables 7.22, 7.23, 7.24).

Silver chub tend to be fishes of larger deeper sections of rivers and their backwaters and they seem to prefer somewhat reduced turbidities (Cross 1967, Cross and Moss 1987, Pflieger 1997). Peters and Holland (1994) considered silver chubs to be an open water generalist species because it used a wide range of depths with no distinct preference for current velocity. This places them in the deep (> 0.6 m), slow to moderate current velocity (<0.6 m/s) categories in the spatial niche classification (Hardy and Associates 1992).

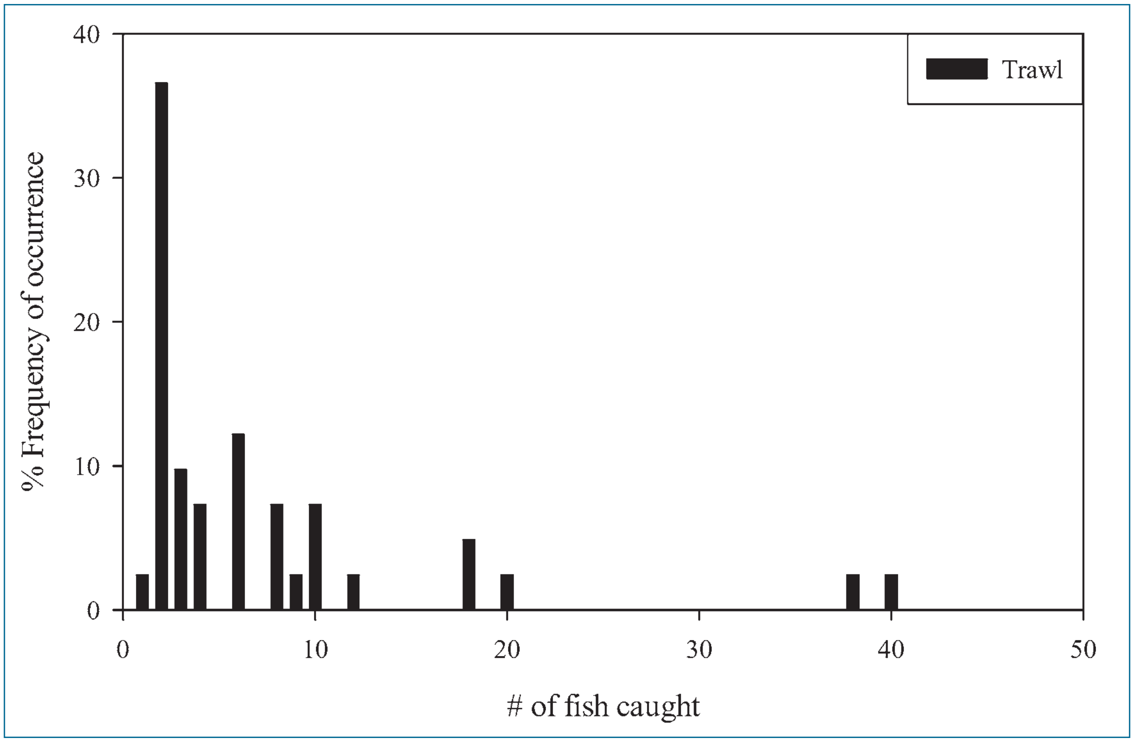


Figure 7.3 Percent frequency of the occurrence of silver chub in trawl samples in the lower Platte River, Nebraska.

*Table 7.20. Comparisons of samples with silver chubs to samples without for the seine sampling in the lower Platte River, Nebraska . * Denotes where normality and equal variance of the data existed, the means were compared with a t-test. (MCV= mean column velocity (m/sec), BV = bottom velocity (m/sec), Temp = temperature (ºC), DO = dissolved oxygen (mg/L), Sp Cond = specific conductivity (S/cm), TSS = total suspended solids (mg/L)*

Parameter	Fish/no fish	Number	Missing	Median	25%	75%	p value
Depth	fish	43	11	0.37	0.27	0.53	0.056
	No fish	209	29	0.47	0.31	0.68	
MCV	fish	43	13	0.22	0.09	0.35	0.176*
	No fish	209	48	0.27	0.13	0.45	
Temp	fish	43	15	26.1	23.8	29.1	<0.001
	No fish	209	42	23.3	17.7	26.1	
DO	fish	43	15	8.3	7.0	11.7	0.814
	No fish	209	42	8.7	7.3	10.8	
Sp Cond	fish	43	15	528	458	715	0.171
	No fish	209	47	505	439	580	
TSS	fish	43	33	112	97	144	0.047
	No fish	209	114	163	115	282	

Table 7.21. Comparison of samples with silver chub to samples without for substrate from the seine sampling in the lower Platte River, Nebraska.

	Size	Missing	% sand	% gravel	% silt	% rock
Substrate fish	43	14	77.2	1.3	21.5	0.5
Substrate none	209	38	73.4	1.6	23.8	1.1

Table 7.22. Number of silver chub captured in combined depth and velocity categories during seine sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	6	2	0	0	8
	0.30-0.60	9	8	1	0	18
	0.60-0.90	3	1	0	0	4
	>0.90	0	0	0	0	0
	Total	18	11	1	0	30

Table 7.23. Percent use by silver chub captured in combined depth and velocity categories during seine sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)				
		<0.30	0.30-0.60	0.60-0.90	>0.90	Total
Depth (m)	<0.30	20.0	6.7	0.0	0.0	26.7
	0.30-0.60	30.0	26.7	3.3	0.0	60.0
	0.60-0.90	10.0	3.3	0.0	0.0	13.3
	>0.90	0.0	0.0	0.0	0.0	0.0
	Total	60.0	36.7	3.3	0.0	100.0

Table 7.24. Normalized selected habitats by silver chub captured in combined depth and velocity categories during seine sampling in the lower Platte River, Nebraska.

		mean column velocity (m/s)			
		<0.30	0.30-0.60	0.60-0.90	>0.90
Depth (m)	<0.30	0.69	0.57	0.00	0.00
	0.30-0.60	0.92	0.84	1.00	0.00
	0.60-0.90	0.39	0.22	0.00	0.00
	>0.90	0.00	0.00	0.00	0.00

Age and growth:

Silver chub specimens may reach lengths greater than 150 mm at age 3 in Wisconsin (Becker 1983) and some specimens from Lake Erie have attained age 4 and lengths over 200 mm (Kinney 1954). Silver chub were the second most abundant chub species encountered in the lower Platte River during the study. Specimens ranged in size from 20 to 110 mm total length. Even though numbers were low, all specimens captured in May and June 2001 and 2002 were over 75 mm (Kopf 2003). By July and August, substantial numbers of individuals less than 60 mm appear in the collections along with those larger than 80 mm and by September there were three apparent cohorts (age classes) (Kopf 2003). From this it appears that silver chubs in the Platte River attain a length of about 40 mm by the end of their first summer of growth (age 0) and between 70 and 90 mm by the end of their second summer (age 1). This is somewhat slower than the growth reported by Becker (1983). He reports mean lengths at annulus formation of 79, 127 and 146 mm for ages 1, 2 and 3, respectively. It also appears that in the Platte River, fish first spawn at age 1 and these fish make up a majority of the spawning population.

Length-Weight:

The length-weight regression for silver chubs was calculated by Kopf (2003). The regression for males was Log_{10} W = -5.364 + (3.134 (Log_{10} Total Length)) and for females it was Log 10W = -6.388 + (3.673 (Log_{10} Total Length)). Fulton condition factors (K(TL)) averaged 0.124 for males and 0.868 for females and showed no significant difference due to size of fish or month through the sampling season (May to September) even though high values occurred during the months of July through September. Swingle 1965 found Fulton condition factors ranging from 0.75 to 0.89 for silver chub in Alabama. A length weight relationship of Log $_{10}$W = -4.876 + (3.062 (Log_{10} Standard Length)) was reported by Kinney (1954) in western Lake Erie. Our data show that the male fish are thinner than those reported by Swingle.

Population Density:

Based on the average area sampled by trawls during our study the catch per unit area of silver chubs ranged from 0.42 to 1.33/100m^2 during 2001 and 2002, respectively. The density tended to increase from less than 0.5fish/100m^2 at the Leshara and the Elkhorn River sites to over 1.33/100m^2 at the Schilling site (Table 7.25). This pattern of increasing density downstream agrees, in general, with that found by Yu (1996), except that in 1992 he also found high densities of silver chub (1.25/100m^2) at Columbus, NE. In contrast, Yu (1996) generally found densities of silver chubs along the Clarks to Louisville length of the Platte River to be below 0.5/100m^2. This may indicate that silver chub are using shallow water, sampled by grid electrofishing and deeper water, sampled by trawls at about the same densities in the lower Platte River and it may be further evidence of their habitat generalist tendencies (Cross 1967, Becker 1983).

Reproductive Status:

All of the 8 female silver chubs that contained well developed eggs were larger than 75 mm. GSI values for female silver chubs ranged from 0.299 to 5.698 and averaged 0.868. The maximum value agrees closely with the GSI value of 5 reported by Becker (1983) for fish from the Wisconsin River.

Associated Species:

Silver chub were collected with 28 species of fish, 17 species in seine samples and 24 species in trawl samples (Table 7.26). Shoal chub and channel catfish were collected most frequently with silver chubs (38) followed by river shiner (36) and sand shiner (34). This diverse assemblage of associated species supports the observation of Cross and Moss (1987) who considered silver chubs to be tolerant of the greatest diversity of river habitats from backwaters to open channels. Becker (1983) collected 23 species of fish with silver chub in the Wisconsin River. Shorthead redhorse, northern hog sucker, golden redhorse and spotfin shiner were the most common species, in order of abundance, in those collections of silver chub.

Flathead Chub Distribution:

Flathead chub are the most widespread of the chub species in Nebraska, having been collected in the Platte River system all the way to the Wyoming state line, but recent studies by Lynch and Roh (1996) failed to find them in the North Platte River drainage. They have also been collected in the Niobrara River to west of Valentine and into the headwaters of the Loup River and Elkhorn River systems. They were formerly (pre 1970) found in the Republican River system, but there are no recent records for them in this river.

Habitat use:

Flathead chubs were captured at depths which ranged from 0.23 m to 1.16 m and bottom velocities from 0.24 to 0.56 m/s (Kopf 2003). Substrate texture ranged from 75% sand and 25% gravel to 100% sand with the latter condition being the most frequently occurring condition. Flathead chub inhabit a wide range of habitat conditions from quiet pools to swift main channels (Olund and Cross 1961, Cross 1967). In the Platte River (Peters and Holland 1994) found that they primarily used water depths less than 0.45m with current velocities of 0.1 to 0.4 m/s. Hardy and Asscociates (1992) indicated that their preference was for shallow depths (< 0.3 m) with slow to moderate velocities (< 0.6 m/s). Our results would expand the depth range to deep (>0.6 m) on that scale. Werdon (1992) considered flathead chub to be characteristic of higher velocity areas within the Missouri River basin. In our collection with the trawl, flathead chub were found in moderate velocity habitats and depths ranging to over 1 m.

Age and Growth:

Flathead chub may grow to nearly 250 mm (Pflieger 1997) and live to age 4. Flathead chub were uncommon in our collections during this study (Kopf 2003). The 16 specimens captured ranged in size from 29.8 to 95.6 mm total length. All specimens less than 45 mm were judged to be immature, since their gender could not be determined. It seems unlikely that fish between 30 and 40 mm caught during July would be age 0 and therefore we assign them to age class 1. However, several of the fish in the 45 to 55 mm size category were identified as males. The smallest individuals identified as females were over 70 mm total length. It may be that flathead chub females do not mature until they are age 2, but that males mature at age 1. This is corroborated by the findings of Fisher et al. (2002), who found that female flathead chubs don’t mature until age 3 and may live to age 5. In contrast, Fisher et al. (2002) also state that all flathead chubs less than 100 mm are age 1 or younger. This does not fit our data from the Platte River.

Length-Weight:

No length-weight regression for flathead chubs collected during this study was calculated. Condition factors for the specimens collected ranged from 0.649 to 1.144 and

Table 7.25. Comparison of silver chub densities (N/100 m2) for locations along the Platte River from Clarks, NE to the confluence with the Missouri River. Data adapted from Yu (1996) and Kopf (2003).

Location (River Mile)	1992 (Yu 1996)	1993 (Yu 1996)	2001 / 2002 (Kopf 2003)
Clarks (134-135)	0	0.13	-
Columbus (100-101)	1.25	0.13	-
Rogers (80-81)	0.38	0.25	-
North Bend (69-70)	0.13	0	-
Leshara (48-49)	-	-	0.50
Elkhorn R. (32-33)	-	-	0.42
Louisville (15-16)	1.00	0.50	0.78
Schilling WMA(0-1)	-	-	1.33

Table 7.26. Frequency of occurrence by species associated with silver chub from trawl and seine samples collected in the lower Platte River, Nebraska.

Species common name	Frequency of occurrence from trawls	Frequency of occurrence from seines	Frequency of occurrence total
Channel catfish	30	8	38
Shoal chub	27	11	38
River shiner	26	10	36
Sand shiner	26	8	34
Red shiner	9	11	20
River carpsucker	7	6	13
Emerald shiner	5	7	12
Freshwater drum	6	3	9
Shovelnose sturgeon	8	1	9
Plains minnow	3	3	6
Quillback	4	2	6
Flathead chub	0	3	3
Brassy minnow	2	1	3
Common carp	1	1	2
Fathead minnow	1	1	2
Suckermouth minnow	2	0	2
Johnny darter	2	0	2
Sauger	2	0	2
Flathead catfish	2	0	2
Blue catfish	2	0	2
White perch	2	0	2
Gizzard shad	0	1	1
Bigmouth buffalo	0	1	1
Blue sucker	1	0	1
Bigmouth shiner	1	0	1
Green sunfish	1	0	1
Bluegill	1	0	1

averaged 0.787. Fogle (1963) reported an average condition factor of 0.71 for flathead chubs in South Dakota. Our data is similar to that reported for South Dakota.

Population Density:

Flathead chub densities calculated during this study were small, ranging from 0.04 to 0.07/100m^2. No flathead chubs were collected at the Leshara site and their densities were highest in collections at the Elkhorn River site (Table 7.27). Yu (1996) collected flathead chub from Columbus to North Bend in the lower Platte River at densities up to 2.63/100m^2 at North Bend in 1993 (Table 7.27).

Reproductive Status:

Females comprised 4 and males 8 of the 16 flathead chub for which gender could be determined. The GSI values for the female flathead chubs ranged from 0.26 to 1.25. These fish were caught in May and early June. If these fish spawn in July and August as Martyn and Schmulbach (1978) found in South Dakota, then their eggs may have been still in development. Additionally, since these fish were small for mature females, they may have been a year away from reproduction (Fisher et al. 2002).

Associated Species:

Flathead chub were collected in association with 15 other species of fish, nine in trawls and 14 in seines (Table 7.28). River shiners occurred most frequently with flathead chubs (6) followed by red shiner (5) and then shoal chubs and silver chubs (4). Several authors have pointed to the common association among flathead chubs and other chub species (Stewart, 1981 Werdon 1992, Gelwicks et al. 1996) and this is similar to what we observed in our collections.

Table 7.27. Comparison of flathead chub densities (N/100 m^2) for locations along the Platte River from Clarks, NE to the confluence with the Missouri River. Data adapted from Yu (1996) and Kopf (2003).

Location (River Mile)	1992 (Yu 1996)	1993 (Yu 1996)	2001 / 2002 (Kopf 2003)
Clarks (134-135)	0	0	-
Columbus (100-101)	0	0.25	-
Rogers (80-81)	0.25	0.13	-
North Bend (69-70)	0	2.63	-
Leshara (48-49)	-	-	0
Elkhorn R. (32-33)	-	-	0.12
Louisville (15-16)	0	0	0.03
Schilling WMA(0-1)	-	-	0.05

Table 7.28. Frequency of occurrence by species associated with flathead chub from trawl and seine samples collected in the lower Platte River, Nebraska.

Species common name	Frequency of occurrence from trawls	Frequency of occurrence from seines	Frequency of occurrence total
River shiner	2	4	6
Red shiner	2	3	5
Shoal chub	2	2	4
Silver chub	1	3	4
Emerald shiner	2	1	3
Channel catfish	2	1	3
Freshwater drum	0	3	3
Plains minnow	0	2	2
River carpsucker	0	2	2
Sand shiner	1	1	2
Shovelnose sturgeon	1	1	2
Fathead minnow	0	1	1
Common carp	0	1	1
Bigmouth buffalo	0	1	1
Bluegill	1	0	1

Flathead Chub

Shoal Chub

Silver Chub

CHAPTER 8

PHENOLOGY AND RELATIVE ABUNDANCE OF LARVAL FISHES IN THE LOWER PLATTE RIVER

INTRODUCTION

Until recently, most studies of river fishes have largely ignored their eggs, larvae and other early life stages (Brown and Coon 1994, Scheidegger and Bain 1995, Wolf et al. 1996). However, the presence of the larval stage of a species can give an indication of the spawning success for that year and provide an early indication of the year-class-strength later in the life of that cohort (Hergenrader et al. 1982, Franzin and Harbicht 1992). Prior to the studies of Hofpar (1997) and Reade (2000) Hergenrader et al. (1982) collected a limited amount of information on larval fish in the Platte River. Both Hofpar and Reade collected larval sturgeon and Reade (2000) collected chub larvae, but Hergenrader et al. (1982) collected neither of these taxa in the Platte River.

The objective of this study was to document the phenology and relative abundance of larval recruitment for pallid sturgeon, shovelnose sturgeon, sturgeon chub and associated species in the lower Platte River.

METHODS

Larval fish were sampled at four sites in the lower Platte River to describe the chronology of reproduction and hatching of all species in the lower Platte River following the protocol developed by Reade (2000). These sites were located near Two Rivers SRA (RM 41), US Highway 6 Bridge (RM 27.9), Nebraska Highway 50 Bridge (RM 15.5) and Schilling WMA (RM 0.5 – 2.8). Nets used for larval fish sampling were rectangular, 0.5 m high by 1.0 m wide by 5 m long made from 0.6 mm mesh Nytex. Each net was equipped with a current meter to measure average water velocity through the net during the time it was deployed, which in turn allowed determination of the water volume sampled. Nets were typically set in pairs for up to 15 minutes as determined by visual inspection of net clogging. A sample at a site consisted of 4 net sets. Time of sampling began at either midnight (0000 hours); 0300 hours; 0600 hours; 0900 hours; noon (1200 hours); 1500 hours; 1800 hours; or 2100 hours. Samples were preserved in 10% formalin in the field and transported to the lab for analysis.

Sampling commenced in May and continued through July of 2000 and 2001 but generally terminated by the end of June during 2002, 2003 and 2004. During 2000, 2001 and 2002 time for regular sampling was chosen at random and each site was sampled once per month starting the first week in May and continuing until August. In addition, the site at the US Highway 6 Bridge was sampled every 3 hours for a 24-hour period on weeks alternating with the regular sampling to determine diel periodicity of larval drift. In 2003, the sampling protocol was modified to try to identify more specifically the timing and location of sturgeon spawning in the areas downstream from the mouth of the Elkhorn River (RM 32.8). A site near the Nebraska Highway 50 Bridge (RM 15.5) and the site at the Highway 6 Bridge (RM 27.9) were sampled simultaneously every other week at three-hour intervals commencing at 1800 hr and concluding at 0600 hr. In 2004, the site at RM 15.5 was moved to the vicinity of the Schilling WMA (RM 0-0.5). The final sampling, commenced on 9 June at 18:00 hours and was completed on 10 June at 06:00 hours, was set immediately downstream from a radio tagged shovelnose sturgeon which had remained stationary over the previous week near the Nebraska Highway 50 Bridge (RM 15.5). These samples were collected because it was suspected that this behavior indicated potential spawning activity.

In the laboratory, specimens were sorted from extraneous material, identified to the lowest taxonomic category practicable, categorized by developmental stage, and enumerated. The number of each taxon and developmental stage was expressed per unit of water volume and number per net. All specimens were retained as vouchers and are either in the collections of the Nebraska State Museum or at the larval fish laboratory at Colorado State University in Fort Collins, Colorado.

RESULTS AND DISCUSSION

Six sites in the lower Platte River were sampled from 2000 to 2004. In addition, Reade (2000) also sampled sites near Columbus at RM 106 (32 samples) and North Bend at RM 72.5 (28 samples) in 1998 and 1999. The site near Two Rivers State Recreation Area at RM 41 was sampled from 1998 to 2002 (68 samples). The site at the US Highway 6 Bridge (RM 27.9) was sampled from 1998 to 2004 (1,362 samples). The site downstream from the Nebraska Highway 50 Bridge (RM 15.5) was sampled from 2000 to 2004 (193 samples). The site near Schilling WMA (RM 0.5 to 2.8) was sampled in 2002 and 2004 (154 samples).

The number of larvae collected, by family by year from 2000 to 2004, is summarized in Table 8.1 along with results from Reade (2000) who sampled using a similar protocol. This presentation includes fish from all sampling efforts in each year. The highest catch of larvae occurred in 2004 and the lowest catch of larvae occurred in 2001. The number and taxa of eggs and larvae collected by location from the lower Platte River is summarized in Table 8.2 and the number and taxa of juveniles collected by location from the lower Platte River is summarized in Table 8.3.

Sturgeon larvae were collected from the US Highway 6 Bridge to the mouth of the Platte River. Macrhybosis spp. (chub) larvae were collected at all sites except North Bend. Goldeye eggs were collected from the US Highway 6 Bridge to the mouth of the Platte River. Gizzard shad larvae, cyprinid larvae, common carp larvae, catostomid larvae and fish eggs, were collected at all six sites. Lepomis spp. larvae were collected at all sites except North Bend. Freshwater drum were collected at all sites except Columbus. Blue sucker larvae were collected at North Bend, the US Highway 6 Bridge , Louisville and Schilling WMA. Sander spp. larvae were collected from Two Rivers SRA to the mouth of the

Platte River. Channel catfish larvae were collected at Columbus, the US Highway 6 Bridge and Louisville. Brook silversides larvae were collected at Two Rivers SRA, the US Highway 6 Bridge and Louisville. Yellow perch larvae were collected at North Bend, Two Rivers SRA and the US Highway 6 Bridge. Mosquitofish larvae were collected at Columbus and Two Rivers SRA. Goldeye, centrarchid and Pomoxis spp. larvae were collected at the US Highway 6 Bridge and Schilling. Other larval taxa were collected only at the US Highway 6 Bridge.

Sturgeon larvae:

Between 1998 and 2004, 14 sturgeon (family Acipenseridae: Scaphirhynchus spp.) larvae were collected (Table 8.2 and Figures 8.1 and 8.2) between the dates of 15 May and 9 June During 1998 and 1999 Reade (2000) collected three sturgeon larvae between the dates of 26 May during 1999 and 23 and 24 June during 1998 (Table 8.4, Figures 8.1 and 8.2). In addition, Hofpar (1997) collected one sturgeon larva on June 10, 1996 near Fremont, NE (RM 57). The three larvae collected during the 2000 to 2002 sampling years were collected at the U.S. Highway 6 Bridge (RM 27.9). Of the three larvae collected during 2003, one was collected at the U.S. Highway 6 Bridge on 15 May, and the other two were collected downstream of the Nebraska Highway 50 Bridge at RM 15.5, one each on 15 May and 23 May. In 2004, four out of the five Scaphirhynchus spp. larvae were collected on 27 and 28 May at the US Highway 75 Bridge at RM 2.8. The change in sampling location was the result of the effect of high discharge in the Missouri River that had backed the Platte River up near the bridge. Usually we would have sampled at the Schilling WMA (RM 0.5). The fifth larva sampled in 2004 was collected on 9 June near the Nebraska Highway 50 Bridge at RM 15.5 during the collections downstream from the radio-tagged shovelnose sturgeon.

Based on morphological features, all sturgeon larvae collected are probably less than 1 day post hatch (Darryl Snyder: personal communication). Sturgeon larvae this young can only be identified to genus and not to species unless DNA analysis is used. DNA analysis was not possible, because the samples were fixed in formalin. All sturgeon larvae, with one exception, were collected following increases in water temperature. A relationship between sturgeon spawning and discharge is still unclear, but all except the specimen collected during 2000 were associated with a decline in discharge. In 2001, 2003 and 2004, collection sturgeon larvae were captured following peak discharges greater than 21,000 cfs. This agrees with the

Table 8.1. Summary of the number of larvae collected by family, from the lower Platte River, NE.

Year (volume m^3) Family	1998 (29,156)	1999 (28,121)	2000 (26,154)	2001 (26,730)	2002 (26,334)	2003 (25,834)	2004 (22,303)
Acipenseridae	1	2	1	1	1	3	5
Lepisosteidae	-	2	1	9	3	-	-
Hiodontidae	-	-	-	-	-	-	3
Clupeidae	161	113	113	181	196	24	3
Cyprinidae	5,249	14,418	2,267	1,671	3,619	3,409	4,546
Catostomidae	505	1,349	331	195	95	566	2,387
Ictaluridae	29	14	20	17	12	5	-
Atherinidae	4	3	1	-	2	1	-
Poeciliidae	1	-	9	-	-	-	-
Centrarchidae	84	54	12	27	13	-	-
Percidae	3	3	4	2	2	3	-
Sciaenidae	126	110	112	178	196	24	284
Total	**6,163**	**16,068**	**2,871**	2,281	**4,139**	**4,035**	**7,228**

Table 8.2. Fish larvae collected at all study sites in the lower Platte River, Nebraska during larval drift net sampling from 1998 to 2004.

Taxon	Columbus	North Bend	Two Rivers	US Highway 6	Louisville	Schilling WMA
Scaphirhynchus spp.				7	3	4
paddlefish				1		
Lepisosteus spp.				1		
Shortnose gar				15		
goldeye				1		2
Gizzard shad	4	8	6	432	15	18
Cyprinids	84	128	256	13607	5946	858
carp	150	11	3	4556	225	54
Macrhybopsis spp.	1	0	27	8625	594	74
Catostomids	43	94	30	2534	1970	668
Blue sucker		1		52	9	39
Ictalurids				4		
Channel catfish	1			73	4	
Flathead catfish				15		
Western mosquitofish	1		1	0		
Brook silversides			1	8	2	
Centrarchids				18		9
Lepomis spp.	2		2	117	8	9
Largemouth bass				7		
Pomoxis spp.				19		1
Percids				1		
Johnny darter				1		
Yellow perch		1	1	3		
Sander spp.			3	3	3	1
Freshwater drum		2	36	579	337	83

findings of Reade (2000) who collected larvae in 1998 and 1999. In 2000 and 2002, peak discharges greater than 21,000 cfs were not present early in May, but sturgeon larvae were still collected.

Christiansen (1975) found that shovelnose sturgeon spawned late in May through early June in Wisconsin when water temperatures were between 19 and 21ºC. Coker (1930) considered the peak of the spawning season to be early May on the Mississippi River in Iowa. Cross (1967) suggested that sturgeons only enter streams tributary to the Missouri River during years when discharge is high enough to allow spawning. The conditions when we collected sturgeon larvae (Table 8.4) are similar to these published accounts.

When sturgeon larvae were collected, there were two taxa of eggs, 16 taxa of larvae and 27 taxa of juvenile and adult life stages present during the same samplings (Table 8.5). Cyprinid (minnow) larvae, catostomid (sucker) larvae and fish eggs were present during 100 percent of the samplings when sturgeon larvae were collected. Red shiner juvenile/adults and common carp larvae were present during 90 percent of the same samplings. River shiner juvenile/adults, chub larvae and freshwater drum larvae were each present during 70 percent of the same samplings. The other taxa collected were present during 60 percent or fewer of the samples when sturgeon larvae were collected (Table 8.5).

Chub larvae:

A total of 9,321 chub larvae (Macrhybopsis spp.) were collected between 2000 and 2004. Macrhybopsis spp. larvae were collected from 11 May to 15 August at temperatures ranging from 13.6 to 31.0ºC (Figure 8.3). Mean daily discharge, when chubs were collected ranged from 1,410 to 34,900 cfs (Figure 8.4). Chub larvae in the Platte River were in low numbers during the discharge events and high following the peaks of these events. The highest numbers of chub larvae that Reade (2000) collected followed a large (39,370 cfs) discharge event in 1999. Robinson et al. (1998) noted that larval stages of four native fishes in the Little Colorado River probably peaked during the descending limb of spring runoff peaks. Because of the preponderance of shoal chub present in the samples collected by trawl and seine it is

Table 8.3. Juvenile and adult fish collected during larval drift net sampling at all sites from 1998 to 2004.

Taxon	Columbus	North Bend	Two Rivers	Highway 6	Louisville	Schilling WMA
Shortnose gar				1		
Longnose gar				1		
Gizzard shad	7	43	1	119		10
Cyprinids	23	1	51	586	14	13
Red shiner	12	1	272	461	53	34
Common carp	2	2	1	377	3	3
Hybognathus spp.	2			19	2	
Plains minnow	2			26		
Macrhybopsis spp.				47	2	1
Shoal chub		3		94	13	1
Silver chub				12	1	1
Notropis spp.				30	2	13
Emerald shiner	2		3	28	2	5
River shiner	1	1	10	208	26	7
Sand shiner		1	7	135	14	74
Fathead minnow	4		10	152	1	
Flathead chub	1		1			
Rudd					3	
Catostomids	1			9	1	
Carpiodes spp.		1		142	1	1
River carpsucker				2		1
Shorthead redhorse				4		
Black bullhead				1		
Channel catfish	2	1	1	199	73	12
Flathead catfish				32		5
Grass pickerel				1		
Northern pike				1		
Western mosquitofish	2	1	1	2		
Brook silversides	1		5	7		1
Brook stickleback		1		18	1	
Centrarchids				9		
Lepomis spp.	1	5	1	201	17	24
Green sunfish				1	1	
Bluegill	2			48	3	1
Micropterus spp.				2		
Largemouth bass	1	2		89	1	1
White crappie		1		51	2	10
Johnny darter				1		
Yellow perch				2		
Sander spp.				0		1
Sauger				1		
Walleye				1	2	
Freshwater drum		1		42	1	

Larval drift net set

most likely that the larval specimens can be attributed to this species. Cross (1967) and Pflieger (1997) both considered the reproduction for speckled chubs to extend from May into August at water temperatures over 20 ^{o}C.

Two taxa of eggs, 22 taxa of larvae, and 39 taxa of juvenile and adult life stages were collected during the same samplings as chub larvae (Table 8.6). Cyprinid larvae were present during 100 % of the sampling when chub larvae were collected. Fish eggs were present in 98.1 % of the same samplings, and catostomid larvae were present in 90.6 % of the same samplings. Freshwater drum larvae, red shiner juvenile/adults and gizzard shad larvae were present in 81.1, 75.5 and 71.7 % of the same samplings as chub larvae, respectively. Larval common carp and cyprinid juvenile/adults were present in 69.8 and 66.0 % of the same samplings as chub larvae, respectively. The other taxa and life stages we collected were present in less than 53 % of the same samplings as chub larvae (Table 8.6).

Other larval taxa:

Gar larvae (Lepisosteidae) were collected in 4 out of the 7 years (Table 8.1). Most of these were identified as shortnose gar. Gar larvae were collected as early as 4 June and as late as 2 July. In Kansas gars spawn in May and early June (Cross 1967). In South Dakota shortnose gar spawned at water temperatures between 19 and 24^{o}C which occurred between the dates of 20 May and early July (Carlander 1969).

A total of 791 gizzard shad (Clupeidae) larvae (1.8% of the total) was collected between 1998 and 2004 (Table 7.1). Larvae were collected from 11 May to 3 August at water temperatures ranging from 16.2 to 29.9 °C (Figure 8.5). Mean daily discharge ranged from 1,480 to 34,900 cfs when gizzard shad larvae were collected (Figure 8.6). The lower number collected during 2003 and 2004 is probably related to our truncating the sampling season to May and June. Cross (1967) states that gizzard shad usually spawn from late May into June, but there may be a second spawning later in June. This falls well within the period when we collected gizzard shad larvae. Gizzard shad comprised 5.5% of the larval fish that Hergenrader et al. (1982) collected in the Platte River.

Minnow larvae (Cyprinidae) outnumbered all other families of fish in the drift (82.2%) with a total of 35,179 larvae (Table 8.1). Common carp and chub (Macrhybopsis

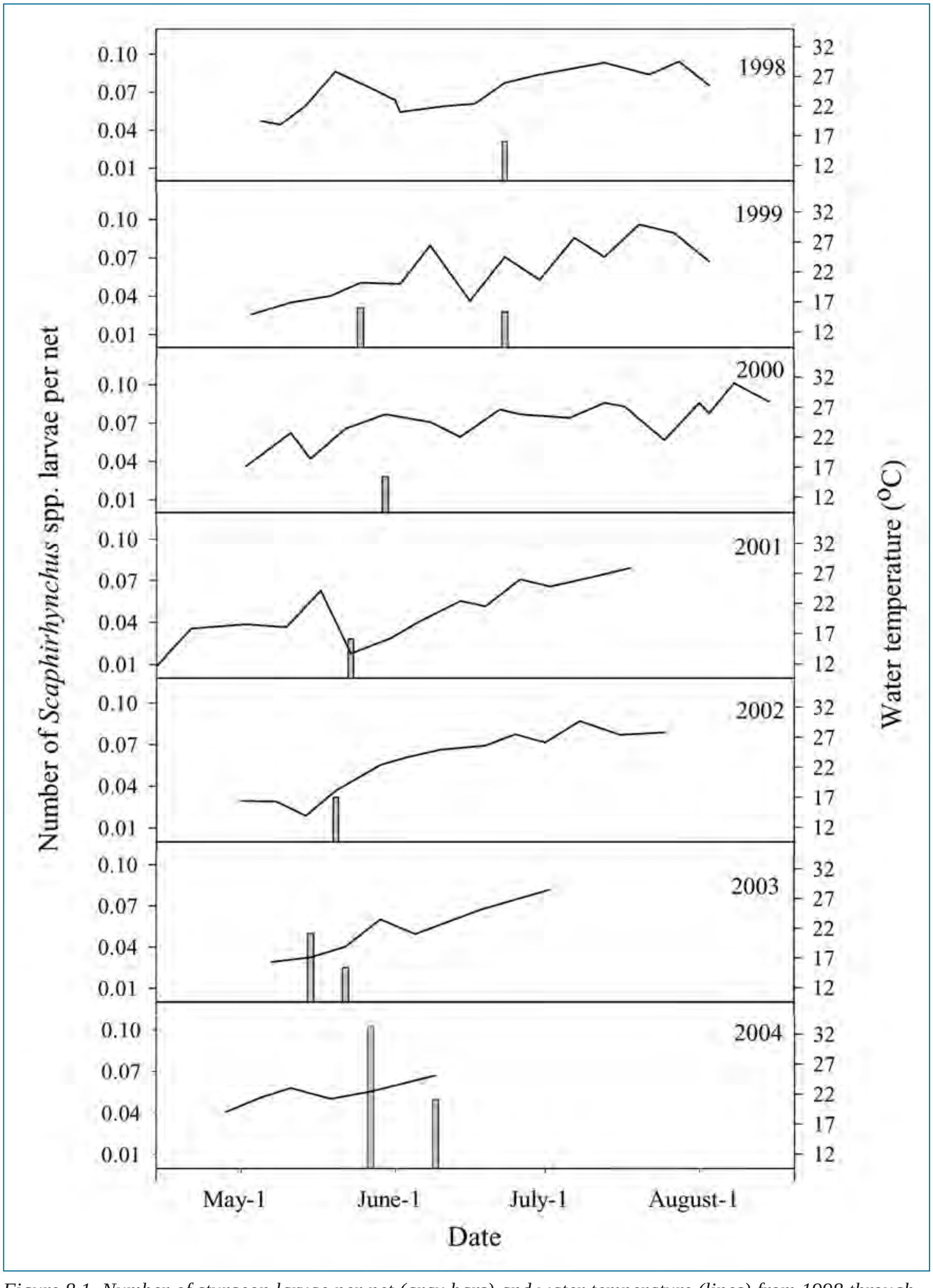


Figure 8.1. Number of sturgeon larvae per net (gray bars) and water temperature (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

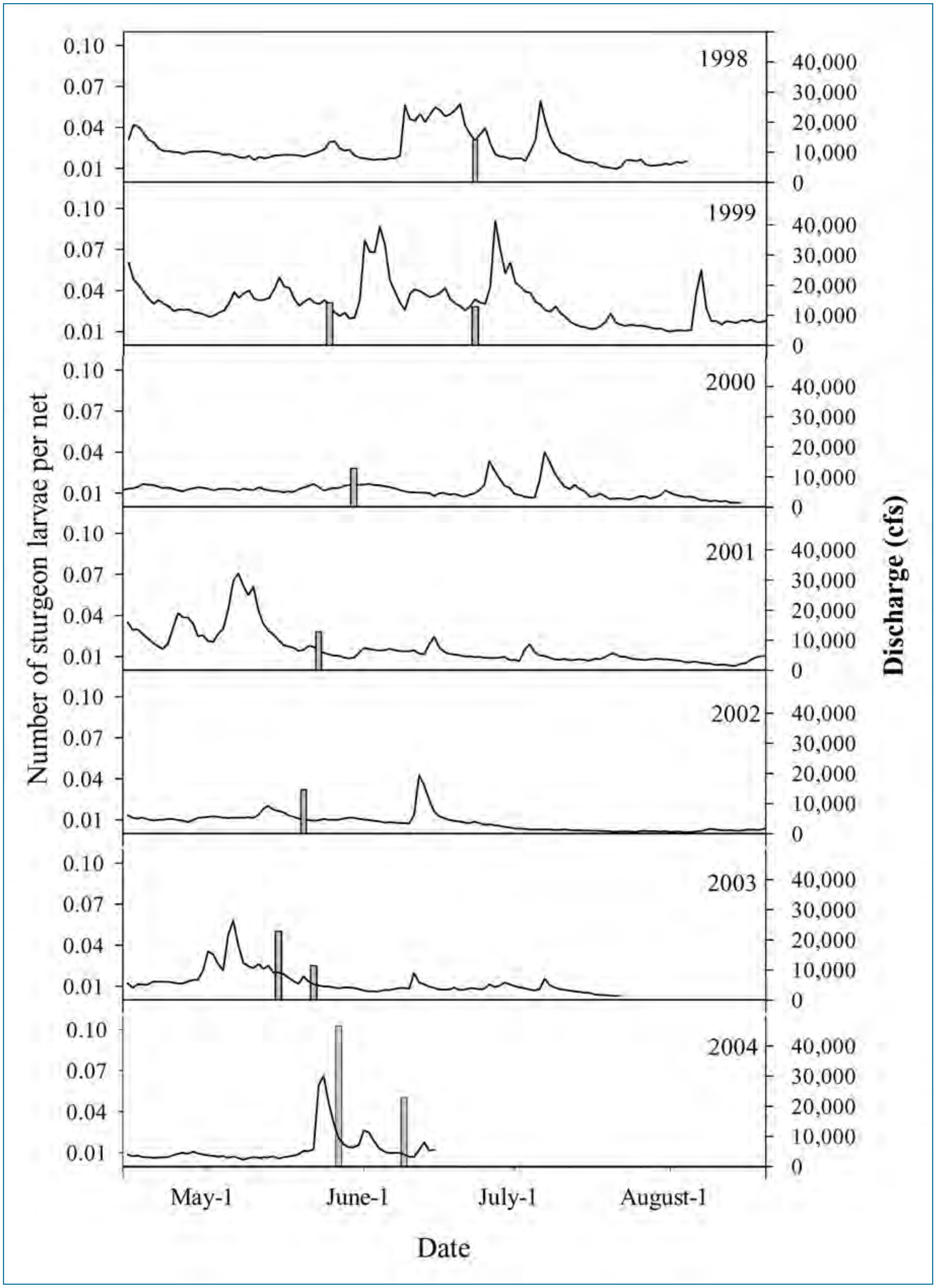


Figure 8.2. Number of sturgeon larvae per net (gray bars) and mean daily discharge (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

Table 8.4. Year, (time of day) and water temperature (ºC) at the time when sturgeon larvae were captured in the lower Platte River, Nebraska, 1998 to 2004. Locations of sampling sites are near the US 73, 75 Bridge (RM 2.8), near the NE 50 Bridge (RM 15.5), and near the US 6 highway Bridge (RM 27.9). Collections by Reade (2000) are indicated by an asterisk (*).

MONTH/ DAY	RM 2.8	RM 15.5	RM 27.9	TEMPERATURE
May 15	2003 (18:00)			18.1
May 15			2003 (21:00)	17.8
May 21			2002 (06:00)	15.8
May 23			2001 (21:00)	13.6
May 23	2003 (03:00)			18.5
May 26			1999 (00:00)*	20.5
May 27		2004 (18:00)		22.9
May 28		2004 (03:00)		21.3
May 28		2004 (03:00)		21.3
May 28		2004 (06:00)		20.7
May 31			2000 (03:00)	24.8
June 9	2004 (18:00)			27.1
June 23		1998 (21:00)*		27.4
June 24		1999 (03:00)*		25.2

spp.) larvae were the only taxa that could be separated from other cyprinid larvae. Therefore, our reference to cyprinids refers only to those larvae that could not be identified beyond the family level. A total of 20,816 cyprinid larvae (48.7%) was collected between 1998 and 2004. Cyprinid larvae were collected from 10 May to 15 August and water temperatures ranged from 13.6 to 31.0 °C (Figure 8.7). Mean daily discharge ranged from 593 to 34,900 cfs when cyprinid larvae were collected (Figure 8.8). Cyprinids comprised 30% of the larval fish that Hergenrader et al. (1982) collected in the Platte River.

A total of 4,998 common carp larvae (11.7%) was collected between 1998 and 2004. Larvae were collected between 13.6 and 29.9 °C (Figure 8.9). Mean daily discharge ranged from 1,010 to 34,900 cfs when larvae were collected (Figure 8.10). Carp spawning may occur from April to August in Wisconsin (Becker 1983) and March to September in Missouri (Pflieger 1997). Mraz and Cooper (1957) found that the greatest activity occurs between the temperatures of 18 and 24 ºC. Carp comprised 9.3% of the larval fish that Hergenrader et al. (1982) collected in the Platte River.

A total of 5,428 sucker (Catostomidae) larvae (12.7%) was collected from 1998 to 2004. This constitutes 12.7 percent of all larvae collected (Table 8.1). Of the 5,428 sucker larvae collected, 26.6 % of these were collected on 9 and 10 June 2004 near the Nebraska Highway 50 Bridge. Catostomids comprised 46.5% of the larval fish that Hergenrader et al. (1982) collected in the Platte River.

Blue sucker were the only larvae identifiable beyond the family level. Therefore, all other sucker larvae are referred to as catostomids. Catostomids were collected from 28 April to 3 August at water temperatures ranging from 13.6 to 29.9 °C (Figure 8.11) and mean daily discharges between 1,700 and 34,900 cfs (Figure 8.12). The most abundant juvenile and adult sucker species in the lower Platte River are the river carpsucker and the quillback. Cross (1967) and Pflieger (1997) considered that their spawning seasons in Kansas and Missouri extended from late May to late July. Other species

Table 8.5. Percent occurrence of other taxa and life stages during sampling times when Scaphirhynchus spp. larvae were collected. Percentages are based on occurrence during the same samplings.

Taxon	Life stage	Percent occurrence
Unidentifiable	Eggs	100
Cyprinids	Larvae	100
Catostomids	Larvae	100
Red shiner	Juv/Ad	90
Common carp	Larvae	90
River shiner	Juv/Ad	70
Macrhybopsis spp.	Larvae	70
Freshwater drum	Larvae	70
Sand shiner	Juv/Ad	60
Gizzard shad	Larvae	60
Cyprinids	Juv/Ad	50
Common carp	Juv/Ad	40
Bluegill	Juv/Ad	40
Pomoxis spp.	Larvae	40
Carpiodes spp.	Juv/Ad	30
Brook stickleback	Juv/Ad	30
Lepomis spp.	Juv/Ad	30
Largemouth bass	Juv/Ad	30
Blue sucker	Larvae	30
Lepomis spp.	Larvae	30
Goldeye	Eggs	20
Gizzard Shad	Juv/Ad	20
Shoal chub	Juv/Ad	20
Emerald shiner	Juv/Ad	20
Fathead minnow	Juv/Ad	20
Catostomids	Juv/Ad	20
Centrarchids	Larvae	20
Hybognathus spp.	Juv/Ad	10
Plains minnow	Juv/Ad	10
Macrhybopsis spp.	Juv/Ad	10
Notropis spp.	Juv/Ad	10
Channel catfish	Juv/Ad	10
Grass pickerel	Juv/Ad	10
Western mosquitofish	Juv/Ad	10
Brook silversides	Juv/Ad	10
White crappie	Juv/Ad	10
Johnny darter	Juv/Ad	10
Sauger	Juv/Ad	10
Freshwater drum	Juv/Ad	10
Paddlefish	Larvae	10
Channel catfish	Larvae	10
Brook silversides	Larvae	10
Largemouth bass	Larvae	10
Johnny darter	Larvae	10
Yellow perch	Larvae	10
Sander spp.	Larvae	10

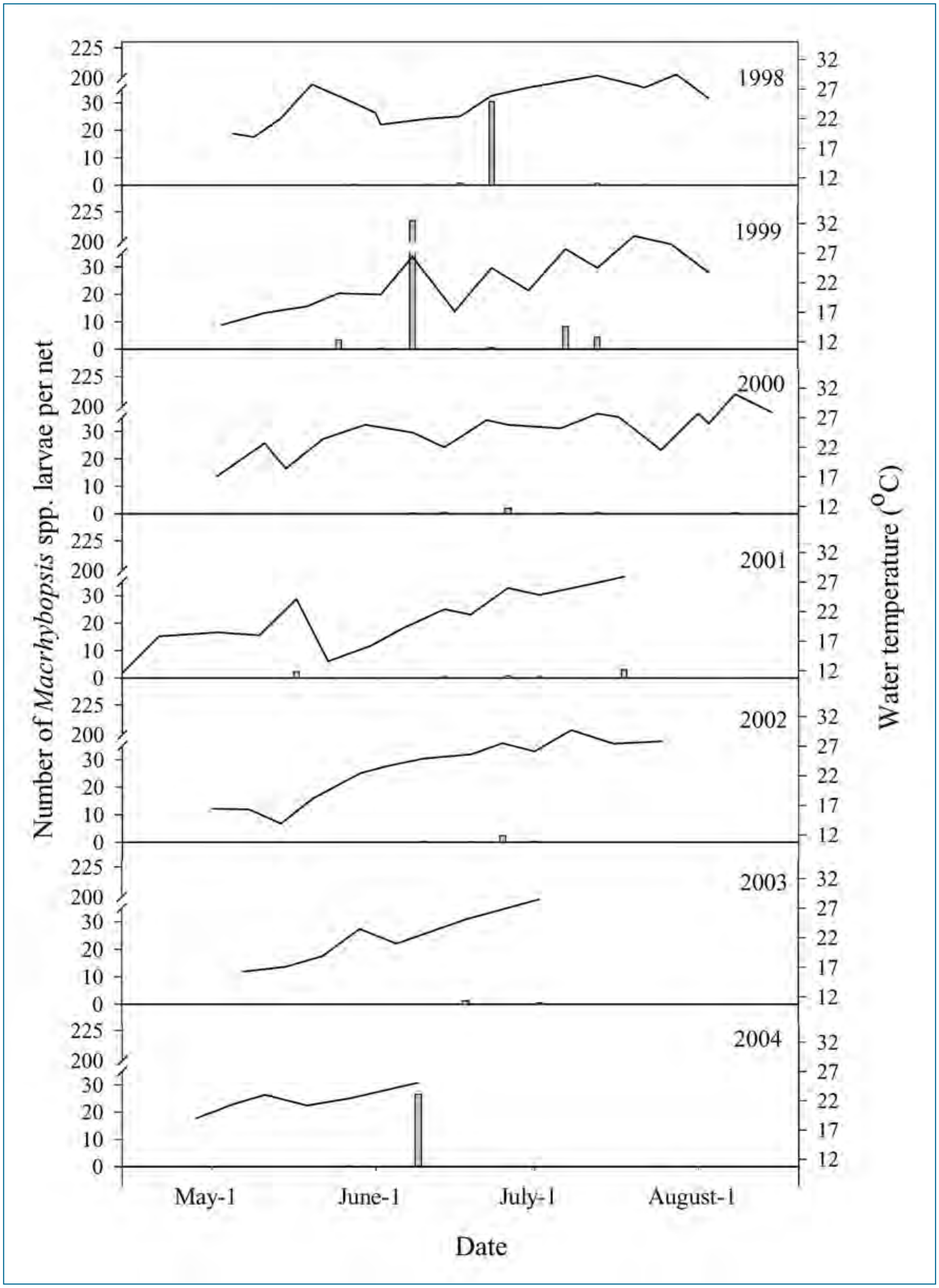


Figure 8.3. Number of chub larvae per net (gray bars) and water temperature (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

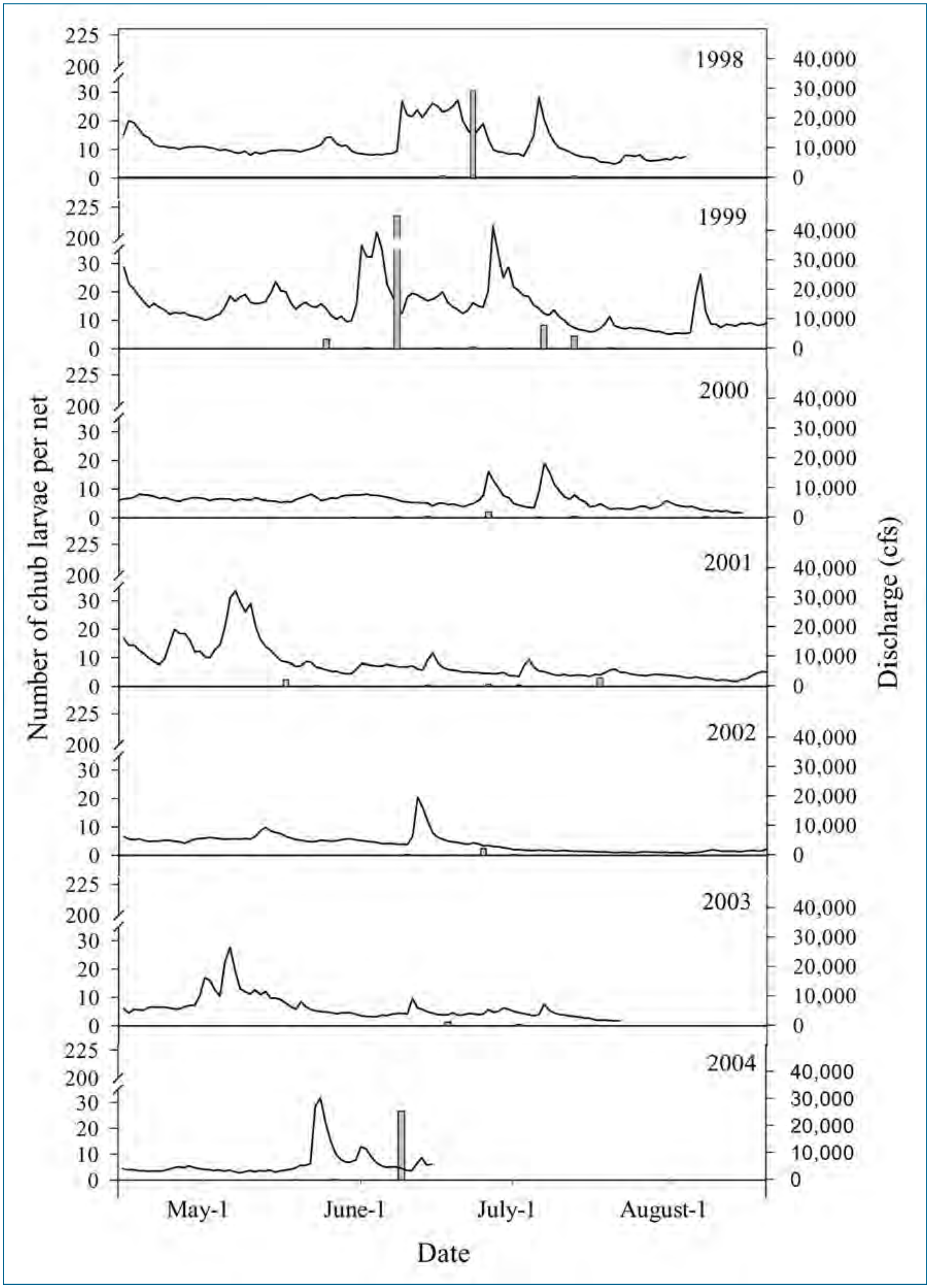


Figure 8.4. Number of chub larvae per net (gray bars) and mean daily discharge (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

Table 8.6. Percent occurrence of other taxa and life stages during sampling times when chub larvae (Macrhybopsis spp.) were collected. Percentages are based on occurrence during the same samplings.

Taxa	Life stage	Percent occurrence
Cyprinids	Larvae	100.0
unidentifiable	Eggs	98.1
Catostomids	Larvae	90.6
Freshwater drum	Larvae	81.1
Red shiners	Juv/Adult	75.5
Gizzard shad	Larvae	71.7
Common carp	Larvae	69.8
Cyprinids	Juv/Adult	66.0
River shiner	Juv/Adult	52.8
Lepomis spp.	Larvae	49.1
Channel catfish	Juv/Adult	47.2
Sand shiner	Juv/Adult	39.6
unidentifiable	Larvae	39.6
Common carp	Juv/Adult	37.7
Carpiodes spp.	Juv/Adult	37.7
Lepomis spp.	Juv/Adult	34.0
Shoal chub	Juv/Adult	32.1
Falthead minnow	Juv/Adult	32.1
Gizzard shad	Juv/Adult	28.3
Notropis spp.	Juv/Adult	26.4
White crappie	Juv/Adult	26.4
Emerald shiner	Juv/Adult	24.5
Bluegill	Juv/Adult	24.5
Largemouth bass	Juv/Adult	24.5
Macrhybopsis spp.	Juv/Adult	22.6
Freshwater drum	Juv/Adult	22.6
Channel catfish	Larvae	22.6
Plains minnow	Juv/Adult	18.9
Silver chub	Juv/Adult	17.0
Pomoxis spp.	Larvae	17.0
Hybognathus spp.	Juv/Adult	15.1
Brook stickleback	Juv/Adult	15.1
Centrarchids	Larvae	15.1
Catostomids	Juv/Adult	13.2
Scaphirhynchus spp.	Larvae	13.2
Brook silversides	Larvae	13.2
Flathead catfish	Juv/Adult	11.3
Shortnose gar	Larvae	9.4
Brook silversides	Juv/Adult	7.5
Centrarchids	Juv/Adult	7.5
Blue sucker	Larvae	7.5
River carpsucker	Juv/Adult	5.7
Shorthead redhorse	Juv/Adult	5.7
Walleye	Juv/Adult	5.7

Table 8.6. (continued)

Taxon	Life stage	Percent occurrence
Ictalurids	Larvae	5.7
Flathead catfish	Larvae	5.7
Largemouth bass	Larvae	5.7
Goldeye	Eggs	3.8
Western mosquitofish	Juv/Adult	3.8
Green sunfish	Juv/Adult	3.8
Yellow perch	Juv/Adult	3.8
Longnose gar	Juv/Adult	1.9
Shortnose gar	Juv/Adult	1.9
River shiner	Juv/Adult	1.9
Grass pickerel	Juv/Adult	1.9
Largemouth bass	Juv/Adult	1.9
Johnny darter	Juv/Adult	1.9
Sander spp.	Juv/Adult	1.9
Sauger	Juv/Adult	1.9
Lepisosteus spp.	Larvae	1.9
Percids	Larvae	1.9
Johnny darter	Larvae	1.9
Yellow perch	Larvae	1.9
Sander spp.	Larvae	1.9

like northern shorthead redhorse and white sucker may spawn as early as late April (Cross 1967) and may constitute some of the early larvae in our collections.

A total of 101 blue sucker larvae (0.2%) was collected from 1998 to 2004. These larvae were collected from 2 May to 3 June at water temperatures ranging from 14.9 and 23.6 °C (Figure 8.13) at mean daily discharges between 4,310 and 15,470 cfs (Figure 8.14). Our collections dates for blue sucker larvae agree with observations of adults in breeding condition and collections of larvae from Kansas (Cross 1967) and Missouri (Pflieger 1997).

A total of 1,030 freshwater drum (Sciaenidae) larvae (2.4%) was collected from 1998 to 2004 (Table 8.1). Freshwater drum comprised 3.5% of the larval fish that Hergenrader et al. (1982) collected in the Platte River.

Drum larvae were collected from 11 May to 3 August at water temperatures ranging from 13.6 to 29.9°C (Figure 8.15) with mean daily discharges between 1,700 and 34,900 cfs (Figure 8.16). In Wisconsin drum spawned in the Mississippi river at temperatures between 19 and 22ºC (Becker 1983). Most summaries of drum spawning seasons emphasize dates between early May and late June (Becker 1983, Cross 1967, Pflieger 1997), but Schneider and Hasler (1960) note that drumming, which is thought to be related to spawning activity may continue into August.

Larvae of goldeye, channel catfish, flathead catfish, mosquitofish, brook silversides, Lepomis spp., largemouth bass, yellow perch and Percidae were collected between 1998 and 2004. Because these taxa, combined represent less than one percent of all larvae collected, no further analyses were conducted.

From 1998 to 2004, 32,284 fish eggs were collected. Eggs were collected during all sampling events, except three, at a range of temperatures (Figure 8.17) and discharges (Figures 8.18). The three sampling events with no eggs were 14 April 2001, 1 May 2002, and 16 May 2002. Hergenrader et al. (1982) collected 159 fish eggs from the Platte River.

Conclusions:

The collection of sturgeon and chub larvae in the lower Platte River confirms the use of this river for reproduction by these taxa. As stated earlier, sturgeon were collected downstream of the Elkhorn River and chubs were collected downstream of Columbus. However, since the larvae could not be identified to species, this does not confirm or eliminate the spawning of pallid sturgeon or sturgeon chub in the Platte River. It is probable, given the large number of adult shovelnose sturgeon and other chub species in comparison to pallid sturgeon and sturgeon chub that the larvae were not the species of concern. Yet the documentation of spawning by these genera suggests the potential for spawning by these rare species.

Since we caught and tracked shovelnose sturgeon to the vicinity of Columbus during our studies of habitat at times when sturgeon spawning could be occurring it raises the possibility that sturgeon may be spawning farther upstream than we collected their larvae. In addition, Hofpar (1997) caught sturgeon larvae as far upstream as Fremont, NE (RM 57) during a time when flows in the Platte River were higher. Several collections of large numbers of chubs also occurred at times of higher flows on the lower Platte River. This makes the period from late April to early June particularly important to the life history of sturgeon and chub species in the Platte River.

Cross and Moss (1987) discussed the influences of flow regulation and limitation on the species diversity in Kansas rivers. In addition, Dieterman and Galat (2004) pointed to the importance of long distances of undammed rivers to maintain the thermal regime and long drift corridors to allow for the development of chub larvae. The continuing loss of flow volume and fluctuation is almost certainly confining quality habitat for sturgeons and chubs and associated species to more downstream reaches of the Platte River.

Larval nets.

Larval sturgeon

Sample bucket on a larval net.

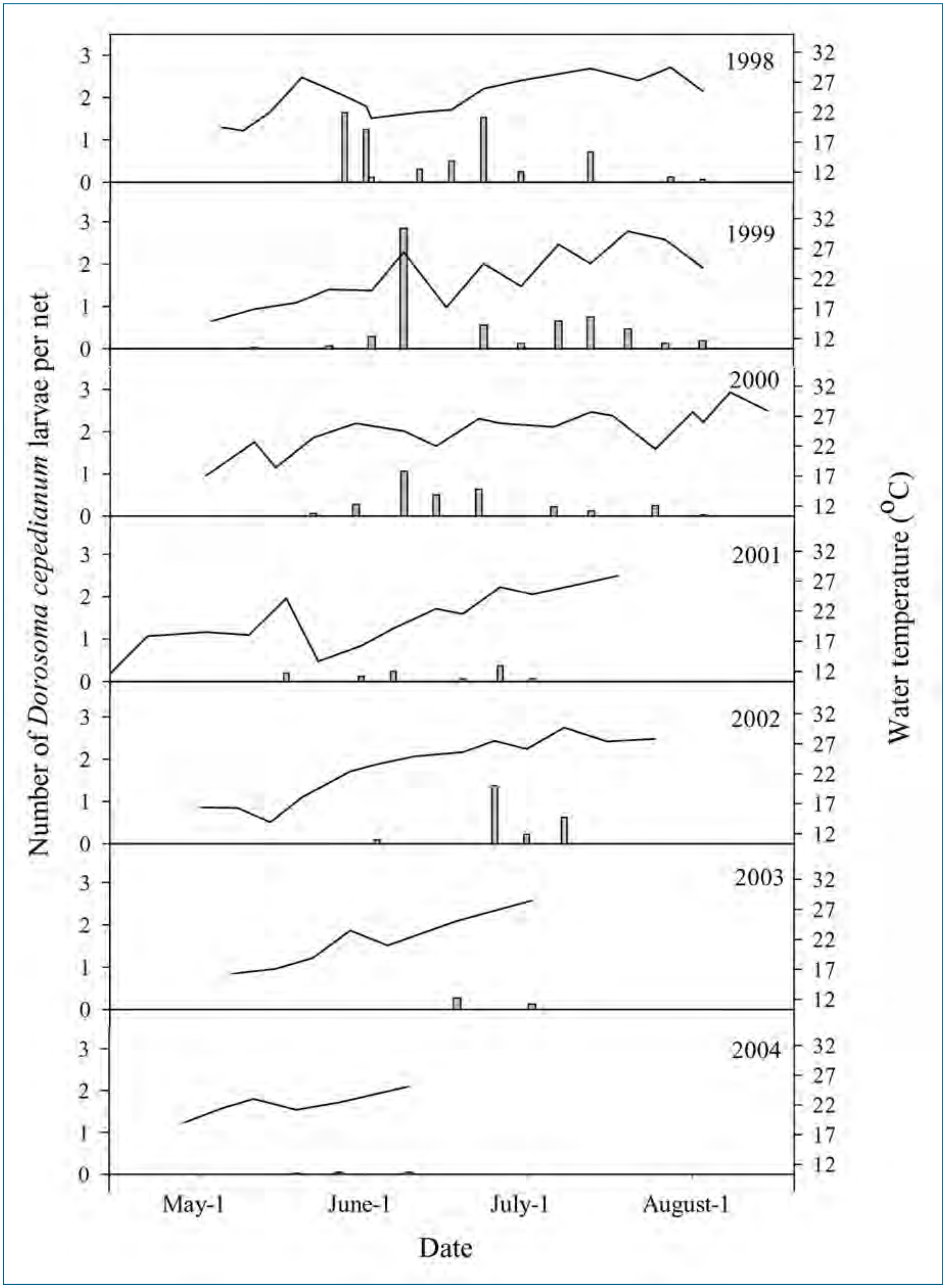


Figure 8.5. Number of gizzard shad larvae per net (gray bars) and water temperature (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

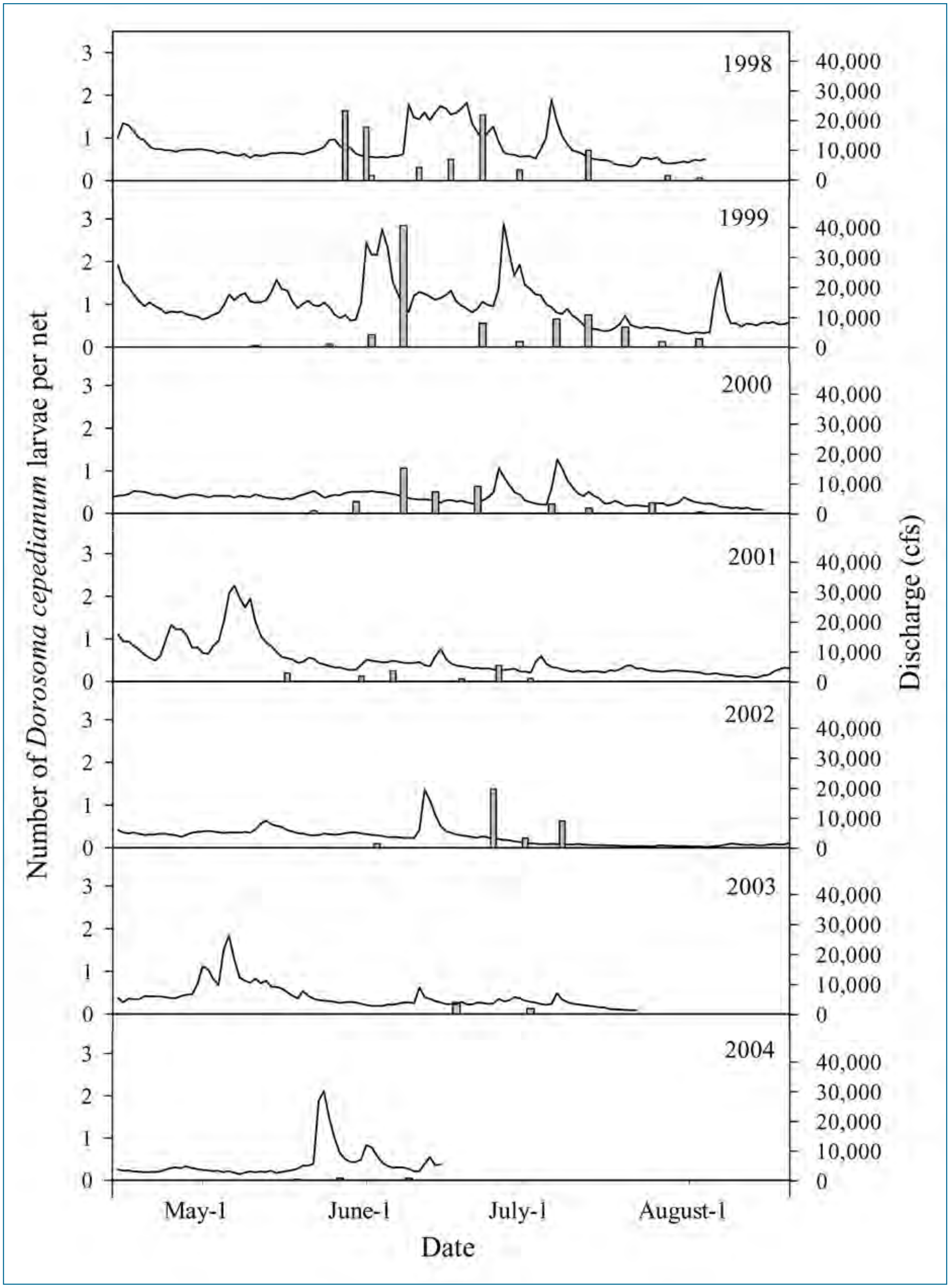


Figure 8.6. Number of gizzard shad larvae per net (gray bars) and mean daily discharge (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

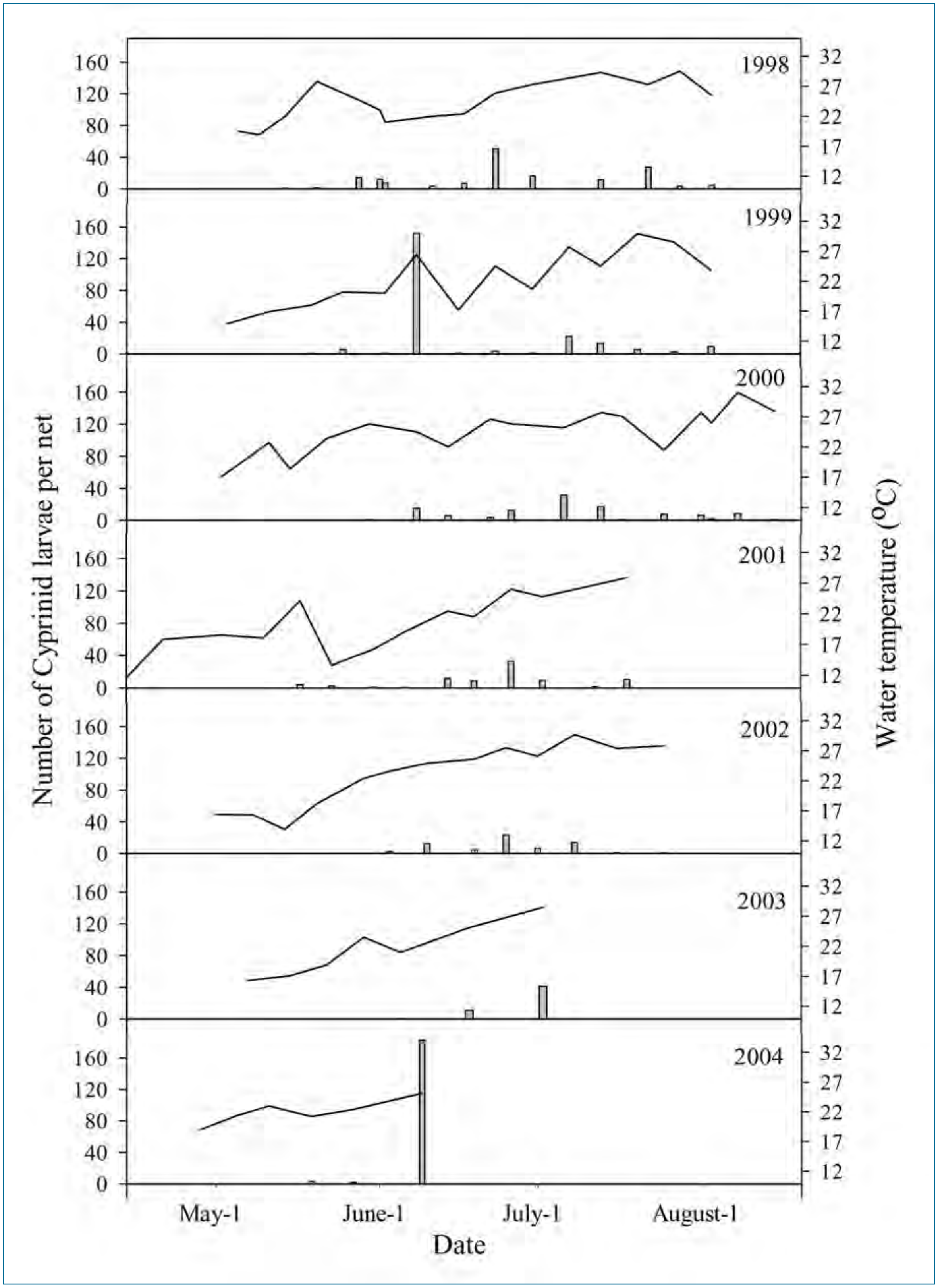


Figure 8.7. Number of cyprinid larvae per net (gray bars) and water temperature (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

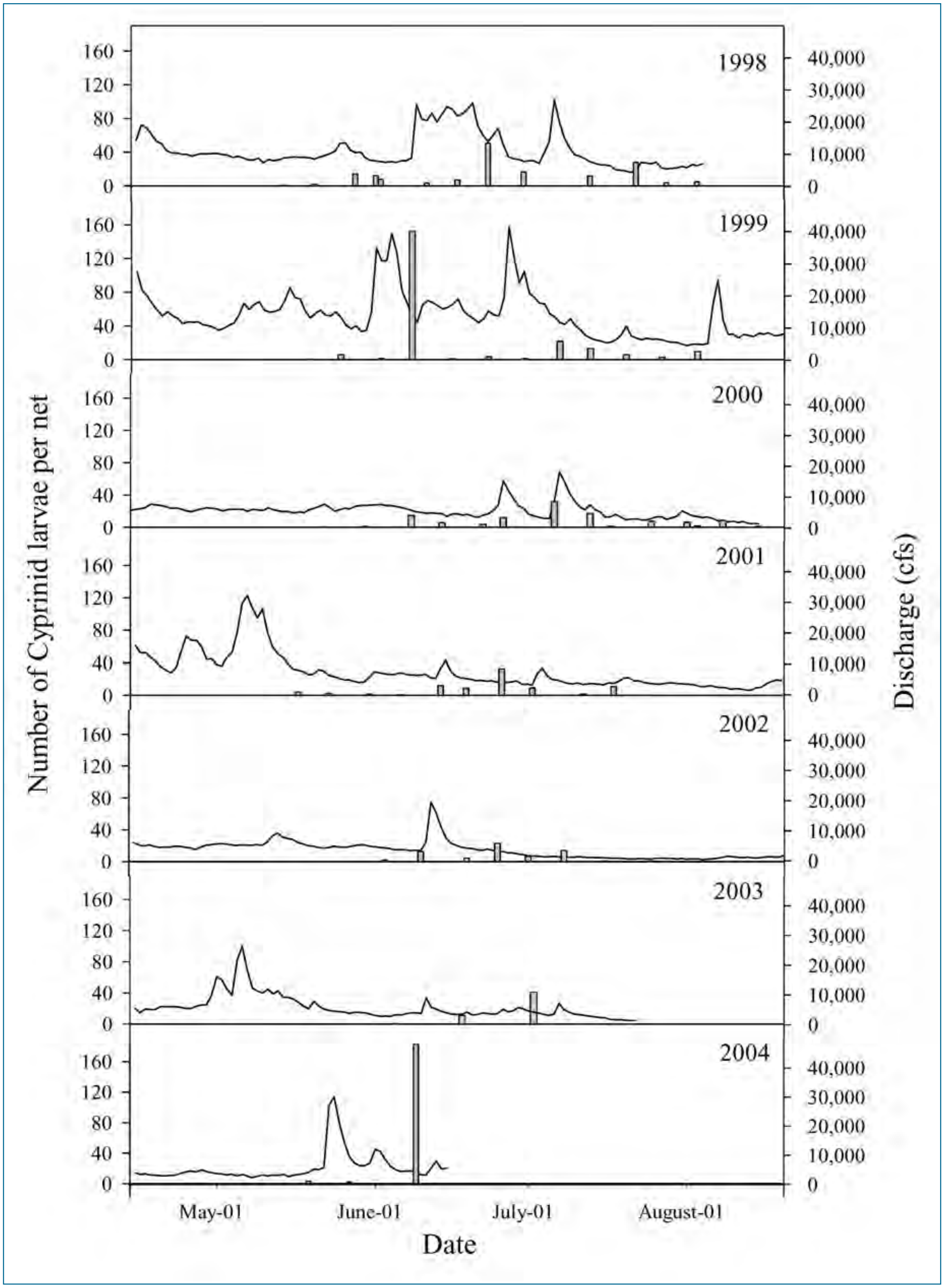


Figure 8.8. Number of cyprinid larvae per net (gray bars) and mean daily discharge (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

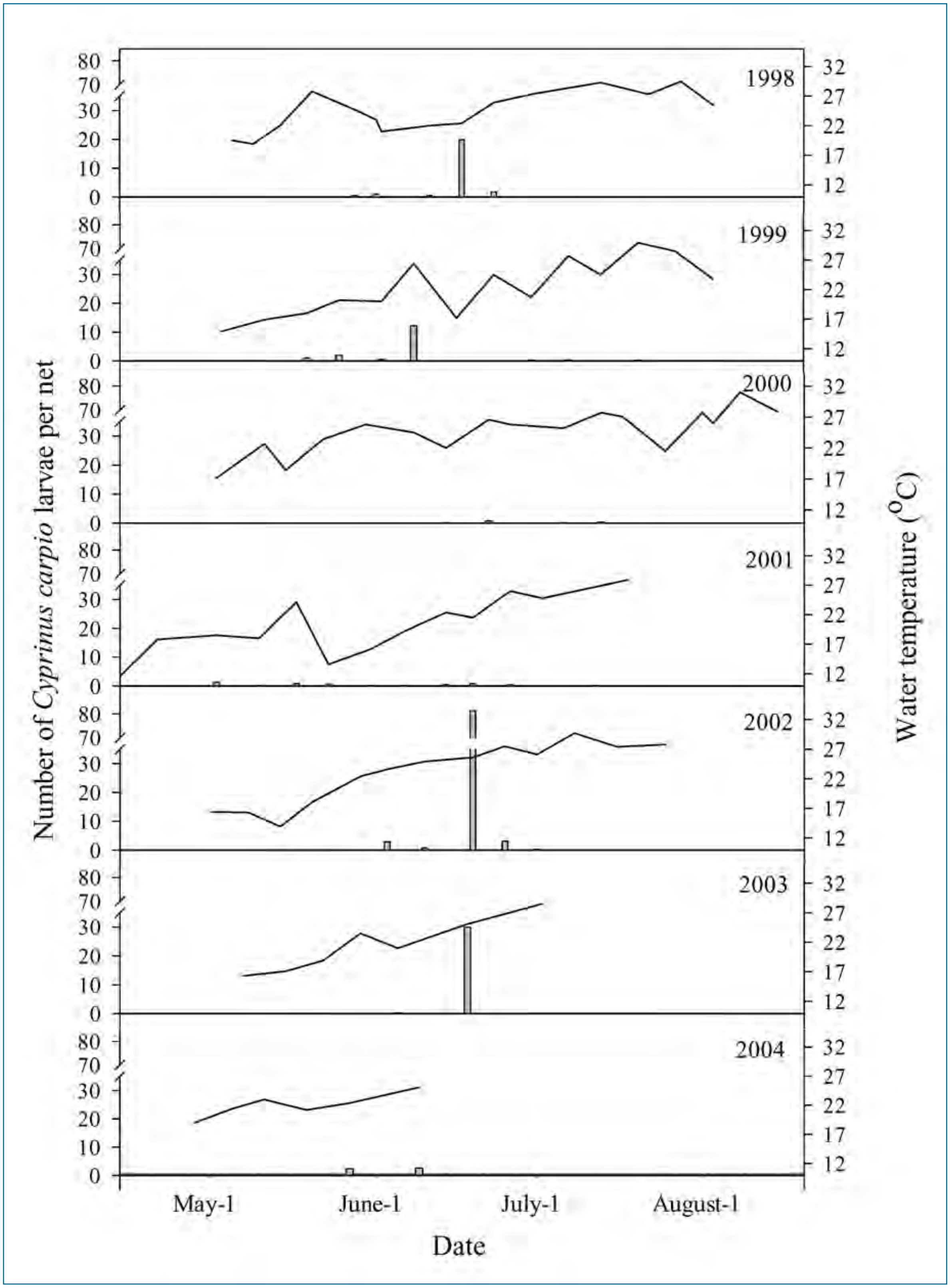


Figure 8.9. Number of common carp larvae per net (gray bars) and water temperature (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

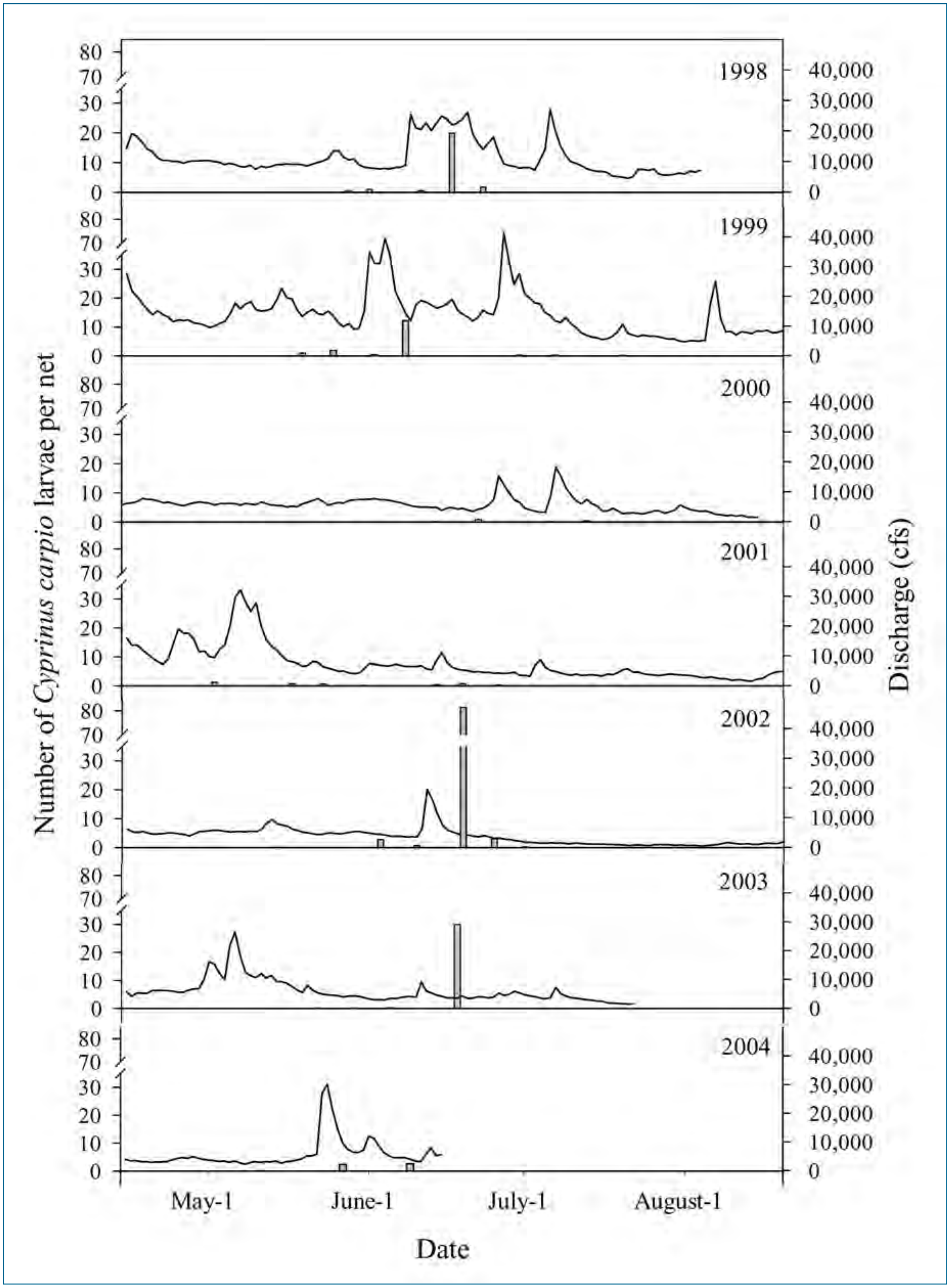


Figure 8.10. Number of common carp larvae per net (gray bars) and mean daily discharge (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

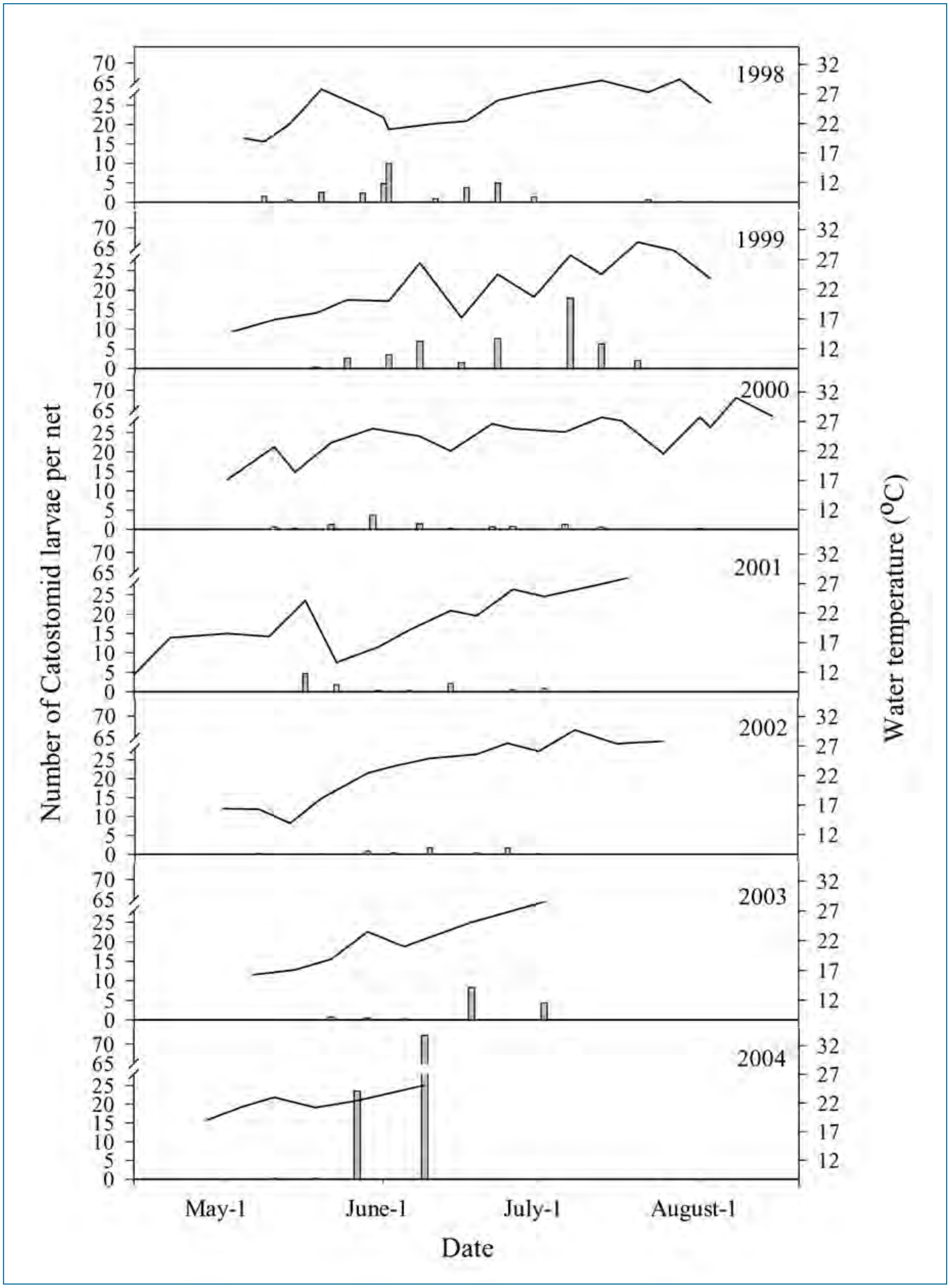


Figure 8.11. Number of Catostomid larvae per net (gray bars) and water temperature (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

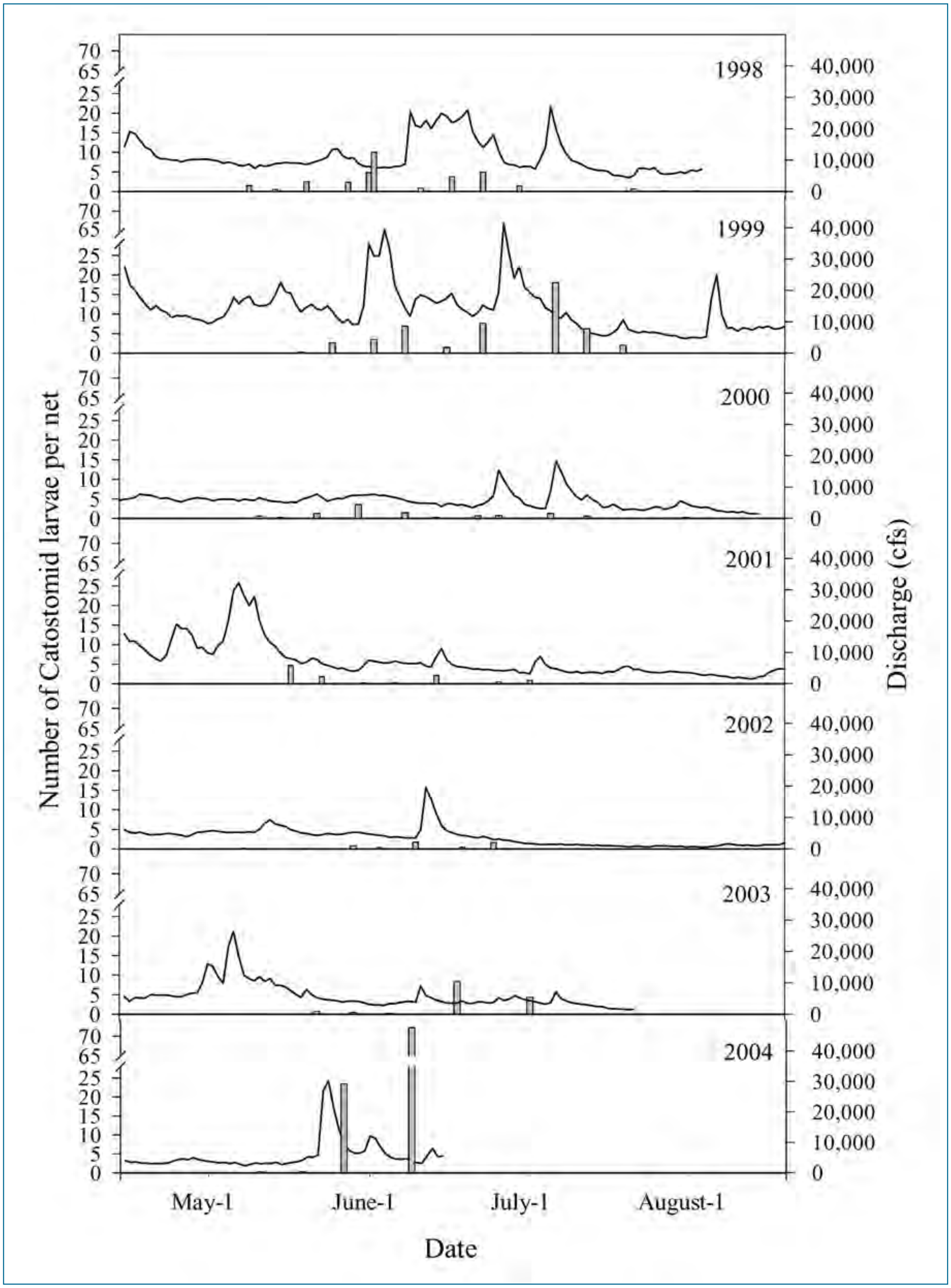


Figure 8.12. Number of catostomid larvae per net (gray bars) and mean daily discharge (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

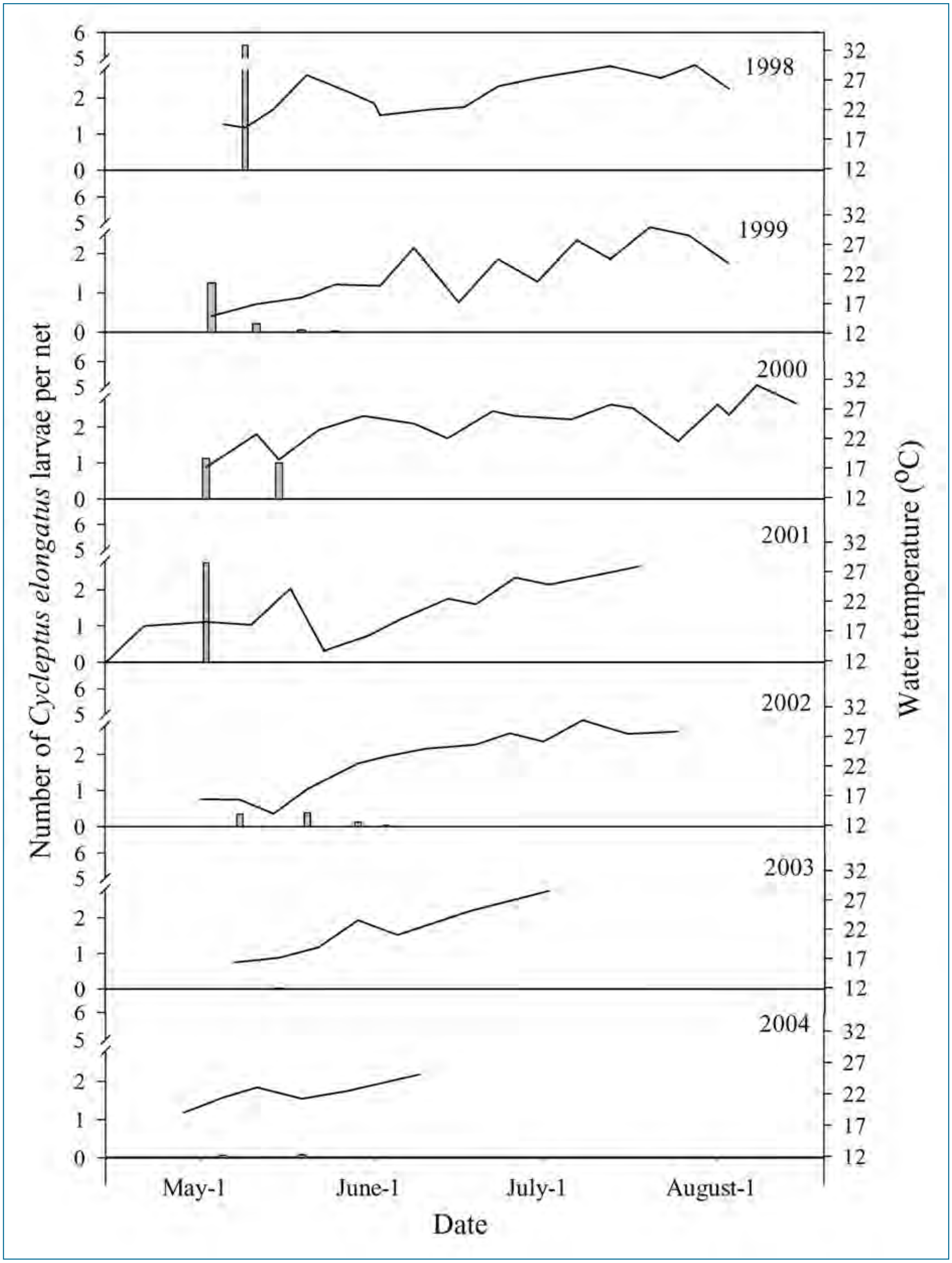


Figure 8.13. Number of blue sucker larvae per net (gray bars) and water temperature (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

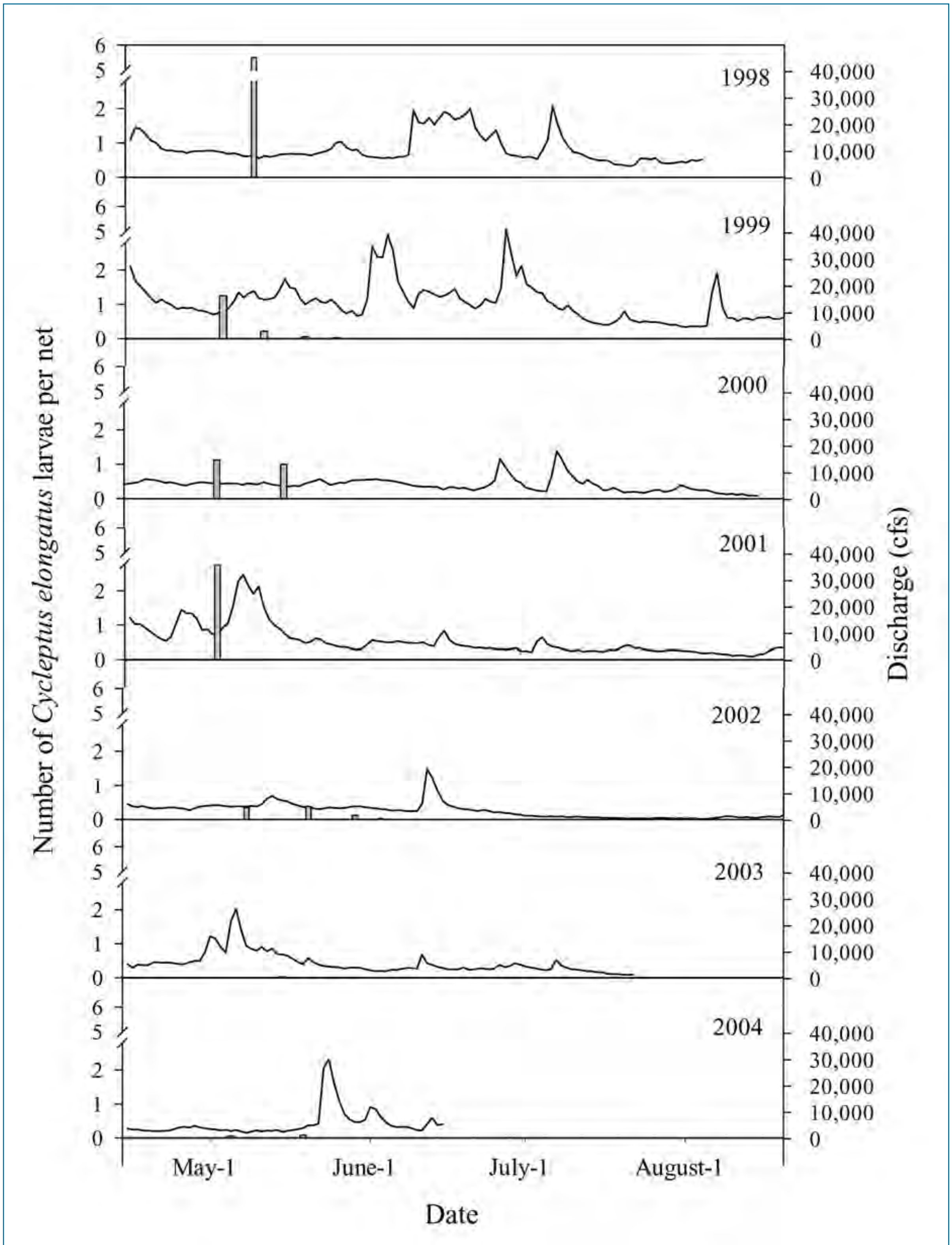


Figure 8.14. Number of blue sucker larvae per net (gray bars) and mean daily discharge (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

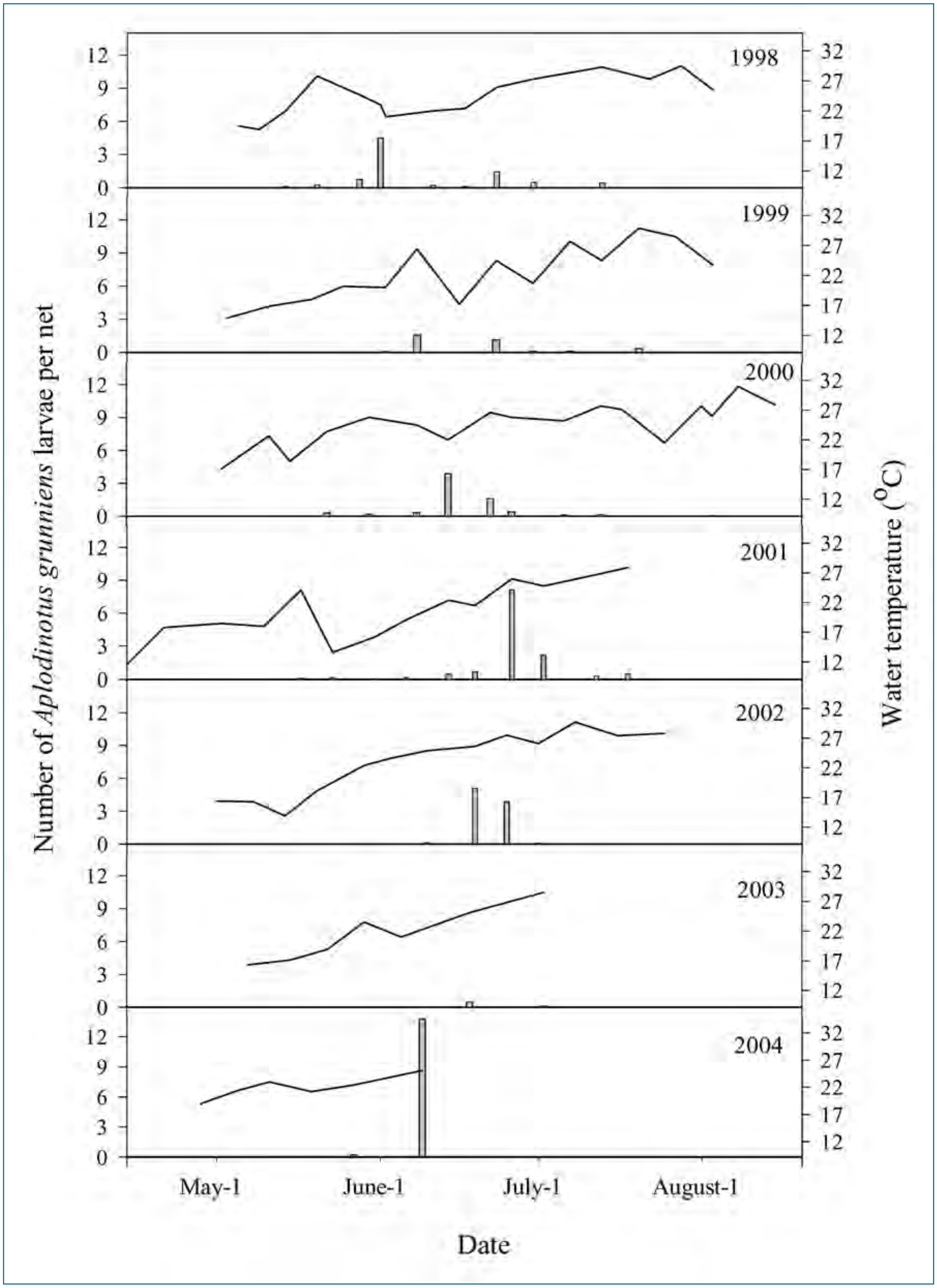


Figure 8.15. Number of freshwater drum per net (gray bars) and water temperature (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

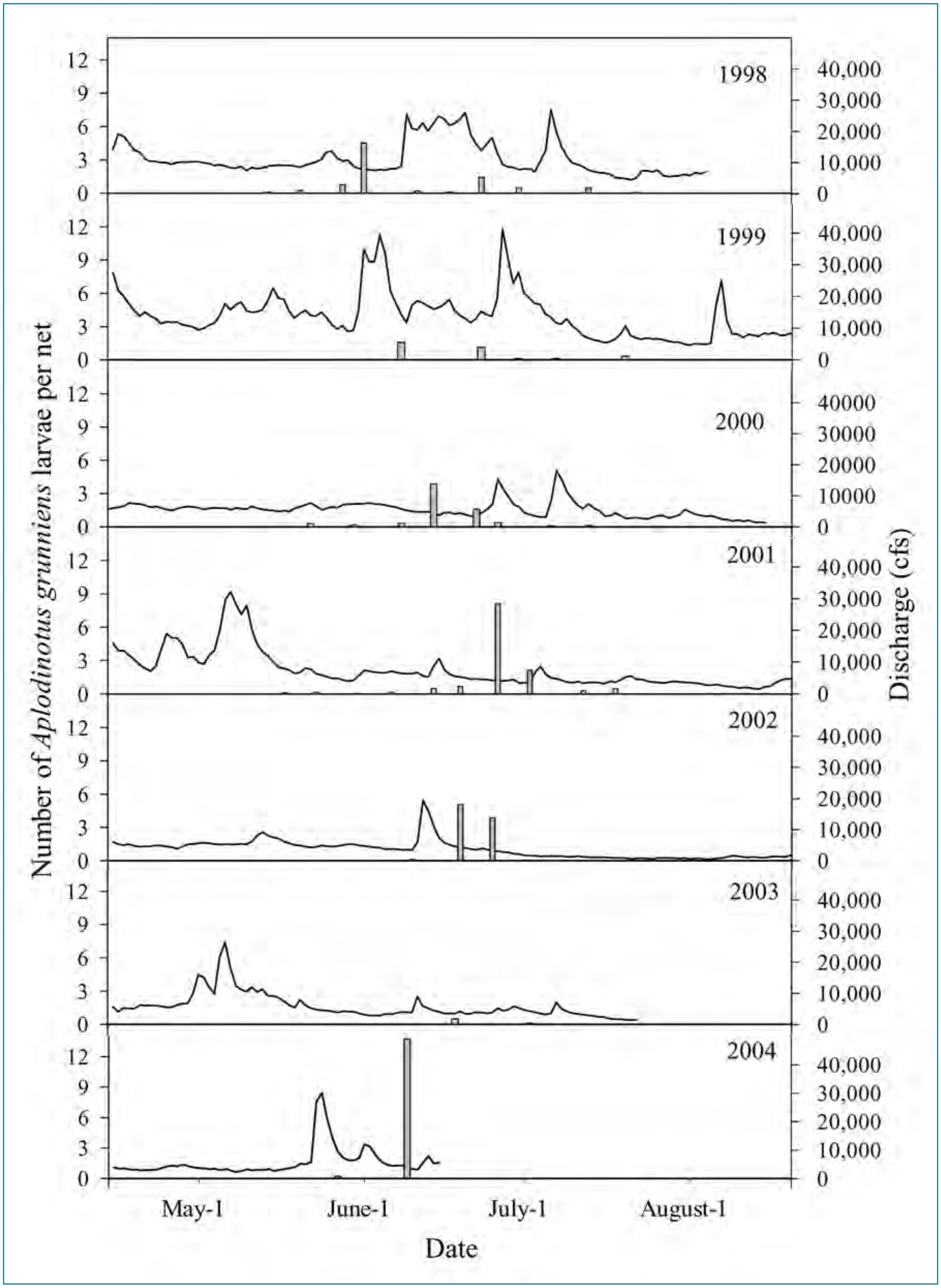


Figure 8.16. Number of freshwater drum larvae per net (gray bars) and mean daily discharge (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

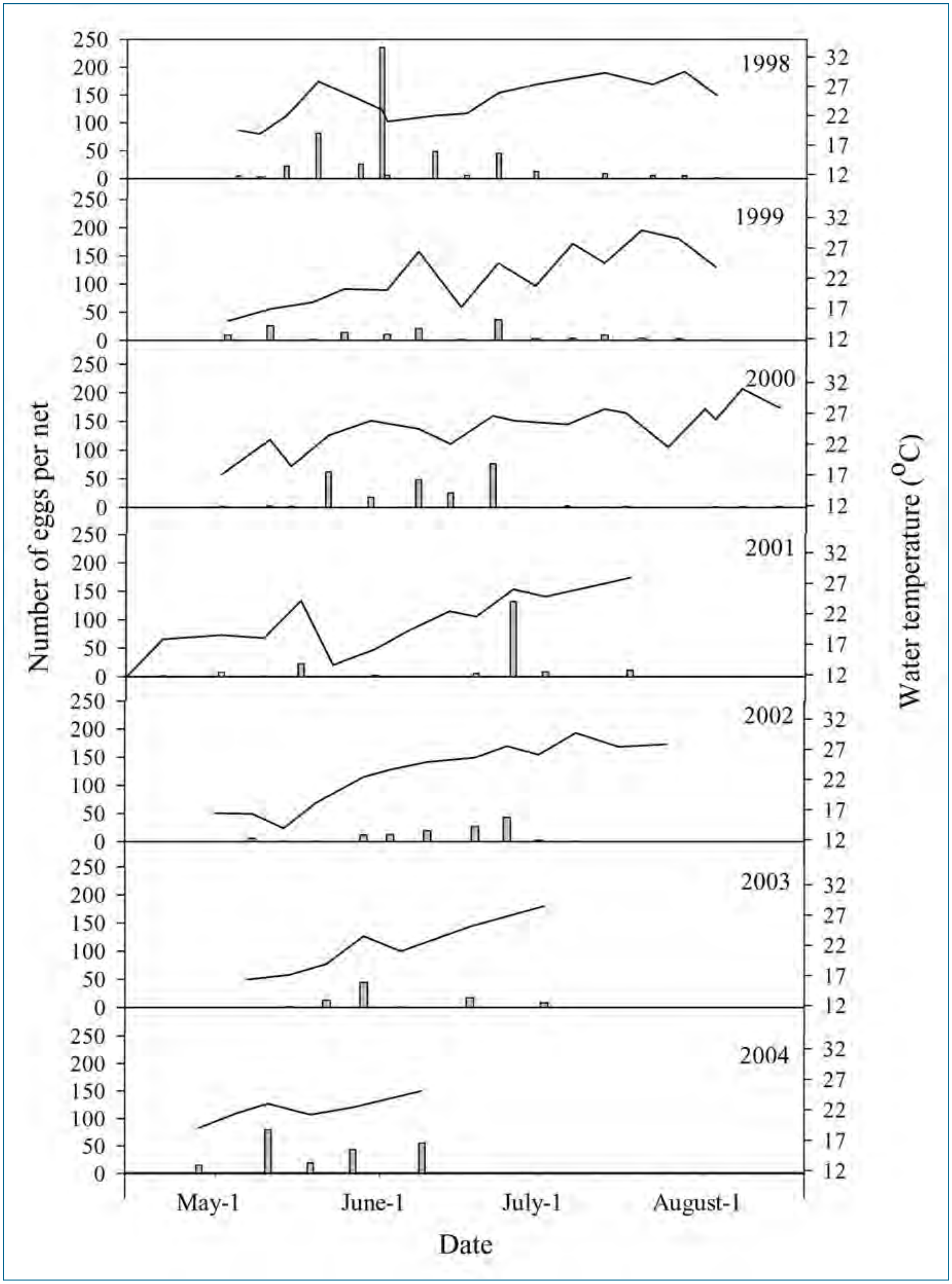


Figure 8.17. Number of eggs per net (gray bars) and water temperature (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

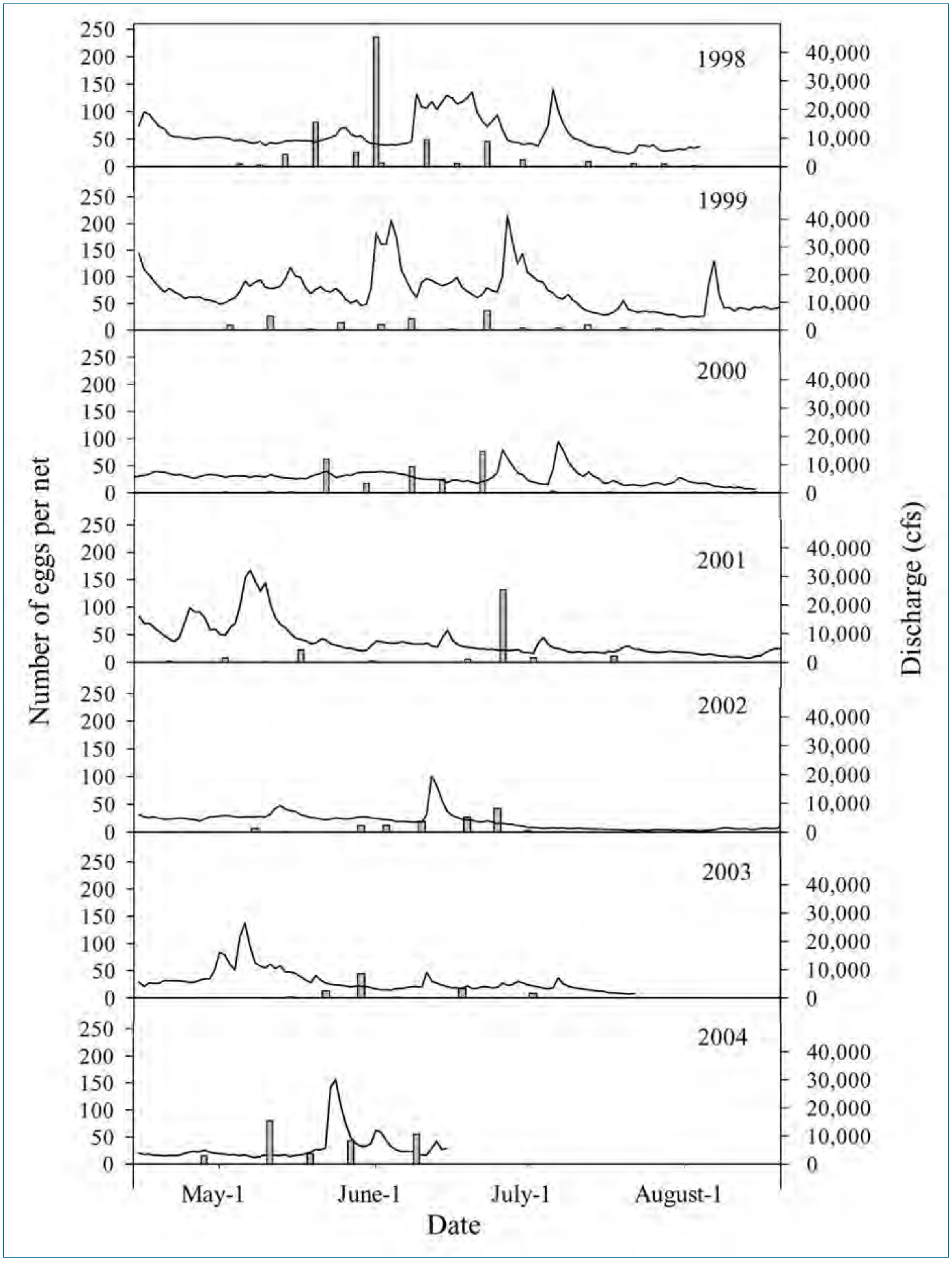


Figure 8.18. Number of eggs per net (gray bars) and mean daily discharge (lines) from 1998 through 2004 (1998 and 1999 data from Reade (2000)).

CHAPTER 9
CREEL SURVEY OF THE LOWER PLATTE RIVER

INTRODUCTION

Recreational angling for sturgeon is a small but important spring activity in the lower Platte River according to the 1992 and 1993 angler creel surveys (Holland and Peters 1994). These surveys found that most anglers fished primarily for channel catfish, but in the lower 40 km of the river and especially near the Schilling WMA, shovelnose sturgeon fishing was popular in the early spring, where they comprised 4.0 and 5.3% of the catch in 1992 and 1993, respectively. Harvest of shovelnose sturgeon was over 73% of the total sturgeon caught during both years.

Unintentional harvest of pallid sturgeon by shovelnose sturgeon anglers is a concern for conservation and recovery efforts for the pallid (USFWS 1993) and limitations on sturgeon fishing is one potential way to avoid this source of mortality. Montana, Missouri, Nebraska and Iowa allow the sport fishing harvest of shovelnose sturgeon, but North Dakota, South Dakota and Kansas prohibit the harvest of all sturgeon. Nebraska has maintained a recreational fishery for shovelnose sturgeon on the Platte River and on the Missouri River below the confluence with the Big Sioux River. In Nebraska on the Missouri River commercial fishing is allowed for rough fish only. The species that may be commercially harvested in Nebraska are: black bullhead, yellow bullhead, freshwater drum, yellow perch in addition to common carp, grass carp, silver carp, bighead carp, bigmouth buffalo, smallmouth buffalo, river carpsucker, quillback, white sucker, longnose gar, shortnose gar and gizzard shad. Missouri has allowed commercial fishing for shovelnose sturgeon in the Missouri River, but several ongoing studies continue to evaluate this harvest (Herzog et al. 2005). Studies in the Wabash River have documented differences in shovelnose sturgeon population structure which are attributed to commercial harvest (Kennedy et al. 2007), but we found no studies that have documented similar impacts by sportfishing harvest.

As part of our study, we wanted to evaluate the impact of angling on sturgeon and therefore our objective was to document the catch of sturgeon by anglers in the lower Platte River. We also wanted to evaluate the ability of anglers to distinguish pallid from shovelnose sturgeon.

METHODS

This objective was accomplished by conducting a focused creel survey in the Platte River approximately from the Ak-Sar-Ben aquarium at Schramm Park SRA (RM 22) downstream to the mouth of the Platte at the Schilling WMA (RM 0). The survey was an access point creel with standard stops along the road at Schramm Park SRA, Louisville SRA (RM 16.5) and Schilling WMA.

The creel survey followed a stratified multi-stage probability sampling regime designed using the WinFin computer program produced by the NGPC. A total goal of 10 survey days was performed each month, from 1 April through 31 May, with the number of creel days per month stratified between weekdays and weekends/holidays. Each creel day was further stratified into 4 time periods and count times were randomized within these time periods. During each count the creel clerk recorded the number of anglers present. Clerks interviewed anglers to collect information on what they were fishing for, duration of their trip and number and species of fish captured and harvested. All sturgeons in the creel were measured and barbel clips collected for DNA analysis. To estimate overall catch, the number of anglers was divided by the number of time periods sampled within the month, then multiplied by the total number of time periods within the month. This resulted in an estimated angler effort for the month. An estimate of average angler catch was calculated by dividing the total number of fish reported by the total number of anglers surveyed. The estimate of total monthly catch by anglers was calculated by multiplying the average angler catch by the estimated angler effort for the month.

To evaluate the ability of anglers to discern the differences between pallid and shovelnose sturgeon, each angler was asked to identify pallid and shovelnose sturgeon from photos (Figure 9.1). The creel survey clerks also passed out flyers to increase the awareness of local anglers about pallid sturgeon conservation efforts.

Figure 9.1. Photograph of shovelnose sturgeon (left) and pallid sturgeon (right) used to test anglers on their ability to identify species.

RESULTS AND DISCUSSION

A total of 247 anglers was surveyed during this study. In 2002, we surveyed 89 anglers over the course of 23 days, 11 days in April and 12 days in May. In 2003, we surveyed 81 anglers over 32 days, 16 each in April and May. During 2004, we surveyed 77 anglers over 20 days, 10 each in April and May. All of these anglers were fishing from the shore. The majority of anglers were fishing at the Schilling WMA (199), followed by Schramm SRA (35) and then Louisville SRA (13). Generally the highest number of anglers was counted during the late afternoon and evening hours (1700 to 2000 hrs).

The 247 anglers surveyed reported catching 84 shovelnose sturgeon during the 2002-2004 creel survey period. Of those, 72 were reported from Schilling WMA and 12 from Schramm SRA. Anglers at Schilling reported keeping 34 of the 72 sturgeon (48.6% harvest rate) that they caught and those at Schramm reported keeping only one sturgeon (8.3% harvest rate). Total shovelnose sturgeon catch by year was 26 in 2002, 18 during 2003 and 40 in 2004. Only during 2002 were more sturgeon caught during April than May (15 vs. 11). The next two most common species caught by anglers in our surveys were channel catfish (64) and freshwater drum (43). Those three species comprised over 88% of the 216 total fish reported in the creel.

Expanding the creel reports by month by year gives us an estimate of the total catch of 900 sturgeon during the period surveyed. Table 9.1 summarizes the estimated number of shovelnose sturgeon, channel catfish and freshwater drum caught by anglers during April and May 2002 to 2004. Based on the estimated total catch of 900 shovelnose sturgeon during this study and the overall estimated percent harvested of 43%, we estimate that 387 sturgeon were harvested over the three year period.

The test of angler's ability to distinguish shovelnose from pallid sturgeon showed a marked difference between anglers fishing for sturgeon and those just fishing in the lower Platte River. Sturgeon anglers were able to correctly identify shovelnose and pallid sturgeon an average of 87% of the time while other anglers were able to correctly identify the species an average of 66% of the time. However, on a year by year basis the general anglers improved their correct response rate from 55% in 2002 to 64% in 2003 and 78% in 2004. In contrast, sturgeon angler responses were 86% in 2002, 86% in 2003, and 88% in 2004.

Our collections of sturgeon in the Platte River over the past four years (2000 to 2004) have captured 15 pallid sturgeon and 1,541 shovelnose sturgeon. Assuming equal vulnerability to sampling techniques, this equals a less than 1% chance that any sturgeon caught is going to be a pallid sturgeon. The creel information indicates a probable catch of about 300 sturgeon per year by anglers in the lower Platte River. If their catch is approximately the same as ours, they could be capturing about 3 pallid sturgeon per year. The worst that anglers scored on the identification quiz was 55% correct and the best was 88%. The worst case scenario is that anglers in the Platte River may take two pallid sturgeon per year by mistake and the best case scenario is that they may take one. With the educational materials that we and the Nebraska Game and Parks Commission have distributed, it seems that most current anglers are aware of the importance of protecting pallid sturgeon.

Table 9.1. Estimated numbers of shovelnose sturgeon, channel catfish and freshwater drum caught from the lower Platte River during April and May, 2002-2004.

YEAR	Shovelnose sturgeon		Channel catfish		Freshwater drum	
2002	April 164	May 112	April 164	May 52	April 228	May 2
2003	April 36	May 100	April 172	May 48	April 76	May 8
2004	April 216	May 272	April 84	May 100	April 60	May 60
Totals All Years	416	484	420	200	364	70

CHAPTER 10

GIS MODELS OF HABITAT TYPE AVAILABILITY, RIVER CONNECTIVITY, AND DISCHARGE IN THE LOWER PLATTE RIVER

INTRODUCTION

As an outgrowth of the discharge records summarized in Chapter 1, the water quality sampling summarized in Chapter 3, and the habitat use and movement information for pallid and shovelnose sturgeon presented in chapters 4 and 5, respectively, this chapter introduces an analysis of the relationships among the data presented in those chapters. The goal of this chapter is to present two different models that were constructed to aid in understanding the relationships between river discharge and habitat requirements of pallid and shovelnose sturgeon. The first model, called the Lower Platte River Habitat Type Availability Model, focuses on developing a relationship between available habitat types and river discharge. After developing a relationship between the types of available habitats and discharge, we weighted the model with sturgeon habitat use to describe the changes in sturgeon habitat with respect to discharge. The second model, called the Lower Platte River Connectivity Model, focuses on developing a relationship between the connectedness of the migratory pathway and river discharge (IFC 2004). The combination of the two models provides a method to view quantity and accessibility of instream habitats in the lower Platte River with respect to changes in river discharge.

The development of the relationship between discharge and habitat availability is useful for several purposes. First, this relationship would provide a generalized model of habitat dynamics for a relatively large section (103 RM) of the Platte River. Secondly, this relationship would allow information gathered on habitat needs of the biotic community associated with the specific river habitats to be analyzed with respect to discharge. This is especially important on the lower Platte River given the occurrence of endangered and threatened species in this stretch of the river. The fish, pallid sturgeon and sturgeon chub, and the sandbar nesting birds, the least tern and the piping plover, have habitats which are potentially influenced by river discharge.

The information derived from these GIS models is used in conjunction with the habitat descriptions of the pallid and shovelnose sturgeon. We used data on the more common shovelnose sturgeon as well as data collected directly from pallid sturgeon in the lower Platte River.

The objectives of the Lower Platte River Habitat Type Availability Model were:

To develop relationships between the observed quantities of instream habitat types and river discharge.

To determine the quantity of instream habitat types throughout the lower Platte River at different discharges using aerial images.

To determine the relationships for the amount of suitable habitat for sturgeon species to river discharge.

The objectives of the Lower Platte River Connectivity Model were:

To determine the linear extent of a pathway through the river in relation to river discharge.

To compare movement rates of radio-tagged shovelnose sturgeon to river discharge conditions to see if fish movement correlates to the availability of a migratory pathway.

METHODS

Lower Platte River Habitat Type Availability Model

Digital orthoquadrangle (DOQ) images were collected for the area covering the lower Platte River for 1993, 1994 and 1999. These DOQs were from the National Aerial Photography Program (NAPP). The 1:40,000 scale aerial photographs were taken at 20,000 feet above land surface with a 6 inch focal length camera. The scanned images were rectified to orthographic projections of 1 m resolution based on the National Mapping Standards and cast on the Universal Transverse Mercator Projection (UTM) on the North American Datum of 1983 (NAD83). The images for the NAPP within each year were acquired over a number of different days as the flight lines for the images covered the segment of the state in a north-south direction. A portion of the images for the 1993 state coverage were reacquired in 1994, presumably as a result of unsatisfactory image quality. A total of 7 different dates were used to develop the 1993 (1994) images and 5 dates for the 1999 images. Since the images were acquired on different days, discharge values were not consistent across the combined image of the 103 RM river segment therefore, contiguous image groups were developed for individual dates. An additional flight on was made on 15 August 2003 to acquire images during drought conditions. The images were acquired from approximately 6,000 feet above land surface with a Nikon F4 digital camera with images taken from a port in the bottom of a small aircraft. Each contiguous image group was digitized, classified and post-processed individually. Each image group was projected into NAD83 UTM zone 14 prior to digitizing.

The first step in the process was to digitize and classify the aerial photos. All of the habitat classification was done at the 1:5,000 scale using on-screen digitizing methods in ArcGIS 8.3 (ESRI, Inc. 2004). The habitat was classified into five groups: exposed sandbars, woody islands, sandbar complexes, open water and no data. Exposed sandbars were sandbars that lacked woody vegetation and appeared to be above the surface of the water. Woody islands were exposed islands or sandbars with trees. Sandbar complexes included areas where the bottom was visible or deeper water between exposed sandbars no more than 50 m apart. Open water was defined as water too deep to see the bottom but not inside a sandbar complex. No data areas were areas of high reflectance or bridge crossings and were not used in further analyses. Images were classified by a research technician trained in the classification methods and checked for consistency and errors by a supervisor.

After the digitization process was completed and all of the polygons for the various habitat classes were created, the polygons were converted into a grid format that was based on the maximum extent of the river polygons with a cell size of 3 m^2. After each of the grids was developed, all grids were combined into a single continuous grid for the group of images from a single date. From this continuous grid we were able to determine total area for each habitat type within the classified section of the river. All cells outside of the river were not classified and were set to no data to eliminate them from further analysis. To rectify the classified images from the 2003 flight, the images were fitted to the 1999 images as the base map. This was accomplished using the warp function in ArcGIS with a minimum of 18 control points spaced along the shoreline of the river at identifiable landmarks. Unfortunately, many of the images of the 2003 flight had insufficient overlap with the adjacent images to create useful river sections, so only 3 segments were able to be used in the effort. Figures 10.1 and 10.2 show examples of how the classification looks, although to provide better visualization the sections are much smaller than those used in the analysis.

The quantities of each habitat type within each section were recorded from the attribute table within the GIS. These quantities were converted into percent coverage by removing no data cells and dividing each habitat type into the total of all habitat types within the river section.

Mean daily discharge was recorded from the USGS gage sites chosen with respect to distance and the locations of major tributaries. In locations where gaged tributaries entered downstream of an upstream main river gage, discharge readings from more than one gage were combined. The percentages for each habitat class were then plotted against the mean daily discharge for the nearest gage site on the Platte River.

To develop the relationships between habitat quantity and discharge, the curve of best fit was solved for the data using Table Curve 2D 5.01(Systat 2002). Selection of the most appropriate curve followed methods outlined in the curve-fitting software. This process generally followed the criteria simultaneously increasing adjusted r^2 values, reducing parameterization, eliminating of the unstable or undefined regions, and examining the curve ends with the goal of choosing the simplest equation that describes the curve. Once each curve for the habitat type vs. discharge was determined independently, all the equations were adjusted together in a spreadsheet by requiring that the sum of all equations total 100% at all discharge rates.

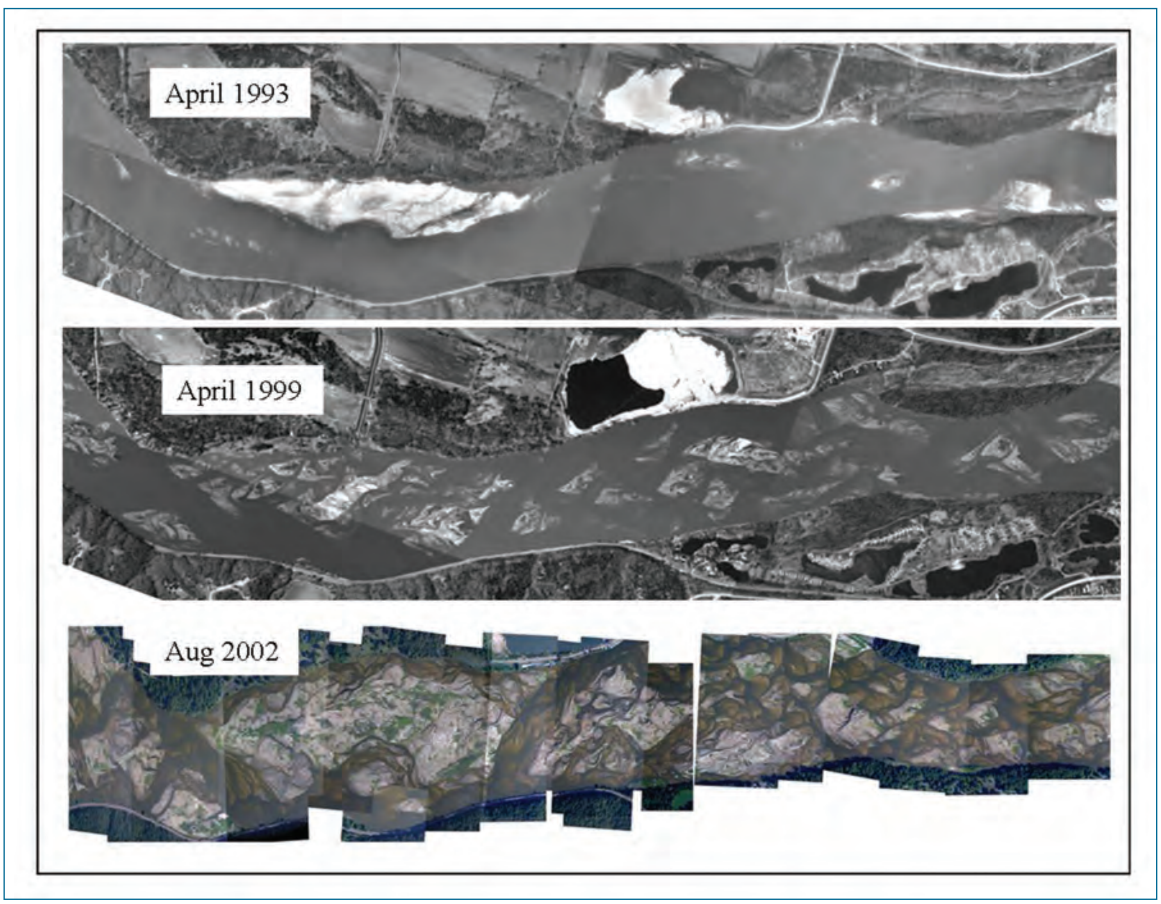


Figure 10.1. Examples of aerial images used in the analysis. The images are from the region around South Bend on the Platte River, NE.

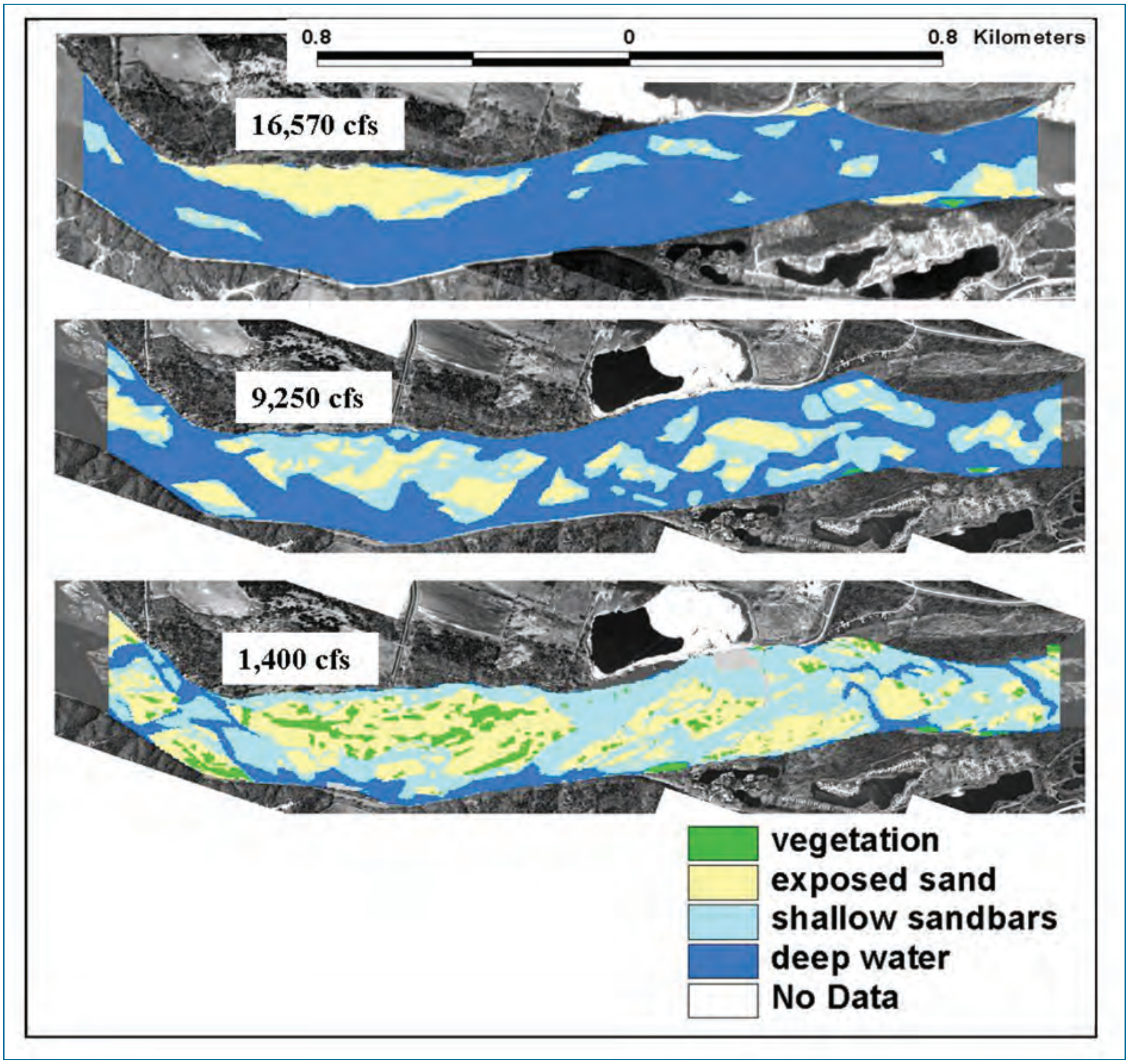


Figure 10.2. Examples of habitat type classification of the aerial images with associated discharge rates. The bottom image shows the resultant rectification for the 2002 data (1,400 cfs) to the 1999 base-map.

Determination of habitat quality of the instream habitat types: To determine the quality of the habitat types classified in the aerial image data transect data from the Nebraska Game and Parks Commission IFIM (NGPC 1993a, b.) were used. These data were collected in the 1980s and were taken over a range of flows from 1,181 to 6,767 cfs. The data collected along each transect included bed elevation (depth), mean column velocity, substrate, and cover. The bed elevation of each transect was plotted and sections of transects were classified as exposed sandbars (points above the water line), open water (points deeper than 0.5 m for sections greater than 50 m) and shallow sandbar complexes (points not in other categories). Each point was then classified as a specific habitat type to go along with its physical habitat measurements. The four habitat variables of depth, mean column velocity, substrate, and cover were compared using a T-test between the two water covered habitat types (open water and shallow sandbar complexes). Variables that were statistically different were used in the subsequent habitat selection analysis. Figures 10.3 and 10.4 show an example of this process. Overall, this provided an estimate of the proportions of depth and mean column velocities within each habitat type classified in the aerial images.

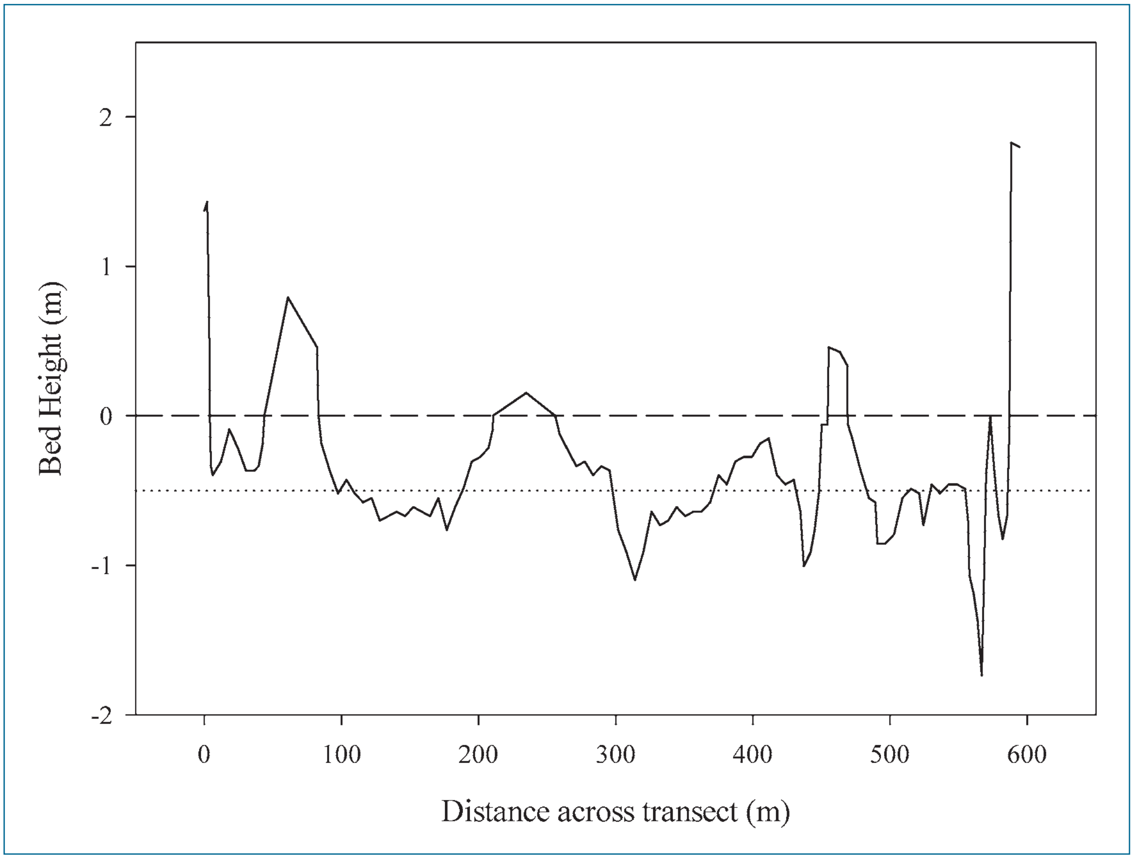


Figure 10.3. River bed heights (solid line) along and example transect from the 1985 survey of the Platte River at Cedar Creek, NE when discharge was 5,116 cfs. The water surface (0 m) is represented by the dashed line and the dotted line indicates the estimated limit of visibility into the water

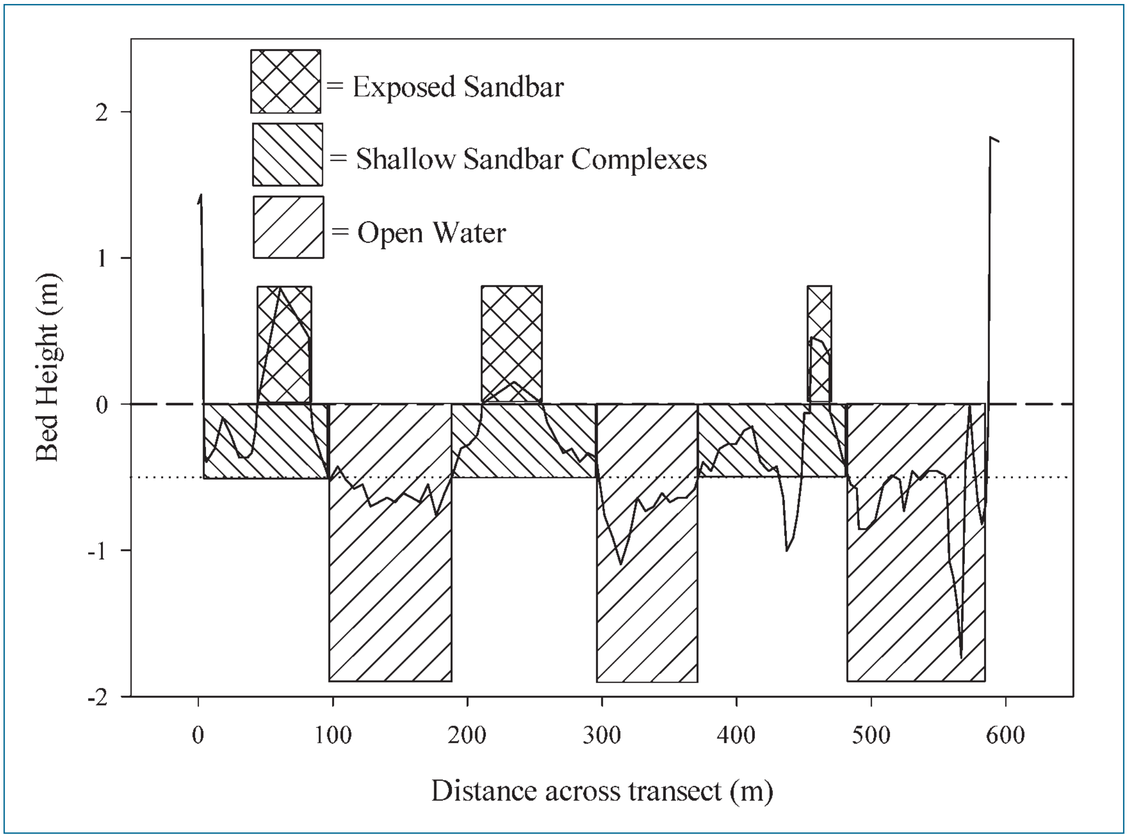


Figure 10.4. Classification of the habitat types for the points along the Cedar Creek transect (Figure 10.3) as defined in the aerial image section. The boxes indicate the habitat type into which the points were classified.

To integrate the extent of the habitat with the quality of the habitat for sturgeon, a chi-squared test was used to compare the availability of each habitat variable with the observed use of these habitat variables. Data for shovelnose sturgeon is from the telemetry section of this study and the data for pallid sturgeon is a combination of the telemetry data from this study and the telemetry data on stocked pallid sturgeon in the lower Platte River (Snook 2001, Snook et al. 2002). The results of sturgeon habitat selection for depth and velocity were used to weight each habitat category. The suitability for each habitat type was assumed to be equal to the average of the amount of suitable depths and velocities within the category. To develop the relationship between suitable habitat for shovelnose and pallid sturgeon and discharge, the sum of the proportion of suitable habitat at each discharge level was determined and the resultant curve was solved with Table Curve 2D 5.01(Systat 2002) following the criteria described previously.

Lower Platte River Connectivity Model

After the digitized classification was developed (as described in previous section), an additional 25m buffer was placed around sandbar complexes that extended into the open water. The buffer was set to 25 m, which is less than 5% of the average river width. The buffer was used to approximate the edge habitat near sandbar complexes in deeper water that may have been misclassified due to the gradual transition from one habitat type to the other. The assumption in the buffering strategy was if 5% or more of the width of the river was open water habitat fish, could find a way to swim through the river section. The corollary assumption to this is that if less than 5% of the width of the river was open water the fish were likely to not move through the shallow sandbar complexes. In the Platte River the main channel frequently shifts and twists down the channel bed. For readers unfamiliar with the shallow, sandbed rivers like the Platte River in Nebraska, the deeper sections could roughly be construed as the run and pool habitats of a typical riffle-run-pool river sequence. Connectivity for open water fishes would be the extent of these habitats between shallow riffles. Figure 10.5 shows the shallow sandbar complexes characteristic of the lower Platte River and the lack of a defined deepwater channel at low discharge rates.

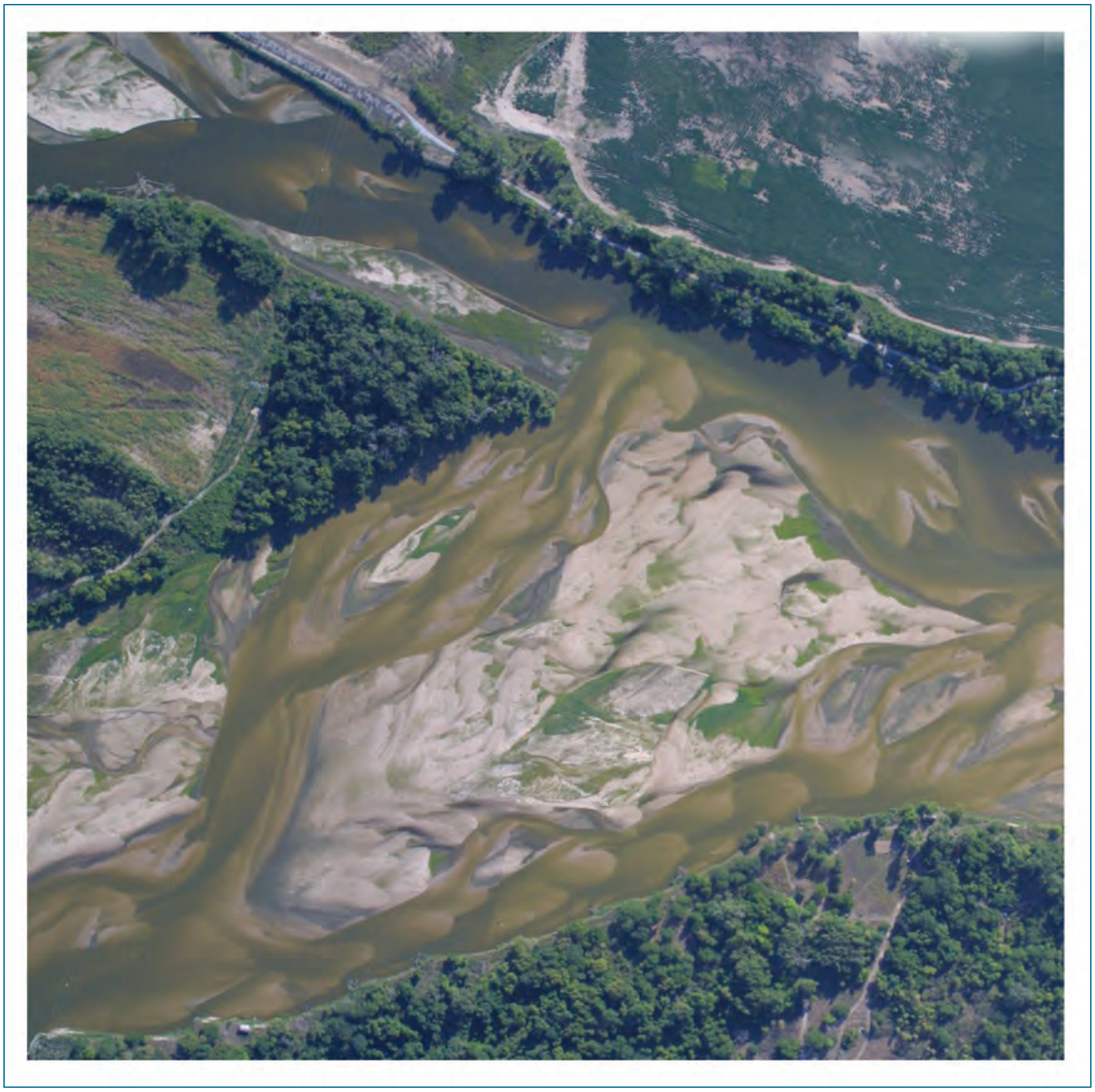


Figure 10.5. Confluence of the Platte River (bottom left) and Elkhorn River (top left) showing the characteristic shallow sandbar complexes and the lack of a defined channel which allow for passage of open water fishes. Note the increased discharge provided by the Elkhorn River creates a channel along the north bank of the Platte River. Also note that deep water is available within the sandbar complexes although it is not continuous channel. This image is a composite of two images from the flight on 15 August 2003 at a discharge of 1,400 cfs below the confluence.

After the buffers were placed on the habitat, the maximum linear extent of open water was measured for each image group. The measurement was converted to a percentage by dividing the maximum linear extent of open water by the total linear extent of the river section. Results of the proportion of the river connected were plotted against river discharge and the curve of best fit was solved using Table Curve 2D 5.01 (Systat 2002) following the similar criteria as described in first section. Figure 10.6 shows an example of the determination of maximum linear extent for the aerial images show in Figure 10.1.

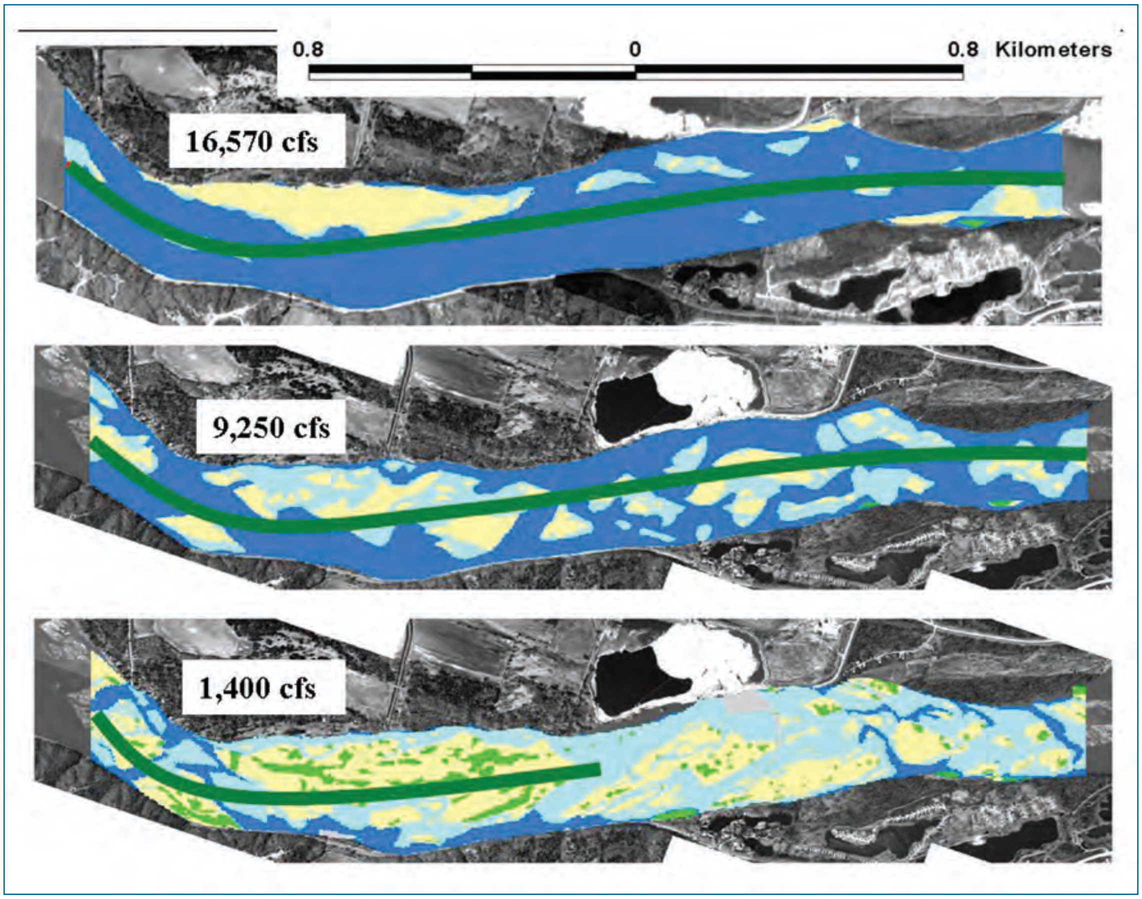


Figure 10.6. An example of aerial images (Figure 10.1) classified at three discharge levels. The green lines represent the maximum linear extent of the open water habitat type (blue color) for the classified images at the various discharge rates.

RESULTS

A description of the 26 image groups containing the date images were acquired, gage location, discharge, section length, and GPS bounding coordinates are provided in Table 10.1. On average the sections were about 11.9 km long (range 2.8 to 31.3 km) and the discharge varied from 0 to 21,000 cfs. The zero discharge was from August 2002 in the vicinity of Columbus, NE when the river bed of the Platte River was completely dry.

Lower Platte River Habitat Suitability Model:

The process classified 219,122,848 m^2 of instream habitat for the 26 sections into the four categories: open water, shallow sandbar complexes, exposed sandbars, and woody islands. The amount and percentage of the habitat types varied considerably with discharge (Table 10.2).

Determining the relationships between each habitat type and discharge resulted in four different response curves. For woody islands, no relationship was detected (adjusted r^2 = 0.0, Figure 10.7). The distribution and amount of woody islands was not a function of discharge over the range of flows in the analysis. For exposed sandbars, the amount peaked at no flow and decreased rapidly to 2,500 cfs and then flattened out (Figure 10.8). The curve that best fit the exposed sandbar data (adjusted r^2 = 0.89) was described as a Lorentzian Cumulative Curve (Equation 10.1)

Equation 10.1. The function of exposed sandbars (y) at a given discharge (x) in the lower Platte River (where: a = 0.09976, b = 1.08377, c = 29.38736, d = -17.43732).

$$y = \frac{a}{\pi}\left[\arctan\left(\frac{x-b}{c}\right) + \frac{\pi}{2}\right] + d$$

For shallow sandbar complexes, the amount peaked around 2,000 cfs and decreased rapidly to around 7,000 cfs and then flattened out (Figure 10.9). The curve that best fit the data (adjusted r^2 = 0.87) was described as a natural logarithm of x rationals (Equation 10.2).

Equation 10.2. The function of shallow sandbar complexes(y) at a given discharge (x) in the lower Platte River (where: a = 0.00749, b = -0.47214, c = 0.00283, d = 0.05705).

$$y = \frac{a + c\ln x}{1 + b\ln x + d(\ln x)^2}$$

Table 10.1. Descriptive information for the aerial images used for habitat classification from the lower Platte River, NE. The gage site represents the nearest USGS gage for classified image. In some cases, discharge was determined from a combination of USGS gages. Gage sites are as follows: LSV = Platte River at Louisville, NE; ASH = Platte River at Ashland, NE; LES = Platte River at Leshara; ELK = Elkhorn River at Waterloo, NBD = Platte River at North Bend, NE; LPC = Loup Power Canal at Genoa, NE; LPR = Loup River at Genoa, NE; DCN = Platte River at Duncan, NE. GPS coordinates are in decimal degrees and are located approximately mid-channel at the upstream and downstream ends of the river section. UPGPSW = upstream GPS west, UPGPSN = upstream GPS north, DGPSW = downstream GPS west, DGPSN = downstream GPS north.

Site ID	Date	Gage Site	Discharge (cfs)	Length (km)	UPGPSW	UPGPSN	DGPSW	DGPSN
1	15-Aug-2002	DCN	0	5.7	-97.3801	41.3962	-97.3218	41.3970
2	15-Aug-2002	LES	958	4.5	-96.3578	41.2468	-96.3605	41.2191
3	15-Aug-2002	LSV	1,400	4.7	-96.2254	40.9979	-96.1718	41.0079
4	1-Apr-1999	DCN	2,450	5.1	-97.3801	41.3962	-97.3218	41.3970
5	22-Apr-1993	DCN	2,840	11.0	-97.4431	41.3748	-97.3211	41.3965
6	1-Apr-1999	DCN+LPR	4,080	3.3	-97.3218	41.3970	-97.2836	41.3965
7	21-Mar-1994	DCN+LPR+LPC	4,690	2.8	-97.3175	41.3985	-97.2833	41.3996
8	18-Apr-1994	NBD	5,610	5.0	-96.8182	41.4497	-96.7599	41.4526
9	4-Apr-1999	LES	5,680	16.4	-96.3534	41.2537	-96.3130	41.1209
10	4-Apr-1999	LES	5,680	13.9	-96.5665	41.4357	-96.4318	41.3664
11	1-Apr-1999	DCN+LPR+LPC	5,820	3.5	-97.2836	41.3965	-97.2459	41.3845
12	16-Apr-1993	NBD	6,350	38.3	-97.2419	41.3833	-96.8235	41.4487
13	6-Apr-1999	NBD	6,570	15.8	-97.1304	41.3859	-96.9672	41.4408
14	21-Mar-1994	DCN+LPR	6,580	3.7	-97.2833	41.3996	-97.2462	41.3838
15	4-Apr-1999	ASH	7,760	11.8	-96.3182	41.1281	-96.3072	41.0368
16	14-Apr-1993	ASH-ELK	7,830	12.1	-96.3532	41.2536	-96.3203	41.1581
17	4-Apr-1999	LSV	8,480	31.3	-96.2557	41.0172	-95.9338	41.0586
18	6-Apr-1999	LES	8,800	8.3	-96.4417	41.3713	-96.3985	41.3089
19	22-Apr-1993	NBD	10,400	24.4	-96.7555	41.4525	-96.4903	41.3992
20	2-Apr-1993	ASH-ELK	10,740	6.5	-96.3794	41.2995	-96.3562	41.2469
21	6-Apr-1999	LSV	10,800	4.5	-96.2343	41.0041	-96.1850	41.0030
22	14-Apr-1999	ASH	14,400	7.2	-96.3172	41.0463	-96.2488	41.0157
23	16-Apr-1993	ASH	15,000	21.0	-96.3187	41.1279	-96.1837	41.0048
24	26-Mar-1993	LSV	15,500	29.4	-96.1940	41.0010	-95.8810	41.0532
25	22-Apr-1993	ASH-ELK	18,920	12.7	-96.4547	41.3782	-96.3698	41.2911
26	19-Apr-1999	LSV	21,000	5.6	-95.9438	41.0579	-95.8808	41.0531

Table 10.2. Area and percent for the habitat types classified from the aerial images of the lower Platte River, NE. Site ID's correspond to location information in Table 10.1. OWTR = open water, SSBC = shallow sandbar complexes, EXSB = exposed sandbars, WDIL = woody islands. Percentages are calculated as a proportion of the Total Area – WDIL.

Site ID	Discharge (cfs)	OWTR (m^2)	OWTR (%)	SSBC (m^2)	SSBC (%)	EXSB (m^2)	EXSB (%)	WDIL (m^2)	Total Area (m^2)
1	0	0	0	0	0	2,750,598	100	416,331	3,166,929
2	958	0	0	785,016	32	1,638,342	68	693,198	3,116,556
3	1,400	152,271	5	1,456,947	46	1,553,022	49	0	3,162,240
4	2,450	22,086	1	2,096,109	88	265,437	11	458,982	2,842,614
5	2,840	807,939	13	4,243,563	68	1,211,832	19	383,535	6,646,869
6	4,080	312,795	21	860,202	57	338,337	22	821,160	2,332,494
7	4,690	472,167	37	464,850	36	339,165	27	131,751	1,407,933
8	5,610	1,789,488	65	581,247	21	378,585	14	337,005	3,086,325
9	5,680	6,575,418	71	1,993,383	22	701,640	8	1,731,609	11,002,050
10	5,680	4,414,248	55	2,265,021	28	1,373,319	17	1,676,934	9,729,522
11	5,820	999,324	44	724,878	32	523,854	23	726,696	2,974,752
12	6,350	13,801,968	71	2,817,054	14	2,877,984	15	5,755,185	25,252,191
13	6,570	4,363,668	45	3,482,262	36	1,912,086	20	1,081,017	10,839,033
14	6,580	1,175,427	54	631,026	29	384,408	18	56,754	2,247,615
15	7,760	4,522,914	67	1,441,071	21	783,180	12	1,190,196	7,937,361
16	7,830	5,926,383	82	578,457	8	720,765	10	1,749,105	8,974,710
17	8,480	11,682,639	62	4,388,157	23	2,694,276	14	3,761,748	22,526,820
18	8,800	3,881,376	75	1,174,779	23	125,010	2	1,990,818	7,171,983
19	10,400	10,541,880	73	1,851,552	13	2,110,644	15	5,573,349	20,077,425
20	10,740	2,431,188	57	838,089	20	990,036	23	547,029	4,806,342
21	10,800	1,750,491	59	746,001	25	470,160	16	0	2,966,652
22	14,400	4,353,462	95	202,968	4	48,924	1	816,525	5,421,879
23	15,000	11,280,402	86	806,436	6	1,085,751	8	2,436,984	15,609,573
24	15,500	12,296,934	68	3,104,397	17	2,761,308	15	3,917,322	22,079,961
25	18,920	6,157,746	79	1,001,970	13	665,658	9	2,590,200	10,415,574
26	21,000	2,851,551	95	121,527	4	33,957	1	319,410	3,326,445

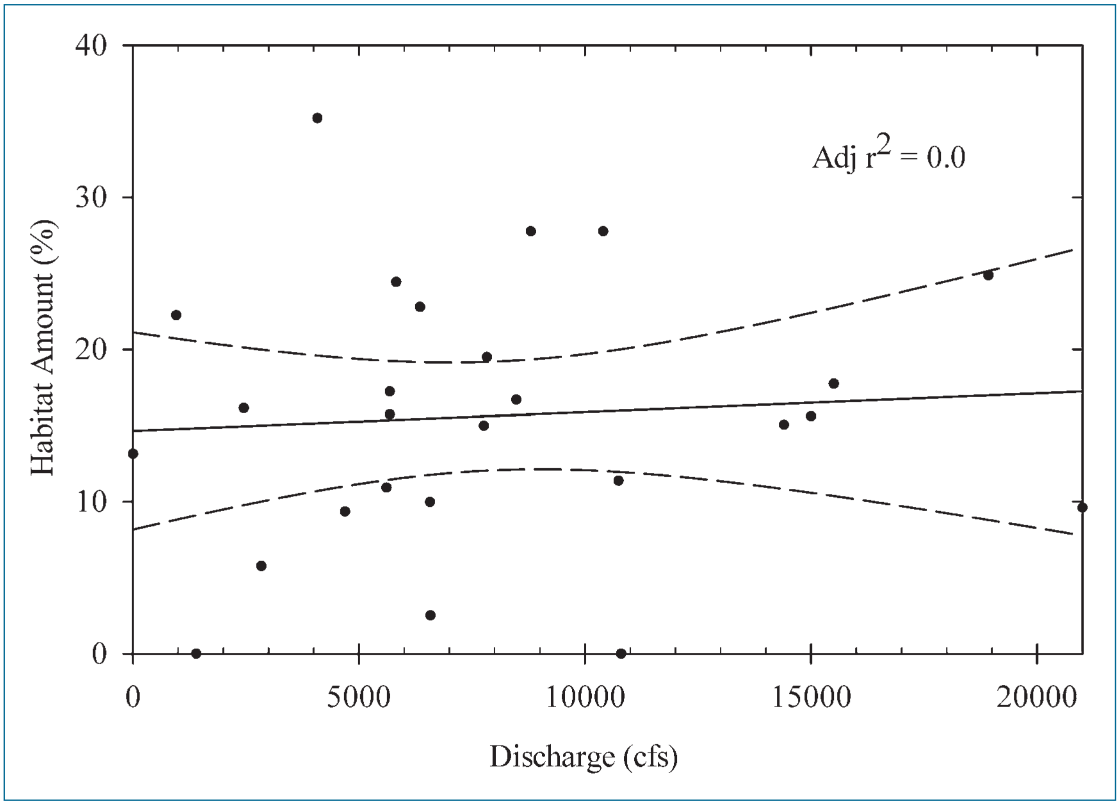


Figure 10.7. Regression line of best fit for woody islands from the aerial photo classification. The solid line represents the fitted line, the dashed lines are the 95% confidence intervals about the line, and the dots are the observations.

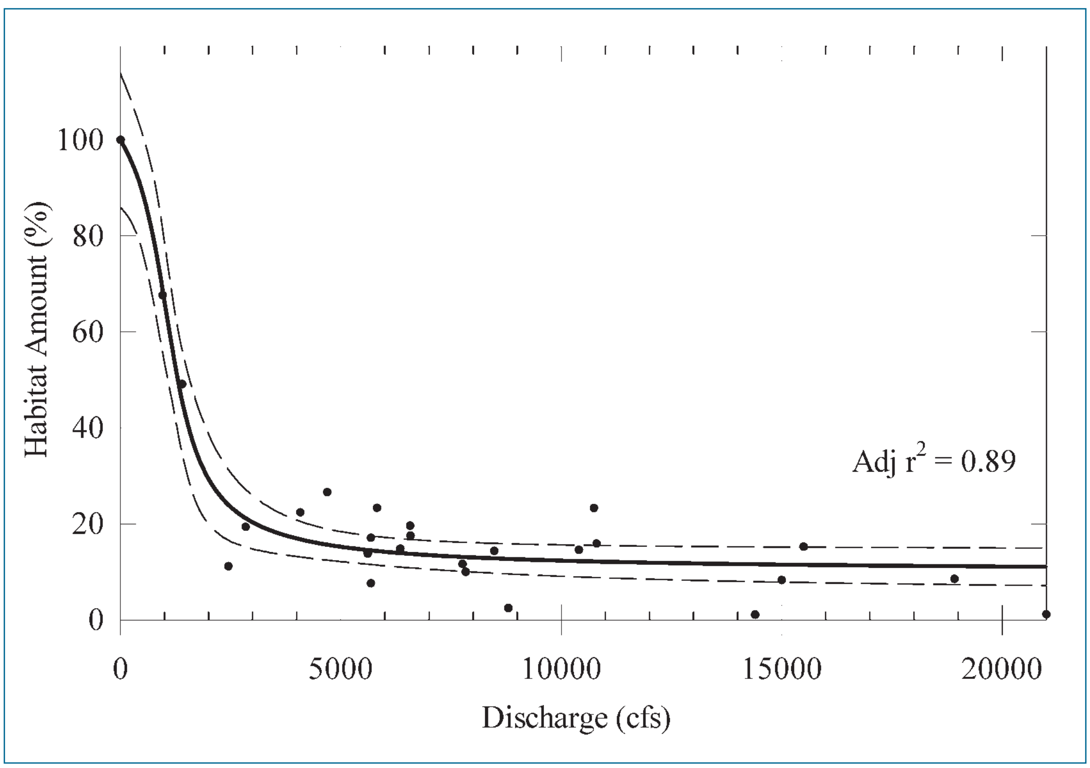


Figure 10.8. Regression line of best fit for exposed sandbars (Equation 10.1) from the aerial photo classification. The solid line represents the fitted line, the dashed lines are the 95% confidence intervals about the line, and the dots are the observations.

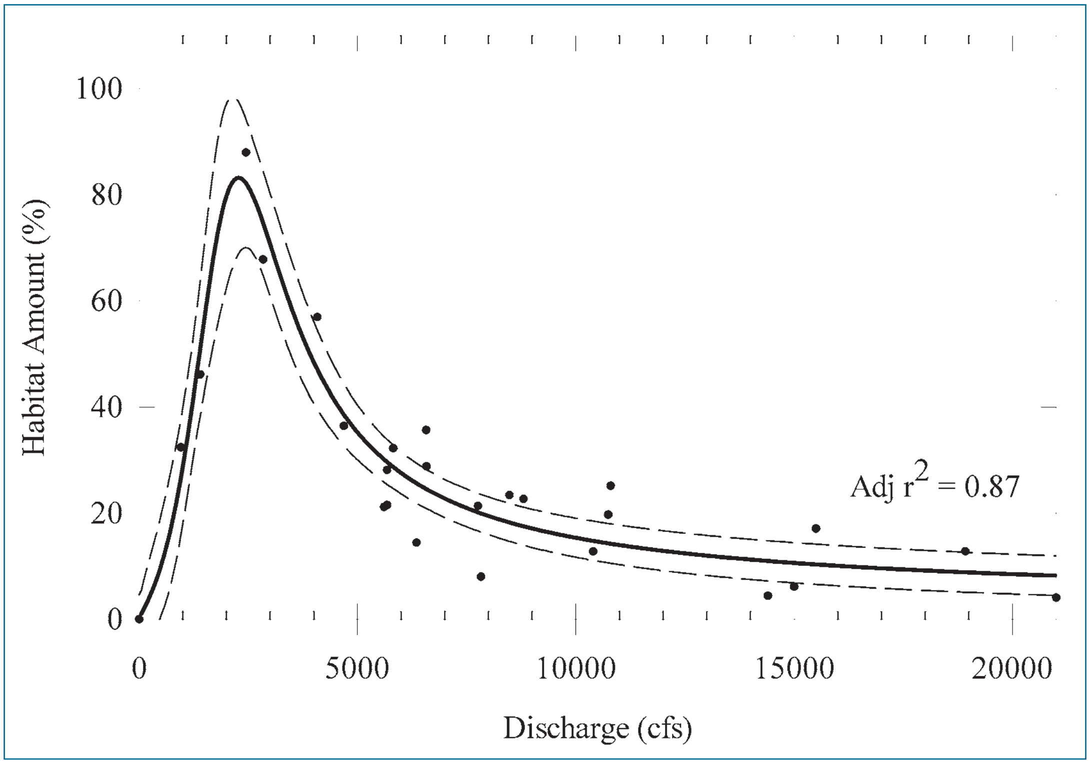


Figure 10.9. Regression line of best fit for shallow sandbar complexes (Equation 10.2) from the aerial photo classification. The solid line represents the fitted line, the dashed lines are the 95% confidence intervals about the line, and the dots are the observations.

For open water, the amount reached its maximum around 7,000 cfs from lower quantities at lower discharge rates (Figure 10.10). The curve that best fit the data (adjusted r^2 = 0.87) was described as a logistic dose response peak (Equation 10.3)

Equation 10.3. Equation for the function of open water(y) at a given discharge (x) in the lower Platte River (where: a = 0.79317, b = 133.85995, c = -3.65680).

$$y = \frac{a}{1+\left(\frac{x}{b}\right)^{c}}$$

The simultaneously corrected curves for the habitat types vs. discharge result in a pattern where the river starts as all exposed sand at no discharge, and rapidly changes to shallow sandbar complexes at low to moderate discharges and then moves to an open water system at higher discharge rates (Figure 10.11). Even at the highest discharge rates, some exposed sandbars and shallow sandbar complexes were still visible.

To determine the habitat quality of the different habitat classes, the Nebraska Game and Parks transect data were classified into similar types as the aerial photos. The data for the transects were collected between 1983 and 1987 from North Bend, Louisville, and Cedar Creek along the lower Platte River. Discharge rates during the times that data were collected ranged from 1,181 to 6,767 cfs. There was a significant difference between open water categories for depth ($p < 0.001$ and velocity ($p < 0.001$) when compared with shallow sandbar complexes. There was no difference for substrate ($p = 0.82$) or cover ($p = 0.69$) categories between open water and shallow sandbar complexes, so these were dropped from further analysis. This process provided a description of the distribution of depths and mean column velocities typically found within the habitat categories over a range of discharges.

To compare this to sturgeon habitat suitability, the proportion of records from the radio-tracking studies on shovelnose and pallid sturgeon were grouped into even sized bins and compared to the habitat availability in the transect data. Chi-square selectivity analysis determined areas of selection, neutral use, or avoidance for shovelnose and pallid sturgeon vs. habitat availability. For depth use, wild pallid sturgeon neutrally use or select waters deeper than 0.8 m in the lower Platte River, and shovelnose sturgeon neutrally use or select waters deeper than 0.6 m (Figure 10.12). For mean column velocities, pallid sturgeon neutrally use or select waters faster than 0.7 m/s in the lower Platte River, and shovelnose sturgeon neutrally use or select waters faster than 0.5 m/s (Figure 10.13). We applied these as criteria for depth and velocity conditions favorable to sturgeon use.

Combining the depth and velocity criteria to the proportions of depths and velocities in the habitat types resulted in an estimate of suitable habitat for pallid sturgeon and shovelnose sturgeon, equations 10.4 and 10.5

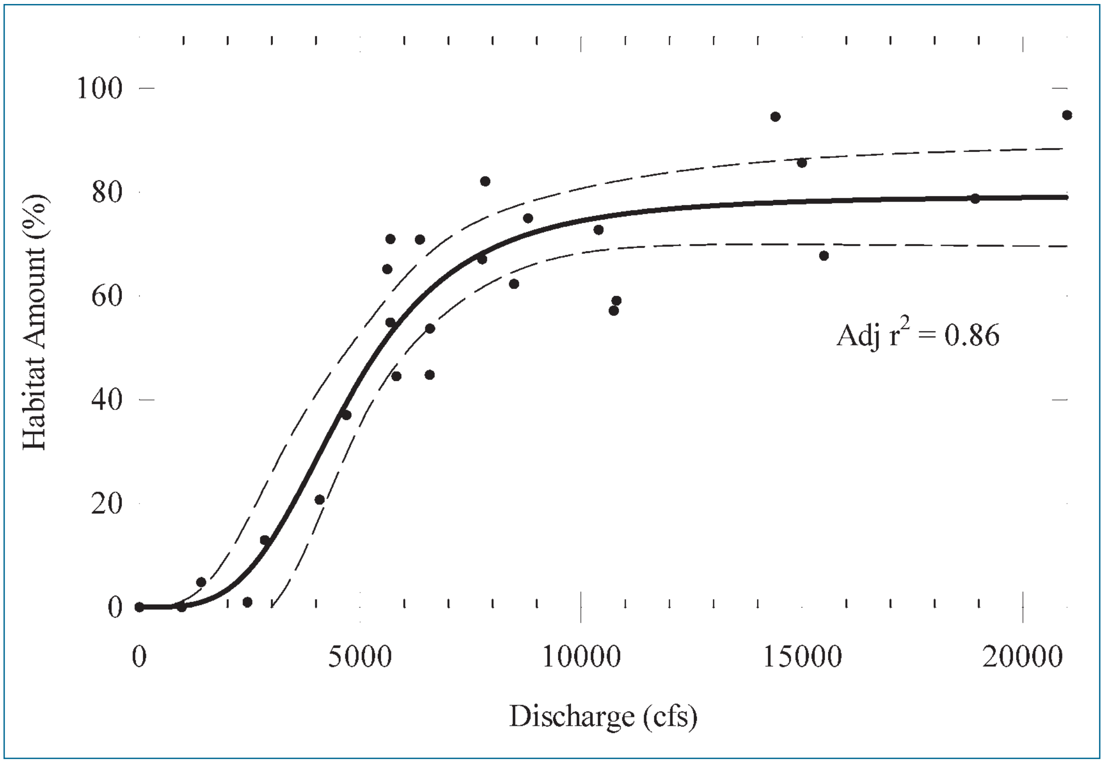


Figure 10.10. Regression line of best fit for open water (Equation 10.3) from the aerial photo classification. The solid line represents the fitted line, the dashed lines are the 95% confidence intervals about the line, and the dots are the observations.

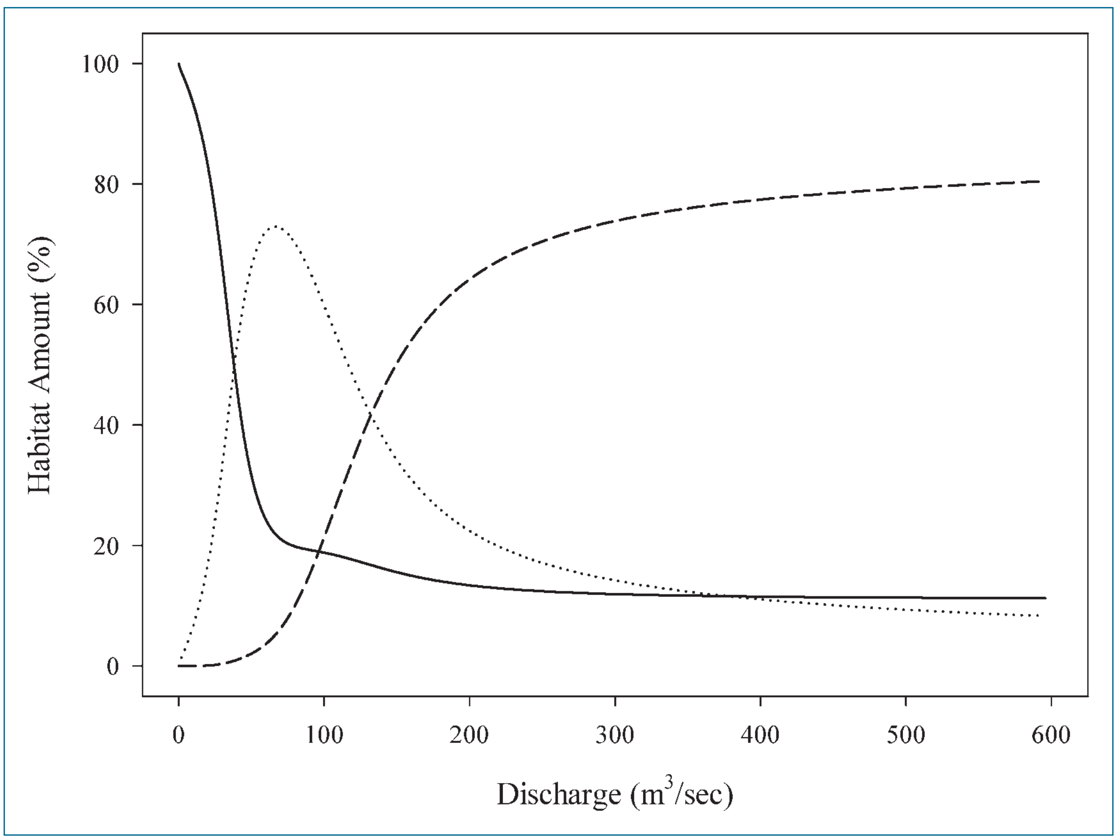


Figure 10.11 The simultaneously adjusted curves for the habitat type vs. river discharge. The solid line represents exposed sandbars, the dotted line is shallow sandbar complexes, and the dashed line represents open water.

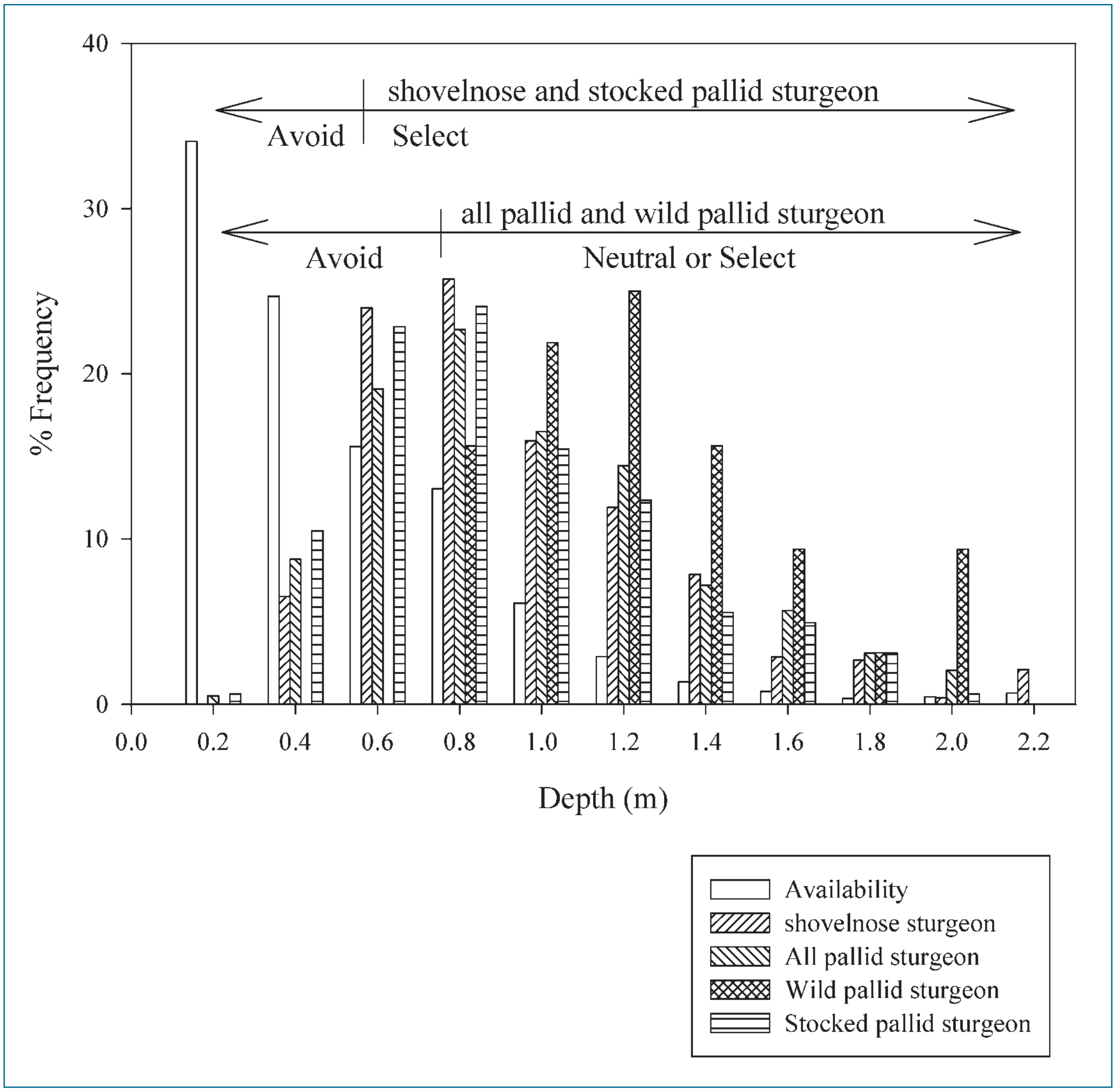


Figure 10.12. Sturgeon habitat use vs. depth availability in the lower Platte River. Selectivity determined with Chi-Square selectivity Index.

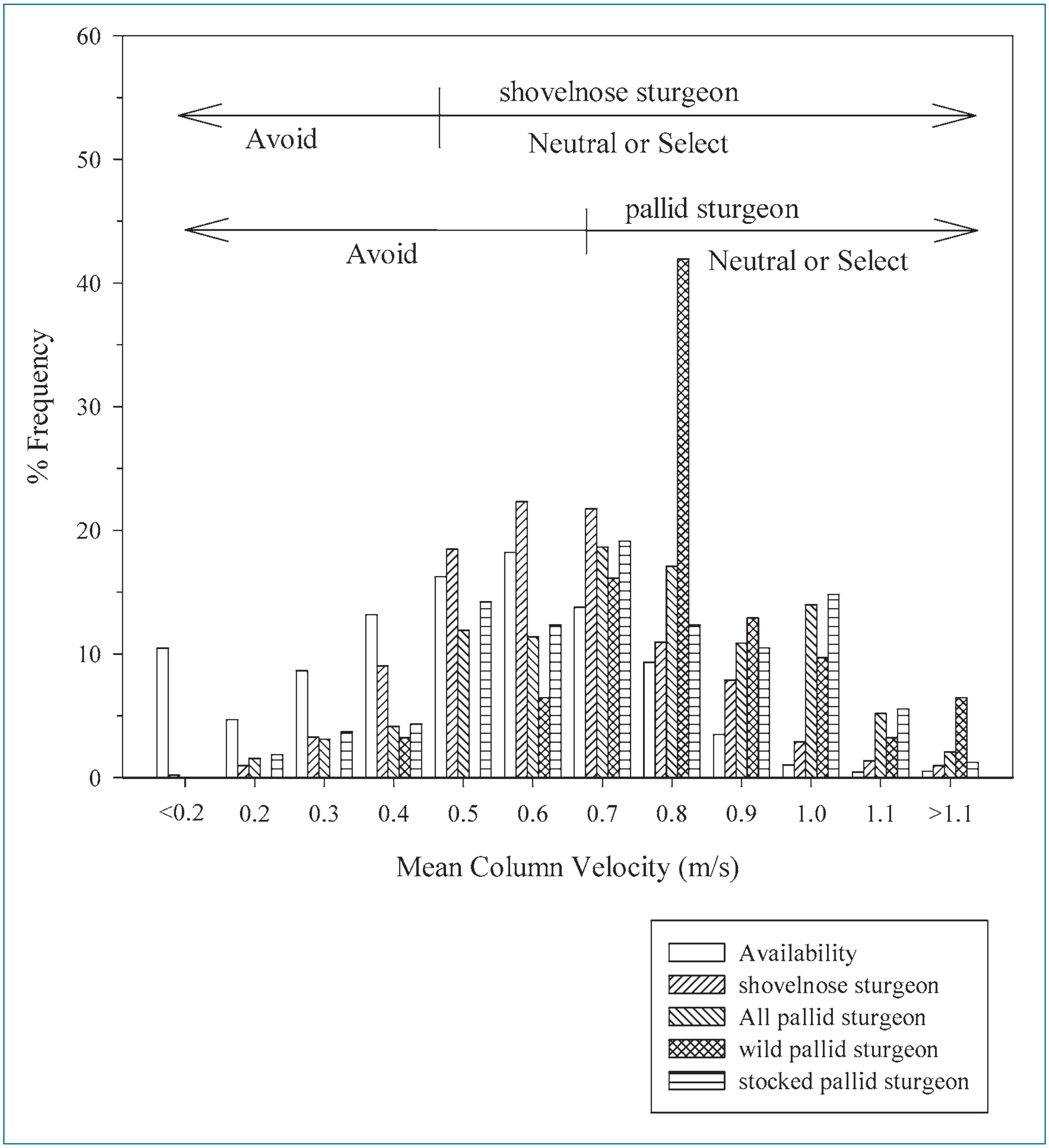


Figure 10.13. Sturgeon habitat use vs. mean column velocity availability in the lower Platte River. Selectivity determined with Chi-Square selectivity Index.

Equation 10.4. The curve for pallid sturgeon habitat suitability (y) vs. discharge (x) in the lower Platte River (where: a = -6.455, b = 39.275, c = 115.637, d = 55.158).

$$y = \frac{a}{\pi}\left[\arctan\left(\frac{x-b}{c}\right)+\frac{\pi}{2}\right]+d$$

Equation 10.5. The curve for shovelnose sturgeon habitat suitability (y) vs. discharge(x) in the lower Platte River (where: a = 65.252, b = 111.030, c = 63.300).

$$y = a\exp\left[-\exp\left(-\frac{x-\ln(\ln 2)-b}{c}\right)\right]$$

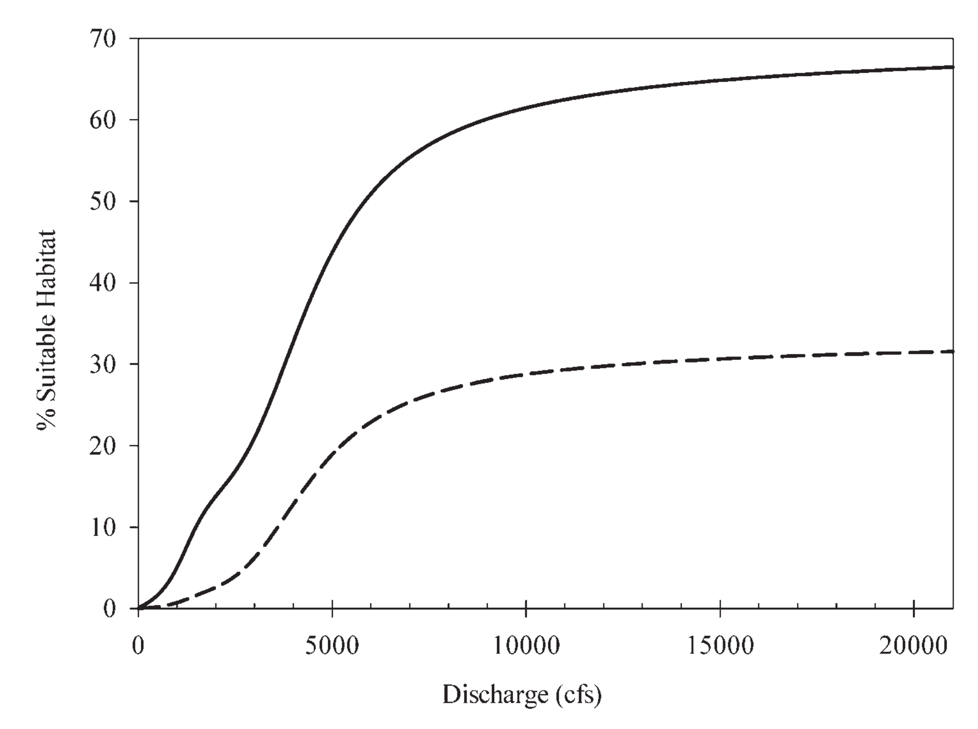


Figure 10.14. Suitable habitat vs. discharge for sturgeon in the lower Platte River. The dashed line represents pallid sturgeon (Equation 10.4) and the solid line represents shovelnose sturgeon (Equation 10.5).

respectively, at a given discharge. By solving this over a range of discharges and determining the curve of best fit, we found that the relationship for both sturgeon species followed the same general shape. There was little to no suitable habitat at low discharge rates to 2,000 cfs. Percent suitable habitat rapidly increased through 6,000 cfs and reached an asymptote near 9,000 cfs (Figure 10.14). The pallid sturgeon curve always showed lower percent suitable habitat than the shovelnose sturgeon curve because of their habitat selection for deeper and swifter waters.

These equations for sturgeon habitat suitability vs. discharge can be used in many ways, since a value of x (discharge) computes a value for y (percent suitable habitat) for that species in the lower Platte River. Two examples (Figures 10.15 and 10.16), were obtained using the average daily discharge values for 1 January through 31 December from the gages at Louisville, North Bend and Duncan on the Platte River. The resultant graphs show average daily percent suitable habitat for pallid sturgeon (Figure 10.15) and shovelnose sturgeon (Figure 10.16). These graphs suggest that more habitat is available during the spring and fall of the year than during the summer for shovelnose sturgeon. Over the last 50 to 70 years of record, from these gage records, it appears that there has been little suitable habitat for pallid sturgeon in lower Platte River during the summer season.

Lower Platte River Connectivity Model

The classified images of the lower Platte River were broken up into 29 contiguous sections. The sections average 8.2 km in length and a total of 237.4 km of river segments covering all of the 163 km of river in the lower Platte at least once over multiple discharge rates were used for this analysis. Some of the 26 image groups used in the previous analysis had areas of “no data” that restricted the use of these sections for connectivity estimates. In some cases the single image group was broken into two groups on each side of the “no data” region. The locations, lengths, and connectivity are shown for each section in Table 10.3.

The percent connected value was plotted against the discharge value and the curve of best fit was calculated for the distribution of data points (Equation 10.6). The curve (Figure 10.17) was highly informative (adjusted $r^2 = 0.86$) and reflected a pattern where the river was generally unconnected at low discharge levels, then rapidly increased in connectivity between 3,200 and 5,600 cfs, and appeared to be almost completely connected by 8,000 cfs. These discharge levels generally correspond to the flows where the lower Platte River converts from primarily shallow sandbar habitat to open water habitat as seen in the habitat relationships developed in the Lower Platte River Habitat Suitability Model.

Equation 10.6. The relationship for the curve of river connectivity (y) vs. discharge (x) in the lower Platte River (where: a = 100.083, b = 124.107, c = 38.099).

$$y = \frac{a}{1 + \exp\left(-\frac{x-b}{c}\right)}$$

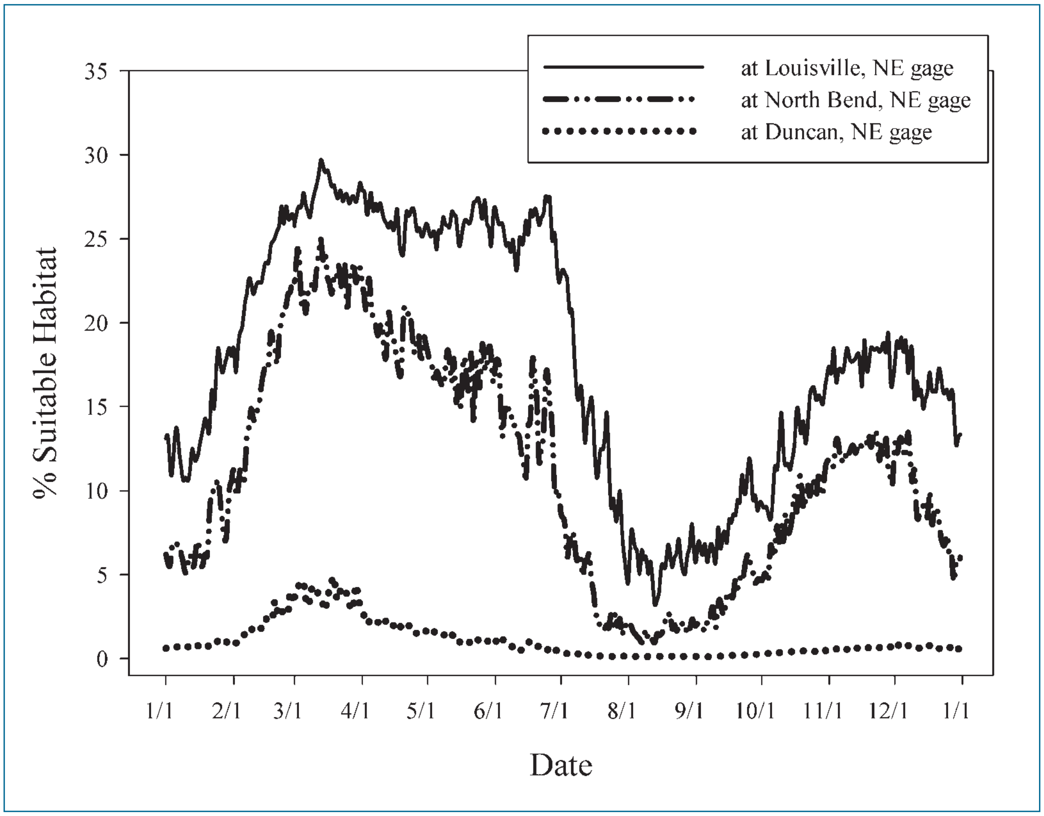


Figure 10.15. Mean suitable habitat for pallid sturgeon in relation to average daily discharge recorded at three gage locations in the lower Platte River. Average daily discharge is based on the complete published record from the USGS for each gage site.

From the river connectivity relationship, we calculated the average monthly connectedness for sections of the lower Platte River by determining the percent connected between USGS gage site from the average month discharges over the period of record. By showing river connectivity, average monthly water temperature, and average monthly shovelnose sturgeon movement in the same graphic, it is apparent that the shovelnose sturgeon's migratory movements coincide with conditions of river connectivity and appear to be triggered by changes in water temperature. The annual monthly cycle of river connectivity, temperature and shovelnose sturgeon movement are displayed in Figures 10.18 to 10.29 for January to December, respectively.

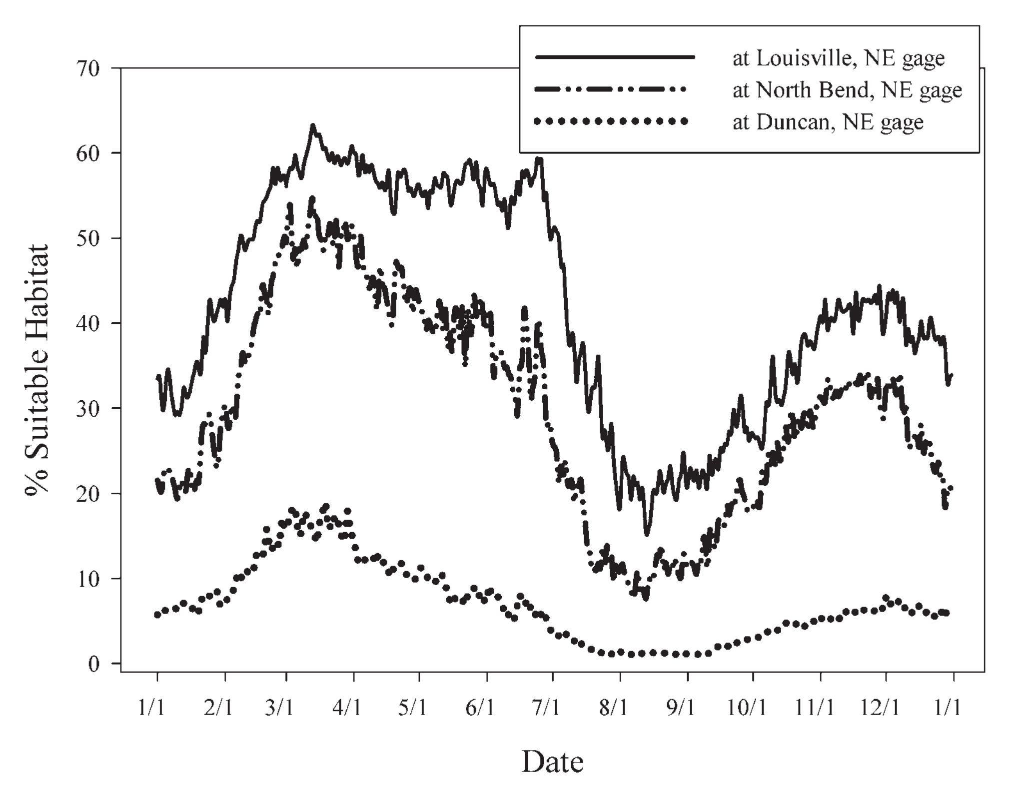


Figure 10.16. Mean suitable habitat for shovelnose sturgeon in relation to average daily discharge recorded at three gage locations in the lower Platte River. Average daily discharge is based on the complete published record from the USGS for each gage site.

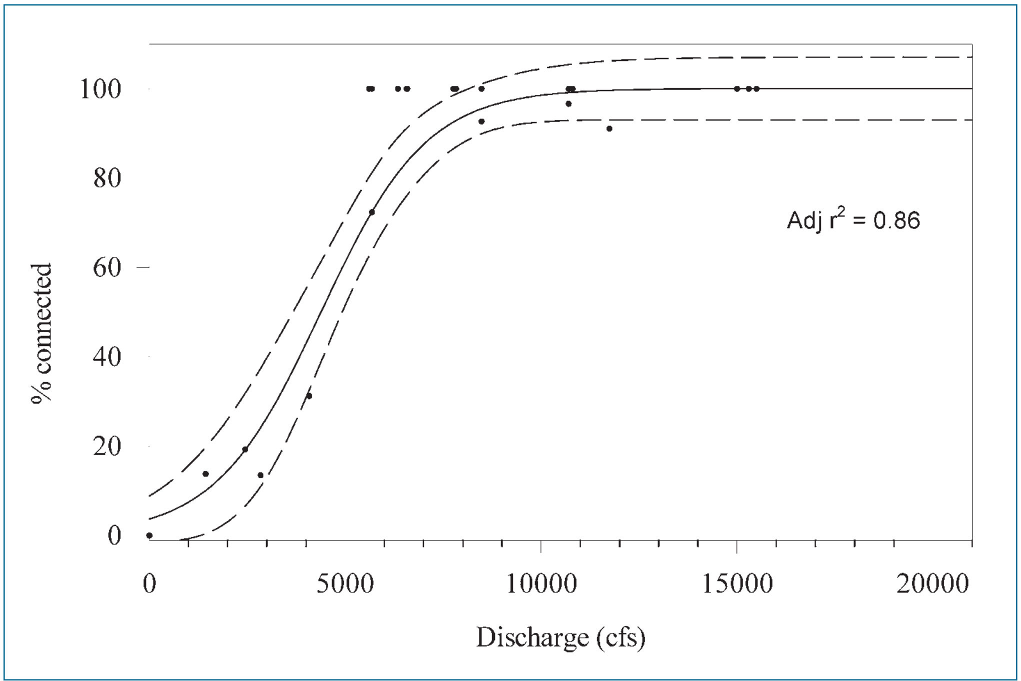


Figure 10.17. Curve of best fit for river connectivity vs. discharge (Equation 10.6) for the lower Platte River. The solid line represents the fitted line, the dashed lines are the 95% confidence intervals about the line, and the dots are the observations.

Table 10.3. Date, discharge, location, section length, longest connected segment, and percent connected within the segment for the classified aerial images. GPS location area at the approximate midstream point of the river.

Date	Discharge (cfs)	Upstream GPS W	Upstream GPS N	Downstream GPS W	Downstream GPS N	Section Length (m)	Longest connected segment (m)	Percent Connected
8/15/2002	0	-97.372724	41.397715	-97.320979	41.396877	4,629	0	0.0
8/15/2002	1,440	-95.943929	41.057734	-95.880847	41.05313	5,665	781	13.8
4/1/1999	2,450	-97.320687	41.397708	-97.282103	41.399205	3,277	632	19.3
4/22/1993	2,840	-97.443057	41.374605	-97.320309	41.396375	11,034	1,487	13.5
4/1/1999	4,080	-97.282103	41.399205	-97.246196	41.384091	3,581	1,118	31.2
4/18/1994	5,610	-96.818211	41.449519	-96.759852	41.452479	5,024	5,024	100.0
4/4/1999	5,680	-96.353339	41.253634	-96.329839	41.19317	8,043	8,043	100.0
4/4/1999	5,680	-96.329839	41.19317	-96.316788	41.120951	8,375	6,059	72.3
4/16/1993	6,350	-96.879212	41.457384	-96.823455	41.448584	4,809	4,809	100.0
4/16/1993	6,350	-97.092429	41.392642	-96.965535	41.446522	12,934	12,934	100.0
4/16/1993	6,350	-97.241841	41.383514	-97.183778	41.379117	5,172	5,172	100.0
4/6/1999	6,570	-97.130484	41.385838	-97.059774	41.412016	6,889	6,889	100.0
3/21/1994	6,580	-97.282259	41.399263	-97.246134	41.383851	3,599	3,599	100.0
4/4/1999	7,760	-96.313046	41.121732	-96.309919	41.038654	10,673	10,673	100.0
4/14/1993	7,830	-96.353445	41.253612	-96.320133	41.158152	12,059	12,059	100.0
4/4/1999	8,480	-96.088864	41.054706	-95.935115	41.058673	13,611	13,611	100.0
4/4/1999	8,480	-96.199711	40.998149	-96.088864	41.054706	11,611	10,761	92.7
4/22/1993	10,700	-96.454643	41.378231	-96.369482	41.291046	13,020	13,020	100.0
4/22/1993	10,700	-96.631066	41.439423	-96.490571	41.399328	13,103	13,103	100.0
4/22/1993	10,700	-96.755691	41.451736	-96.643403	41.439455	10,410	10,058	96.6
4/6/1999	10,800	-96.234066	41.003989	-96.18809	41.002829	4,503	4,503	100.0
4/2/1993	11,740	-96.379451	41.298393	-96.357539	41.246914	6,569	5,982	91.1
4/16/1993	15,000	-96.308599	41.037664	-96.245979	41.013809	6,112	6,112	100.0
4/16/1993	15,000	-96.313032	41.122609	-96.308599	41.037664	10,998	10,998	100.0
4/12/1999	15,300	-96.316938	41.048161	-96.248773	41.01537	7,101	7,101	100.0
3/26/1993	15,500	-95.960875	41.059001	-95.880996	41.053369	6,961	6,961	100.0
3/26/1993	15,500	-96.077288	41.057738	-95.960875	41.059001	10,374	10,374	100.0
3/26/1993	15,500	-96.190194	41.001303	-96.077288	41.057738	11,639	11,639	100.0
4/19/1999	21,000	-95.943929	41.057734	-95.880847	41.05313	5,665	5,665	100.0

Table 10.4. Discharge, percent connectivity, and the 95% confidence interval range for river connectivity in the lower Platte River, Nebraska.

Discharge	% Connectivity	Range
1000	8	0-15
2000	15	2-26
3000	26	13-40
4000	43	30-55
5000	61	52-71
6000	77	69-85
7000	88	81-94
8000	94	88-99
9000	97	91-100
10000	99	93-100

Table 10.5. Discharge, percent shovelnose sturgeon habitat and percent pallid sturgeon habitat in the lower Platte River, Nebraska.

Discharge	% Shovelnose habitat	% Pallid habitat
1000	5	1
2000	14	3
3000	21	6
4000	33	13
5000	44	19
6000	51	23
7000	55	25
8000	58	27
9000	60	28
10000	61	29

CONCLUSIONS

The results of the Lower Platte River Habitat Type Availability Model support the conclusion that the habitat to discharge relationship is most accurately modeled with non-linear curves. The habitat to discharge relationship changes more rapidly at low discharge rates than at high discharge rates. There are two transitional phases as discharge increases. First, as water floods the dry river bed at low discharges, there is rapid transition of habitat from exposed sandbars to shallow sandbar complexes. This transition is also characterized by a lateral increase in the wetted area of the river bed. The second transition phase occurs at moderate discharges, where the transition from shallow sandbar complexes to open water habitats happens. This second transition is also characterized by a decrease in lateral expansion as the river bed is fully inundated and an increase in vertical expansion as the river fills up constrained by its banks. Given the non-linear relationship between habitat and discharge, small changes in discharge can result in large changes in suitable habitat if the discharge is near a transition phase.

The selection of deep and swift water by sturgeon in the Platte River support the findings that open water habitats are the primary habitats for sturgeon. Pallid sturgeon are found in deeper and swifter waters than shovelnose sturgeon, and the much lower overall percentages of useable habitat for the habitat categories (2% of shallow sandbar complexes and 16% of open water habitats) than for shovelnose sturgeon (39% of shallow sandbar complexes and 81% of open water habitats). This suggests that shovelnose sturgeon have always been more common in the Platte River, based on a larger area of suitable habitat. But this difference in habitat doesn't account for the difference in population size (1.25 pallid sturgeon to 1,000 shovelnose sturgeon; our estimate, Chapter 5). Considering habitat suitability alone, shovelnose sturgeon were likely to be 5 to 20 times more common than pallid sturgeon in the Platte River. Although not estimated for the Platte River, Forbes and Richardson (1905) estimated that pallid sturgeon comprised 1 in 5 river sturgeon collected in the lower Missouri River supporting the contention that habitat requirements only account for a portion of the current differences in population sizes.

The Lower Platte River Habitat Type Availability Model was developed over a wide range of discharge conditions reflecting conditions found in the lower Platte River from no flow to bank full flow conditions. There are no overbank flood flows modeled in this analysis, and the importance of such flows is not able to be effectively addressed. The development of the equations relating habitat types to discharge is important as it allows the development of habitat suitability relationships for any species of concern that uses exposed sandbars, shallow sandbar complexes or open waters in the Platte River. Obvious extensions of the results of this model are for predicting suitable habitat for the sandbar nesting birds, such as piping plovers or least terns or for shallow water forage fishes, such as sand shiners and river shiners. The model may prove transferable to other shifting, sandbed rivers with adjustments for bed slope, sediment size, and river width and may aid in the conservation of native species in those systems.

The Lower Platte River Connectivity Model suggests a physically based relationship between river connectivity and discharge. The river connectivity relationship is associated with the vertical expansion of water during the second transition phase described previously. As the discharge increases and the river transitions to mostly open water habitats, the connectivity among habitat rapidly increased and, ultimately, most of the river is connected at higher discharges. The results of the river connectivity model do not relate to the quantity of habitat available locally within any section of river, but only describes whether or not a pathway between the habitat patches exists.

In comparisons of river connectivity to shovelnose sturgeon movements, the movement of the fish seems to correlate to periods of high river connectivity. Temperature appears to be the cue to initiate upstream movement in the spring, but most long distance movements, both upstream and downstream, are completed prior to the low summer discharges and therefore times of low connectivity. This may hold evolutionary significance as the sturgeon may time their spawning migration in the Platte River to coincide with the times of naturally high flows. In addition to the evolutionary significance, this movement pattern related to river connectivity has significance to water managers. Continued development of surface waters of the Platte River Basin and the retention of spring flow behind dams is likely to decrease average spring discharge rates in the lower Platte River, with a corresponding decrease in river connectivity. If the lower Platte River is consistently unconnected in the spring of the year, sturgeon may not be able to access the habitats available to them in the river and may decrease the likelihood of the fish completing a successful spawning run.

Sturgeon, in the lower Platte River, require water flows sufficient to provide habitat and to allow movement to and from spawning localities. Specifically, discharge criteria, for both pallid sturgeon and shovelnose sturgeon, which maintain the connectivity in the lower Platte River are most important during the spring. During the rest of the year, discharge rates for suitable habitat conditions are the priority.

River connectivity is important for sturgeon migration up and down the river. These migrations, suspected spawning runs, occur during spring and early summer with peak movements upstream during April and May followed by downstream movements in June and July. Average discharge greater than 8,000 cfs during these months would likely provide migratory pathways, since at this level connectivity approaches 100% (Table 10.4). This table also indicates that average monthly discharge less than 6,000 cfs would be ineffective at assuring connectivity within this reach of the Platte River.

Specific discharge rates to protect instream habitat for sturgeon show that more water equals more habitat, although the amount of habitat begins reaching an asymptote around 8,000 cfs. This upper inflection point for the curve suggests a diminishing rate of habitat creation for each additional 1,000 cfs above that discharge (Table 10.5). Approximately 50% of the maximal amount of habitat is available around 4,500 cfs for pallid sturgeon and 4,100 cfs for shovelnose sturgeon (Table 10.5).

These two GIS based models of sturgeon habitat and river connectivity highlight the importance of and the challenges facing the sturgeon in the lower Platte River. The lower Platte River's relatively natural active channel, that still contains the meandering channels, shifting sandbars, and scour holes, provides areas of suitable habitat for shovelnose and pallid sturgeon throughout much of the year. The natural spring rise in discharge provided by the waters of the Loup and Elkhorn Rivers allows migratory sturgeon to move through the river to find and return from suitable spawning areas. Clearly, with the large shovelnose sturgeon population and the use of the river by the endangered pallid sturgeon, the lower Platte River is one of the last remnants of semi-natural, high quality habitat in the mid Great Plains area. The challenge facing the sturgeon in the lower Platte River comes from their habitat requirements of deep, swift waters. If the discharge levels of the lower Platte are decreased, the amount and interconnectedness of these suitable habitats for sturgeons are likely to decrease.

The analysis presented summarizes the habitat needs for the pallid and shovelnose sturgeon in the lower Platte River and their need for connectivity within the system for migration and potentially for reproduction. A missing component (and there are surely others) is their need for food resources which habitats in the Platte River must provide to support a sustainable biotic community. Hesse (1993, 1994) and others have documented the demise of the forage fish community in the Missouri River caused by channelization and flow alterations. Taken to its extreme, the flow recommendations for sturgeon habitat and channel connectivity could be interpreted to fo ster a similar fate for the Platte River. However, examination of the needs for chub species and the diverse assemblage of fishes which require the shallow water conditions in the Platte River (Peters et al. 1989, Peters and Holland 1994) indicate the need for maintaining a balance between the amount of deepwater and shallow water habitats.

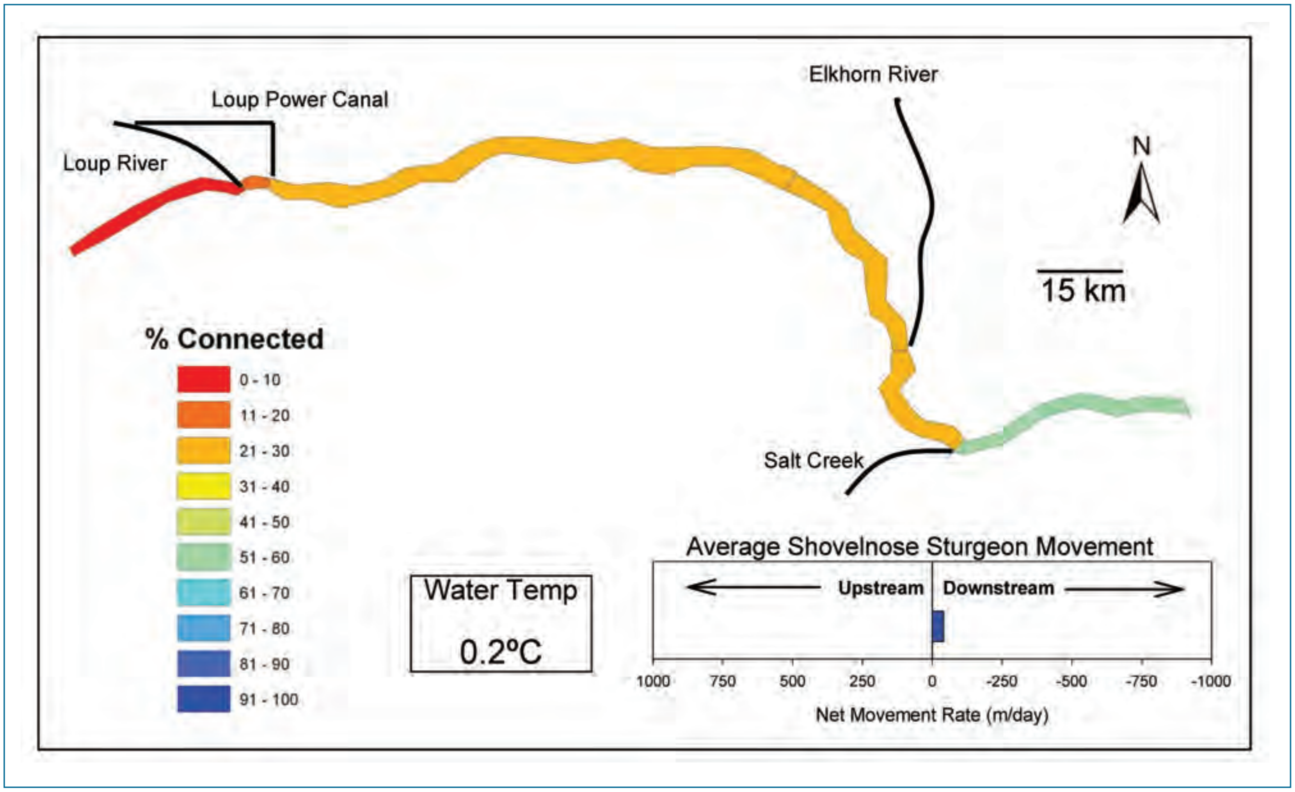


Figure 10.18. River connectivity for average monthly conditions in January for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

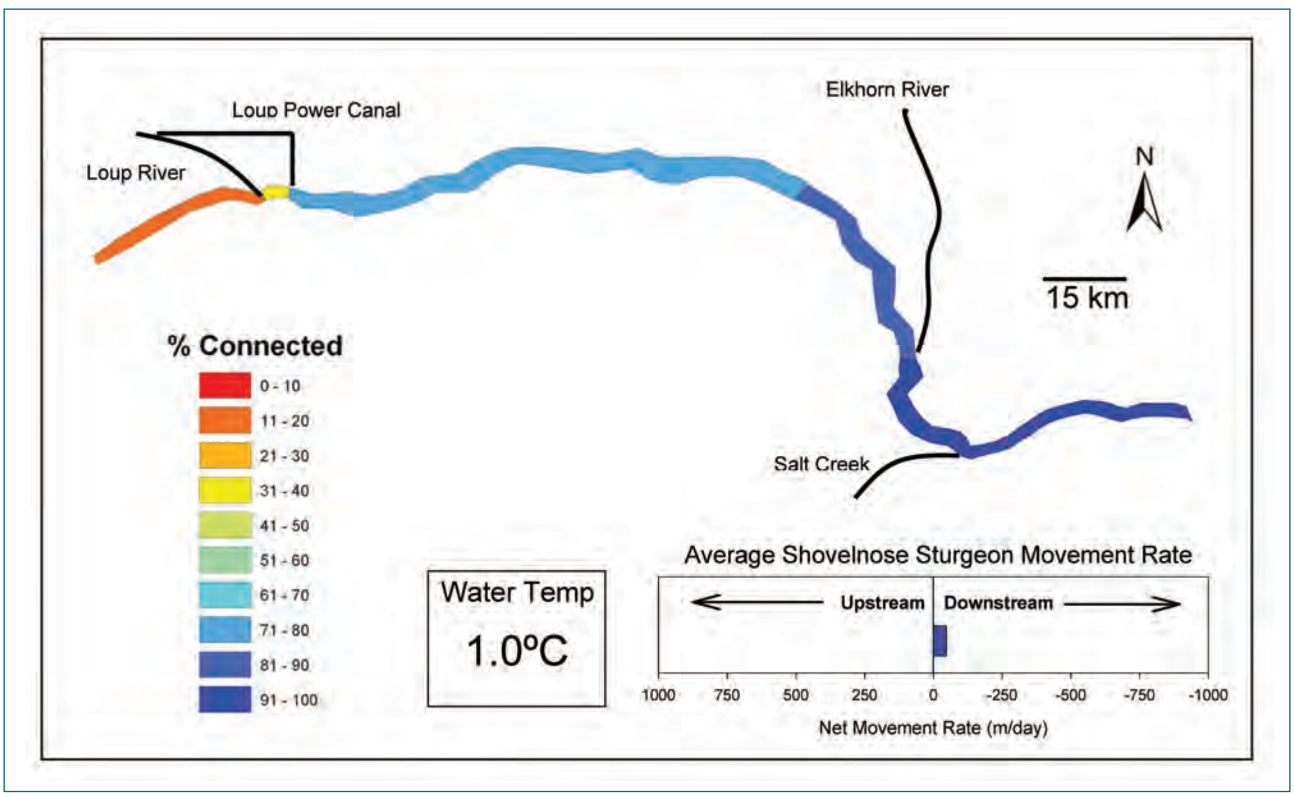


Figure 10.19. River connectivity for average monthly conditions in February for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

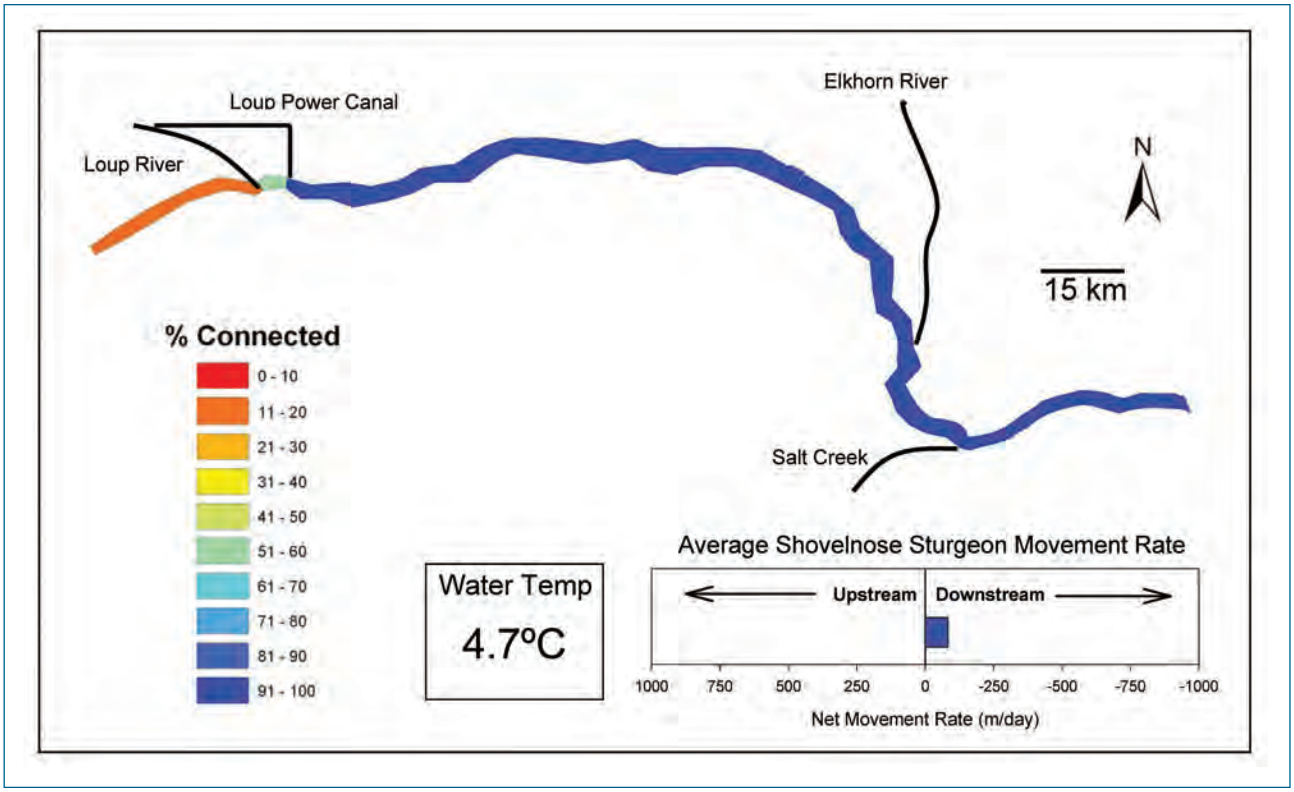


Figure 10.20. River connectivity for average monthly conditions in March for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

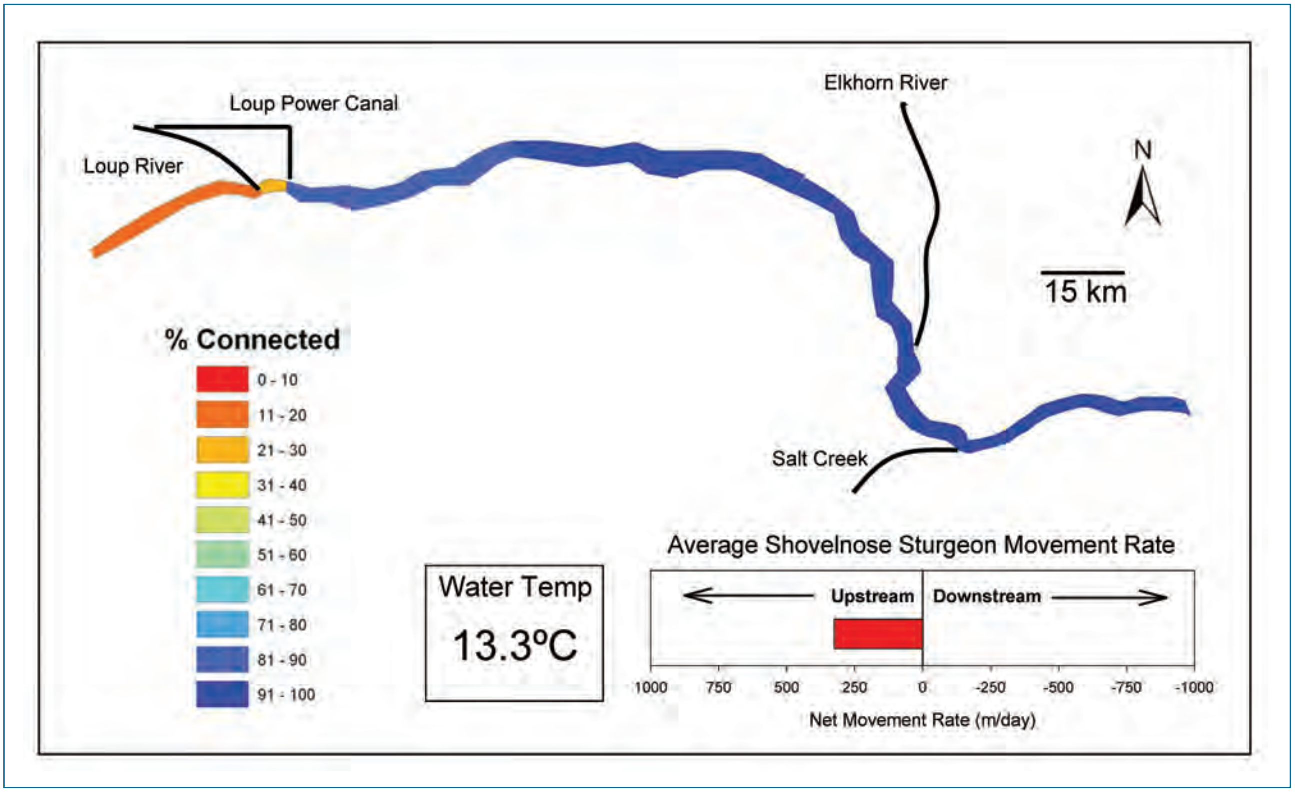


Figure 10.21. River connectivity for average monthly conditions in April for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

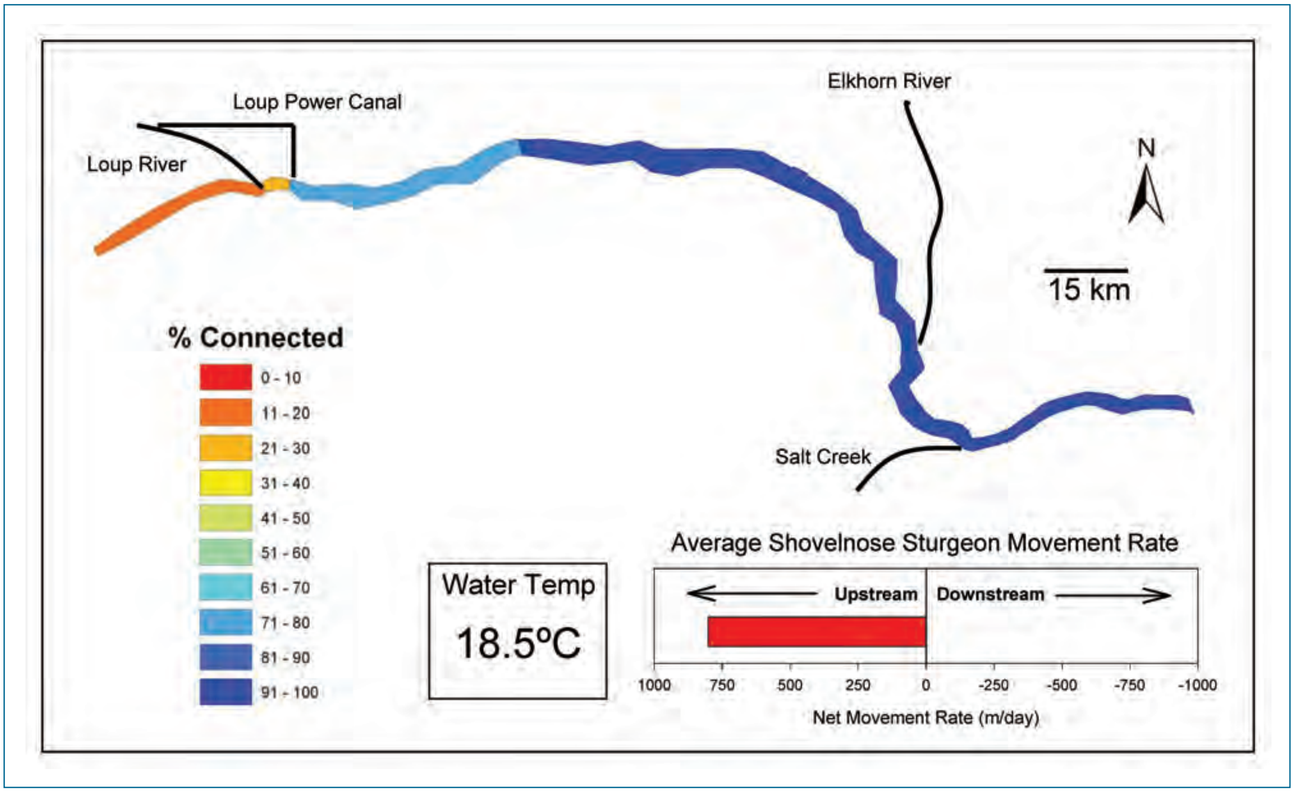


Figure 10.22. River connectivity for average monthly conditions in May for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

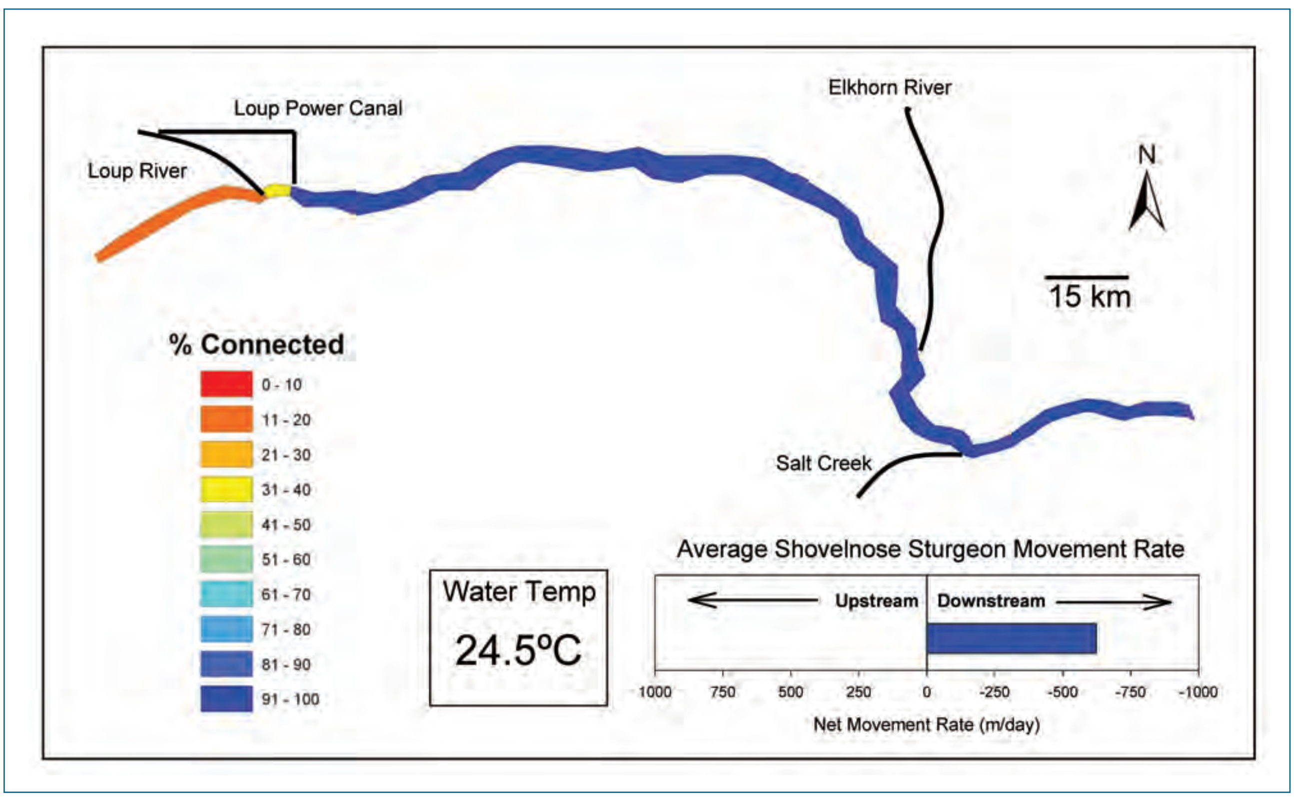


Figure 10.23. River connectivity for average monthly conditions in June for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

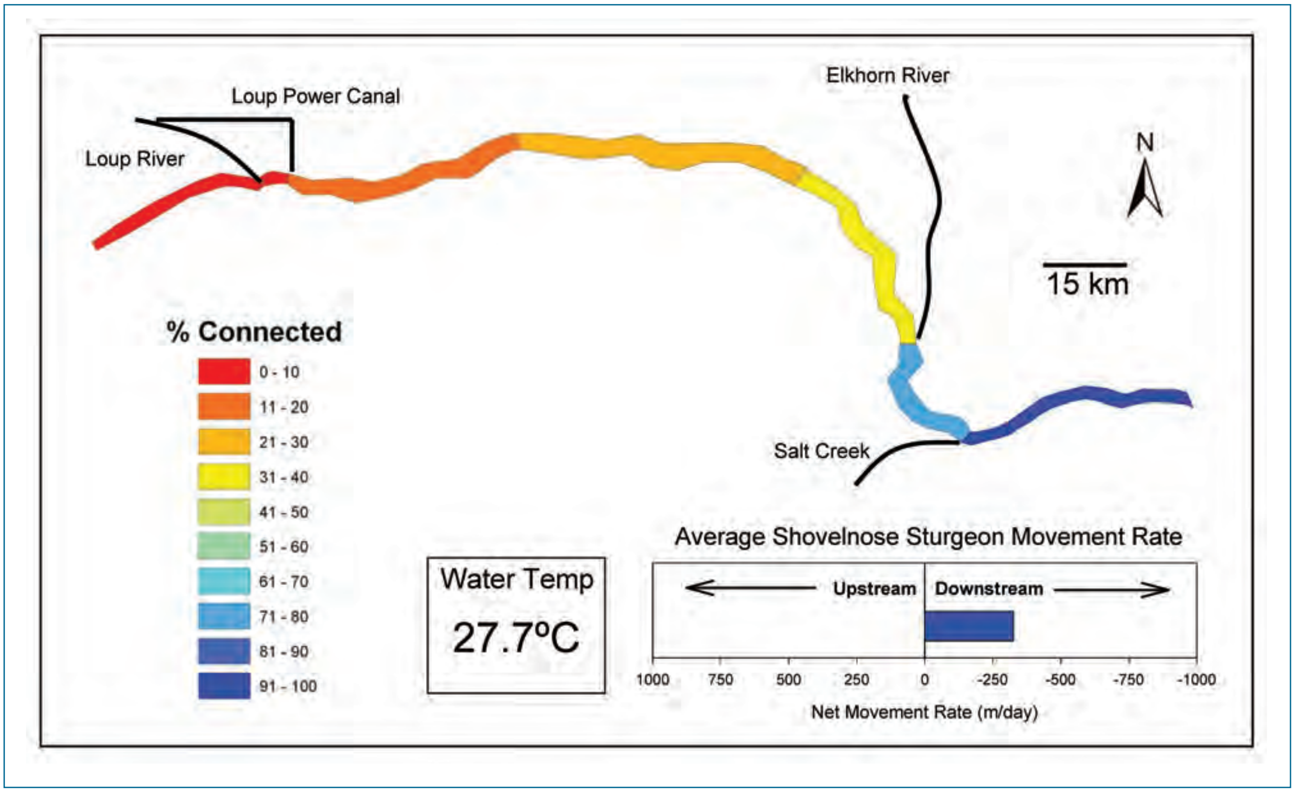


Figure 10.24. River connectivity for average monthly conditions in July for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

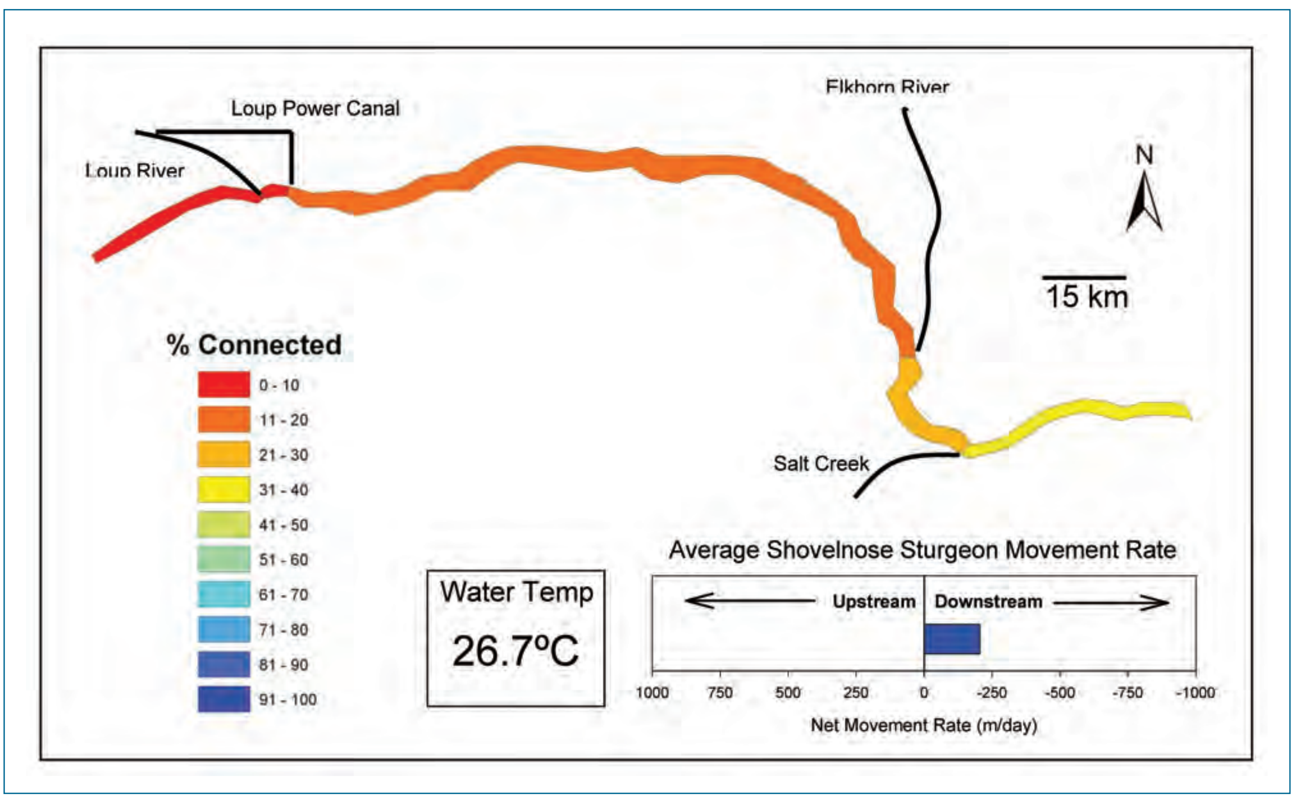


Figure 10.25. River connectivity for average monthly conditions in August for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

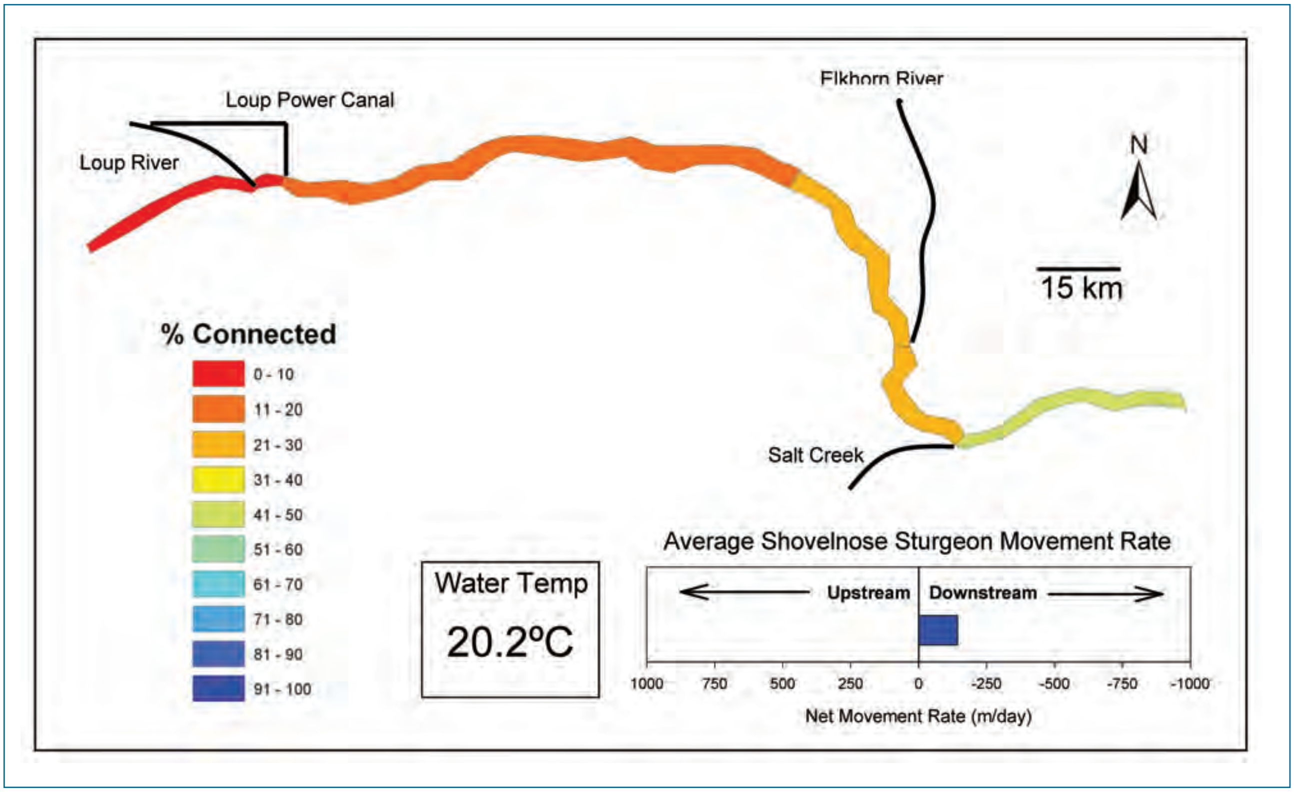


Figure 10.26. River connectivity for average monthly conditions in September for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

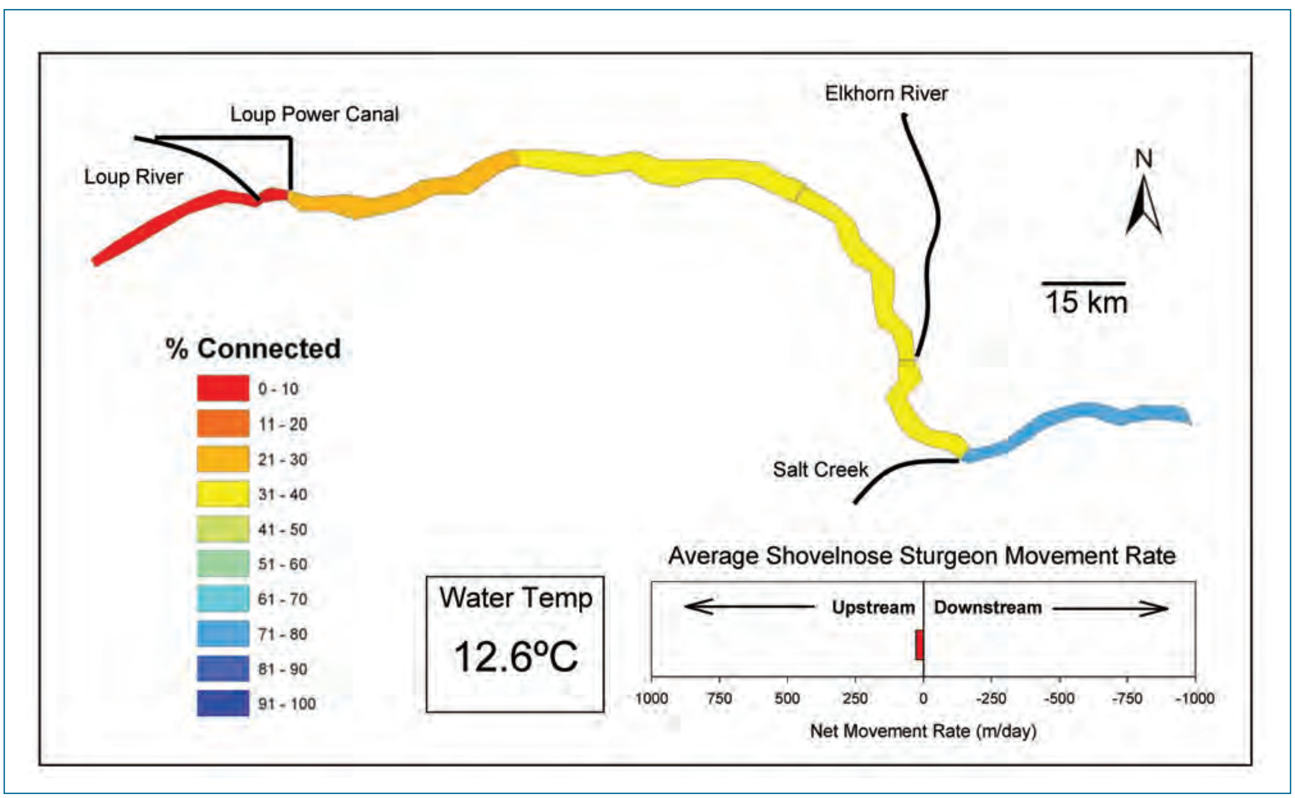


Figure 10.27. River connectivity for average monthly conditions in October for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

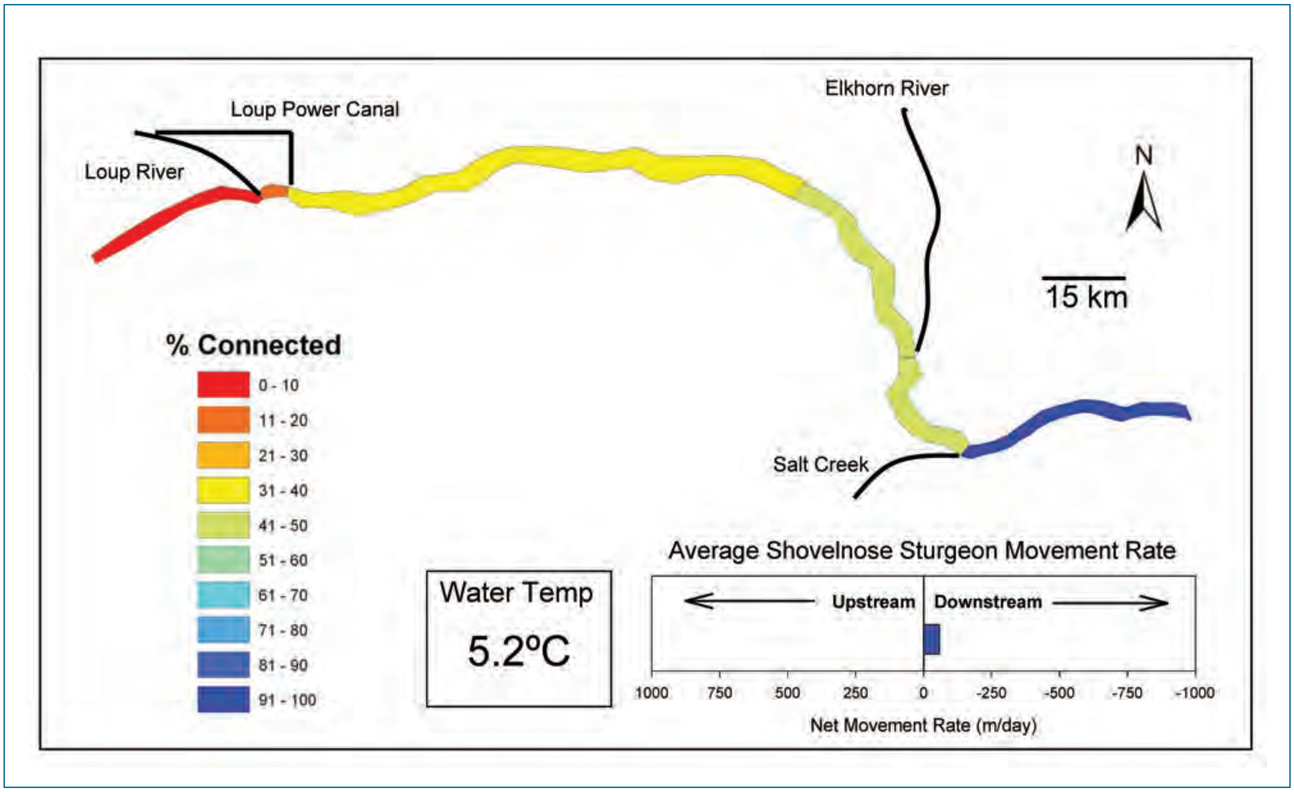


Figure 10.28. River connectivity for average monthly conditions in November for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

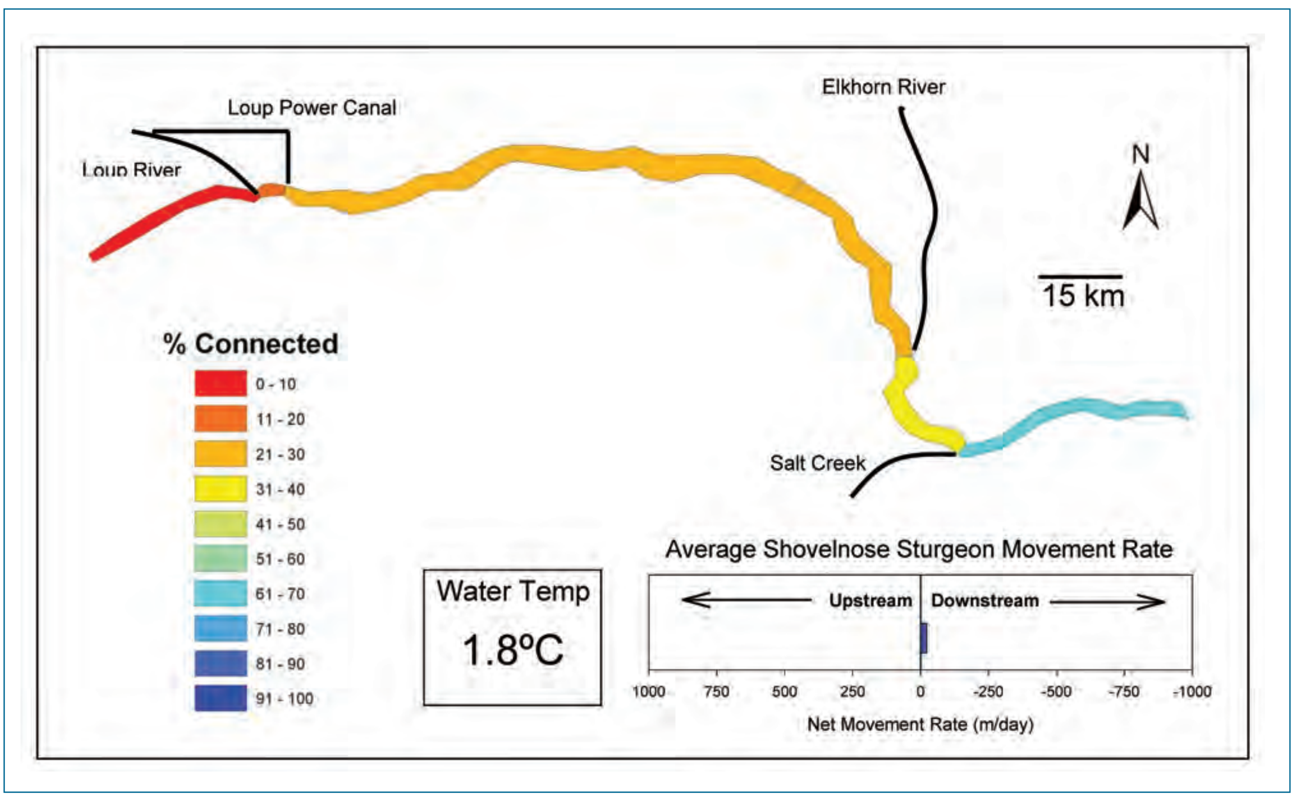


Figure 10.29. River connectivity for average monthly conditions in December for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement.

CHAPTER 11

MANAGEMENT RECOMMENDATIONS FOR STURGEON AND CHUB POPULATIONS, IN THE LOWER PLATTE RIVER

INTRODUCTION

The final objectives for the Pallid Sturgeon / Sturgeon Chub Task Force and the Nebraska Game and Parks Commission in funding this research were to develop management recommendations for sturgeons and chubs. In addition, we proposed to facilitate appropriate recovery efforts for pallid sturgeon and sturgeon chub in the lower Platte River. At the time when this research was initiated there was a proposal to list the sturgeon chub as a federally endangered species. Subsequent to the initiation of this project, additional information about sturgeon chub populations resulted in the withdrawal of this proposal at the federal level, but sturgeon chub is still a Nebraska state listed endangered fish species.

Management recommendations:

The following ideas represent our considered opinions about how management can foster the continued existence of the sturgeon species and the chub species of the lower Platte River and the ecosystem upon which they depend.

Chapter 1 Recommendations:

The existence of this ecosystem depends upon a continuing reliable flow of water in the Platte River at a magnitude and timing of discharge that maintain the shifting sand bar habitat and scour channels that allow for production of food organisms, creation of suitable habitats and enable passage of sturgeon adults and fry.

1. We recommend that historical flow volumes and discharge patterns are used as a guide to the management of future flow recommendations for the lower Platte River.

Chapter 2 Recommendations:

It is obvious from the analysis in this report and other publications that no single type of collection gear is sufficient to sample all life stages of fish species like sturgeons and chubs. In fact, it is increasingly apparent that one sampling gear will not perform equally in different bodies of water. This means that in order to document the benefit (or detriment) of any management action, future sampling in the Platte River will require a multi-gear approach, such as we have used.

2. We recommend using a combination of drifted trammel nets, trawls and trotlines to monitor the long term trends in sturgeon populations and habitat use. This monitoring should also be coordinated with ongoing efforts in the Missouri River (Quist et al. 2005), since it is also apparent that Platte River sturgeon populations are virtually continuous with those in the Missouri River system.

3. We recommend continuation of telemetry efforts for pallid sturgeon in the lower Platte River to be a very prudent emphasis of continuing research. Any future studies in the Platte River should be coordinated with the efforts of USGS researchers that are using telemetry technology that allows depth and water temperature to be monitored during critical phases of the sturgeon's life cycle. Work in the Platte River could provide excellent opportunities to locate spawning sites for pallid sturgeon and then to monitor the fate of larval and juvenile life stages. It will also allow the evaluation of sturgeon stocking programs as these fish develop into adults.

4. To monitor the health of chub populations we recommend that a combination of trawls and seines would be the most effective protocol. The addition of electrofishing grids may be useful to further define chub habitat use in specific areas.

Chapter 3 Recommendations:

Overall the water quality appeared to be relatively good in the lower Platte River during this study. However, we observed an apparent reaction of pallid sturgeon to a treated water discharge. Several radio-tagged pallid sturgeon were staging upstream from the mouth of the Platte River in an apparent beginning to their upstream spawning run. All of the fish moved out of the Platte River when the water became milky from a discharge from the Omaha Metropolitan Utilities District water supply treatment plant. What are the materials in the discharge that could cause the pallid sturgeon's reaction and how can future events be avoided? These are important unanswered questions related to the current operation and future development of water treatment facilities and their Clean Water Act permitted discharges.

An additional area of water quality that appears to be an emerging threat to long-lived animals like sturgeons and humans is the role of endocrine disruptors in the environment. The contaminants are not, in general, the traditional nutrients and oxygen demanding wastes, but rather materials that include breakdown products of herbicides, surfactants and other products that act as endocrine disrupters. These materials have effects on reproductive cycles and development at very low concentrations and are just now being investigated in water supplies of the world. We are fortunate that studies in our area by other researchers in Nebraska (M. Schwarz: personal communication and A. Kolok: personal communication) are elucidating some effects of these materials in the Platte River basin. The magnitude of this affect on the reproductive capabilities of sturgeon and other species is currently unknown.

5. We recommend that the reactions of pallid sturgeon to water discharges from a variety of sources, especially those related to water treatment facilities, be developed to evaluate the effects on pallid sturgeon populations and life histories.

How will management of the Platte River influence the survival of the pallid sturgeon as a species? The primary driving forces in the creation and maintenance of the habitats in any river are river discharge, sediment supply and channel morphology (Leopold 1994). In the Platte River, without discharges sufficient to move the substrate on a regular basis, the sand bars will become stabilized and channel habitats will fill in. The loss of channel habitats would restrict the ability of sturgeon to access upstream habitats, and sturgeon will be confined to ever smaller portions of the Platte River. Concurrently, the availability of sandy sediments is also important to the functioning of a braided river like the Platte River. Without a source of sediment (sand) rich water, the lower Platte River could turn into the narrow, sediment "hungry" stream typified by the Platte River west of Kearney, NE (NRC 2005). Finally, the restriction of channel width or the armoring of the river bank may change the dynamic equilibrium that results in the shifting sandbar nature of the lower Platte River into a ditch-like system similar to the lower Missouri River. To ensure the continuance of the characteristic habitats of the lower Platte River, protection of habitat forming peak flows, sediment sources and natural channel morphology are vital to the long term health of the Platte River ecosystem.

6. We recommend additional geomorphological studies be instituted for the lower Platte River to answer questions of how river bank armoring and restrictions on the supply of sediment and water will influence the structure of the river (Quist et al. 2005).

An additional flow related issue for the overall health of the lower Platte River is the occurrence of power peaking fluctuations in discharge. How these fluctuations affect the reproduction, recruitment and growth of fishes and invertebrates in the lower Platte River is currently unknown.

7. We also recommend that future studies be designed to address potential impact of power peaking on the lower Platte River ecosystem.

Chapter 4 Recommendations:

Pallid sturgeon were found to use habitats in the Platte River which are similar to those in the Missouri River, except they tend to be on the shallower end of the depth range for most studies. These shallow conditions may require adjustments in the way certain types of sampling gear are commonly deployed in mainstream Missouri River habitats.

8. We recommend that future studies in the Platte River be designed to be comparable to those underway in the Missouri River so that the relative importance of the lower Platte River to the overall recovery effort of the pallid sturgeon can be better evaluated.

Chapter 5 Recommendations:

Shovelnose sturgeon populations in the Platte River have been found to use the river up to and beyond the mouth of the Loup River, depending on discharge levels. The habitats used by shovelnose sturgeon in the Platte River tend to be slightly shallower with slightly slower velocities that those used by pallid sturgeon.

9. We recommend that studies on shovelnose sturgeon populations be continued to evaluate the health of the lower Platte River ecosystem.

Chapter 6 Recommendations:

The habitats used by pallid sturgeon are also used by other fish species upon which they may depend for food resources. We found that several chub species, especially shoal chub, occur more frequently in the vicinity of sturgeon than in other areas. Now that gastric lavage and colonic flushing are available as tools for evaluating food consumption by sturgeons in general, and pallid sturgeon in particular, the significance of this observation can be evaluated. This could lead to studies to determine potential energy budgets in different river habitats. If appropriate food is limited for pallid sturgeon in the Missouri River system, then this may aid in understanding the importance of the lower Platte River to the recovery of pallid sturgeon.

10. We recommend that studies be initiated to evaluate pallid sturgeon food habits in the lower Platte River to coordinate with similar studies on the Missouri River.

Chapter 7 Recommendations:

Sturgeon chubs, shoal chubs, flathead chubs and silver chubs are characteristic turbid water fish species of Great Plains rivers. Both sturgeon chubs and shoal chubs have been identified from pallid sturgeon digestive tracts and their habitat requirements are similar to those of both pallid sturgeon and shovelnose sturgeon.

11. We recommend that chub populations on the lower Platte River be monitored as indicators of habitat changes that may be linked to the habitats needed by sturgeon species.

Chapter 8 Recommendations:

A critical aspect of the life history of pallid sturgeon and shovelnose sturgeon that is generally unknown throughout the Missouri – Mississippi Rivers is the location, timing and success of spawning and larval recruitment. We captured Scaphirhynchus larvae less than one day old in the Platte River in every year of our study. This confirms that Scaphirhynchus spawning is taking place in the Platte River. Larval chubs were also collected in the Platte River and these may be important food resources for pallid sturgeon.

12. We recommend a continuation of larval and juvenile fish sampling in coordination with the ongoing efforts on the Missouri River. A potential benefit from this coordinated effort would be the ability to compare sturgeon spawning success in the relatively natural instream habitats of the Platte River with that of the highly modified Missouri River. This comparison may aid in understanding the early life history dynamics limiting the overall recovery efforts for pallid sturgeon (Quist et al. 2005).

Chapter 9 Recommendations:

At this time, it appears that recreational anglers are not substantially harming the shovelnose sturgeon population in the Platte River. On the other hand any take of an endangered species like the pallid sturgeon is reason for concern.

13. We recommend that State and Federal officials employ a combination of coordinated educational and legal approaches to ensure that anglers can accurately identify pallid sturgeon to avoid unintentional take and minimize angling threats to this species.

14. We further recommend that angling regulations in all States along the Missouri River be reviewed to evaluate ways to protect pallid sturgeon populations.

Chapter 10 Recommendations:

Discharge is one of the primary factors which influence habitat quality and habitat connectivity in the Platte River. In addition, the timing of discharge fluctuations and the occurrence of flooding flows shapes and maintains the habitat in this braided river.

15. We recommend that Platte River instream flow allocations be adjusted to protect the habitat and river connectivity needed to support healthy populations of pallid and shovelnose sturgeons.

16. We further recommend that the mosaic of shallow water and deep water habitats be protected to support the production of food resources for the sturgeon species in the lower Platte River.

Overall conclusions:

The lower Platte River is one of the last shifting sandbar rivers characteristic of the Great Plains. The lower Platte River is also the only shifting sandbar river that is connected to a free flowing section of the Missouri River. As a result, the lower Platte River retains a relatively intact native biota making it a unique but stressed ecosystem. We recommend protection for and enhancement of the habitats in the Platte River ecosystem by managing its discharge, sediment supply and instream habitats. This management is critical to the recovery of pallid sturgeon, other threatened and endangered species and the rest of the biota, so that more species do not become imperiled.

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NEBRASKA TECHNICAL SERIES

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18........	Ecology and Management of Sturgon in the Lower Platte River, Nebraska

Introduction

Purpose

The purpose of this Biological Opinion (Opinion)is to provide a written report concluding whether the continued issuance of surface water appropriations, an action under the jurisdiction of the Nebraska Department of Natural Resources (DNR, formerly known as the Department of Water Resources), will likely jeopardize the continued existence of endangered and/or threatened species in Nebraska, result in the destruction or adverse modification of critical habitat or promote the conservation of endangered or threatened species in the lower Platte River. A biological opinion may include reasonable and prudent alternatives for an action with a jeopardy determination and/or recommendations as to how an action would enhance conservation of an endangered or threatened species or critical habitat. This evaluation includes effects on the target species and designated critical habitats in the action area.

In accordance with Nebraska's Nongame and Endangered Species Conservation Act, the Nebraska Game and Parks Commission (Commission) consults with other state agencies to address potential impacts to state-listed threatened and endangered species. In the 1990s concerns were raised regarding consultations between DNR and the Commission on surface water appropriations in the lower Platte River basin below Columbus between February 1 through July 31 and the potential for adverse impacts to the pallid sturgeon and sturgeon chub. It became evident, however, that inadequate scientific data existed on the ecological requirements of the pallid sturgeon and sturgeon chub.

To address this need for inforamtion, a Commission Federal Aid and Sportfish Restoration project was initiated that focused on the ecological relationship of two sturgeon species (pallid sturgeon and shovelnose sturgeon *Scaphirhyncus platorynchus*) with fish species typical of shifting sand-bed rivers. To accomplish these goals the study delineated five objectives:

- Objective 1 was to document habitat use, relative habitat preference, and species assemblages associated with adult and juvenile sturgeon in the lower Platte River.
- Objective 2 was to document the phenology and relative abundance of larval recruitment for sturgeon and associated species in the lower Platte River.
- Objective 3 was to determine how changes in river discharge influence habitat use by sturgeon life stages in the lower Platte River.
- Objective 4 was to document the catch of sturgeon by anglers in the lower Platte River.
- Objective 5 was to develop educational materials and management recommendations for the sturgeon fishery in the lower Platte River.

In 1999, the Nebraska Game and Parks Commission, along with a consortium of Natural Resources Districts and Public Power and Irrigation districts, developed a committee to investigate the possibilities of funding research on the Platte River to study the pallid sturgeon and sturgeon chub. This committee formally signed an Interlocal Cooperative Agreement for the Pallid Sturgeon and Sturgeon Chub Study of the Lower Platte River (Interlocal Agreement) with the last signatory on October 25, 1999 which formalized the Pallid Sturgeon / Sturgeon Chub

Task Force (Task Force). On May 18, 2000, the Task Force approved the funding of a five-year study on pallid sturgeon, sturgeon chub, and associated species in the lower Platte River. The primary goal of the study funded by the Task Force was to quantitatively describe habitat use by pallid sturgeon and sturgeon chub in the lower Platte River. Additional analyses evaluated the ecological relationships among pallid sturgeon and sturgeon chub, and other fish species typical of shifting sand-bed rivers, exemplified by the Platte River. This study was done in conjunction with the Federal Aid and Sportfish Restoration project. The Task Force study delineated five objectives:

- Objective 1 was to document habitat use, relative habitat preference, and species assemblages associated with adult and juvenile pallid sturgeon and sturgeon chub in the lower Platte River.
- Objective 2 was to document the phenology and relative abundance of larvae for pallid sturgeon, sturgeon chub and associated species in the lower Platte River.
- Objective 3 was to determine if changes in ambient river habitat conditions influence habitat use by pallid sturgeon and sturgeon chub life stages in the lower Platte River.
- Objective 4 was to document the catch of sturgeon by anglers in the lower Platte River.
- Objective 5 was to develop management recommendations and educational materials to facilitate appropriate recovery efforts for pallid sturgeon and sturgeon chub in the lower Platte River.

Dr. Ed Peters and Dr. Jim Parham with the University of Nebraska at Lincoln were contracted with to complete the study. A report on the completed study was submitted to the Task Force and to the Commission in May, 2005. The results of this study are referenced throughout this document. The report was subsequently peer reviewed by numerous professionals int eh field of sturgeon ecology, environmental science and statisticsl evaluations. The May 2005 report has been revised and is in press in the Commission's Technical Series.

There was agreement between the Commission and DNR that during the five year research study, up to 5,000 acre feet of surface water applications would be considered "no jeopardy." It is the Commission's understanding that this agreed upon amount has not yet been fully allocated. At the conclusion of the study, the Commission prepared this Opinion as referenced in a November, 1999 letter from the Commission to DNR that stated, "A biological opinion is being prepared following the approval of the Interlocal Agreement by our Board of Commissioners … Future research such as that provided by funding the previously mentioned Interlocal Agreement will hopefully provide the information we need to answer these questions and to determine the effect of future depletions on these species. A more detailed biological opinion will be sent to the DNR at a later date." Therefore, this Opinion is the agreed upon result of the Interlocal Agreement signed by the last signatory on October 25, 1999 attached to the November, 1999 letter.

Action Considered and Action Area

This Opinion examines the effects continued issuance of surface water appropriations that would affect the hydrology of the lower Platte River beginning from the date this Opinion is submitted to the DNR. For the purposes of this Opinion, the lower Platte River is defined as the area stretching from the confluence of the Loup River near Columbus to the mouth of the Platte River (Figure 1). Flows of the lower Platte River are highly dependent on the Loup River Basin, the Elkhorn River Basin and the Salt Creek Basin. Therefore, the action area of this Opinion includes the Loup River Basin, Elkhorn River Basin, Salt Creek Basin and Lower Platte River Basin.

Flows from the Platte River watershed above Columbus are an important component of the lower Platte River, but future depletions to these upstream flows are outside the scope of this consultation and not addressed in this Opinion. The effects of depletions to flows upstream of Columbus are addressed by the Platte River Recovery Implementation Program (Program) implemented by the three Platte River basin states and the U.S. Department of the Interior on January 1, 2007. The Program's primary focus is to improve and protect endangered species habitat in the central reach of the Platte River, and to avoid or offset new depletions to flows upstream of Columbus. Federal actions resulting in depletions to the Platte River downstream of Columbus (i.e., in the Loup River, Elkhorn River, Salt Creek and lower Platte River tributary basins) are outside the scope of the Program, and are not provided Endangered Species Act compliance via the U. S. Fish and Wildlife Service Biological Opinion issued on June 16, 2006.

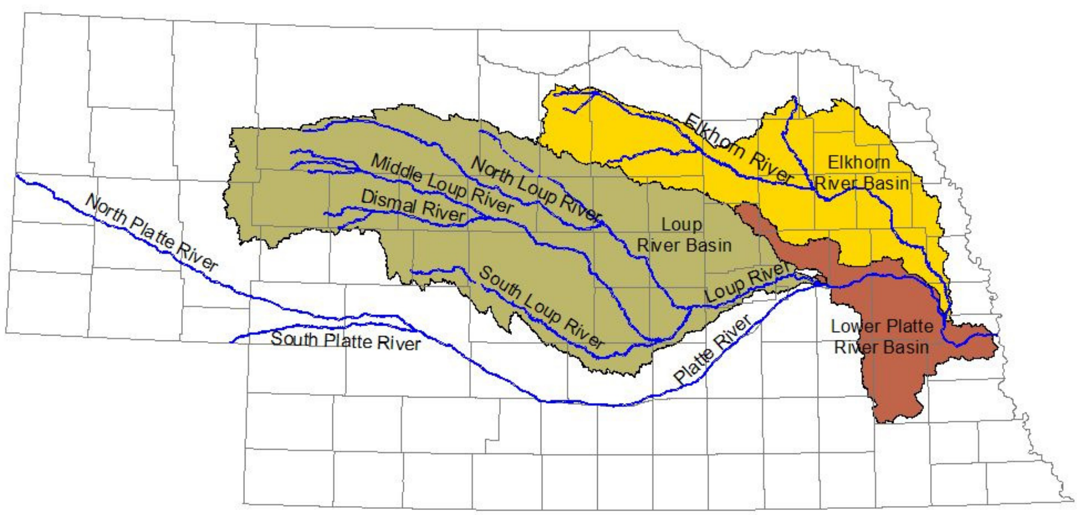


Figure 1: Action area of this Biological Opinion.

Surface water appropriations are granted through a permitting system, administered by the DNR. Surface water appropriations are granted for natural flow, storage, storage use, for wells within 50 feet of a stream and for pumping from a natural lake. Water in the lower Platte River is utilized for irrigation, municipal use, domestic and commercial use and as instream flows for the fish community. Half of the public water supply for the Omaha Metropolitan Area and all of the public water supply for Lincoln is dependent on flows from the lower Platte River recharging the respective ground water well fields.

Additionally, this document provides the details referenced in the Commission September 25th, 2007 addendum data request to the August 3, 2007 data request for at-risk species information for the annual evaluation of water supplies for Fully Appropriated Basins. These letters were prepared in response to the July 10, 2007 DNR request for information about the location of threatened and endangered species in Nebraska for DNR's annual evaluation of the state's water supplies, specifically requesting information regarding species that might be affected by low stream flows in areas of the state not considered Fully or Over Appropriated. This document also provides the details are referenced in the October 10th, 2007 review of the draft Fully Appropriated Basin Report

Species

State listed species in the action area include the interior least tern (*Sternula antillarum athalassos*), piping plover (*Charadrius melodus*), pallid sturgeon (*Scaphirhyncus albus*), sturgeon chub (*Macrhybopsis gelida*), river otter *(Lutra canadensis*), western prairie fringed orchid (*Platanthera praeclara*), bald eagle (*Haliaeetus leucocephalus*), lake sturgeon (*Acipenser fulvescens*), blacknose shiner (*Notropis heterolepis*), finescale dace (*Phoxinus neogaeus*), northern redbelly dace (*Phoxinus eos*), American burying beetle (*Nicrophorus americanus*), Salt Creek tiger beetle (*Cicindela nevadica lincolniana*) and small white lady's slipper (*Cypripedium candidum*).

While the above species occur in the action area as illustrated in Figure 1, this Opinion only addresses those species occurring in the lower Platte River. **Specifically, the target species of this Opinion includes the interior least tern, piping plover and pallid sturgeon.** The sturgeon chub, river otter and lake sturgeon were not included in this Opinion due to the lack of information regarding specific habitat requirements for these species in the lower Platte River. The bald eagle was not included due to the abundance of the species statewide and the lack of knowledge regarding flow requirements of this species in the lower Platte River. The western prairie fringed orchid, blacknose shiner, finescale dace, northern redbelly dace, American burying beetle, Salt Creek tiger beetle and small white lady's slipper do not occur along the lower Platte River or habitats in the immediate vicinity of the lower Platte River, therefore they were not included as target species.

The Opinion was prepared as prescribed in rules and regulations of the Nebraska Game and Parks Commission governing the inter-agency consultation process, and under the authority of the Nongame and Endangered Species Conservation Act (Act) §37-807(3). The legislative intent of the Act is, "That it is the policy of this state to conserve species of wildlife for human enjoyment, for scientific purposes, and to insure their perpetuation as viable components of their ecosystems." The Act requires that, "All state agencies shall, in consultation with and with the assistance of the Commission, utilize their authorities in furtherance for the purposes of the act by carrying out programs for the conservation of endangered species and threatened species, by taking such action necessary to insure that actions authorized, funded or carried out by them do not jeopardize the continued existence of such endangered or threatened species or result in the destruction or modification of habitat of such species which is determined by the Commission to be critical." The Act jurisdiction is within the State of Nebraska, so determinations of a species status are based on their occurrence within the state boundary, not the individual species' entire range.

Data and Resources

The biological information and data considered in this Opinion represents the best data currently available. Species records were obtained from a variety of sources and have been incorporated into the Natural Heritage Database using strict standards for species occurrences records. All records have been geospatially referenced using Geographic Information Systems (GIS) technology. A series of research projects performed by the University of Nebraska-Lincoln in conjunction with the Commission developed the habitat use and movement data for a variety of species inhabiting the lower Platte River, including the pallid sturgeon and sturgeon chub. As part of a five-year project on sturgeon ecology conducted by the University of Nebraska-Lincoln, sturgeon habitat use and preference data and seasonal movement tendencies were related to historical flow records in order to develop a habitat connectivity model in the lower Platte River. These studies have been reviewed by leading scientists in the appropriate fields of study. Platte River historical flow records were obtained from USGS river gage records. Additional hydrological analyses that modeled both normative and extreme flows of the lower Platte River system were conducted by Dr. Parham on contract with the Commission. These analyses allow the Commission to put the biological information and data considered in this Opinion in the historical context of the Platte River hydrograph. Specific references are noted, wherever necessary, within the Opinion and are listed in the reference cited section.

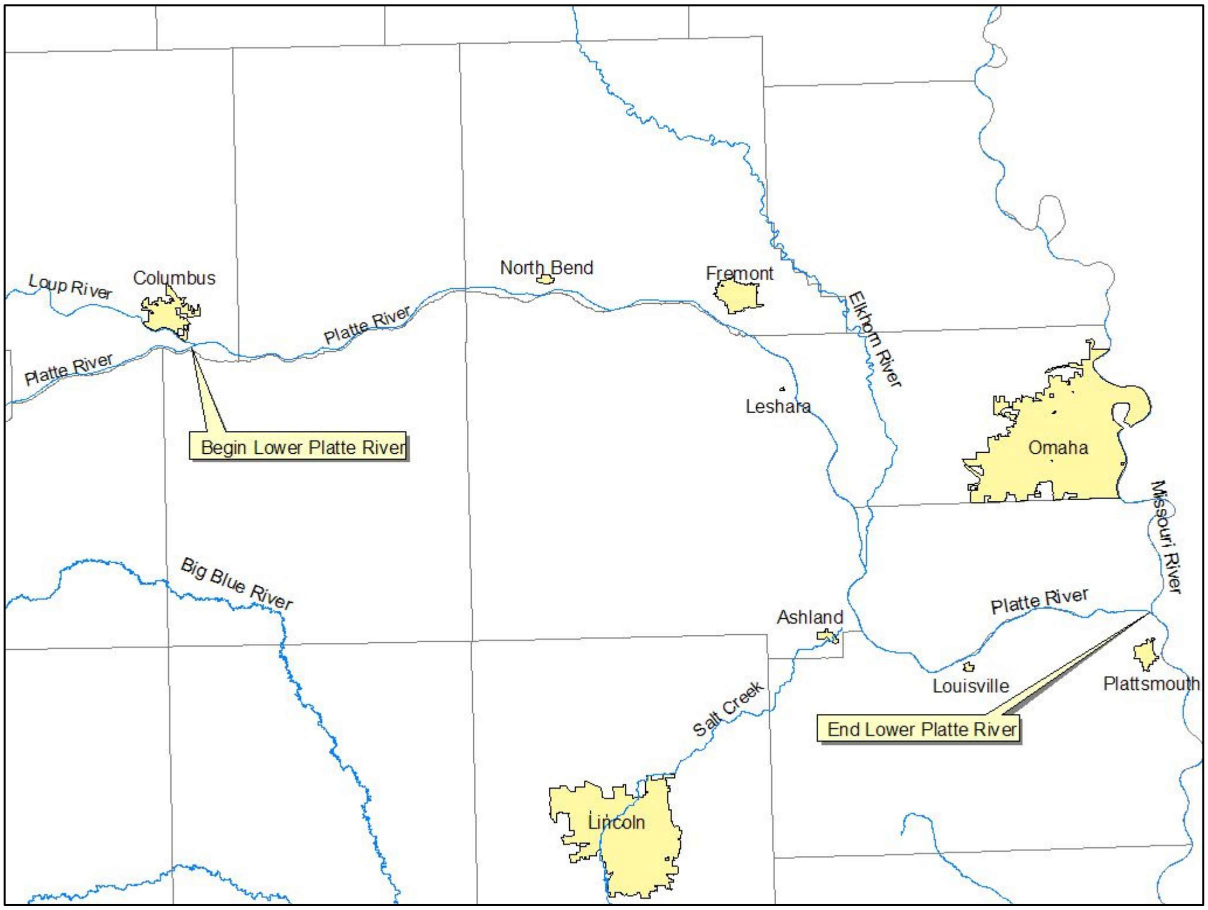


Figure 2: Map of the lower Platte River, large tributaries, population centers and significant landmarks mentioned in this document.

Status of Species

Interior Least Tern (*Sternula antillarum athalassos*)

Least terns are the smallest members of the subfamily Sterninae and family Laridae of the order Charadriiformes. The least tern was previously in the genus *Sterna*, but was recently re-classified by the American Ornithologists' Union Committee on Classification and Nomenclature – North America and placed within the genus *Sternula* (Banks et al. 2006). This bird measures 21-24 cm long with a wingspan of 51 cm. It can be distinguished from other terns by its black crown, white forehead and underparts, pale gray back and wings, and black-tipped yellow-orange bill.

The American Ornithologists' Union (AOU) recognizes three subspecies of the least tern, California (*S. a. browni*), eastern (*S. a. antillarum*), and the interior (*S. a. athalassos*) (American Ornithologists' Union 1957). The California least tern is also listed as endangered in California and is federally endangered. The eastern least tern has received state protection, but is not federally listed. On May 28, 1985, the U.S. Fish and Wildlife Service (Service) designated as an endangered species the population of least tern occurring in the interior of the United States (interior least tern) (50 F.R. 21792). Under Neb. Rev. Stat. § 37-806 any species determined to be threatened or endangered pursuant to the federal Endangered Species Act shall be similarly listed under the Nebraska Nongame and Endangered Species Conservation Act. Unless otherwise indicated, this Opinion covers only the interior least tern.

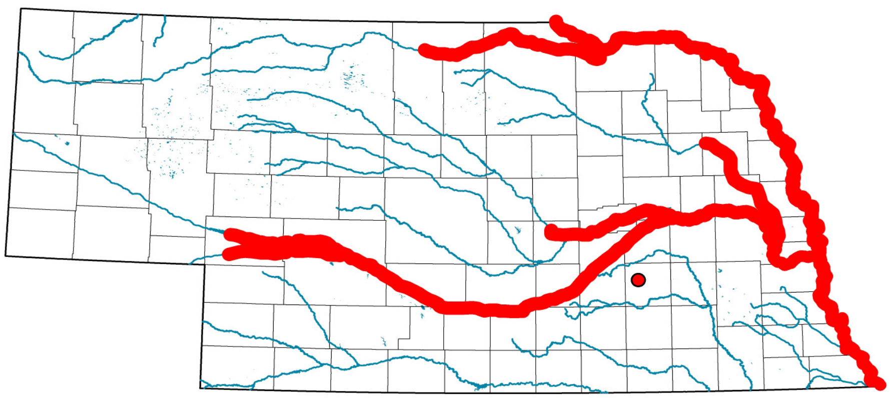
Distribution

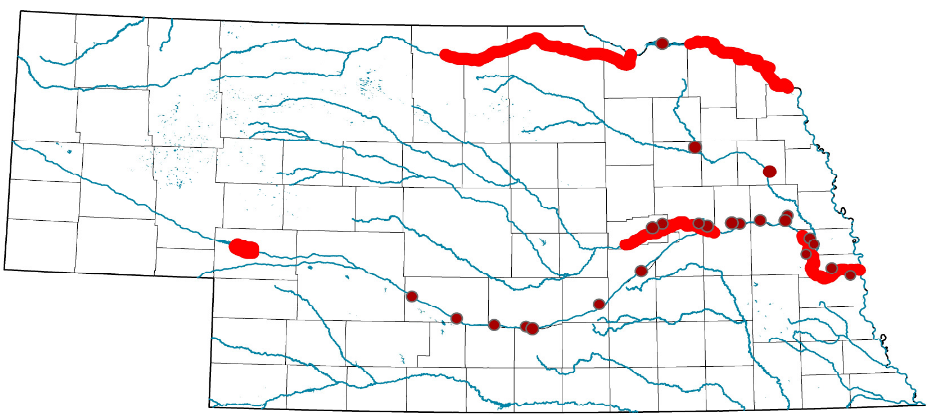
The historical breeding range for the interior least tern extended from Texas to Montana and from eastern Colorado and New Mexico to southern Indiana. This species nested along the Missouri, Mississippi, Colorado, Arkansas, Red, and Rio Grande river systems. All subspecies of the least tern apparently were abundant through the late 1880s (Bent 1963). The interior least tern continues to breed in most of the aforementioned river systems, but its distribution is generally fragmented and restricted to the less altered and more natural or little disturbed river segments.

The first historical observation of the least tern in Nebraska was recorded along the Missouri River by the Lewis and Clark expedition of 1804. Prior to settlement by European American, the least tern was apparently a common breeding species on riverine habitat throughout much of Nebraska, including along the Missouri, Platte, Elkhorn, lower Loup, and Niobrara Rivers (Ducey 2000, Bruner et al. 1904, Sharpe et al. 2001). Taylor and Van Vleet (1888) described it as "abundant in June, July and August and breeding in the state," and Bruner et al. (1904) described it as "a common migrant and not a rare breeder." A record of five nests at what is now North Kirkpatrick Wildlife Management Area, York County, discovered by Tout (1902) is the only nesting record away from riverine systems and their neighboring habitats in Nebraska.

On the Platte River system, historically least terns were observed in Platte County in 1857 and east of Ash Hollow, Keith County, in 1859 (Ducey 2000). In Lincoln County, Tout (1947) described least terns as, " a regular summer resident and breeder on the sandbars of the Platte River and its forks." Tout (1947) noted consistent use of the South Platte River with a colony of 17 nests and several chicks in 1926, and noted similar nesting patterns and locations in 1927. In 1928 Tout (1947) found 18 nests in the same vicinity and in 1929 found 22 nests, all in relatively the same area. Benckeser (1948) found a small colony of six least tern pairs on the South Platte River two miles east of Brule, Keith County, 10 July, 1948.

At the Platte River south of Lexington, Wycoff (1960) reported finding 35 nesting least terns in 1949, 20 in 1950, 24 in 1953, and 25 in 1954. These birds were nesting on a "low, sandy island not over 75 feet wide, about 200 feet long, and lying nearly a quarter-mile west of the Platte River bridge which is straight south of Lexington, Nebraska."





The lower Platte River from Columbus to the mouth, lower portions of the Loup River, the lower Niobrara River and a few stretches of the Missouri River below Ft. Randall Dam and Gavins Point Dam are the only river segments in Nebraska that still provide naturally occurring sandbar nesting habitat used by least terns. Because riverine nesting habitat has been severely reduced or eliminated in the central and upper Platte River, nesting rarely occurs there; sand and gravel pits adjacent to the river now provide the majority of the nesting habitat. The Loup River has been highly altered in the reach below Genoa with a canal diversion system to a hydropower facility (Figure 3).

Reproduction

Interior least terns are migratory birds. They spend the winter in South America and typically arrive in Nebraska in May and begin establishing feeding and nesting territories. They are colonial birds and are often found nesting with piping plovers. Ziewitz et. al (1992) found that least terns initiated nesting on the Platte River from May 19 to June 23, but nest initiation can occur later into the first two weeks of July (Jorgensen 2007) . Sidle (1992) found that most fledging is completed by July 31.

Least terns nest on sparsely vegetated riverine sandbars, sand and gravel spoil piles, fly-ash disposal sites of power plants, dike fields, reservoir shorelines, wetlands and other artificial habitats such as rooftops. Colony sites are usually located in open expanses of sand or pebble beach within the river channel or reservoir shoreline. Least terns prefer sites that are well-drained and away from the water line. In both the Yellowstone River and Mississippi River, least terns select sites for nesting that were exposed longer above river levels throughout the breeding season than non-nesting habitats (Bacon 1996, Smith and Renken 1991).

Least terns are dependent on ephemeral, early successional habitat (Thompson et al. 1997). Birds select sites that lack vegetative cover (Dirks 1990, Ziewitz et al. 1992), but may nest on sites with up to 30 percent vegetative cover (Schulenberg and Placek 1984, Dryer and Dryer 1985, Landin et al. 1985, Rumancik 1985). Nesting habitat will continue to change and become unattractive to terns without intervening periods of disturbance. For instance, suitable river sandbars are maintained by the hydrology of the river and the movement of its alluvial bedload. Eventually, least terns will abandon heavily vegetated nesting sites. Unconsolidated material such as small stones, gravel, sand, debris, and shells are important components of nesting substrate.

A pair will make several shallow nest scrapes in open, gravelly areas, but will only use one for nesting. Both adults will incubate the eggs and will re-nest if a nest is lost, an adaptation to highly variable river conditions. Incubation lasts approximately 21 days. The newly hatched young are weak and helpless, and must be attended to by both adults. Chicks are able to fly about 20-21 days after hatching, but do not become competent at fishing until after migrating from the breeding grounds in the fall (Hardy 1957, Tomkins 1959, Massey 1972, 1974). They are dependent on their parents for food even after they become strong fliers.

Demographic Parameter Estimates

Information on survival is limited, and variable between the life stages of least terns. Available information suggests adult survival is relatively high. Thompson (1982) estimated mean adult survival along the Texas Coast at 0.853-0.941. Massey et al. (1992) estimated California least tern annual adult survival at 0.88. Renken and Smith (1995) mean annual adult survival for least terns on the Mississippi River was 0.85 ± 0.06.

Estimates of reproductive success, specifically fledge ratios for least terns, are variable and range from 0.28 to 1.26 fledglings per pair. In Nebraska, fledge ratio estimates range form 0.12 to 1.26. However, fledge ratios should be interpreted cautiously. Logistical constraints likely bias fledge ratio estimate include: 1) adults are not individually marked, 2) the colony is visited infrequently, 3) the inability to monitor all young until they fledge (Erwin and Custer 1982), and 4) emigration/immigration of juvenile birds to non-natal colonies. Lingle's (1993b) and Kirsh's (1992) work are the only studies where birds were individually marked, thus overcoming a major source of potential bias. Fledge ratios from these studies range from 0.12 to 0.49. Kirsch's (1992) estimated fledge ratios for birds breeding at sandpits ranged from 0.19 to 0.32. It should be noted that Kirsh (2001) was highly critical of estimates from Nebraska Public Power District and Central Public Power and Irrigation District (e.g. Peyton and Wilson 2000).

Table 1. Published estimates of least tern fledge ratios.

YEAR	FLEDGE RATE	LOCATION	SOURCE
1986	0.5	Mississippi River Valley – river sandbars	Smith and Renken 1993
1987	0.7	Mississippi River Valley – river sandbars	Smith and Renken 1993
1988	1.4	Mississippi River Valley – river sandbars	Smith and Renken 1993
1989	0.2	Mississippi River Valley – river sandbars	Smith and Renken 1993
1987	0.19	Lower Platte River – spoil piles	Kirsch 1992
1987	0.12	Lower Platte River – river sandbars	Kirsch 1992
1988	0.16	Lower Platte River – spoil piles	Kirsch 1992
1988	0.29	Lower Platte River – river sandbars	Kirsch 1992
1989	0.38	Lower Platte River – spoil piles	Kirsch 1992
1989	0.31	Lower Platte River – river sandbars	Kirsch 1992
1990	0.32	Lower Platte River – spoil piles	Kirsch 1992
1990	0.19	Lower Platte River – river sandbars	Kirsch 1992
1988-1989	0.49	Central Platte River	Lingle 1993b
1991-2000	0.86	Central Platte River – gravel mines and artificial sandbars	Plettner 2000
1992	0.76	Lower Platte River – protected nests (fenced)	Lackey 1994
1992	0.30	Lower Platte River – unprotected nests	Lackey 1994
1988-2000	0.35	NE - Fort Randall Dam to Niobrara	USACE 1998 and unpubl. data
1988-2000	0.67	NE - Lewis and Clark Lake	USACE 1998 and unpubl. data
1988-2000	0.87	NE - Gavin's Point Dam to Ponca	USACE 1998 and unpubl. data
1988-2000	0.74	NE – Combined Mis. River Adj. to NE	USACE 1998 and unpubl. data
1992-2000	1.26	NE – Lake McConaughy	Payton and Wilson 2000
1992-2000	0.91	Upper Platte River	Payton and Wilson 2000
1995	1.27	Lower Mississippi River	Sznell and Woodrey 2003
1996	0.28	Lower Mississippi River	Sznell and Woodrey 2003
1999	0.58	Lower Platte River – gravel mines	Marcus 1999
2000	0.88	Lower Platte River – gravel mines	Marcus 2000
2001	0.67	Lower Platte River – gravel mines	Marcus 2001
2002	1.23	Lower Platte River – gravel mines	Held et al. 2002
2003	1.07	Lower Platte River – gravel mines	Held et al. 2003
2004	0.69	Lower Platte River – gravel mines	Held et al. 2004
2005	0.72	Lower Platte River – gravel mines	Held unpubl. data

Foraging

Interior least terns consume small fish captured from shallow water areas. Foraging habitat for least terns includes side channels, sloughs, tributaries, shallow-water habitats adjacent to sand islands and the main channel (Dugger 1997). They hunt by hovering, searching and diving and catching small fish in their bills. Least terns forage almost exclusively upon small, narrow bodied, schooling fish (Atwood and Kelly 1984, Wilson et al. 1993, Schweitzer and Leslie 1996). Least terns feed on *Fundulus*, *Notropis*, *Campostoma*, *Pimephales*, *Cyprinella*, *Morone*, *Dorosoma*, *Lepomis*, and *Carpiodes* minnow species when the appropriate size is available.

The proximity of suitable foraging areas is a factor in reproductive success (Dugger 1997). Areas that appear to be suitable nesting habitat may not be utilized due to the distance to foraging areas. Least terns will forage a distance away from nesting sites, but the cost of this energy exertion in relation to nesting success is not well defined, nor is the distance that birds are able to travel for foraging. A Nebraska study found that least terns were observed foraging within 328 feet (100 meters) of the colony (Faanes 1983). Another study found that birds nesting at sand and gravel mining sites and other artificial habitats may fly up to 3.2 km to forage at riverine sites (Smith and Renken 1990). However, recent radio telemetry work, conducted on the Missouri River by the Northern Prairie Wildlife Research Center of the U.S. Geological Survey suggests that terns may be moving farther from the colony for foraging than previously published (Stucker, personal communication 2007).

Evidence suggests that terns forage most efficiently in areas with shallow water, as these areas have higher density and richness of small fishes that compose tern forage when compared to deep-water habitats (Tibbs and Galat 1997). Nesting typically coincides with the timing of lowest flows in major river systems (historically, in the summer), providing easy access to forage species in shallower water (Dugger 1997).

Mortality

Causes of mortality, for both adults and fledged juveniles, range from natural predators to unnatural human disturbance. Lingle (1993b) reported that about 53 percent of adult least tern and piping plover deaths along the central Platte River were due to predation, another 33 percent from weather, and 13 percent of adult deaths could be attributed to humans. Adult least terns have also been killed under the tires of all-terrain vehicles while incubating nests, in addition to documented deaths from shooting (Lingle 1993b, Smith and Renken 1993).

Least terns are a relatively long lived species. Limited adult annual survival estimates from all populations range from 0.80 to 0.88 (Renken and Smith 1995, Massey et al. 1992, Thompson et al. 1997). Natural longevity can exceed 20 years and the record longevity record is 24 years 1 month (Thompson et al. 1997).

Flooding is also a cause of mortality. Least terns utilize a highly dynamic system, and although their reproductive cycle is in sync with the historic hydrograph of many of Nebraska’s major rivers, nests are inundated. Least terns will re-nest there is sufficient conditions and time in the season.

Artificial and Alternative Habitats

Range wide, least terns will nest in locations other than riverine sandbars, but in Nebraska, quality alternative habitat is limited. Historic nesting patters clearly indicate that least terns were utilizing sandbars in the river channel. However, available habitats used by least terns for nesting have changed through time as human development has encroached on breeding areas and natural ecological changes have occurred (Thompson et al. 1997). The distribution patterns and habitats used today begin with development along the Platte River. Wycoff's (1960) observations of least terns near Lexington covered 17 years and he remarked,

> "During the years which followed the building of the dams in the hills along the south side of the Platte River, thus insuring a more continuous flow of water, the sandy river bed became covered with sprouting cottonwoods, willows, and many acres of cockleburs and sweet clover. No open places were left for the terns."

The "dams" mentioned above refer to the water storage reservoirs associated with the Tri-County Irrigation Project that was completed in the early 1940s (CPPID 2007). During this time period, Wycoff (1960) observed for the first time, least terns (and piping plovers) nesting at sandpits, specifically "Kirkpatrick's sandpit." In 1959, apparently most of the least terns in this area were nesting at the Luther sandpit and by 1955 Wycoff (1960) noted that "terns appeared to have completely lost any interest in the old nesting place," referring to the river sandbar where he originally observed nesting least terns.

Least terns use sandpits that result from gravel/sand mining operations as nesting habitat. These sandpits are often found in close proximity to the river, but evidence suggests that these artificial habitats are ecological "sinks." Lower fledge ratio estimates from sandpits illustrate that although a direct cause of lower fledge ratios cannot be determined, the sandpit habitat is not adequate for population maintenance or recovery. Kirsch (1992) estimated that fledge ratios ranged from 0.19 to 0.32, similar to Lackey's (1994) estimated 0.30. These estimates are well below estimates of 1.0 or greater that are suggested for population maintenance (Thompson 1982, Dugger 1997, Aron 2005).

Lingle (1988) reported that least tern nest losses varied between natural and artificial habitats. The major cause of nest failure on natural riverine sandbars was flooding, while nest failure at sandpits was the result of predation and abandonment. Sandpits may provide temporary habitat, but these habitats will become overgrown as the sand mining is completed, unless extensive maintenance is implemented. Other sites are converted to housing developments, which no longer provide nesting habitat. Sandpits offer only a temporary habitat that without considerable management, do not offer a viable, long-term solution for least tern nesting habitat.

Other than sandpits, least terns will readily nest along reservoir shorelines, such as Lake McConaughy, when water levels are sufficiently low. This type of habitat is temporary and use by least terns is relatively low, even with ample habitat in recent years (32 birds in 2005, Lott 2005).

Continuing Threats:

Habitat Loss and Degradation – Changes in natural river hydrology due to channelization, diversion of river flows for irrigation and hydropower production, construction of reservoirs, bank stabilization (rock armoring, revetment, hard points), levees and unnatural, managed river flows have contributed to the elimination of much of the least tern's sandbar nesting habitat (Funk and Robinson 1974, Hallberg et al. 1979, Sandheinrich and Atchison 1986).

Sediment and sediment movement in association with variable discharges are key components of sandbar habitat creation. In much of the least tern's range, sediment had been reduced from flowing water as it settles out in reservoirs. Historical high flows, which are now tempered, are important to introduce and transport organic material from the floodplain to the river system supports the system's productivity.

Human Disturbance - Human disturbance affects tern productivity in many locations, (Massey and Atwood 1979, Goodrich 1982, Burger 1984, Dryer and Dryer 1985, Dirks and Higgins 1988, Schwalbach 1988, Mayer and Dryer 1990). Many rivers have become the focus of recreational activities, and sandbars, where they exist, are fast becoming the recreational counterpart of coastal beaches. Human presence reduces reproductive success (Mayer and Dryer 1988, Smith and Renken 1990). Domestic pet disturbance and trampling by grazing cattle are other factors that have contributed to the population decline.

Pollution/Contaminants - Pollutants entering the waterways within and upstream of breeding areas can negatively impact water quality and fish populations in nearby foraging areas. Strip mining, urban and industrial pollutants, and sediments from non-point sources can all degrade water quality and fish habitat, thereby impacting small-fish populations on which least terns depend (Wilbur 1974, Erwin 1983). In addition, because least terns are relatively high on the food chain, they are in a position to bioaccumulate contaminants which may render eggs infertile or otherwise affect reproduction and chick survival (USFWS 1983, Dryer and Dryer 1985).

A 1997 report by the U.S. Fish and Wildlife Service (Allen and Blackford, 1997) concluded that selenium (Se) and mercury toxicity may be causing decreased least tern reproduction. The study evaluated concentrations of arsenic, mercury, selenium and organochlorines compounds in interior least tern eggs collected from Montana, North Dakota, South Dakota, Nebraska and Kansas from 1992 -1994. The recommended threshold for selenium impacts on avian reproduction is 3 µg/g dry-weight (Allen et al. 1998). Concentrations of selenium in 20 least tern eggs collected from Nebraska in 1992 averaged 4.32 milligrams per kilogram (mg/kg) dry weight from the Platte, North Platte and Elkhorn Rivers. Eighteen of the least tern eggs from Nebraska had selenium concentrations above the normal background concentration of 3 mg/kg dw for waterbird eggs (USDOI, 1998) and two of these eggs were within a 6-10 mg/kg dw range for decreased egg viability (Hamilton et al., 2004). These concentrations of selenium in least tern eggs are a particular concern as avian species can differ substantially in embryo sensitivity to selenium (Skorupa et al., 1993; Skroupa et al 1998 as cited by USDOI, 1998) and least tern sensitivity to selenium toxicity is unknown.

Principal anthropogenic sources of Se to aquatic ecosystems include coal-fired power plants and irrigation return flows (Schmitt, 2002). There are naturally high Se concentrations in Upper Cretaceous marine and sedimentary bedrock which underlies the lower Platte River (USDOI, 1998) and watersheds that drain into the lower Platte River are dominated by irrigated land. However, a low evaporation index for central and eastern Nebraska indicates that a Se problem due to irrigated lands is unlikely (USDOI, 1997). Runoff from cattle feedlots also may contribute Se releases into the lower Platte River as Se is often used as a feed additive by large livestock operations (Sims, 1995) and feedlot runoff is known to enter the Elkhorn River (Schwarz et al. 2006).

Disease – Diseases such as West Nile Virus have potential to negatively impact rare species, especially those that are reduced to a small portion of their former range. West Nile Virus has been attributed to at least one death of a least tern (Pavelka 2006, personal communication).

Predation - Predation is a significant cause of mortality for least terns. Predators include dogs or coyotes (*Canis latrans*), skunks (*Mephitis spp.*), raccoon (*Procyon lotor*), great-horned owls (*Bubo virginianus*), American crows (*Corvus brachyrhynchos*), great blue herons (*Ardea herodias*), barred owls (*Strix varia*), mink (*Mustela vison*), American kestrel (*Falco sparverius*), black-billed magpie (*Pica pica*), bull snake (*Pituophis melanoleucus sayi*), and garter snake (*Thamnophis spp.*) (Lingle (1993a, Renken and Smith 1995). Predation may occur at varying intensity if the river channel is not dynamic such that sandbars are only located in limited areas where predators learn of nesting activities and prey upon colonies annually. With the loss of much least tern nesting habitat, predation has become a significant factor affecting least tern productivity in many locations (Massey and Atwood 1979, Jenks-Jay 1982). Additionally, sandpits present unique challenges as colonies are not isolated by flowing water and more easily subjected to different predators using adjacent terrestrial habitats.

Current Status

Long term trends are difficult to quantify for the least tern on a region wide scale. Focused survey efforts for the entire distribution of the least tern have only recently been implemented. The first range wide least tern survey was completed in 2005, although least terns were previously counted in the International Piping Plover Census. From the 2005 survey, there were a total of 17,591 least terns counted from 489 colonies. Most terns were counted on rivers (89.0%). The Platte River system had 7.4% of the total number of colonies. The Platte River system contributed a total of 588 adults including 53 adults from 2 colonies on the lower Platte River and 328 adults from 13 colonies on sandpits associated with the lower Platte River (Lott 2005).

Since 1987, the Commission has coordinated a standardized survey of all least tern and piping plover nesting along the lower Platte River from Columbus to Plattsmouth, including both riverine and sandpit nests. Although numbers of adults least terns remains relatively consistent, available riverine habitat has declined dramatically across Nebraska, to the point that the lower Platte River is one of the few remaining locations where terns are nesting in natural habitats (See Environmental Baseline Section for further details). As stated previously, sandpits provide nesting habitat, but the long-term availability of these habitats is questionable.

Recovery Objectives

In 1990, the Service published the *Interior Population of the Least Tern Recovery Plan* (USFWS 1990). That plan includes recovery goals for the least tern along major river systems throughout the species range. Major recovery steps outlined in the plan include: a) determine population trend and habitat requirement; b) protect, enhance, and increase populations during breeding; c) manage reservoir and river water levels to the benefit of the species; d) develop public awareness and implement educational programs about the least tern, and; e) implement law enforcement actions at nesting areas where there are conflicts with high public use.

The recovery plan details conditions necessary for the removal of the least tern from the list of threatened and endangered species. The essential habitat throughout its range needs to be properly protected and managed, and species distribution and population goals need to be reached and maintained for a period of ten years. Specifically, the recovery plan recommends that the following distribution and numbers of adult birds be maintained for ten years:

Missouri River system - 2,100
Lower Mississippi system - 2,200-2,500
Arkansas River system - 1,600
Red River system - 300
Rio Grande River system - 500

The recovery plan also specifies a geographic distribution of these totals within each river system. Within the Missouri River system, the plan calls for 1,120 of the 2,100 adult terns to be distributed in Nebraska, as follows:

Missouri River - 400 (shared with South Dakota on the Missouri River)
Niobrara River - 200
Loup River - 170
Platte River – 750

Piping Plover (*Charadrius melodus*)

The piping plover is a migratory shorebird of the subfamily Charadriinae, family Charadriidae, and order Charadriiformes. Inland and coastal breeders have been formally recognized as different subspecies (AOU 1957). Atlantic Coast birds are referred to as *C.m. melodus* and inland birds, including Nebraska breeders, are referred to as *C.m. circumcinctus* (AOU 1957). More recent information (Haig and Oring 1988), however, suggests subspecific classification may not be valid (Haig and Oring 1988, Wilcox 1959).

Adult birds weigh between 43 and 63 grams, are 17-18 centimeters (cm) long, and have a wingspan 11.0-12.7 cm long. Both sexes are sand-colored with white undersides, and the legs are orange. During the breeding season, adults develop an orange bill, and a single black forehead band and breast band.

In 1986, the piping plover gained federal and state protection in the United States and is now listed as threatened in the Great Plains region. Under Neb. Rev. Stat. § 37-806 any species determined to be threatened or endangered pursuant to the federal Endangered Species Act shall be similarly listed under the Nebraska Nongame and Endangered Species Conservation Act.

Distribution

Piping plovers are territorial shorebirds that spend three to four months on northern United States and southern Canada breeding sites. Piping plovers historically bred in three areas of North America: a) Atlantic coastal beaches from Newfoundland to South Carolina, b) beaches of the Great Lakes, and c) the northern Great Plains/Prairie region from Alberta to Ontario and south to Nebraska (USFWS 1988a). The current distribution is similar, except that plovers nesting in the Great Lakes have almost disappeared (Haig and Oring 1988a). The piping plover winters along Gulf Coast beaches and sand/mudflats from Florida into northern Mexico (Laguna Madre). Large numbers of piping plovers winter along the Texas coast (Ferland and Haig 2002, Plissner and Haig 1992, Plissner and Haig 1997).

Prior to settlement by European American, the piping plover was apparently a common breeding species on riverine habitat throughout much of Nebraska, including along the Missouri, Platte, Elkhorn, lower Loup, and Niobrara rivers (Ducey 2000, Bruner et al. 1904, Sharpe et al. 2001) (Figure 4). In addition to riverine habitat, there are several breeding records from the Sandhills, specifically Cherry and Garden Counties from the early 20th Century (Sharpe et al. 2001, Ducey 1988). Three or four pairs of piping plovers nested at Salt Lake, Lancaster County, in 1922 (Pickwell 1925).

On the Platte River, piping plovers were apparently very abundant in the 1860s (Ducey 2000). In Lincoln County, Tout (1947) considered piping plover a “common summer resident and breeder here during some years” where it was found on “sand bars in the bed of the Platte and its north and south forks.” Wycoff (1960) noted piping plovers breeding in association with least terns near Lexington, Dawson County in the 1940s and 1950s. Additional breeding records from the Platte River systems prior to 1960 are from Hall, Platte, Douglas, and Cass Counties (Ducey 1988).

Today the piping plover is found on sandbars of the lower Niobrara, lower Platte and portions of the Loup River. In addition to riverine habitat, there are several breeding records from the Sandhills of north central Nebraska from the early 20th Century (Sharpe et al. 2001). Today the piping plover is found on sandbars of the lower Niobrara, lower Platte River and at low densities and a few locations along the Lower Loup River (Figure 4).

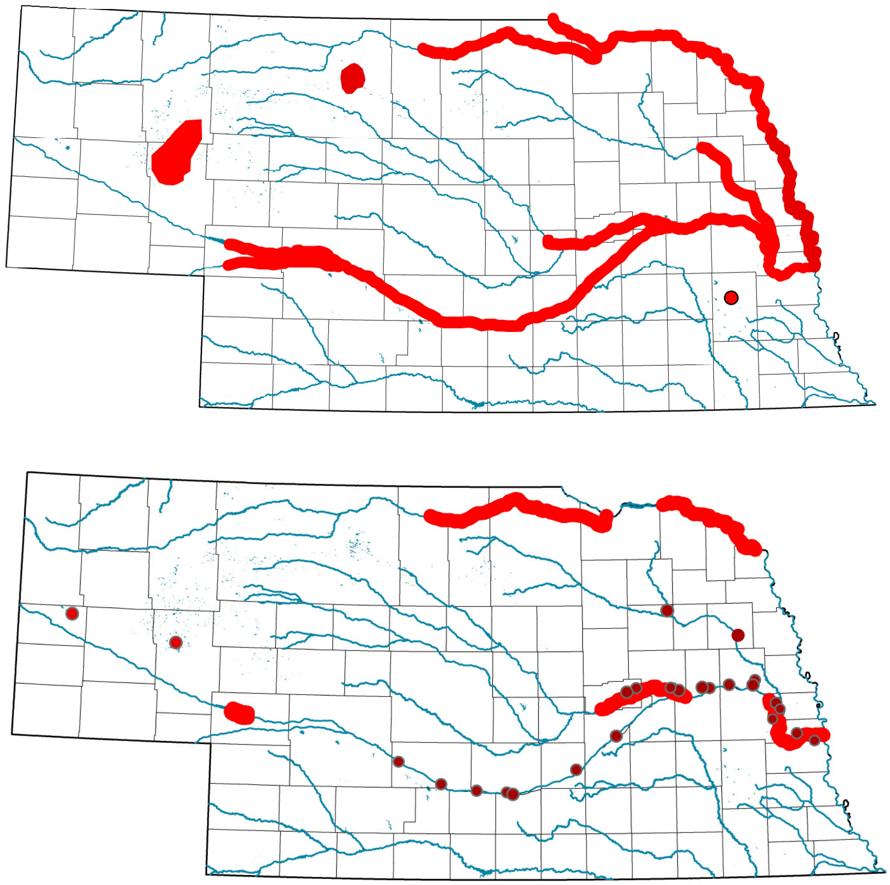


Figure 4. Historic (top) and current (bottom) breeding distribution of the piping plover in Nebraska. Modern breeding sites along central Platte, lower Loup and Elkhorn Rivers are limited to sandpits (dark red dots).

Reproduction

Piping plovers arrive on breeding areas in late April and early May (Thompson et al. 1997, Sharpe et al. 2001). Adults may return to the same areas in succeeding years (Wilcox 1959, Cairns 1982, Haig and Oring 1988b, Wiens and Cuthbert 1988). Nest initiation may begin by late April and continue until early July (USACE 1998).

Piping plovers are semi-colonial and are a relatively timid species. Piping plover often nest in association with least terns. Least terns are aggressive and mob intruders that enter nesting colonies. Piping plovers likely reap the benefits of early predator detection and reduced predation because of this relationship. Similar associations have been noted between red phalaropes (*Phalaropus fulicarius*), another timid shorebird, and another mobbing larid, the Sabine's Gull (*Xema sabini*; Smith et al. 2007)

They nest on sparsely vegetated sandbars, aggregate mining spoil piles, and reservoir shorelines. Nesting habitats on the Platte, Niobrara, and Missouri rivers typically are dry sandbars located midstream in wide, open channels, with less than 25 percent vegetative cover (Faanes 1983, Schwalbach 1988, Ziewitz et al. 1992). The optimum range for vegetative cover on nesting habitat has been estimated at 0 to 10 percent (Armbruster 1986). Schwalbach (1988) and Ziewitz et al. (1992) suggest that birds select higher nest sites when available and sites away from the water's edge. This suite of habitat conditions provide wide, horizontal visibility; protection from terrestrial predators; isolation from human disturbance; greater distance from avian predator perch sites; and sufficient protection from rises in river levels and flooding when sandbars are of sufficient height (USFWS 2000 and 2003a). The absence of any or all of these conditions can negatively impact reproduction.

Ziewitz et al. (1992) measured characteristics of nesting habitat of least terns and piping plovers in the central and lower reaches of the Platte River. At the time of this study, most nesting birds were in the lower Platte River. They found that birds nested in areas where the channel was wider with a greater area of sandbars. They recommended that sandbars be at least 3.58 acres in size and that they be 2.99 feet above river level for maximum flooding protection, but should be at least greater than 1.48 feet in height.

Nests are small scrapes or shallow depressions, frequently lined with small pebbles or shell fragments (USFWS 1988a). Both adults actively defend the nesting territory, generally by performing injured-wing feigning display when human or other predator approach nests or chicks (Cairns 1982, Haig 1992). Egg laying typically begins the second or third week of May. Both sexes share incubation responsibilities, which can last for 25 to 31 days (Wilcox 1959, Cairns 1977, Wiens 1986, Haig and Oring 1988a) (USFWS 2000).

Piping plover chicks are precocial, leave the nest almost immediately, and are able to feed themselves within a few hours. Adults will accompany the chicks and lead them to and from foraging locations, provide shelter during inclement weather, and attempt to protect them from predators (Wilcox 1959, Cairns 1982). Most adults raise only one brood of up to four chicks per nesting season. Upon the loss of eggs or newly hatched chicks, a pair may renest up to four times. Renesting efforts characteristically result in fewer than the typical four eggs being produced (Lingle 1988, USFWS 1988a).

Nesting is typically complete by July 31 (Sidle et al. 1992) and piping plovers begin fall migration in late July and August (Cairns 1982, Prindiville-Gaines and Ryan 1988).

Demographic Parameter Estimates

Information on survival is limited. Root et al. (1992) estimated mean adult survival in the northern Great Plains at 0.664 ± 0.057 (SE). With additional data, Larson et al.(2000) re-analyzed and revised the earlier estimate to 0.737 ± 0.092. Larson et al. (200) also estimated juvenile survival to be 0.318, however this estimate is likely biased downward for multiple reasons. Juvenile survival from the Atlantic Coast is somewhat higher (0.48; Melvin and Gibbs 1996).

Estimates of reproductive success, specifically fledge ratios, are variable and range from 0.3 to 1.5 fledglings per pair. In Nebraska, fledge ratio estimates range form 0.37 to 1.93. Fledge ratios should be interpreted cautiously. Kirsh (2001) was highly critical of estimates from Nebraska Public Power District and Central Public Power and Irrigation District (e.g. Peyton and Wilson 2000). Logistical constraints likely bias fledge ratio estimate including: 1) adults are not individually marked, 2) the colony is visited infrequently, and 3) the inability to monitor all young until they fledge (Erwin and Custer 1982) and 4) emigration/immigration of juvenile birds to non-natal colonies.

Table 2. Published estimates of Piping Plover fledge-ratios in Nebraska

YEAR	FLEDGE RATE	LOCATION	SOURCE
1986-1990	0.52	Central Platte River	Lingle 1993b
1991-2000	1.34	Central Platte River – gravel mines and artificial sandbars	Plettner 2000
1992	0.71	Lower Platte River – protected nests (fenced+exclosure)	Lackey 1994
1992	0.44	Lower Platte River – unprotected nests	Lackey 1994
1988-2000	0.37	NE - Fort Randall Dam to Niobrara	USACE 1998 and unpubl. data
1988-2000	0.51	NE - Lewis and Clark Lake	USACE 1998 and unpubl. data
1988-2000	0.75	NE - Gavin's Point Dam to Ponca	USACE 1998 and unpubl. data
1988-2000	0.70	NE – Combined Missouri. River Adj. to NE	USACE 1998 and unpubl. data
1992-2000	1.15	NE – Lake McConaughy	Peyton and Wilson 2000
1992-2000	1.07	Upper Platte River	Peyton and Wilson 2000
1999	0.73	Lower Platte River – gravel mines	Marcus 1999
2000	1.50	Lower Platte River – gravel mines	Marcus 2000
2001	1.93	Lower Platte River – gravel mines	Marcus 2001
2002	1.19	Lower Platte River – gravel mines	Held et al. 2002
2003	0.86	Lower Platte River – gravel mines	Held et al. 2003
2004	0.72	Lower Platte River – gravel mines	Held et al. 2004
2005	0.83	Lower Platte River – gravel mines	Held unpubl. data

Foraging

Piping plovers forage visually for invertebrates in shallow water and associated moist substrates (Cairns 1977, Cuthbert et al. 1999, Whyte 1985). Open, wet, sandy areas provide foraging areas. Along the Platte River, prey consists primarily of beetles and small soft-bodied invertebrates from the riverine waterline and opportunistically take prey from drier sites at sandpits (Lingle 1988).

Artificial and Alternative Habitat

As with least terns, piping plovers will use artificial habitats such as sandpits. Again, sandpits provide transitory habitat, and should not be considered a long-term alternative to riverine habitat. Others have concluded that “sandpits do not provide the full complement of essential elements for tern and plover reproduction, and is not a suitable substitute for riverine nesting habitat” (NRC 2005). Similarly the U.S. Fish and Wildlife Service (2002) stated that “sandpits are artificial and temporary in nature, not all of the necessary biological and physical features that are essential to the conservation of the species are present at sandpits” and “sandpits do not provide for piping plover recovery in the long term.” Sandpits are effectively biological sinks, even when intensive management efforts are employed. Fledge ratio estimates for piping plovers breeding at unmanaged sites have been well below levels required for population maintenance (Lackey 1994). Fledge ratio estimated to maintain numbers range from 1.13 to 2.0 fledgling per pair (Prindiville Gaines and Ryan 1988, Ryan et al. 1993, Plissner and Haig 2000, Larson et al. 2002, Melvin and Gibbs 1994). Even when intensive protection efforts that include nest predator exclosures, electric fences, and other techniques are utilized, fledge ratios are generally below the aforementioned levels required for population maintenance.

Reasons for low fledge rates at sandpits are complex, but may be associated with available food resources. Catch rates and density of invertebrates, the prey base for piping plovers, is higher for river channel habitat sites than gravel mines (Corn and Armbruster 1993). They also found that invertebrates are distributed more or less uniformly across riverine foraging habitat, but decline with increasing distance from the water's edge at sand pit locations. Research has found that invertebrate abundance also increased more dramatically over the course of the summer on riverine sites when compared to sand pit sites (Corn and Armbruster 1993). These patterns of invertebrate occurrence translated into greater foraging activity on river channel habitat sites even when birds nested off the river (Corn and Armbruster 1993b). Their research emphasizes the importance of river channel habitat for foraging. Lingle (1988) observed banded piping plovers known to be nesting at sandpits foraging 0.5-mile away in riverine habitat.

The issue of forage availability is critical to the survival and reproduction of piping plovers. Chick mortality is correlated with reduced growth rates (Cairns 1982), potentially a result of reduced prey availability. Piping plover chicks studied along the Atlantic coast typically tripled their weight during the first two weeks after hatching; and chicks that failed to achieve at least 60 percent of this weight gain by day 12 were unlikely to survive (USFWS 1996a). D. Catlin (Virginia Tech University, personal communication, August 2007) found that chicks with slower growth rates spend more time in the pre-fledge state, thus increasing the time they are vulnerable to predators.

Piping plovers will also use shorelines of reservoirs when water levels are sufficiently low and will use sandhill lakes. In Nebraska, uses of these locations is minimal compared to historical use of riverine sandbars. Lake McConaughy currently provides habitat and piping plover are utilizing the available habitat, but this is a temporary habitat that will be either overgrown or inundated.

Continuing Threats

Habitat Loss and Degradation - Since the early 1900s, habitat alteration and destruction from channelization, irrigation, and the construction of reservoirs on our nation's large river systems constitute the primary reason for the species' decline and current status according to the Recovery Plan. Bank stabilization via rock armoring, revetment and hard points and levee construction have also altered the river form and corresponding function. These alterations to the historic hydrograph have subdued the lower Platte River's capacity to build high sandbars and scour existing sandbars which is necessary for successful nesting.

Sediment and sediment movement in association with variable discharges are key components of sandbar habitat creation. In much of the piping plover's range, sediment had been reduced from flowing water as it settles out in reservoirs. Historical high flows, which are now tempered, are important to introduce and transport organic material from the floodplain to the river system. These over bank flows and resulting input of organic material support the system's productivity.

Human Disturbance - Human disturbance affects piping plover productivity (Massey and Atwood 1979, Goodrich 1982, Burger 1984, Dryer and Dryer 1985, Dirks and Higgins 1988, Schwalbach 1988, Mayer and Dryer 1990). Many rivers have become the focus of recreational activities, and sandbars provide popular areas. Human disturbance, particularly pedestrians, is frequently the key hurdle facing piping plover chicks and other shorebirds attempting to forage along the waters' edge (Elliot 1999, Fackelmann 1991, Rodgers and Smith 1995).

Carney and Sydeman (1999) conducted a literature review on the effects of human disturbance and found that human presence reduced reproductive success in *Charadriiformes*. Direct losses resulting from human presence include trampling under foot, crushing of nests by all-terrain vehicles, as well as predation by dogs. Rodgers and Smith (1997) studied flushing distances and energy expenditure for loafing, foraging, and flushed waterbirds. They concluded availability and access to disturbance-free foraging grounds may be as important as disturbance-free nesting sites.

Pollution/Contaminants - In the northern Great Plains Region, most of the nesting habitat used by the piping plover is surrounded by agriculture and/or urbanization. Proximity to these land uses puts nesting birds at risk of exposure to numerous fertilizers, pesticides, herbicides, and other chemicals found in agricultural and urban environments (Gilliom et al. 2006).

Fannin and Esmoil (1993) found that addled piping plover eggs collected from nests along the Platte River and adjacent sandpits had selenium and mercury concentrations elevated above background. They reported that selenium in particular may be causing embryo mortality without gross embryological defects being observed. They also reported that impacts of contaminants, combined with habitat degradation, may accelerate population declines.

Disease – Piping plovers are susceptible to disease just as all animals. Of concern is the potential for new viruses for which immunity is lacking to have significant impacts to populations with low numbers. West Nile Virus is a concern and has been confirmed in piping plovers and documented as the possible cause of death (USGS 2004).

Predation - Predation is a significant cause of mortality for piping plovers and includes many of the same predators as least terns. Predators include dogs or coyotes (*Canis latrans*), skunks (*Mephitis spp.*), raccoon (*Procyon lotor*), great-horned owls (*Bubo virginianus*), American crows (*Corvus brachyrhynchos*), great blue herons (*Ardea herodias*), barred owls (*Strix varia*), mink (*Mustela vison*), American kestrel (*Falco sparverius*), black-billed magpie (*Pica pica*), bull snake (*Pituophis melanoleucus sayi*), and garter snake (*Thamnophis spp.*) (Lingle (1993a, Renken and Smith 1995). Predation may occur at varying intensity if the river channel is not dynamic such that sandbars are only located in limited areas where predators learn of nesting activities and prey upon colonies annually. Additionally, sandpits present unique challenges as colonies are not isolated by flowing water and more easily subjected to different predators using adjacent terrestrial habitats.

Current Status

Preliminary results from the 2006 International Piping Plover Census suggest that the U.S. Great Plains/Canadian Prairie region had 4,700 birds, which could indicate an increase in this population. These numbers are not finalized, as data verification is not complete (Elliott-Smith 2007, personal communication).

Since 1987, the Commission has coordinated a standardized survey of all least tern and piping plover nesting along the lower Platte River, from Columbus to Plattsmouth, including both riverine and sandpit nests (See Environmental Baseline Section of this document). These counts indicate that Piping Plover numbers have declined markedly on the Lower Platte River, but numbers have remained relatively stable at sandpits. Kirsh (2001), using the same data concluded a negative “population” trend for the lower Platte River.

Recovery Plan

The Service finalized a recovery plan for the Great Lakes and Northern Great Plains Piping Plover in 1988 that established a recovery goal for the northern Great Plains piping plover population of 1,300 pairs (USFWS 1988a). The recovery plan states that the population must remain stable for a period of at least 15 years. The geographic goals in the recovery plan indicate that 1,300 pairs are to be distributed in the following locations.

Montana - 60 pairs
North Dakota - 650 pairs
    Missouri River - 100 pairs
    Missouri Coteau - 550 pairs
South Dakota -350 pairs
    Missouri River below Gavin’s Point - 250 pairs (shared with Nebraska)
    Other Missouri River sites - 75 pairs
    Other sites - 25 pairs
Nebraska - 465 pairs (including 250 pairs shared with South Dakota on the Missouri River)
    Platte River - 140 pairs
    Niobrara River - 50 pairs

Missouri River - 250 pairs
Loup River system - 25 pairs
Minnesota - 25 pairs at Lake of the Woods

The above recovery goals include 465 pairs of piping plovers to be maintained over a period of 15 years in Nebraska, including 165 pairs on the Platte River and its tributaries. The coordinated surveys to date have documented populations below these levels for Nebraska and the Platte River basin.

Population Viability Analyses of both Least Terns and Piping Plovers

Multiple Population Viability Analyses (PVAs) have been generated for interior populations of least tern and northern Great Plain's populations of piping plovers. PVAs are generally regarded as useful tools for assisting decision-making in endangered species management. At the same time, PVAs have been increasingly criticized for their severe limitations, uncertainty and misuse (Beissinger and Westphal 1998, Fieberg and Ellner 2000, Reed et al. 1998, McCarthy et al. 2003).

The foundation of PVAs are estimated values of vital rates. Examples of vital rates include estimates of survival and fecundity among other estimators. Estimates are often biased and have large variances. For instance, Kirsch (1992) used apparent nest success and this estimate has been used in multiple PVAs (Boyce et al. 2002, Reed 2003). Other studies suggest that apparent nest success generally is positively biased (Mayfield 1961, Johnson 2007). These earlier estimates need further refinement as only recently have methods been developed that enable researchers to produce minimally-biased estimates of nest success (Dinsmore et al. 2002, Rotella 2004). Moreover, least tern and piping plovers typically nest in colonies of varying size and density (Thompson et al. 1997). Estimates of nest success of colonial nesting birds are potentially biased due to a lack of independence of nest fates (Dinsmore and Dinsmore 2007).

Of even greater concern is the inadequate estimates of adult and juvenile survival. Indeed, virtually all studies which are focused on these two species have been relatively short-term in respect to the 10-20 years likely needed to precisely estimate these vital rates (Reed 2003, Beissinger and Westphal 1998). Further confounding available survival estimates is a limited understanding of dispersal for these two species. Lingle noted a philopatry (site fidelity) rate of 26% for least terns on the Platte River, which is relatively low. Dispersal (low site fidelity) often complicates survival analysis because it remains unknown whether marked individuals expired or moved outside the study area (Sandercock 2003). High rates of dispersal also confounds most stochastic PVAs because these models assume a closed population (Beissinger and Westphal 1998).

Vital rates, and in particular reproduction, are heavily influenced by environmental variation. Variation in the amount and quality of nesting habitat for these two species is potentially large from year to year. Kirsh (1992) noted large differences in fecundity at different sites along the Platte River during a relatively short time period. Quality and quantity of suitable habitat has declined over time which will influence vitial rates. Thus, PVA analyses based on older data will likely become obsolete.

Finally, the PVAs that have been created for these two species have not been validated. This is critical because several PVAs were discredited once predictions were tested or evaluated (Hitchcock and Gratto-Trevor 1997; Nichols et al. 1980, Ludwig 1998).

The value of PVAs is that they serve as a tool where the relative impacts of different management strategies can be evaluated. As Plissner and Haig (2000) point out, "population viability models do not serve as predictors of minimum viable population sizes, but rather they are useful as tools providing probabilities of relative success for developing and assessing alternative population management strategies."

Pallid Sturgeon (Scaphirhyncus albus)

The pallid sturgeon was federally listed as an endangered species on September 6, 1990 (USFWS 1990). Under Neb. Rev. Stat. § 37-806 any species determined to be threatened or endangered pursuant to the federal Endangered Species Act shall be similarly listed under the Nebraska Nongame and Endangered Species Conservation Act. The pallid sturgeon is an ancient fish species with five rows of scutes that run the entire length of the body. It possesses a spade-like rostrum, dorsoventrally flattened body, and tough skin. The sturgeons' reduced eyes and larger outer barbels are believed to be adaptations for feeding in turbid, sediment-laden waters (Keenlyne 1989). Pallid sturgeon and shovelnose sturgeon are very closely related and very similar in appearance, but genetics have confirmed they are separate species. Pflieger (1997) reported the principal morphologic features distinguishing pallid sturgeon from shovelnose are the relative lack of scutes on the belly. The pallid is typically lighter in color. Barbel length and relative position as well as the relative length of the rostrum also distinguish this species from the shovelnose sturgeon (Bailey and Cross 1954).

Distribution and Habitat

The pallid sturgeon is endemic to the Missouri River, the lower reaches of the Platte, Kansas, and Yellowstone rivers, the Mississippi River below the confluence with the Missouri River, including several major tributaries of the Mississippi including the Atchafalaya River, Yazoo/Bit Sunflower and St. Francis Rivers (Keenlyne 1989). The pallid sturgeon is believed to once have been fairly abundant before commercial over-harvest and habitat modification. In 1894 commercial fisherman reported harvesting 810 lbs of sturgeon in the Platte River and 7,136 lbs of sturgeon in the Missouri River bordering Nebraska (Brice 1896). These records indicate that sturgeon species were abundant and supported commercial fishing. Since the pallid sturgeon would not be recognized as a separate species until 1905 (Pflieger 1975), it is reasonable to assume that catch statistics for 1894 included pallid sturgeon. Forbes and Richardson (1905) estimated that pallid sturgeon comprised 1 in 5 river sturgeon collected in the lower Missouri River and Keenelyne (1989) reported that "correspondence and notes of researchers suggest that pallid sturgeon were still fairly common in many parts of the Mississippi and Missouri river systems as late as 1967."

Pallid sturgeon are well adapted to life on the bottom in swift waters of large, turbid, free-flowing rivers (Forbes and Richardson 1905, Kallemeyn 1983, and Gilbraith et al. 1988), with braided channels, dynamic flow patterns, flooding of terrestrial habitats and extensive microhabitat diversity (Mayden and Kuhajda 1997). Prior to management of the Missouri River for navigation, this river ecosystem was in a constant state of change, maintained by a variable dynamic intra- and interannual flow regime, ample sediment transport and interactions with the floodplains. The pallid sturgeon, along with many other native species, evolved a life cycle in sync with the ever changing dynamic system of this large river and its tributaries.

Today, these habitats and much of the previously functioning ecosystem have been changed by impoundments and channelization. The deep, high-velocity, single channel of the Missouri River from South Sioux City downstream was engineered for navigation purposes and is severely lacking in available habitat. As stated in the Pallid Sturgeon Recovery Plan (USFWS

1993) "destruction and alteration of habitats by human modification of the river system is believed to be the primary cause of declines in reproduction, growth and survival of pallid sturgeon."

Sturgeon are found in deep areas with swift current and turbidity (Bailey and Cross 1954, Erickson 1992), and pallid sturgeon inhabit higher velocity areas than the smaller and sympatric shovelnose sturgeon (Carlson et al 1985, Bramblett 1996). In the Missouri River in South Dakota, pallid sturgeon most frequently occupy river bottoms where velocity ranges from 0 to 0.73 m/s (Erickson 1992). Other studies in Montana found that pallid sturgeon are most frequently associated with water velocities ranging from 0.46 to 0.96 m/s (Clancey 1990). Bramblett (1996) noted pallid sturgeon occupying bottom velocities ranging from 0.0 to 1.37 m/s. During all seasons, pallid sturgeon used locations of high current velocity (0.5 - 1.5 m/sec) at the channel margin, near sand islands and off the ends of wingdikes, usually over a sand substrate (DeLonay and Rabeni 1998). Parham et al. (2005) found that the upper and lower quartiles of bottom velocity in nets that captured pallid sturgeon were from approximately 0.2 to 0.44 m/s with the median near 0.4 m/s in the lower Platte River. Snook (2001) found that pallids were using bottom velocities ranging from 0.17 to 0.97 m/s. Peters and Parham (2007) found that pallid sturgeon were most frequently captured in the deepest and swiftest pools, riffles and runs of the Platte River which averaged approximately 0.8 m/s.

Pallid sturgeon have been found using a variety of depths, which could be dependent on local conditions. Hurley (1996) found wild pallid sturgeon using depths between 1.8 and 19.1 m in the middle Mississippi River. In Montana, pallid sturgeon were captured from depths that ranged from 1.2 to 3.7 meters in the summer, but they were captured in deeper waters during winter (Clancey 1990). Other pallid sturgeon collected in the upper Missouri, Yellowstone and Platte rivers were captured in depths ranging from 1 to 7.6 meters (Watson and Stewart 1991, USFWS 1993). Bramblett (1996) found pallid sturgeon in depths ranging from 0.6 to 14.5 meters. Snook (2001) found pallid sturgeon to use depths from 0.15 to 1.89 meters in the lower Platte River, and Swigle (2003) found wild pallid sturgeon using habitat averaging 1.3 m in depth. Peters and Parham (2007) found pallids in an average depth of almost 1.6 m in the lower Platte River.

Pallid sturgeon appear to use areas with higher turbidity. Turbidity levels where pallid sturgeon have been found in South Dakota range from 31.3 Nephelometric turbidity units (NTU) to 137.6 NTU (Erickson 1992). Bramblett (1996) found the mean Secchi disc transparency was 7.8 inches at 115 pallid sturgeon locations in the upper Missouri and Yellowstone rivers.

Within large, highly altered river systems, sturgeon select areas of island tips, deep holes near wing bars and other areas where there is a sharp edge in depth such as the downstream end of chutes and in chutes. Snook (2001) found that pallid sturgeon substantially use the downstream edges of alluvial sand bars. It is believed that this habitat gradient provides refugia and/or feeding areas (Sheehan et al. 1998).

Temperature influences pallid sturgeon behavior and habitat use. They have been found in areas where the water temperature ranges from 0° C to 33°C. Swimming ability decreased and mortality increased for some river species below 4° C (Sheehan et al. 1998), so pallid sturgeon at these temperatures seek areas with warmer waters such as downstream island tips, areas below wingdikes, main channel, and the main channel border (Hurley 1996). When temperatures rose above 4° C, pallid sturgeon were restricted to the main channel border and main channel. As temperatures rose to between 10° C and 20° C, pallid sturgeon were increasingly relocated below wingdikes (Hurley 1996).

When evaluating substrates of pallid sturgeon habitat, they showed significant preferences for sandy substrates, and avoided gravel and cobble substrate (Bramblett 1996). Snook (2001) found similar results in the lower Platte River.

Foraging

Food habits of this species range from aquatic invertebrates to fish depending on life stage (Gerrity 2005, Gerrity et al. 2006, Wanner 2006). Carlson et al. (1985) reported that both shovelnose sturgeon and pallid sturgeon have a high incidence of aquatic invertebrates in their diet, but the pallid sturgeon had a greater proportion of fish (mostly *cyprinids*) than did shovelnose. Turbidity is likely a key component of successful foraging for the pallid sturgeon. Modde and Schmulbach (1977) found that pallid sturgeon could be expected to forage efficiently for fish and benthic invertebrates in highly turbid areas. Historically, the turbid environment caused by suspended sediment provided pallid sturgeon with cover while moving from one snag or undercut bank to another. Today in much of the pallid sturgeon's range, the water clarity has increase dramatically. Site-feeding predators such as northern pike and great blue heron may have a competitive advantage over species not equipped by evolution with good eyesight.

Adult pallid sturgeon are primarily piscivorous (Coker 1930, Carlson et al. 1985) and historically were said to rely on large-river minnows as their primary forage. Carlson et al. (1985) determined composition of food categories by volume and frequency of occurrence in the diet of shovelnose sturgeon (n=234), pallid sturgeon (n=9), and presumed hybrids (n=9). Aquatic invertebrates composed most of the diet of shovelnose sturgeon, while larger pallid sturgeon, and presumed hybrids, consumed a greater proportion of fish (mostly cyprinids). Other researchers also reported a higher incidence of fish in the diet of pallid sturgeon than in the diet of shovelnose sturgeon (Cross 1967; Held 1969, Gerrity 2005).

Reproduction

Pallid sturgeon are generally long-lived, and researchers have estimated pallid sturgeon longevity to be in excess of 40 years (USFWS 1993). Males do not become sexually mature until five to seven years of age, and between 533 – 584 mm TL (Fogle 1961) while females are nine to twelve-years-old before egg development begins and the first spawn may not occur until age thirteen to fifteen or 850 mm FL (Keenlyne and Jenkins 1993). It is suspected that these fish do not spawn annually (Keenlyne and Jenkins 1993).

Pallid sturgeon have been found to have mature gametes during seasons coinciding with natural high river flows (Keenlyne and Jenkins 1993) and likely spawn as early as April in the lower portion of their range and as late as June in the northern portion. In their natural environment, male pallid sturgeon may be capable of spawning annually while it may take up to 10 years between spawning events for females, with an individual female spawning only a few times during a normal life span (Keenlyne and Jenkins 1993). Recent data presented by Dave Herzog (Missouri Department of Conservation), at the pallid sturgeon Recovery Team meeting September 28 and 29, 2005 held in Lakewood, Co. suggest that pallid sturgeon may spawn over an extended period. This could be individual fish spawning at multiple times or individual pallid sturgeon within a locality spawning at different times.

The rarity and habitat of the pallid sturgeon have made documenting reproduction and spawning challenging, so limited information is available at this time. Currently, there are multi-state, collaborative efforts to learn basic parameters such as spawning locations, substrate preference, water temperature, and spawning time of year. Another source of general information for pallid sturgeon spawning is the similar shovelnose sturgeon. Given that the pallid and shovelnose sturgeon are known to hybridize, it can be inferred that spawning conditions and associated behaviors must be similar, at least in the highly modified system in existence today (Pflieger (1997).

The spawning cue is likely driven by a number of factors, most of which are tied high spring flows. These include temperature, turbidity, depth, velocity and changes in water chemistry. Higher flows in the spring cause an a) increase in temperature as water surface area increases relative to its volume; b) increase in turbidity as fine sediment and organic matter are contributed by the floodplain; and c) increases in nutrient cycling through similar mechanisms.

Pallid sturgeon hatcheries have determined that ideal spawning temperatures in the hatchery environment range from 15.5 to 18.5°C immediately prior to the spawning. The similar species shovelnose sturgeon are documented to spawn late in May through early June in Wisconsin when water temperatures were between 19 and 21 ^{o}C. (S. Krentz, USFWS, pers. comm. 2001, Christenson 1975)

The larvae drift downstream from the hatching site (Moyle and Cech 1982, Kynard et al. 2002). After a successful spawn, limited data suggest the downstream drift period for larval pallid sturgeon begins at hatching and continues for up to thirteen days, with a decline after day 8 (Kynard et al. 1998).

The pallid sturgeon is a highly mobile fish. Recent recaptures of stocked fish and telemetry results indicate that the pallid sturgeon is capable of large distance movements in a relatively short amount of time. A sturgeon captured at the confluence of the Platte and Missouri River on November 5, 2002 had been stocked at Boonville, MO on April 25, 2002 nearly 400 river miles away (Steffensen, personal communication 2007). It is also believed that sturgeon demonstrate spring spawning migrations. Initiation of pallid sturgeon spawning migrations has been associated with seasonal higher spring flows (Peterman 1977, Zakharyan 1972, Gilbraith et al. 1988) and potentially by rising water temperature (Peters and Parham 2007). Pallid sturgeon will migrate significant distances prior to spawning, suggesting segregation of spawning sites from home areas. In spring of 2007 two radio tagged, gravid, wild female pallid sturgeon were tracked in the Missouri River adjacent to Nebraska. A series of flow pulses resulting from natural runoff from the James River and Big Sioux River occurred in mid May, at which time both females demonstrated rapid upstream movement, followed by slower downstream movement. The females were recaptured and the field scientists confirmed that they had spawned in the upstream reaches of the lower Missouri River (USGS 2007).

There are observations of both sturgeon species migrating up tributaries of the Missouri River in the spring (Bramblett and White 2001, Peters and Parham 2007). Bramblett and White (2001) found that pallid sturgeon moved upstream into the Yellowstone River from the Missouri River in the spring and downstream again later in the year although the pallid sturgeon did use the Yellowstone River in the winter as well. They speculated that long-range spring and summer movements by both shovelnose and pallid sturgeon were associated with spawning activities.

There is also evidence that the lower Platte River is used by sturgeon species for spawning. On May 3, 2001 a wild female pallid sturgeon with late stage eggs was captured in the lower Platte River near Louisville (Peters and Parham 2007). This female sturgeon was implanted with a transmitter and tracked. The female remained in the general vicinity of Louisville until May 24. Until May 29, this fish moved at an average rate of 150 m/d, while from May 29 to June 9, 2001 it moved at an average downstream rate of 1,940 m/d until it entered the Missouri River. As a part of this study, larval sturgeon were caught on May 23, 2001 just prior to the time that this female moved downstream. The larvae collected from this study was determined to be *Scaphirhyncus*, but the specific species could not be determined as larval *Scaphirhyncus* must be greater then 1 inch (25.4 mm in length) to visually determine the species. Larval sturgeon were caught at several different locations, and in all but one case were in association with an increase in water temperature. Between 2000 and 2004, 11 sturgeon (*Scaphirhynchus* spp.) larvae were collected between May 15 and June 9. Reade (2000) collected three sturgeon larvae on May 26, 1999 and June 23 and 24, 1998. In addition, Hofpar (1997) collected one sturgeon larva on June 10, 1996 near Fremont, NE (RM 57). This confirms that sturgeon species use the lower Platte River for spawning in the spring.

In recent years, pallid sturgeon populations have been augmented by release of hatchery-reared fish. Since 1994, thousands of juvenile pallid sturgeons have been released. Despite stocking efforts, pallid sturgeon remain rare throughout their range, and low tag return rates have made it difficult to assess the success of the stocking program. Additionally, given the time it takes for pallid sturgeon to reach sexual maturity, it may take decades following stocking for pallid sturgeon to contribute to the population through spawning. It is important to note that in 1997, 401 pallid sturgeon were stocked into the Platte River at the Nebraska Highway 50 bridge. Sturgeon for this stocking were raised at the Blind Pony Fish Hatchery in Missouri and were tagged with external Floy tags (Zuerlein 2007, personal communication). In 1998, 84 age 6 pallid sturgeon from the same hatchery were released in the Platte River at Two Rivers State Recreation Area (RM 40) and were tagged with passive integrated transponder (PIT) tags and coded wire tags. Ten of these fish were also implanted with radio transmitters. In 1999, 15 age 7 pallid sturgeon were PIT tagged, coded wire tagged and implanted with radio transmitters and released into the Platte River at Two Rivers State Recreation Area (Snook 2001, Snook et al. 2002). During a study by Peters and Parham (2007) in the lower Platte River, each pallid sturgeon captured was evaluated, but none of these fish were originally stocked in the Platte River. The pallid sturgeon captured in this study were a mix of both wild and hatchery raised fish released at other locations. This indicates that both wild and stocked sturgeon from the

Missouri River are utilizing habitat in the lower Platte River. Telemetry evidence confirms that they are moving into and out of the Platte River from the Missouri River.

Continuing Threats

Habitat Loss - Habitat loss and alteration is believed to be the leading cause of decline of pallid sturgeon and continues to threaten its existence. Once a diverse assemblage of braided channels, sandbars, and backwaters, the Missouri River is now confined via bank stabilization and levee construction within a narrow channel of rather uniform width and swift current from Sioux City to Saint Louis, Missouri. Morris et al. (1968) found that channelization of the Missouri River reduced the surface area by approximately 67 percent. Funk and Robinson (1974) calculated that the length of the Missouri River between Rulo, Nebraska, and its mouth (~500 river miles) had been reduced by 8 percent and the water surface area had been reduced by 50 percent following channelization. Six mainstem dams on the Missouri River without fish passage facilities block pallid sturgeon migrations and have inundated historic spawning and nursery areas. The remaining mainstem riverine habitat between dams and downstream of the dams has been further altered by removal of snags, and hypolimnetic (i.e., year-round cold water) releases and an unnatural hydrograph. Similar impacts to the lower Platte River can be seen with reduced high flows and vegetation encroachment.

Sediment and sediment movement in association with variable discharges are key components of habitat creation in large river systems such as the Missouri, Mississippi and Platte rivers. In much of the pallid sturgeon's range, sediment had been reduced from flowing water as it settles out in reservoirs. Historical high flows, which are now tempered, are important to introduce and transport organic material from the floodplain to the river system which maintains turbidity and supports the system's productivity.

Elements of the natural hydrograph (i.e., magnitude, frequency, duration, timing and rate of change) are essential for many life requirements of native large-river fish like the pallid sturgeon and paddlefish. Throughout much of the pallid sturgeon's range, the natural hydrograph has been highly altered. Spring and early summer high flows have been shown to stimulate spawning activities of shovelnose sturgeon. Hesse and Mestl (1993b) showed significant negative relationships between indices of river discharges due to flood control actions in the spring and year class development for a number of native fish in the Missouri River. Invertebrate reproduction, secondary productivity and behavioral migration of fish are closely tied to the natural hydrograph (Hesse and Mestl 1993b).

Hydropeaking is another modification to the natural hydrograph. The lower Platte River, among other locations, is directly impacted by hydropower peaking operation on a regular basis. Hydropower peaking is the operation of hydropower generating facilities to concentrate power generation into certain timeframes, which in turn results in rapid, large magnitude, sub-daily flow fluctuation in the reach below the generating facility. These flows fluctuations on the river can impact water depth as dramatically as one to two feet during a peaking cycle (Figure 5).

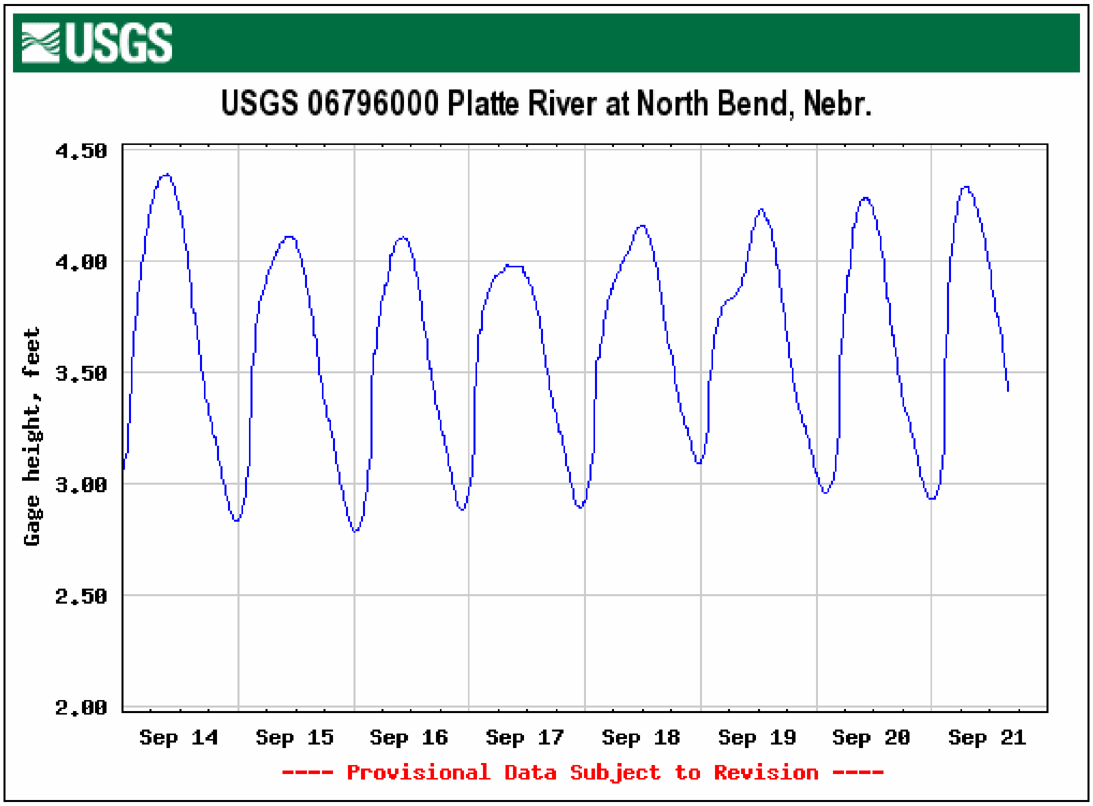


Figure 5. Platte River USGS Gage No 0679600 at North Bend showing fluctuations in gage height September 14-21, 2007, North Bend Gage 7 Day 09-21-07

Commercial Harvest - Sturgeon species, in general, are highly vulnerable to impacts from fishing mortality due to unusual combinations of morphology, habitats and life history characteristics (Boreman 1997). Historically, pallid, shovelnose, and lake sturgeon (*Acipenser fulvescens*) were commercially harvested on the Missouri and Mississippi rivers (Helms 1974). Commercial harvest of sturgeon was documented in the Platte River with 310 lbs of sturgeon taken in 1894 (Brice 1898). Five of the 13 states where pallid sturgeon occur, currently allow commercial fishing for shovelnose sturgeon. It is difficult to distinguish between pallid and shovelnose sturgeon, thus accidental commercial harvest is considered a major threat to the pallid sturgeon. However, surveys of anglers by Peters and Parham (2007) indicate that approximately 87% of sturgeon anglers can recognize the difference between the two species.

Pollution/Contaminants - Pollution is a likely threat to the pallid sturgeon over much of its range. Various fish-harvest and consumption advisories exist or have existed as a result of manmade pollution from the mouth of the Big Sioux River to the mouth of the Platte River, and from near Kansas City, Missouri, to the mouth of the Mississippi River.

Polychlorinated biphenyls (PCBs), cadmium, mercury, and selenium have been detected at elevated concentrations in tissue of three pallid sturgeon collected from the Missouri River in North Dakota and Nebraska. Detectable concentrations of chlordane, DDT (including its metabolites), and dieldrin were also found. The prolonged egg maturation cycle of the pallid sturgeon, combined with an inclination for certain contaminants to be concentrated in eggs, could make contaminants a likely agent adversely affecting development of eggs and embryos, or survival of fry, thereby reducing reproductive success (Ruelle and Keenlyne 1993).

The exposure and effects of environmental contaminants on pallid sturgeon in the lower Platte River were evaluated by using shovelnose sturgeon as a surrogate species (Schwarz et al., 2006). Gross observations and condition indices seem to indicate that shovelnose sturgeon from the lower Platte River are healthy; however, histological examination of the gonads and reproductive biomarkers revealed potential reproductive impairment as indicated by ovicular atresia, abnormal estrogen to testosterone ratios, and high concentrations of vitellogenin in males. Contaminants detected in shovelnose sturgeon at concentrations of concern included PCBs, selenium, and atrazine. The report concluded that these contaminants may be adversely affecting sturgeon reproduction in the lower Platte River and that pallid sturgeon may be especially at risk to these contaminants because they have a more piscivourus diet, greater maximum life-span, and a longer reproductive cycle than shovelnose sturgeon.

In the lower Platte River, the water treatment facilities of Lincoln and Omaha have potential to release pollutants into the river. During a telemetry study in April, 2004, Peters and Parham (2007) documented that pallid sturgeon that were being tracked moved out of the Platte River immediately following a back-flushing operation at the MUD water treatment plant which released an unknown white material into the river. According to NPDES Permit # 000906, MUD is authorized to discharges chemical in back-flushing operations.

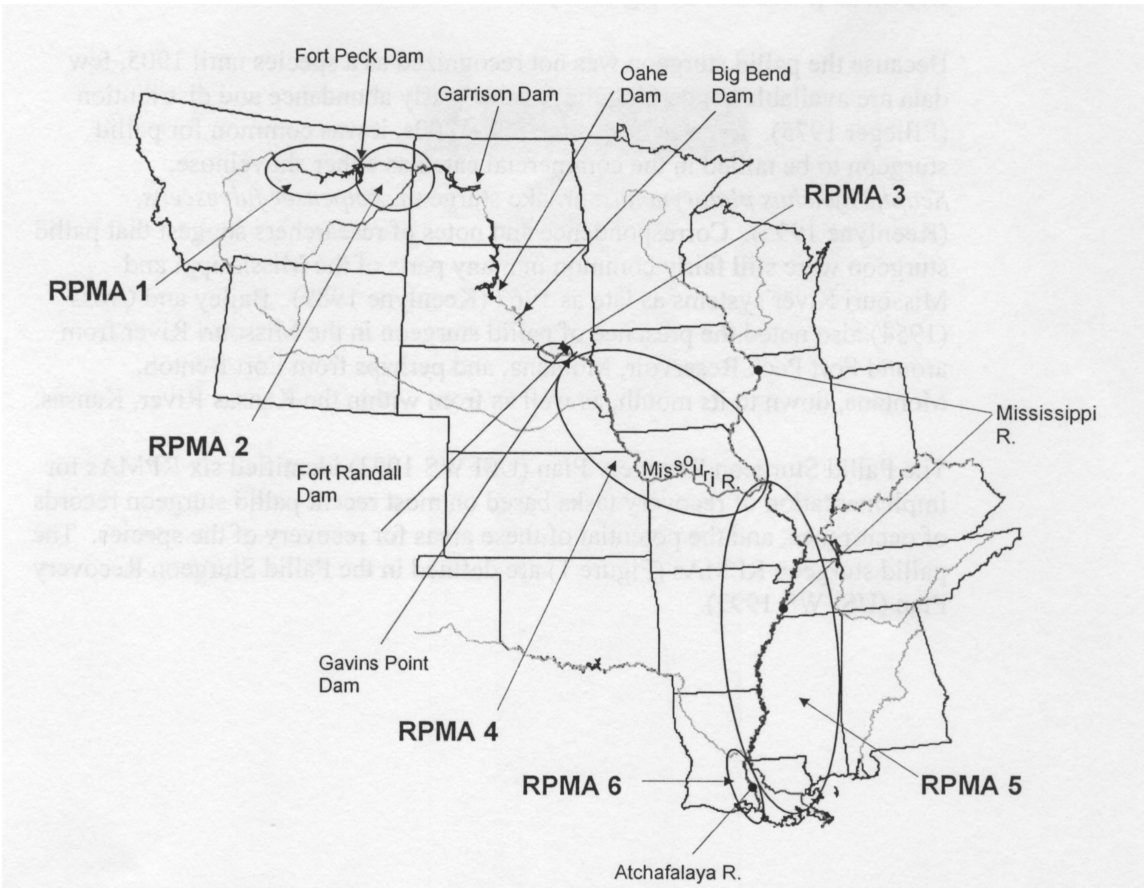
Hybridization – Hybridization is suspected to be a recent phenomenon that indicates limited habitat availability. Carlson et al. (1985) first identified that hybridization had occurred between pallid sturgeon and shovelnose sturgeon in the Missouri and middle Mississippi rivers. Suspected hybrids also have been reported in commercial catches from the lower Missouri River (USFWS 1993). As referenced in USFWS (1993), Bailey and Cross (1954) did not report hybrids, which may indicate hybridization is a recent phenomenon caused by man-induced reductions in habitat diversity and measurable changes in environmental variables such as turbidity, flow regimes, and substrate type (Carlson et al. 1985). Campton et al. (2000) collected data that support the hypothesis that pallid and shovelnose sturgeon are reproductively isolated in less-altered habitats, such as the upper Missouri River.

Hybridization is thought to be related to environmental degradation, because loss of habitat diversity inhibits reproductive isolating mechanisms among fishes, most of which have specific spawning requirements. Also, the loss of total available spawning habitat forces sharing of suitable habitat areas by similar species, resulting in increased hybridization.

Current Status

The distribution of pallid sturgeon stretches 3,515 miles of river through Montana, North Dakota, South Dakota, Nebraska, Iowa, Kansas, Missouri, Illinois, Kentucky, Tennessee, Arkansas, Mississippi and Louisiana. The U.S. Fish and Wildlife Service is committed to the recovery of the pallid sturgeon, and has divided its range into six recovery priority management areas (RPMA). The following discusses the current known status of the pallid sturgeon for each reach.

RPMA 1 is the Missouri River from the headwaters of Fort Peck Reservoir upstream to the confluence of the Marias River, Montana (Figure 6). According to the Pallid Sturgeon 5-Year Review, (USFWS 2007), the sturgeon population in this RPMA has remained relatively unchanged with 52 wild adult fish. The lack of smaller pallid sturgeon suggests that spawning, recruitment, or both are severely limited or absent within this reach. This area is sustained with a hatchery and stocking program.



RPMA 2 is the Missouri River below Fort Peck Dam to the headwaters of Lake Sakakawea and the lower Yellowstone River up to the confluence of the Tongue River, Montana. This population continues to decline. Small sturgeon are absent from this reach, suggesting that spawning and recruitment appear to be limited. This reach contains the Yellowstone River, a major tributary documented with the presence of pallid sturgeon. In 2007, Montana fisheries biologists implanted two gravid female pallid sturgeons, with radio tags and followed them. They found that the fish moved up into the Yellowstone River near Fairview and were surrounded by males that were similarly tracked. Upon recapture, they had spawned. Larval nets captured just hatched sturgeon. Additional studies are pending to determine if the larvae captured are pallid or shovelnose sturgeon, but this conclusively documents that sturgeon spawn in the Yellowstone River, and illustrates the importance of major tributaries of the Missouri River and their use as spawning habitat for sturgeon species (Henckel 2007).

RPMA 3 is the Missouri River from 20 miles upstream of the mouth of the Niobrara (Figure 6). No native wild population of pallid sturgeon are known to survive in this area, but there are hatchery stocked fish present. It appears that the population in this reach is surviving and growing. Additionally, two wild pallid sturgeon were caught in the mouth of the Niobrara River in 1964 and 1973 (Zuerlein, personal communication 2007).

RPMA 4 is the Missouri River downstream of Gavins Point Dam to the Missouri River/Mississippi River confluence. **This stretch includes the confluence with the Platte River.** Population trends in this stretch are not conclusive, but captures of all size classes indicates that hatchery fish are contributing to the population. There is also evidence of spawning in this reach. Three larval pallid sturgeon were collected in the Lisbon Chute, just off the Missouri River (Krentz 2000). Larval sturgeon, that could not be identified to species, were found just below Gavins Point Dam (Mestl, personal communication 2007) and in the Platte River (Peters and Parham 2007). In May of 2007, a female pallid sturgeon implanted with a radio transmitter, spawned just upstream of Ponca State Park, in a reach of river that is unchannelized and a second female spawned near the Big Sioux River in late April or early May (USGS 2007). A gravid female pallid sturgeon in the lower Platte River exhibited expected spawning migration and downstream movement (Peters and Parham 2007). However, smaller fish in this reach are of hatchery origin, so it appears that natural recruitment of pallid sturgeon is still limited in RPMA 4 (US Fish and Wildlife Service 2005).

RPMA 5 extends from the confluence of the Missouri and Mississippi River to the Gulf of Mexico (Figure 6). For this stretch, population trends and status remains unknown. Herzog et al. (2005) documented successful reproduction with the collection of larval pallid sturgeon in this reach. Smaller size classes captured indicate that some level of recruitment is likely occurring in this area.

RPMA 6 is the Atchafalaya distributary system to the Gulf of Mexico. Pallid sturgeon were not documented in this reach until 1991. Hybridization between shovelnose and pallid sturgeon is a problem, and status and trends are not conclusive at this time.

Recovery Plan

Due to the extreme rarity of pallid sturgeon and the large size of its range, capture information is extremely limited at this time. As a result, rangewide trends have been difficult to identify and monitor. The pallid sturgeon is a long-lived species, but as a consequence of the relative lack of known recruitment, natural mortality would cause a decline in numbers over time. The magnitude of this effect cannot be calculated at this time, and the success of hatchery programs may compensate to an unknown degree. The recent Pallid Sturgeon 5-year summary and evaluation (USFWS 2007) stated that “previously established down listing criteria are no longer relevant to a potential future down listing as written.” Each recovery priority management area is faced with problems beyond just total population numbers and male to female ratios. A self-sustaining population can not be maintained without adequately addressing identified threats. A revision of the recovery plan is suggested.

Environmental Baseline

The Platte River

The Platte River headwaters are in the Southern Rocky Mountains and the Wyoming Basin. It begins as two rivers: the North Platte River and South Platte River which converge near North Platte, Nebraska. The Platte River extends across Nebraska where it meets the Missouri River near Plattsmouth. This river system drains over 88,803 square miles (Galat et al. 2005). For the purposes of this report, the lower Platte River is considered to be the area beginning at the confluence of the Platte and Loup Rivers near the city of Columbus, Nebraska and extends downstream approximately 162 km to the Missouri River near Plattsmouth.

Historically, this river meandered across the state with wide shallow braided channels with shifting sand and gravel substrates. In pre-settlement times, the flows of the Platte River were highly influenced by snowmelt in the Rockies. In the late spring and early summer there would be higher discharge from snowmelt, interspersed with higher flows associated with rainfall events throughout the warmer months.

Specialized habitats such as backwaters, sloughs, side channels, and shoreline and deep water habitats along the edges of sandbars and river banks are examples of the diverse habitat types that occur along the Platte River. These varied features of the river provides year-round habitat for numerous species of plants, invertebrates, amphibians, fish and reptiles. The presence of the existing variety of habitats are a reflection of the highly dynamic hydrology of the Platte River system.

Today diversions and depletions from the system have reduced the flows and tempered flooding and ice flows that would have built high sandbars and maintained the open sandbar habitat, such that very little remains. The Platte River basin was originally dominated by grasslands (Galat et al. 2005a, NRC 2005), but today approximately 90% of the land area is used for agricultural production. Irrigated agriculture in the central and lower sub-basins of the Platte River in Nebraska consumes 1,366,400 acre-feet of surface water each year (NRC 2005). The majority of this water is used to grow corn. Due to reduced river flows, much of the Platte River is now narrower with densely vegetated islands. The diversity of habitats mentioned above is much reduced. There are five main-stem dams on the North Platte River. The effects and impacts of these dams are difficult to quantify, but they alter water temperatures below the dams by releasing colder water and altering the hydrograph. They also reduce sediment transport. Evidence of Lake McConaughy's impacts is apparent from flow records. Prior to 1943 (1896-1942), at North Platte, the North Platte River averaged 2,616.8 cfs, but since has averaged 741.6 cfs (Galat et al. 2005). Lake McConaughy was filled in 1943, just upstream of this location.

The lower Platte River still has some geomorphological characteristics similar to those of the historic Platte River, largely due to the influence from large tributaries. The lower Platte River is a mid-size, shallow, braided river with sandbars and islands. The width in some downstream areas has remained relatively constant with approximately 90 percent of the width remaining (Eschner et al.1983). This is in contrast to the narrowing of the active channel that has occurred at upstream sites. Mussetter (2002) reported that along the reach bordered by the Sarpy County levee, a decline of 30-40 percent of stream width had occurred between 1859 and 1985. Land-use changes within the flood plain as well as hydrologic changes are likely both contributing factors in alterations of the active channel.

The lower Platte River's hydrograph and base flow benefit from the influence of the groundwater fed Loup and Elkhorn rivers, which are considered to have some of the most stable flows when compared to rivers worldwide (Bentall 1989). Salt Creek is also a large tributary to the lower Platte River. The flows from these large tributaries are a key component of the more stable, higher flows, and more natural stream characteristics seen in the lower Platte River, relative to the rest of the Platte River (Figure 7). However, this stretch of river should not be considered unaltered or pristine. It has been highly altered due to decreased base flows, decreased flood events, residential flood control levees, bank stabilization, timber encroachment and other development along its banks over time.

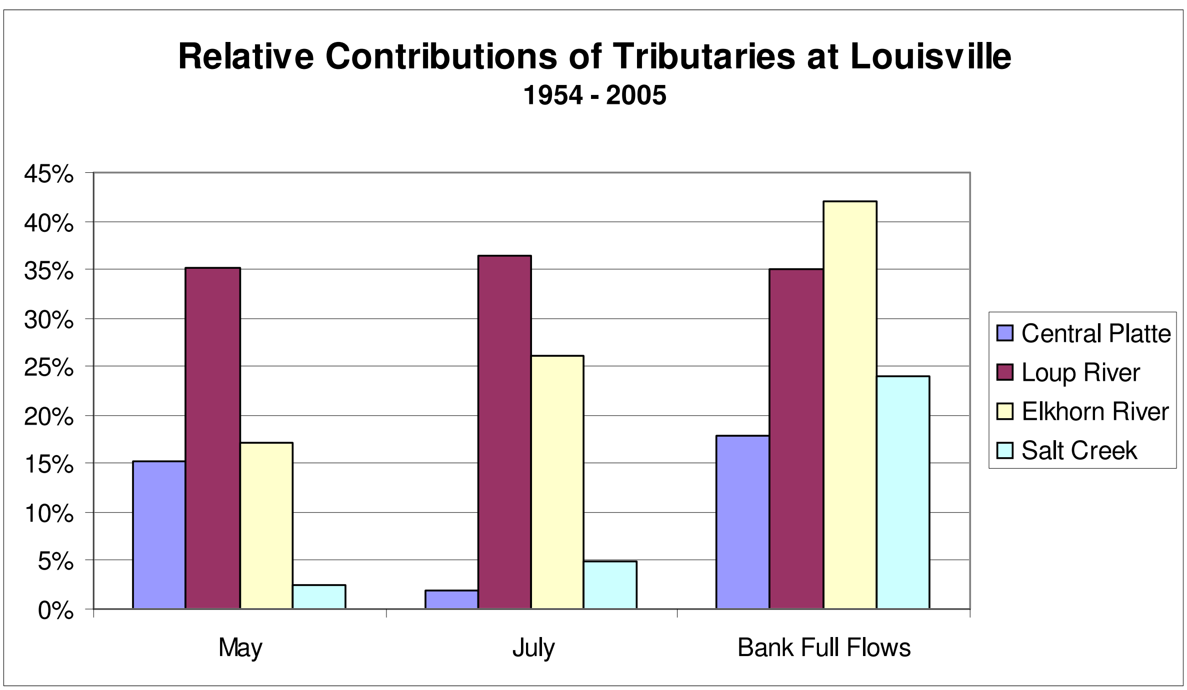


Figure 7: The relative contributions of the larger tributaries to the lower Platte River. May and July statistics were based on the 80% exceedance flows (flows you expect to see in 8 out of 10 years) for the period or record 1954-2005. Bank full flows are based on the 1.5 year bank full flows, representing higher flow events.

The lower Platte River has water temperatures that range from near 0 °C in January (Peters et al. 1989) to temperatures over 40 °C recorded in June, July, and August. USGS records document typical pH values of 8.0, alkalinity of 153.5 mg $CaCO_3$/L, nitrate nitrogen of 1.35 mg/L and phosphate phosphorous of 0.73 mg/L (Galat et al. 2005a). In summer months, water temperatures increase with a decrease in discharge.

Evidence of the reduced flows from the central Platte River can be seen at a USGS gage near Duncan which is just upstream of the Loup confluence. Figure 8 illustrates how the hydrograph has changed drastically with development of the Platte River upstream from the Duncan gage. A smaller spring flood in March followed by a larger pulse in May and June were characteristically observed in records prior to 1910. More recent data suggests a highly altered hydrograph with little to no flood pulse.

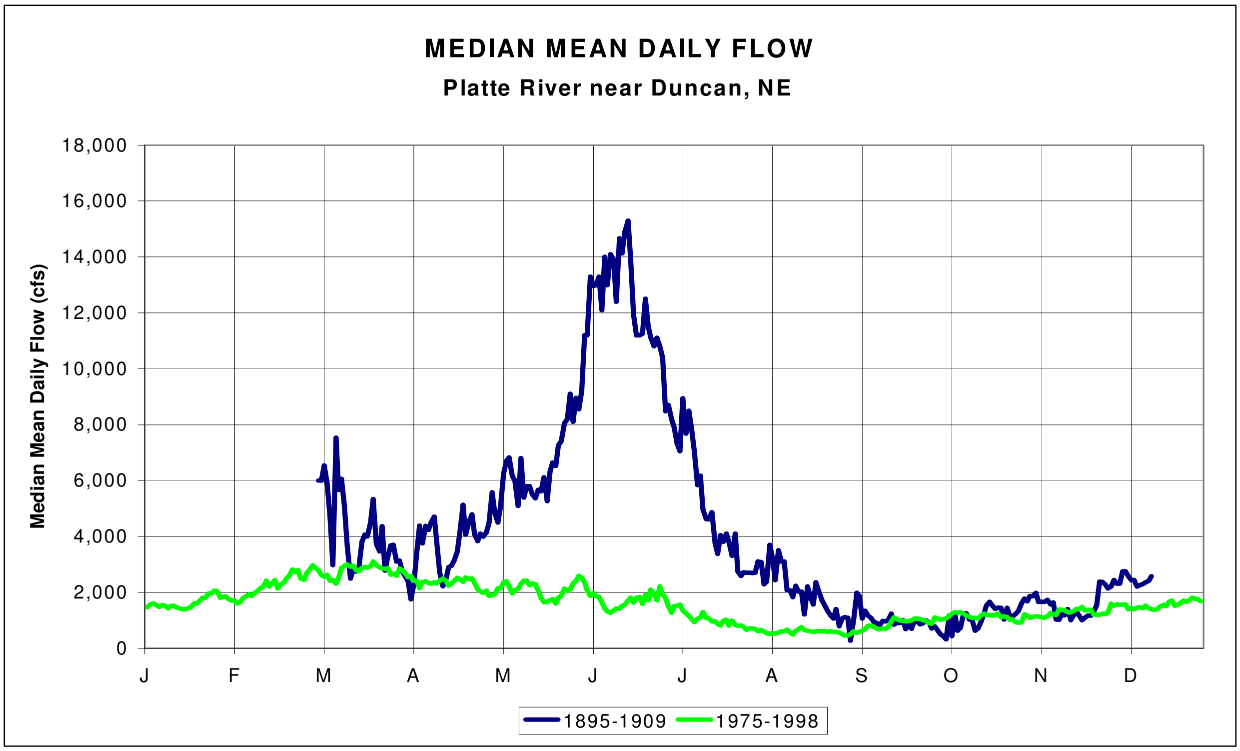


Figure 8: Median mean daily flow in the Platte River at Duncan, Nebraska, in 1895-1909 vs. 1975-98. (Source: USGS gage data, as presented in Platte River FEIS (2006)).

To understand the current status of the central Platte River at Duncan, statistics were generated from January 1, 1954 to December 31, 2005. At this location, the annual median flow was 1,250 cfs. The river flow was zero (dry) 3% of the time, and this most often occurred in August and September. For annual peak flows, the Platte River near Duncan exceeded 4,280 cfs in 8 out of 10 years, 7,000 cfs in 5 out of 10 years, and 13,800 cfs in 2 out of 10 years. The monthly flows that occur 80% of the time are displayed in Figure 9. Every 1.5 years there was a small flood event that approached a peak of 7130 cfs lasting 32 days and was centered in late May. Once every ten years a large flood would peak in late April near 22,500 cfs and last nearly 2 months (54 days) from beginning rise to return to low stable flow conditions. A description based on the median Environmental Flow Characteristics (EFC) at this location resulted in the river as having the highest stable flows in March (1,618 cfs) dropping to lows in August (259 cfs) and with little change in discharge between October and January (1,000 cfs to 1,100 cfs). The Coefficient of Dispersion (CD) is an index that illustrates whether the river is rising and falling with a "natural pattern," with values closer to 1 being "natural" (additional information will be provided with final Parham report). Flows from the central Platte have a relatively normal pattern in March and April with values as high as 0.7 and 0.9 respectively. However in July and August CD values are 2.6 and 3.3 respectively, meaning that the drop in water levels is likely due to withdrawals upstream, not from natural variation. This index does not take into account the historic hydrograph prior to 1954. The Low to Median Flow Ratio (LMR) is an index that provides a measurement of base flow (groundwater) as opposed to runoff. The LMR value at Duncan was 0.34 in March and dropped to 0.0 in July and August, meaning in early spring 1/3 of the flows in the river were due to groundwater, but that in mid summer, only runnoff events provide flows at this location (Table 3). On an annual basis, the base flow was estimated to be 3% of the mean flow (Parham 2007).

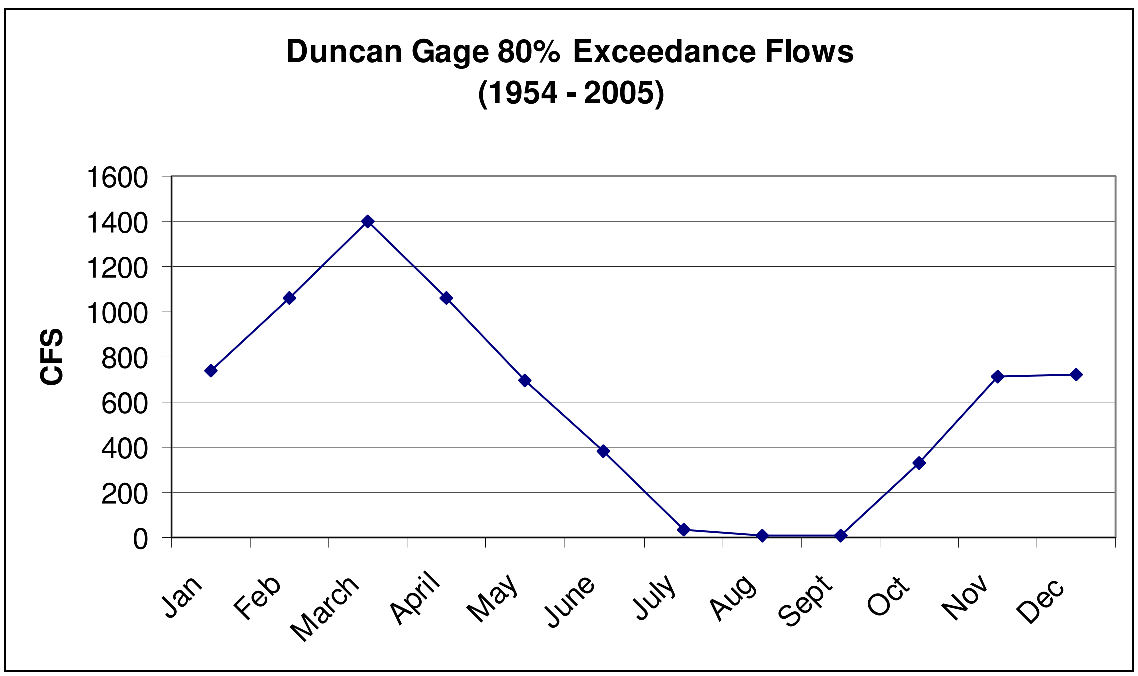


Figure 9: Flows at the Duncan Gage based on the 1954 – 2005 period of record expected to occur 8 out of every 10 years (80% exceedance flows)

Table 3: Coefficient of Dispersion (CD) and Low to Median Flow Ratio (LMR) at the Duncan Gage (January 1, 1954 to December 31, 2005).

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
CD	0.96	0.89	0.74	0.87	1.38	2.17	2.6	3.26	3.3	1.57	1.09	0.97
LMR	0.35	0.35	0.34	0.31	0.17	0.04	0	0	0	0	0.1	0.28

Tributaries to the Lower Platte

Loup River- The Loup River basin is defined as the area of central Nebraska that drains into the Loup River above its confluence with the Platte River. The total basin area includes approximately 15,200 square miles. Major tributaries of the Loup River include Beaver Creek, the Calamus River, the Cedar River, the Dismal River, Mud Creek, the Middle Loup River, the North Loup River, and the South Loup River. Baseflow in the streams in this basin are supplied primarily by ground water discharge with additional contributions from precipitation.

Although the source of water in these streams is relatively consistent, development has impacted Loup Basin flows. There are approximately 15,824 registered wells as of October 1, 2005, and 1,200 surface water appropriations (DNR 2006). The number of new wells and surface water appropriations has grown steadily over the last 20 years, and it is reasonable to expect this trend to continue. The impacts of current water use has not been fully realized due to lag effects. According to the 2006 DNR Annual Report, the lag impact from depletive ground water wells within the legally defined hydrologically connected aquifer, shows that an additional 95 cubic feet per second of daily depletion can be expected from the Basin due to the effect of lag impact from existing wells. In addition to consumptive use, water is being diverted through a series of surface water canals, including the Burwell-Sumter Canal, Farwell Main Canal, Farwell South Canal, Middle Loup Canals, Mirdan Canal, Ord-North Loup Canal, Sargent Canal, Taylor-Ord Canal and the Loup Power Canal.

The annual median flow for the Loup River near Genoa was 120 cfs (for the period of record 1954 – 2005). The flows were zero about 1% of the time. Annual peak flows for the Loup River near Genoa exceeded 6,060 cfs in 8 out of 10 years, 8,880 cfs in 5 out of 10 years, and 16,200 cfs in 2 out of 10 years. Every other year there would be a small flood event that would approach 12,500 cfs lasting 23 days and centered in early May. Once every ten years a large flood would peak in mid June near 38,600 cfs and last 3 weeks from beginning rise to return to low stable flow conditions. This gage is downstream of the intake for the Loup Power Canal, and therefore is influenced by both seasonal flow and the amount of water necessary for power production.

The Loup River Power Canal returns flows to the Platte River approximately 1-2 miles downstream of where the Loup River itself enters the system. The Loup River Power Canal withdrew an annual median flow of 1,800 cfs. Most months the median flow was between 1,200 and 1,900 cfs. This gage reflects a highly modified system, so fewer statistics were generated for this gage.

Contributions of the Loup River System to the lower Platte River can be seen at the gage near North Bend, which is the first gage site downstream of the Loup River confluence. The annual median flow was 3,630 cfs. There were no days with zero flow for the period of record (1954 – 2005). The monthly flows that occur 80 percent of the time are displayed in Figure 10. Every 1.5 years there would be a small flood event that would approach 21,280 cfs lasting 35 days and was centered in mid May. Once every ten years a large flood would peak in late April near 64,900 cfs and last nearly 1.5 months (46 days) from beginning rise to return to low stable flow conditions. The median Environmental Flow Characteristics (EFC) for the lower Platte River near North Bend, NE described the river as having the highest stable flows in March and April (near 4,300 cfs) dropping to lows in August (1,815 cfs) and with another peak in November (3,545 cfs). At this location the CD value was 0.6 in March and 1.3 in July, indicating much more natural fluctuations when compared to the Duncan site. The most stable flows were in March and April. LMR values ranged from 0.54 in March to 0.26 in August, meaning that in March just over half of the flows were from groundwater (baseflow). Annually, baseflow was 19% (Parham 2007). Currently, in the drier summer months, most of the flows after the North Bend gage comes from the Loup River system and the Elkhorn River. The Loup River, on average, contributes 34% of the discharge annually for the lower Platte River, (Peters and Parham 2007).

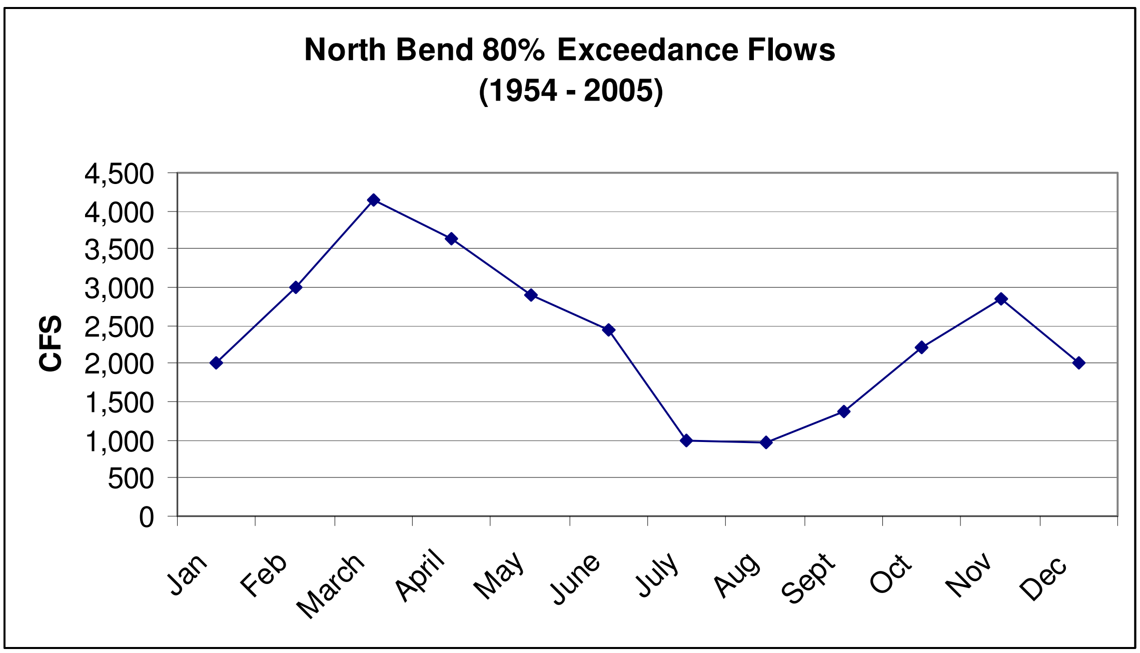


Figure 10: Flows at the North Bend Gage that occur 8 out of 10 years for the period of record from 1954 – 2005 (80% Exceedance Flows).

Table 4: Coefficient of Dispersion (CD) and Low to Median Flow Ratio (LMR) at the North Bend Gage (January 1, 1954 to December 31, 2005).

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
CD	0.77	0.66	0.6	0.6	0.86	1.3	1.3	1.16	0.93	0.73	0.5	0.74
LMR	0.39	0.45	0.54	0.56	0.46	0.4	0.22	0.26	0.37	0.51	0.52	0.32

Hydrocycling

The Loup Public Power District (LPPD) has a hydropower station near Columbus, Nebraska that utilizes water diverted from the Loup River. LPPD has been generating hydropower since March 5th, 1937. The Loup River near Genoa (USGS gage location) has highly modified flow characteristics since it is downstream of the intake for the Loup Power Canal. Loup Public Power (LPPD) utilizes a form of hydropeaking to generate power, where water is stored and passed through the station into lower-lying watercourses. This leads to frequent, regular alteration between rising and falling flow rates which differs fundamentally from the natural flow regime (Figure 11). Hydropeaking impacts the hydraulics of the system through rapid and significant changes in discharge, velocity and bed stress. It also impacts the chemical and physical water quality as the diurnal cycle of turbidity and temperature is impacted, and the morphology of the river is also altered through changes to the sediment load. The two terms hydrocycling or hydropeaking may have different definitions, but the impacts of frequent fluctuations in the flow regime remain significant to the riverine ecosystem, regardless of the definition used.

The preponderance of research in other river systems affected by hydropeaking clearly describes impacts to various biological resources. Aquatic invertebrates and terrestrial invertebrates that use gravel bars, and native fish populations have been documented to be impacted by hydropeaking (Gersich and Brusven 1981, Danks 1991, Cereghino and Lavandier 1998, Cereghino et al. 2002, Van Looy et al. 2007, Troelstrup and Hergenrader 1990, Freeman et al. 2001). Results in the lower Platte River (Peters et al. 1989) report that macroinvertebrate colonization and production along hard materials and woody and plant debris was impacted by repeating water level fluctuations as occurs with diel discharges from LPPD hydropeaking activities.

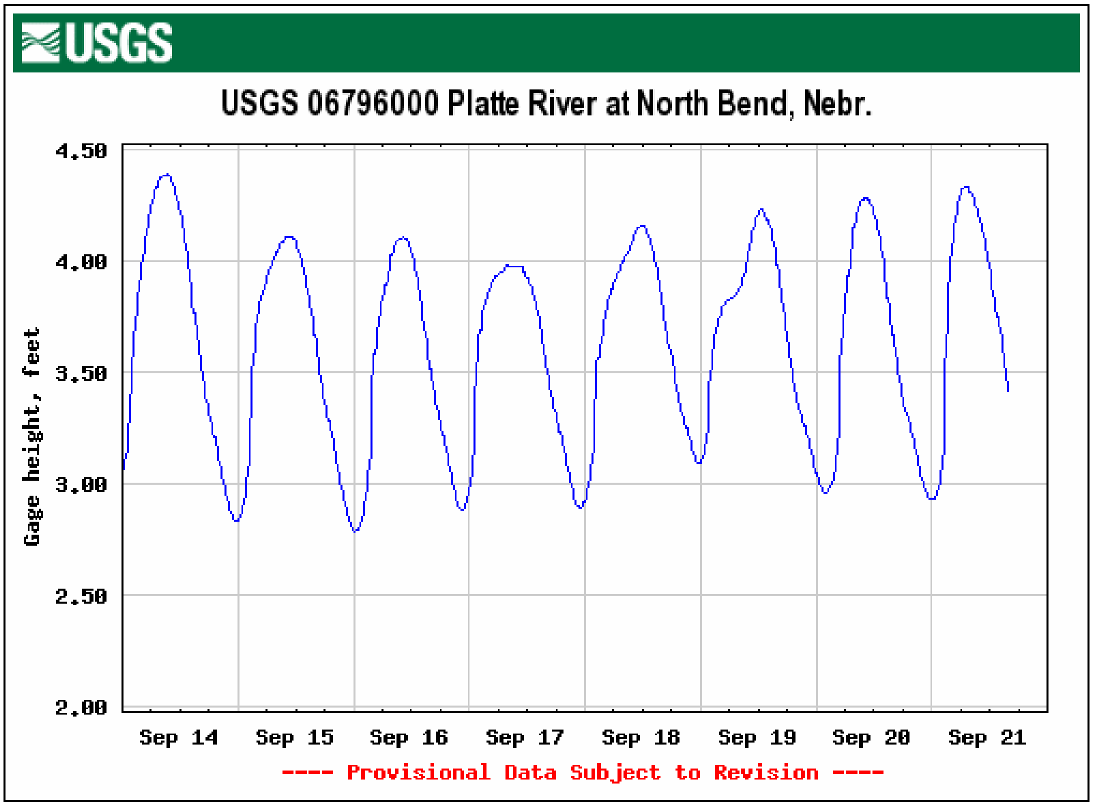


Figure 11. Platte River USGS Gage No 0679600 at North Bend showing fluctuations in gage height September 14-21, 2007, North Bend Gage 7 Day 09-21-07

The severity of impacts to early life stages of fish, and to those species most immediately available to least terns and pallid sturgeon, is of particular concern. Hydrocycling exacerbates these affects on fish and macroinvertebrates by introducing a fluctuating hydrograph on a daily basis that alternately floods and dewaters areas of the active channel. In studies in the lower Platter River, macroinvertebrate colonization and subsequent densities of such fluctuating zones has been shown to be significantly reduced when compared to areas of stable inundation. During the parts of the daily hydrocycle where water releases are shut off, the reduced water flow will recede from bank lines leaving mainly areas of inundated sand habitats which have relatively low productivity levels of macroinvertebrates. Due to the rapid fluctuation in water levels associated with hydrocycling, many fish become isolated into disconnected backwaters, pools and channels that are susceptible to water quality changes, susceptibility to disease and increased predation. Overall, effects of hydrocycling operation on the reproductive success of the fish community are generally negative and most pronounced from mid-spring through the summer.

The availability of invertebrates supported by moist riverine sandbar habitat is important to piping plovers nesting along the central Platte River, whether the plovers are nesting on river sandbars or on adjacent sandpits. As a result, there exists significant potential for adverse impacts. As mentioned in the species status section of this document, piping plovers forage visually for invertebrates in very shallow water associated with moist substrates. Evidence suggests that hydropeaking decreases the number of taxa and density of invertebrates in shallow water and that some taxa such as ephemoptera and trichoptera are extremely intolerant to the diel fluctuations (Troelstrup and Hergenrader 1990).

Sandbars are fundamental to least tern and piping plover nesting. The practice of hydrocycling raises water levels in a cyclic pattern and potentially inundates areas of sandbars that might otherwise provide tern and plover nesting habitat under an appropriate flow regime. Hydropeaking may also expedite sandbar erosion. Several kinds of fluvial processes can destabilize/erode sandbars. Erosion is caused by *shear stresses exerted by river flows* and corresponding entrainment of sediment, and by the erosive effect that *wave action* can have on sandbars (Bauer and Schmidt, 1993). A third sandbar erosion process is driven by *groundwater fluctuations* resulting from short-term changes in river stage (e.g., during hydrocycling). Studies of sand beaches/bars along the Colorado River in Arizona below Glen Canyon Dam suggest that these features are prone to erosional episodes that occur over a matter of hours and are associated with dam operations, including the diurnal hydropeaking of flows (Werrel et al., 1991; Dexter and Cluer, 1999).

LPPD has a water right to divert up to 3,500 cfs of flow from the Loup River above Genoa into their canal system headworks (located roughly 25 miles upstream of Columbus). According to an agreement between LPPD and the Commission, LPPD always passes a minimum of 50-100 cfs of Loup River flow past their point of diversion. However, it is relatively rare for flows of 3,500 cfs to be available at their point of diversion (perhaps only 10-20 days in a typical year). Thus, the majority of the year, LPPD is diverting all but 50-100 cfs of the Loup River flow. LPPD’s average annual intake at the headworks is estimated to be 2,200 cfs.

The hydropower operation also has significant impacts to the amount of sediment that passes down the river, which is an important component of the river ecosystem. Due to the reduced velocity of diverted flow, the suspended sediment carried by the Loup River quickly settles out in LPPD’s canal system, beginning immediately below their headworks along a two-mile-long settling basin. An annual dredging operation removes sediment from the canal system and piles the sediment (mostly medium to fine sand) on adjacent lands.

<u>Elkhorn</u> - The Elkhorn River is located in northeast and north-central Nebraska and joins the Platte River near Gretna. The Elkhorn River Basin includes approximately 7,000 square miles. Major tributaries to the Elkhorn River includes the South and North Forks of the Elkhorn River, Logan Creek and Maple Creek. The flows of the Elkhorn River are largely uncontrolled by reservoirs. Baseflow in this basin is driven by groundwater discharge, with the punctuated spikes in flow by the addition of precipitation. Based on National Wetland Inventory data, there are more than 26,000 acres of wetlands associated with the Elkhorn River (LaGrange 2005).

Portions of this basin are highly developed. There are 12,441 registered ground water wells and 550 surface water appropriations as of October 1, 2005 (DNR 2006). Calculations of the lag effect estimated that an additional 40 cfs of daily depletion will occur in this Basin with no additional wells. Although some areas of this basin have limited potential for additional wells due to the geology of the area, based on current trends, it is probably reasonable to expect additional ground water and surface water use in the basin.

The Elkhorn River is the second largest tributary of the lower Platte River. On an annual basis, the median flow of the Elkhorn River near Waterloo (gage on the Elkhorn River) was 861 cfs. Median monthly flows in the Elkhorn River were highest from March to June with the peak in

June at 1,620 cfs. Figure 12 displays the flows that occur 80% of the time. Every 1.5 years there would be a small flood event that would approach 16,700 cfs lasting 35 days and centered in early June. Once every ten years a large flood would peak in early April near 41,000 cfs and last nearly 50 days from beginning rise to return to low stable flow conditions. The median Environmental Flow Characteristics (EFC) described the river as having the highest stable flows in April (1,040 cfs) dropping to lows in September (503 cfs) and not rising substantially until the following March. The coefficient of dispersion (CD) and LMR suggested a stable base flow and a river that is rising and falling in a relatively natural fashion. The CD had values around 0.9 to 1.6, which relative to other locations along the lower Platte River, remain close 1. The LMR had values of 0.28 in July to 0.47 in October suggesting that consistently there is base flow from groundwater. Table 5 displays the monthly CD and LMR from the Waterloo Gage. On an annual basis, the base flow was estimated to be 26% of the mean flow.

Table 5: Coefficient of Dispersion (CD) and Low to Median Flow Ratio (LMR) at the Waterloo Gage (January 1, 1954 to December 31, 2005).

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
CD	0.93	1.11	1.09	1.32	1.3	1.59	1.22	0.94	0.98	0.94	0.8	0.83
LMR	0.45	0.33	0.37	0.46	0.34	0.29	0.28	0.33	0.38	0.47	0.46	0.41

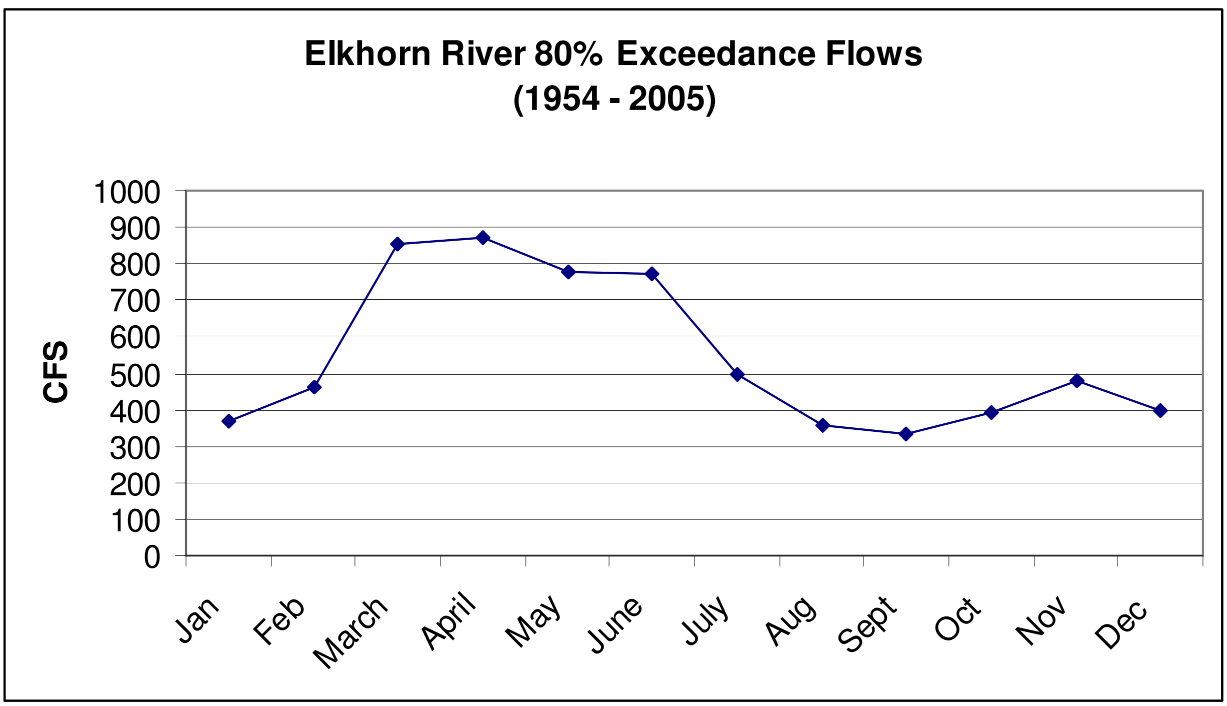


Figure 12: Elkhorn River (Waterloo Gage) flows that occur 8 out of 10 years based on the period of record from 1954 – 2005 (80% exceedance flows).

<u>Salt Creek</u> - The Salt Creek basin drains 1,645 square mile of southeastern Nebraska, encompassing the City of Lincoln. This basin is highly developed and contains ten artificial flood control Salt Creek Reservoirs which create 4,289 surface acres of water. Salt Creek begins

south and west of Lincoln as a meandering stream, but becomes channelized as it wraps through the city. Lincoln also discharges treated sewage water into this creek and all run-off from streets discharge into the system. Major tributaries include the Little Salt Creek, Oak Creek, Wahoo Creek and Rock Creek. This area is dominated by urban development and agriculture. Wetlands associated with Salt Creek are mostly saline; however some freshwater wetlands are also present. A categorization project for the eastern saline wetlands indicated that there were 3,244 acres remaining, but many of these wetlands are highly degraded. The source of the salinity is not understood, but it's postulated that groundwater inflow passes through a rock formation containing salts deposited by an ancient sea (LaGrange et al. 2003)

Salt Creek is the largest tributary of the lower Platte River that drains into the river from the South. It is much smaller than the Loup or Elkhorn rivers with an annual median flow of 146 cfs at the Greenwood gage. The flows that occur 80 percent of the time are displayed in Figure 13. Every 1.5 years there would be a small flood event that would approach 9520 cfs lasting 20.5 days and centered in late June. Once every ten years a large flood would peak in early July near 33,750 cfs and last nearly 78 days from beginning rise to return to low stable flow conditions. The median Environmental Flow Characteristics (EFC) for Salt Creek near Greenwood, NE described the river as having relatively stable flows all year ranging from a high of 168 cfs in March to a low of 99 in October. On an annual basis, the base flow was estimated to be 27% of the mean flow. The CD index ranges from 0.65 to 1.8 indicating that there is some fluctuation, but is rising and falling in a relatively natural fashion. The LMR remains relatively stable. Table 6 displays the CD and LMR values from the Greenwood Gage on Salt Creek. Annually, the base flow was estimated to be 27% of the mean flow.

Table 6: Coefficient of Dispersion (CD) and Low to Median Flow Ratio (LMR) at the Greenwood Gage Gage (January 1, 1954 to December 31, 2005).

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
CD	0.83	0.94	1.07	1.27	1.73	1.8	1.24	0.89	0.83	0.83	0.74	0.65
LMR	0.33	0.36	0.36	0.39	0.29	0.32	0.33	0.44	0.41	0.44	0.47	0.43

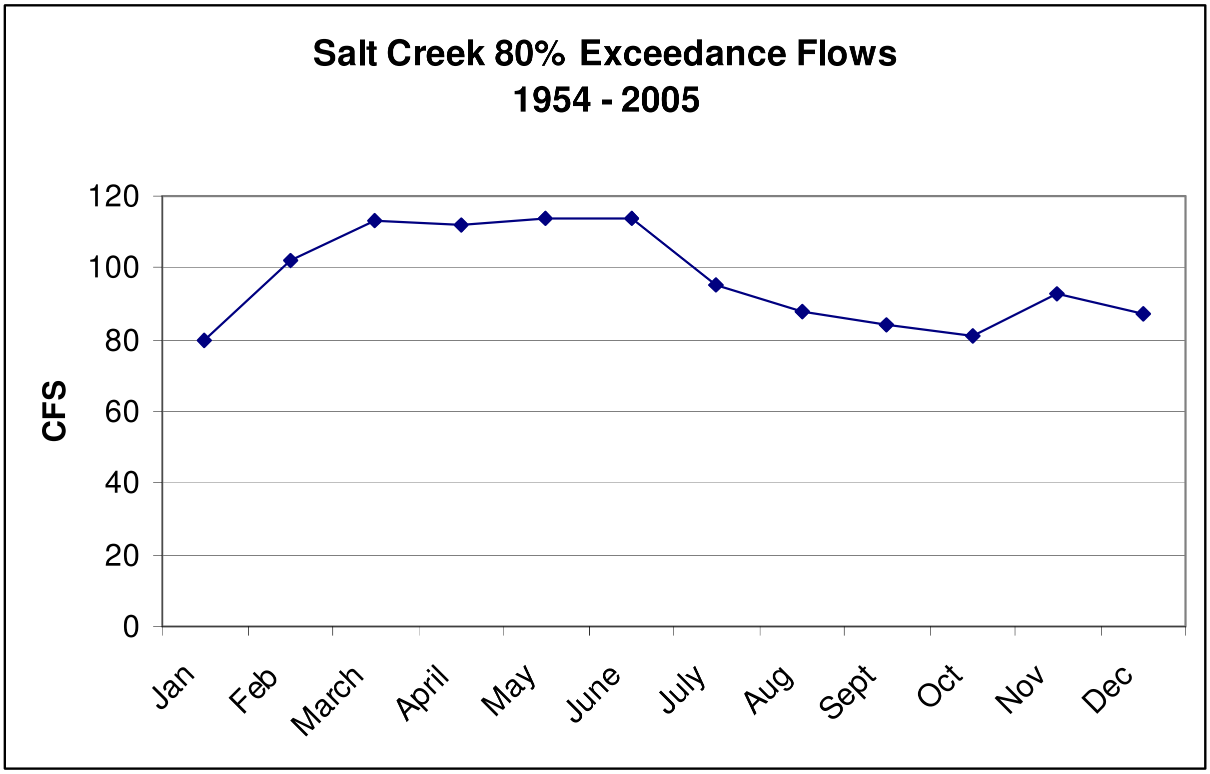


Figure 13: Salt Creek (Greenwood Gage) flows that occur 8 out of 10 years based on the period of record from 1954 – 2005 (80% exceedance flows).

Cumulative Impact of Tributaries at Louisville - Contributions of the flow for the lower Platte River from all tributaries can be evaluated at the Louisville gage. The semblance of a natural hydrograph can still be seen at the Louisville gage, especially when compared to the Duncan gage. A spring rise and a late summer low were clearly observed in the monthly flow data (Figures 14 - 15). The median annual discharge at this gage is 5,230 cfs. Every 1.5 years there would be a small flood event that would approach 39,800 cfs lasting 25 days and centered in mid June. Once every ten years a large flood would peak in mid May near 114,000 cfs and last nearly 3 months (83 days) from beginning rise to return to low stable flow conditions. The median Environmental Flow Characteristics (EFC) for the lower Platte River near Louisville, NE described the river as having the highest stable flows in March (6,360 cfs) dropping to lows in August (2980 cfs) and rising again to peak in the next March. On an annual basis, the base flow was estimated to be 24% of the mean flow. The annual CD 0.93 and LMR (0.28) values reflected a large base flow component to the Platte River's discharge. Table 7 displays the monthly CD and LMR values from the Louisville Gage.

Table 7: Coefficient of Dispersion (CD) and Low to Median Flow Ratio (LMR) at the Louisville Gage (January 1, 1954 to December 31, 2005).

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
CD	0.79	0.79	0.65	0.73	0.89	1.24	1.23	1.18	1.01	0.93	0.62	0.73
LMR	0.44	0.47	0.53	0.54	0.38	0.35	0.22	0.28	0.33	0.51	0.54	0.33

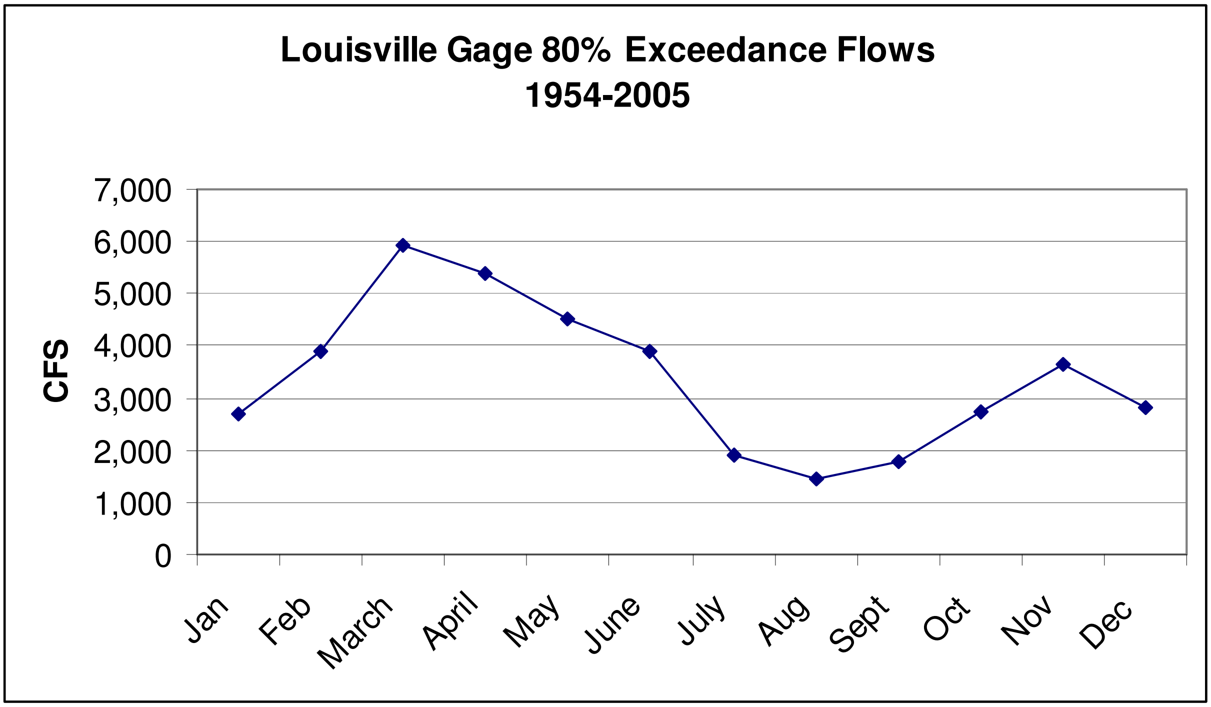


Figure 14: Lower Platte flows at the Louisville Gage that occur 8 out of 10 years based on the period of record from 1954 – 2005 (80% exceedance flows).

The effects of current development and alterations have not been entirely realized at this point in time, and there is anticipated to be less water in the lower Platte River due to the lag effect. The Nebraska Department of Natural Resources has calculated that, "The total calculated depletion at North Bend includes future depletions from the Loup River Basin, and the Platte River Basin and the total calculated future depletion at Louisville includes the future depletions from the Loup River Basin, Elkhorn River Basin and Platte River. The sum of those depletions (i.e., due to lag effects) results in a total depletion in the year 2030 of 110 cfs daily at North Bend and 310 cfs daily at Louisville, if there is no new well development. These estimates are based only on wells within the legally defined hydrologically connected aquifer (DNR 2006).

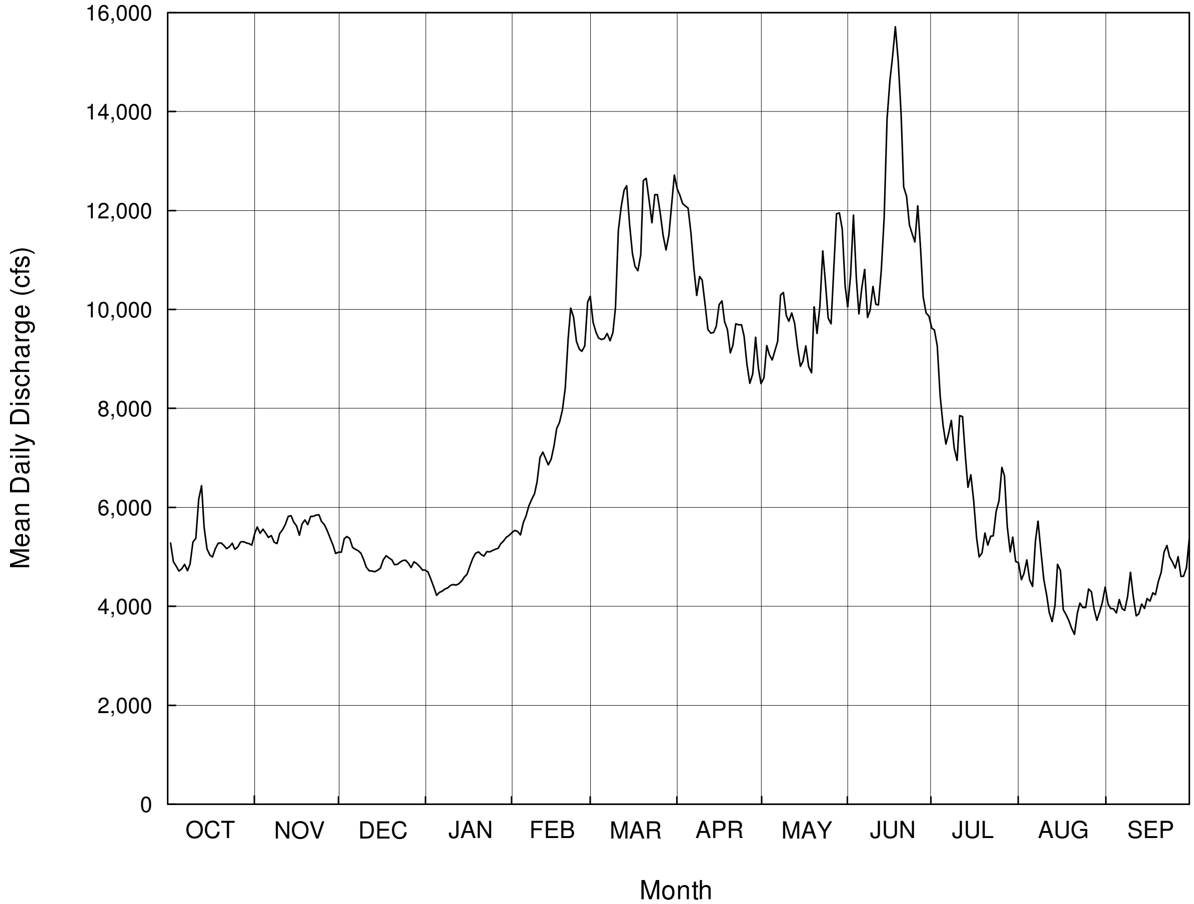


Figure 15: Average annual hydrograph for the Platte River at Louisville (USGS Gage No. 06805500) based on the recorded mean daily flows from 1954 through 2000 (Mussetter Engineering, Inc. January 2000)

Least Terns and Piping Plovers in the lower Platte River

Least terns and piping plovers have a reproductive strategy that in Nebraska is dependent upon highly dynamic riverine systems, which results in ephemeral habitat. In years with high flows, nests might be inundated depending on the timing of high flows, but new sandbars would be created. Floods, such as those on the Platte River in 1983 and 1993, scoured existing sandbars, replenished sand, removed vegetation and created new sandbars. In other years, low and average flows provided ideal nesting conditions on exposed sandbars, surrounded by water (Sidle et al. 1992, Kirsch and Sidle 1999). During a drought period, existing sandbars may sustain for a time, but will slowly become vegetated, and will no longer provide adequate quality nesting habitat for terns and plovers.

Historically, several river systems in eastern Nebraska provided substantial habitat that supported large numbers of least terns and piping plovers. Natural variability across a large geographic scale in these systems increased the likelihood that quality habitat was available at some locations. Today, most of Nebraska's major rivers have been altered, and nesting habitat is becoming scarce.

The Platte River from Keith County to the confluence of the Missouri River has a long history of use by nesting terns and plovers. The historical seasonal and interannual flow variation within the framework of a shallow, braided river with sandy and gravel substrate and were an ideal combination for creating least tern and piping plover nesting habitat. In the late 1980's, Sidle et al. (1988) documented that the Platte River supported approximately 13% of the interior least tern population. Numbers have fluctuated over the years with changing river conditions. The Platte River in Nebraska has accounted for a high portion of least terns (6.2-13.6 percent) (Kirsch and Sidle 1999, Jones 2001). Recent, more rigorous surveys dedicated to the interior least tern in 2005 suggest that the Platte River system numbers have declined and now supports 4.4 percent of the population (Lott, 2005), which accounts for 7% of the Platte River recovery goal.

In the late 1980's, the Platte River provided nesting habitat for 9% of the piping plover population of the northern Great Plains (USFWS 1988) with 2,137 to 2,684 adult plovers in the Northern Great Plains/Prairie region, 28 adults in the Great Lakes region, and 1,370 to 1,435 adults along the Atlantic Coast (Haig and Oring 1985) (USFWS 2000). The International Piping Plover Censuses provide the most reliable information on rangewide population trends and was conducted in 1991, 1996, 2001 and 2006. These surveys indicate a range wide decline for most years in the northern Great Plains/Prairie Canada population (Ferland and Haig 2002, Plissner and Haig 1992, Plissner and Haig 1997). Preliminary results from the 2006 International Piping Plover Census suggest that the U.S. Great Plains/Canadian Prairie region had 4700 birds, which could indicate an increase in this population. However, these numbers are not finalized, as data verification is not complete (Elliott-Smith 2007, personal communication).

The Platte River has been altered and the natural dynamics that recreate the ephemeral habitat that least terns and piping plovers depend on has been diminished or eliminated. Accordingly, tern and plover numbers have declined as riverine nesting habitat decreases and nesting birds then are restricted to artificial, non-riverine habitats such as sandpits. Least terns are now extirpated as a breeding species within the central Platte River upstream of the Loup River, due to modifications made to the Platte River's form and function (NGPC database) (Figure 16). As with the least tern, the piping plover is now extirpated as a breeding species from river sites from the central Platte River from Columbus to Lexington and over much of the central Platte River (Figure 17). Since 1999, there has been no successful reproduction in this stretch of the river channel, with the exception of two restored river sites near Gibbon.

The terns and plovers are still present and routinely use the river for foraging, but are primarily utilizing sandpits near the river for nesting and have also taken advantage of low water levels at Lake McConaughy. Sandpits are currently providing temporary habitat, but as mentioned in the species section of this document, without intensive management, sandpits are essentially biological sinks, and may accelerate population decline either locally or regionally if birds immigrate to these poor quality sites. Locations such as Lake McConaughy also provide only temporary habitat. Additionally, sandpits are ephemeral, and eventually are converted to housing developments or become overgrown after mining stops.

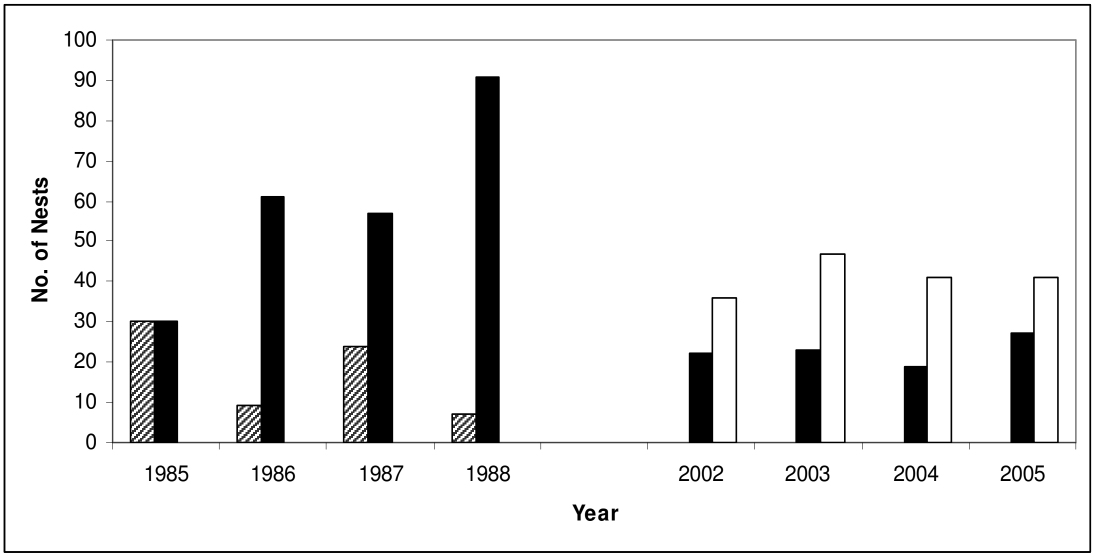
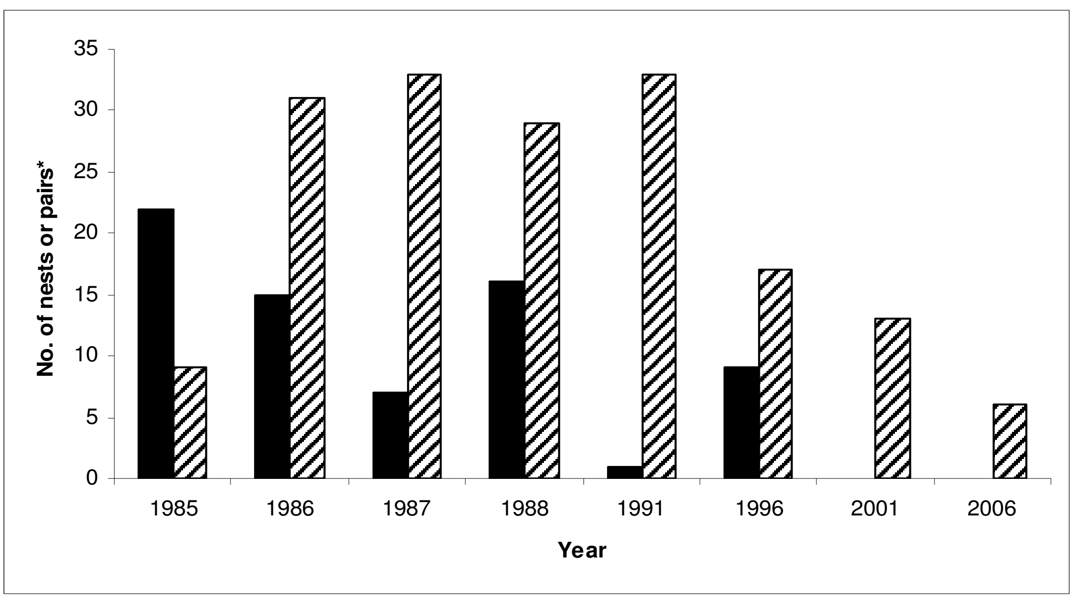


Figure 16: Number of least tern nests recorded at river sandbars (cross-hatched bars), industrial sandpits (black bars), and managed sandpits (white bars) on the central Platte River system from Lexington to Grand Island during two 4-year periods. Graphic shows decline and eventual extirpation of breeding least terns on the river and sole use of sandpits as nesting sites. The majority of nesting least terns in this stretch now occurs at heavily managed sandpits.



The lower Platte River still has least terns and piping plovers nesting on sandbars in the lower Platte River, due to the remaining semblance of the natural hydrograph in portions of the lower Platte River. The stretch of the Platte River benefits from flow and sediment contributions of the Loup River, Elkhorn River and Salt Creek, and the remaining inputs from the central Platte River which when combined with flows from the much reduced central Platte River's reach, are now the foundation of the hydrograph as we see it today. As such, while substantial water resource development has significantly altered the hydrograph of the lower Platte River, it continues to retain a semblance of the seasonal and interanual flow patterns with higher spring flows.

Since 1987, the Commission has coordinated a standardized least tern and piping plover survey along the lower Platte River from Columbus to Plattsmouth that includes both the river and sandpits. Data from these surveys suggests least tern numbers, overall, have remained relatively stable when including both river and sandpit use during this 20 year period on the lower Platte River, but that Piping Plovers have declined (Figure 18-19).

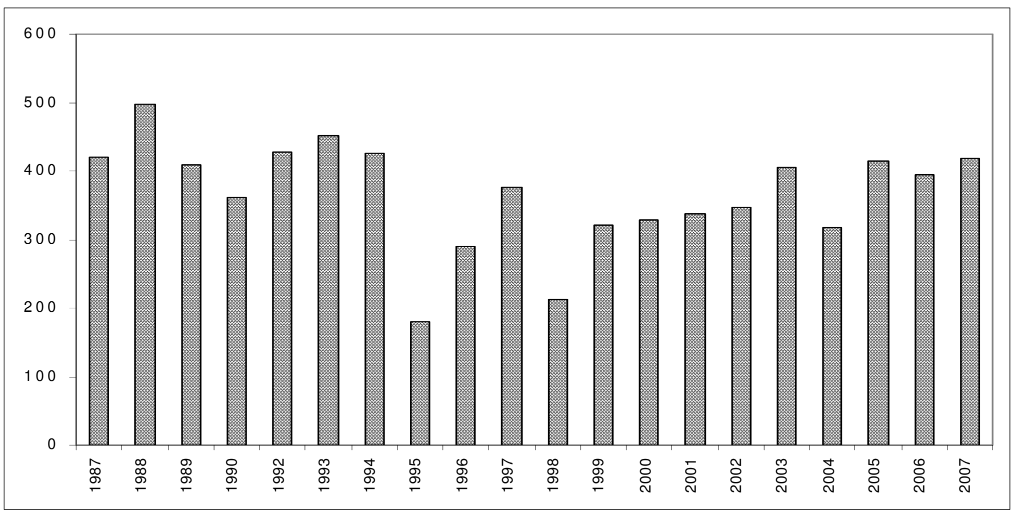


Figure 18. Total nesting least tern population of the lower Platte River, including nesting at both sandpits and riverine sites.

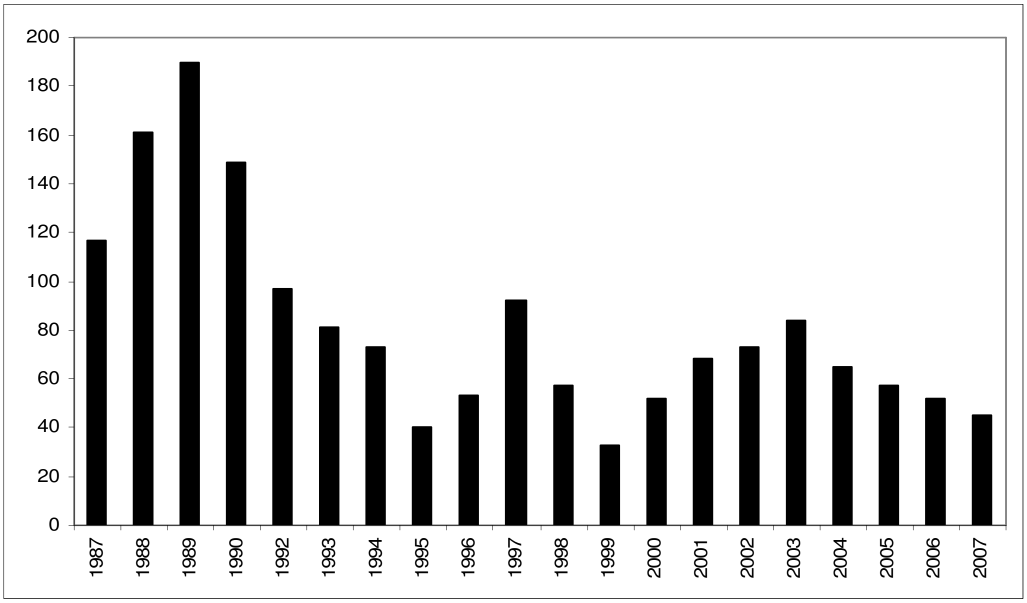


Figure 19: Total nesting piping plover population of the lower Platte River including nesting at both sandpits and riverine sites.

While there is some semblance of a natural hydrograph, the lower Platte River has been altered and the evidence can be seen in least tern and piping plover trends. It is well established that when riverine sites disappear, least terns and piping plovers nest in alternate locations, but in Nebraska the alternate options are limited and suboptimal. The change in nesting locations from riverine to sandpit exemplifies the altered hydrologic regime and declining habitat. As seen in the central Platte River, the gradual relocation of birds from the river sandbars to sandpits is beginning in the lower Platte River (Figures 20 - 23).

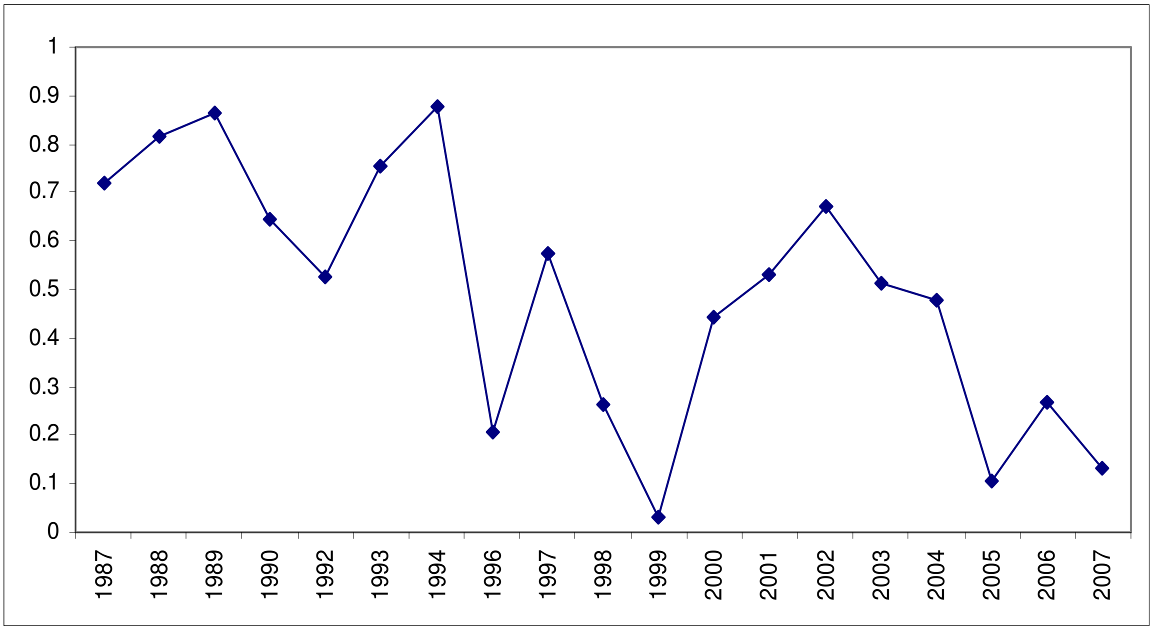


Figure 20: Percentage of piping plovers nesting on the river compared to total nesting locations, including both sandpits and riverine sites.

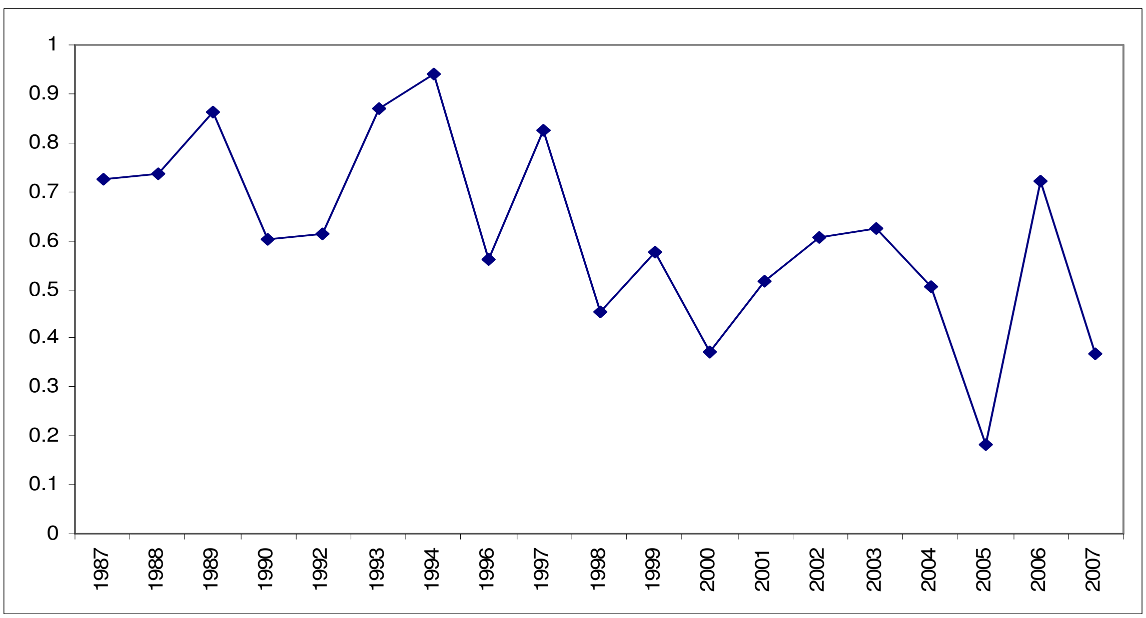


Figure 21. Percentage of least tern nesting on river sites compared to the total (both riverine and sandpit sites) lower Platte River nesting population.

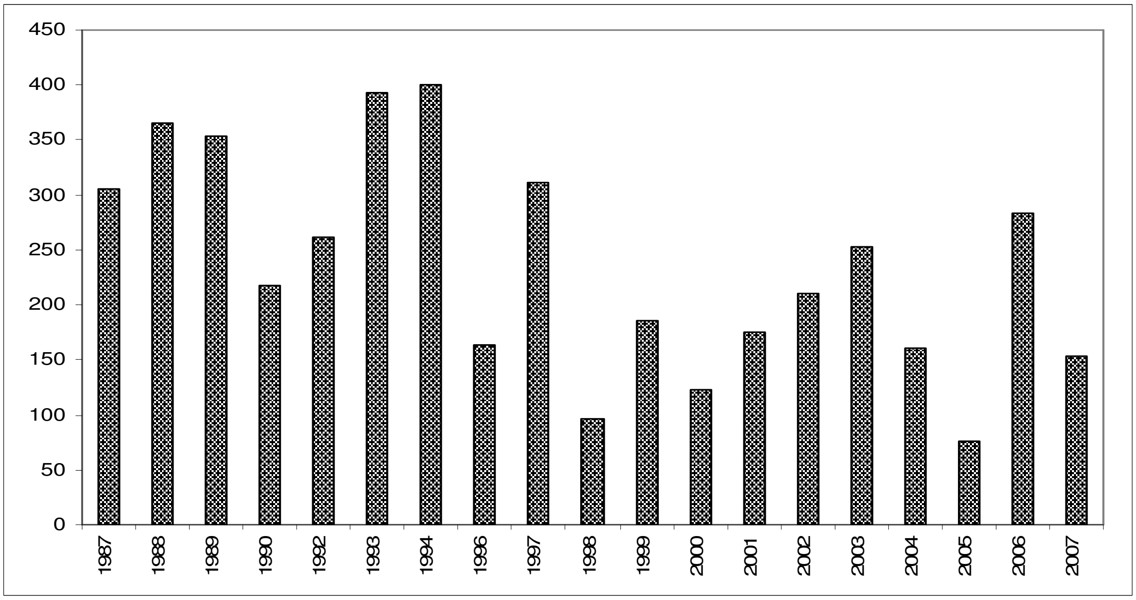


Figure 22. Number of adult least terns nesting on sandbars in the lower Platte River.

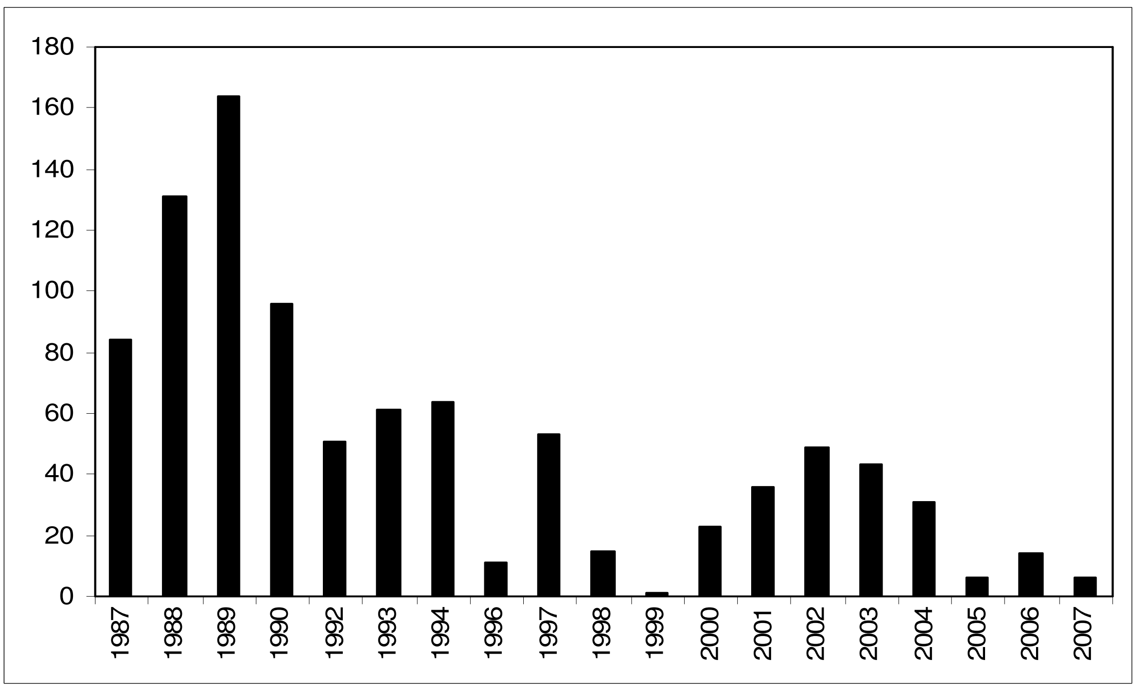
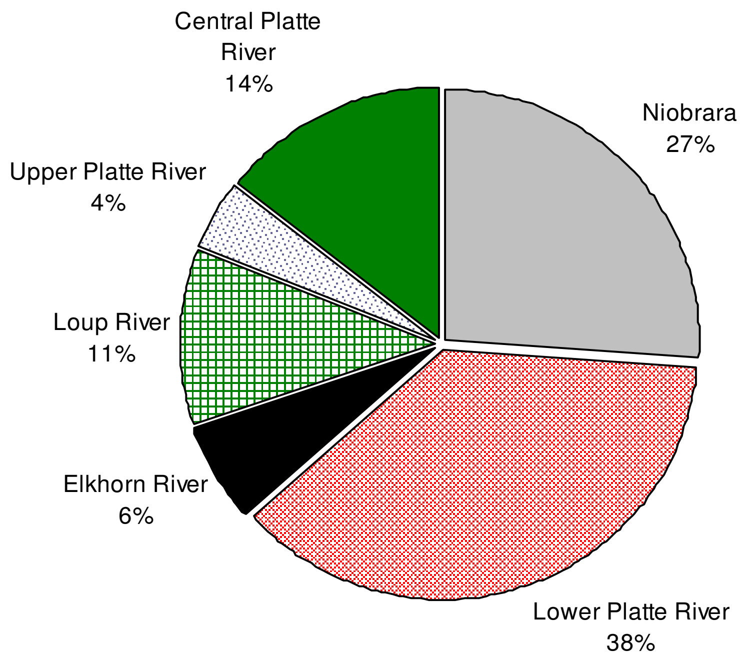


Figure 23: Adult piping plovers using sandbars in the lower Platte River.

These two bird species have limited riverine habitat available in Nebraska, and maintaining the little habitat that remains, is critical. The lower Platte River provides valuable nesting habitat for least terns and piping plovers. In a system that has been highly degraded, with limited available habitat, an area that has 38% of the least terns nesting in Nebraska and 12% of the piping plovers of Nebraska it is important and necessary to maintain for the recovery of the species (Figure 24).

A



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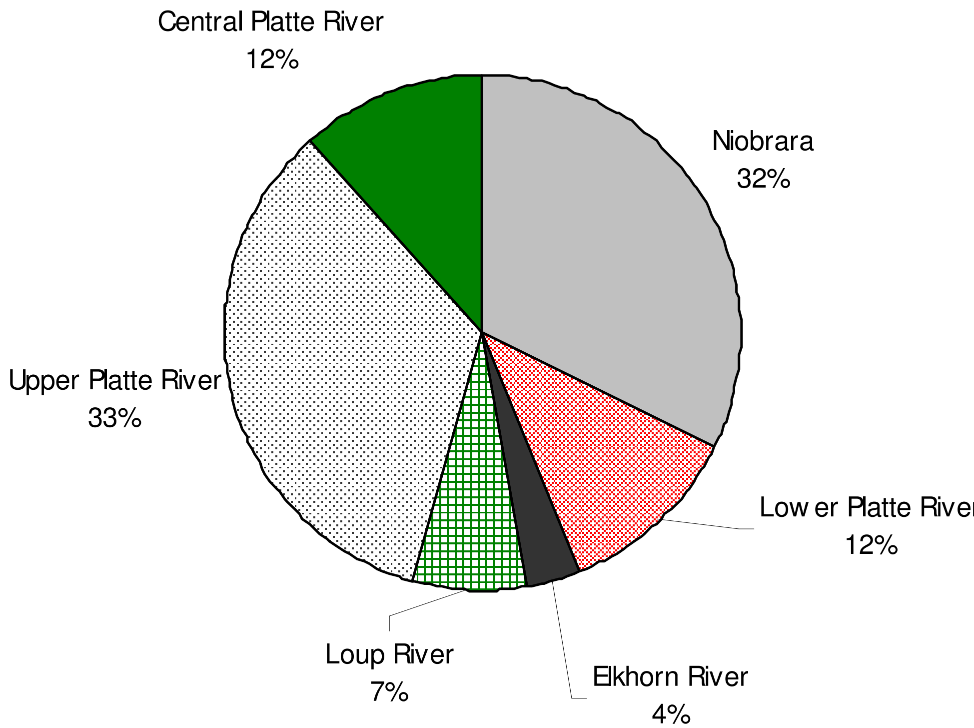


Figure 24: A) Proportion of all least terns recorded in Nebraska occurring on individual river systems (Missouri River excluded) based on 1991, 1995, 2001, and 2005 survey results (Lott 2006, NGPC database). B) Proportion of all piping plovers recorded in Nebraska occurring on individual river systems (Missouri River excluded) based on 1991, 1996, 2001, and 2006 International Piping Plover Survey results (Ferland and Haig 2002, Plissner and Haig 1992, Plissner and Haig 1997, and NGPC database). Note: Upper Platte River includes Lake McConaughy and Missouri River is not considered.

Pallid Sturgeon in the lower Platte River

The pallid sturgeon is an ancient fish species that has adapted over time to the dynamics of large riverine systems. As stated in the Species Section, scientists are just beginning to understand much of the natural history of this elusive, rare species. The pallid sturgeon depends on deeper, turbid waters with higher velocity. Within large river ecosystems, the pallid sturgeon likely used the braided channels and took advantage of the irregular flow patterns which created extensive microhabitat diversity. This species is capable of moving large distances, so it is likely that historically it would move to areas of suitable habitat within the matrix of habitats that composed the Missouri and Mississippi Rivers and their major tributaries. This large fish is influenced by many factors including temperature and velocity when selecting microhabitats. Evidence suggests that the pallid sturgeon, much like its close relative the shovelnose sturgeon, utilize major tributaries such as the Platte River in the spring for reproduction and will also use other major tributaries at other times of the year as well (Bramblett and White 2001; Peters and Parham 2007; Snook 2001).

Throughout the entire range of the pallid sturgeon, there is currently very little evidence of spawning. Larval pallid sturgeon are rarely captured and in some areas there is limited evidence of recruitment of young pallid sturgeon into the population. RPMA 4, which contains the Platte River confluence, does have juvenile pallid sturgeon surviving and limited evidence of successful spawning, which is not the case in other stretches of the pallid sturgeon range. The pallid sturgeon population in the upper portion of the species range exhibits little or no recruitment, and the population in the lower portion of the range suffers from a high degree of hybridization with shovelnose sturgeon. It is this middle section of the species range which may have the greatest overall potential for maintaining the continued existence, and eventual recovery of this species.

The Platte River is the only tributary below Gavins Point Dam that originates in the Rocky Mountains and delivers runoff from mountain snowmelt to the lower basin. The stretch of the lower Platte River benefits from flow and sediment contributions of the Loup River, Elkhorn River and Salt Creek, and the remaining inputs from the central Platte River which when combined with flows from the much reduced central Platte River's reach, are now the foundation of the hydrograph as we see it today. As such, while substantial water resource development has significantly altered the hydrograph of the lower Platte River, it continues to retain a semblance of the seasonal and interanual flow patterns with higher spring flows. A review by the National Research Council (2005) found that the lower Platte River contains the habitat with a flow regime most similar to the original, unaltered habitat of pallid sturgeon.

It is difficult to quantify how many pallid sturgeon are using the lower Platte River, but Peters and Parham (2007) estimated that there are 23,000 to 69,000 shovelnose sturgeon in the lower Platte River. Low catch rates of pallid sturgeon make these types of estimates difficult, but the use by the closely related shovelnose sturgeon illustrate the importance of the lower Platte River to sturgeon species. The relative density of the Platte River population can also be estimated when comparing catch rates between Platte River work and the extensive Missouri River sampling. Peters and Parham in 2004 captured 6 hatchery reared pallid sturgeon in the lower Platte River while Krentz et al. (2005) had a total of 91 recaptures from all of the RPMA 4, meaning that there were 1 recapture for every 2.1 miles of river in the Platte River and 1 recapture per 8.8 miles of Missouri River. Although population estimates are difficult to achieve, "The importance of the lower Platte River for pallid sturgeon has been documented (Snook 2002, Swigle 2003).

Peters and Parham (2007) conducted extensive analysis of pallid sturgeon habitat as related to flows in the lower Platte River. They found that in the lower Platte River, pallid sturgeon were most frequently captured in the deepest and swiftest runs of the river. Pallid sturgeon selected areas with a depth greater than 0.8 m (2.6 ft) with an average depth of approximately 1.6 m (5.3 ft) and a mean column current velocity of 0.8 m/s (2.6 ft/s). They appear to target areas with complex microhabitats as the deep runs where pallids were captured were typically within 50 to 100 m (164 – 328.1 ft) of shallow and exposed sandbars. Pallids were captured when water temperatures were between 10ºC and 17ºC (50°- 62°F). These temperatures coincide with the temperatures reported for sturgeon spawning in a hatchery environment.

These areas of the river that provide suitable habitat will occur within the matrix of various depths and velocities throughout the lower Platte River when there is adequate flow. For the pallid sturgeon to be able to utilize these areas of suitable habitat, the river must be suitably connected for the sturgeon to access the habitat and move through the system as necessary. It is particularly important for spawning sturgeon, as at certain times of the year, they must be able to move and seek out spawning habitat and also have sufficient flows to navigate out of the lower Platte.

The lower Platte River may be one of the few locations in which pallid sturgeon spawn and find refuge and available habitat at other times of the year. Within the degraded middle section of the pallid sturgeon range, the lower Platte River contains the most intact remaining habitat in terms of hydrology and physical habitat, even though those characteristics have declined significantly (NRC 2005). The lower Platte Rive has habitat characteristics that researchers typically associate with sturgeon spawning. These characteristics include sandy substrate, shallow areas for foraging in addition to deeper areas, velocity, temperature, a seasonal hydrograph with appropriate depths and connectivity.

Suspended sediment concentrations in the lower Platte River increase three- to four-fold during the spring. Concentrations during spring average about 1,100 to 1,500 milligrams/liter (mg/l) (USGS, Louisville gage 1972 to 1976), which is higher than that of the Missouri River at Omaha. These springtime sediment concentrations are equivalent to those found in the Yellowstone River, where other pallid sturgeon populations are concentrated and spawning has been documented. The high flows during spring and early summer deliver about 80 percent of the total annual amount of suspended sediment in the lower Platte River. The high sediment load and discharge produces in-channel fish habitats (i.e. sandbars, backwaters, and pools) in the lower Platte River that are lacking or in extremely short supply in the channelized Missouri River.

Several factors make a strong argument that pallid sturgeon are using the lower Platte River for spawning. The most compelling is the fact that larval sturgeon less than one day old have been sampled in the lower Platte River and have been captured in multiple years during May and June.

This confirms that sturgeon (although the larvae could be either shovelnose or pallid) are spawning as far upstream as the US Highway 6 bridge (Peters and Parham 2007) and possibly as far upstream as the Elkhorn River (Hofpar 1997). Given that pallid sturgeon and shovelnose are known to hybridize, it is assumed that spawning conditions and requirements are similar. Therefore it is likely that the lower Platte River has suitable conditions and habitat for pallid sturgeon spawning.

In addition to the presence of larval sturgeon, documented angler catch records indicate higher use of pallid sturgeon in the spring (Heritage data 2007), within the period (April through June) in which pallid sturgeon are believed to spawn. These captures also tend to occur during higher than average flow conditions within that period. Peters and Parham (2007) captured a gravid female pallid sturgeon on May 3, 2001, at approximately Platte River mile 13. This female exhibited behavior that coincides with expected behavior of a spawning female. It remained near Louisville for nearly a month and then left rapidly and entered the Missouri River.

From 1979 through 2001, 19 of the 23 captures of pallid sturgeon in the Platte or Missouri rivers near the Platte River confluence occurred during April, May, and June; the remaining occurrences were in July and September of 1999. Twenty of the 23 occurrences correspond with years when flows in the lower Platte River were above normal for the recent period (Louisville gauge, 1970 to 2001). Since 2001, 15 additional pallid sturgeons were captured in the Lower Platte River. Thirteen of the 15 were captured in April and May with one capture in July and one in September. In 2007, a pallid sturgeon was captured near the Highway 50 Bridge on October 9 (Barada, personal communication 2007). Such spring high flow conditions are particularly important for pallid sturgeon, as these conditions are believed to act as a cue to staging and spawning behavior. These capture records suggest that the Platte River may be used for reproduction, the critical link to continued species persistence and recovery, but is also used at other times of the year.

Discussion and Conclusions

Although the lower Platte River retains most geomorphic characteristics of the historic Platte River, the system is highly altered and the necessary forces that have maintained these characteristics over centuries, have been tempered by land-use development and utilization of the water resource. Least terns, piping plovers and pallid sturgeon each have adaptations suited for the highly dynamic system of the Platte River and have strategies that take advantage of and depend on the habitats created through a complex interaction of flows, sediment, geomorphology, connectivity and climate that varies seasonally (Figure 25).

Habitat forming flows are a key driver of the lower Platte Rivers riparian ecosystem and are critical to maintain the physical, chemical and biological functions essential to this ecosystem. Poff et al. (1997) noted,

> Different habitat features are created and maintained within a river system by a wide range of flows. It is this "predictable diversity of habitat types that has promoted the evolution of species that exploit the habitat mosaic created and maintained by hydrologic variability," with corresponding effects on species distribution, species abundance, and ecosystem function. "Human alteration of the flow regime, changes the established pattern of natural hydrologic variation and disturbance, thereby altering habitat dynamics and creating new conditions to which the native biota may be poorly adapted."

Habitat forming flows are higher flows which sort and transport sediments; move bed material; uproot and dislodge submerged, emergent and streamside vegetation; influence structural stability of stream banks; and prevent vegetation encroachment into the active channel (IFC 2002, Murphy et al. 2004, NRC 2005). Without these flows, 1) associated wetlands are no longer maintained, 2) water tables in the immediate vicinity are not recharged, 3) sandbars and channel areas are not inundated and scoured, 4) sediment collects on bars and channel edges, which causes lowering and narrowing of the stream banks, 5) side channels and backwaters become disconnected and may fill in, 6) tributary confluences aggrade and push out into the main channel and 7) the ratio of pools to riffles is altered (Moriswa 1968; Platts 1979; Leopold and Emmett 1983; Hill et al. 1991 in Annear et al. 2005). Reduction in the frequency, timing, duration and magnitude of the annual and inter-annual hydrograph causes the long-term, and continued, deterioration of the habitats relied upon by the least tern, piping plover and pallid sturgeon (NRC 2005, FEIS 2006). It is these high flows that move sediment in the river which scour out deep channels, that create habitat for pallid sturgeon and deposit and clear sandbars that become nesting areas for least terns and piping plovers. This dynamic interaction is controlled by the range of hydrologic conditions resulting in the availability of quality habitat shifting locations from year to year for these target species.

Habitat forming flows are not easily defined since flows with varied magnitudes have a multitude of impacts and effects. One important habitat forming flow is called bank full flows and are defined as the flow that "just fills the stream to its banks" (Gordon et al.1992 in Annear et al 2004). A more conventional definition of bankfull discharge is:

> "The bank full flow corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders and generally doing the work that results in average morphological characteristics of channels" (Duanne and Leopold 1978 in Rosgen 1996).

This bank full flow could essentially be considered the dominant discharge as it moves the most sediment over time. They may move less sediment per event than a large flood, but they occur much more frequently resulting in more overall sediment moved. Rosgren (1996) suggested that a 1.5 – 2 year flood event is typically close to the bankfull discharge, although the frequency of this discharge is specific to each river type. This level of analysis for the Platte River has never been evaluated, so for the purposes of this Opinion, the maximum discharge with a 1.5 year return period was used for estimating the bankfull discharge for the period of record 1954-2005.

An additional important habitat forming flow occurs when large floods over top the banks of the river. Flows of this magnitude are important for creating habitat above the bank full level and exchanging nutrients and materials between the channel and the flood plain. This nutrient exchange is a key component of a healthy ecosystem and heavily influences the base of the aquatic food chain. Habitats such as high sandbars and deep channels were rapidly created by historical high water events prior to impoundment and diversions in the lower Platte River.

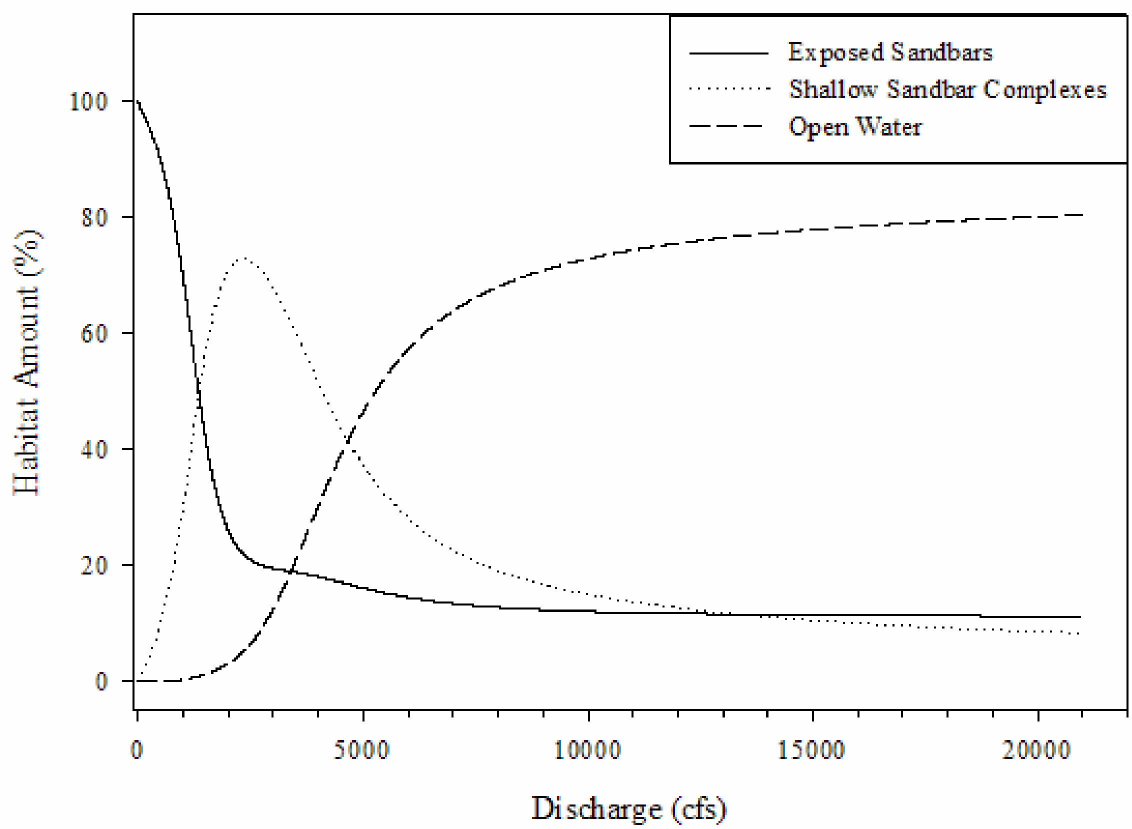


Figure 25: The simultaneously adjusted curves for the habitat type vs. river discharge (Peters and Parham 2007).

Hydrologic Discussion as related to Least Terns and Piping Plovers

Sandbar creating flows range from bankfull discharges to large flood events. Large flood events, which occur infrequently but cause significant change in the appearance of the river channel in a relatively short amount of time by potentially building large sandbars among other changes. These flows that overtop banks inundate the floodplain and introduce nutrients back into the system. Sidle and Carlson (1992) reported a large flood of 32,300 cfs on June 1, 1990 at the North Bend gage and 60,500 cfs at the Louisville gage. This flood reduced vegetation by 78% on sandbars. They reported trees floating down the river. Floods of this magnitude are important, as the riverine and riparian ecosystem is adapted to the large, infrequent events such as these.

Frequency of high flows are also important, as these larger flow events may not occur every year. Flows that overtop sandbars and reduce seasonal and woody vegetation are essential in maintaining sandbar habitat used by nesting least terns and piping plovers in the lower Platte River. In the absence of these higher flows, sandbars are colonized quickly by fast growing species such as cottonwood trees and willows. Cottonwood trees are a fast growing species and can grow 10 meters in four years (Putnam et al. 1960). Peters and Parham (2007) found that once a woody island was established, there was no correlation between moderate flows and the amount of woody island vegetation, meaning that flows as high as 21,000 cfs are not sufficient to remove this vegetation.

The Platte River also requires sediment (primarily sand) which is essentially the building material of sandbar habitats for the target species, as well as the host of other native species that live in association with the river. The quantity and type of sediment carried by a river has a significant effect on the shape and character of the river corridor and, in turn, impact habitat parameters important to the target species (FEIS 2006). The volume of flow and the available supply of sediment determine the volume of sediment that can be transported. A reduction in flow or sediment supply resulting from storage reservoirs and water diversions produces a corresponding reduction in sediment transport capacity (FEIS 2006). Abrupt changes in river flow also impact sediment transport, creating areas of erosion or deposition. The Platte River flow is changed by water diversions and canal returns, causing sediment to be deposited on the channel bed (aggradation) in some reaches and eroded (degradation) from other reaches (FEIS 2006).

Ziewitz et al. (1992) measured characteristics of nesting habitat of least terns and piping plovers in the central and lower reaches of the Platte River. At the time of this study, most nesting birds were in the lower Platte River as opposed to the central Platte River. They found that birds nested in areas where the channel was wide with a greater area of sandbars. They recommended that sandbars be at least 3.58 acres in size and 2.99 feet above river stage for maximum flooding protection, but should be at least greater than 1.48 feet in height.

Bankfull flows (assumed to equal to the peak discharge with a 1.5 year return period) can be estimated from USGS gage records at various points along the lower Platte River. Although bank full flows maximize sediment movement within the channel given their frequency over time, these flows accomplish very little nutrient exchange and habitat creation over the bank full level. However, changes in response to larger flood events (assumed to be a 1 in 10 year peak discharge in subsequent analyses) are more difficult to estimate as the dynamics of overbank flows are highly variable and poorly understood for the lower Platte River. Bankfull flows peak at lower discharge rates but occur more frequently than large floods and therefore have a significant effect on observed habitat conditions in the river. Additionally, the subsequent analysis regarding bankfull discharges are likely conservative as most analysis of bankfull events and sediment movement are focused on streams with harder substrate. The Platte River is a warm water river with a shifting sand bed. It rapidly "smoothes" habitat created by high flow events so high flow disturbance levels must be frequent and or must be of significant magnitude to cause needed sediment movement for in channel habitat maintenance.

While daily, monthly, bankfull, or large flood discharges can be determined from the USGS gage records, estimates of the habitat created at these discharge levels are important to determine the characteristics of sandbars available during least tern and piping plover nesting seasons. Mussetter Engineering, Inc. (2002) calculated the channel characteristics and sediment transport capabilities over a wide range of flows for the lower Platte River in the vicinity of the mouth of the Elkhorn River. Among channel characteristics modeled, an estimate of hydraulic depth was provided for nine main river transects over the range of discharges between 200 and 151,000 cfs. Parham (2007) extended their results by applying a linear regression to the summarized dataset to create a relationship between discharge at channel depth. Conversely, the height of a sandbar created at a given discharge was assumed to be approximately the water surface elevation. Therefore the observed height of a sandbar was assumed to be the difference between water surface elevations estimated at the various discharges. For example, a discharge of 39,800 cfs (bankfull discharge at Louisville) would create channel depths of 4.9 ft. and conversely depositing sand in some areas resulting in shallow sandbars nearly reaching the water surface. If the June discharge after that bankfull flow event was approximately 7,180 cfs then the channel depths would now be approximately 2.1 feet. This would provide an estimated height of exposed sandbars to be 2.8 ft or the difference between water surface elevations at the two discharges. Table 8 shows the estimated bankfull flow, median June flows, and their respectively channel depths for three main river gages and table 9 shows the estimated sandbar heights at these sites.

Table 8: Flow profiles for bankfull discharge (a 1.5 year return using IHA software) for three USGS stream gages, median June discharge from period of record (1954 – 2005) and depths at the corresponding discharges.

	1.5 year return (cfs)	Depth (ft) at 1.5 year return	Median June Discharge (cfs)	Depth (ft) at June Median Discharge
Duncan	7,130	2.1	1,265	1.6
North Bend	21,280	3.3	4,080	1.8
Louisville	39,800	4.9	7,180	2.1

Table 9: Sand bar height for three Platte River gage locations based on the difference between bankfull discharge and median June discharge. June was selected for illustration as this is when nest initiation begins and as flows recede, inundation is more likely.

	Sandbar Height (ft)
Duncan	0.5
North Bend	1.5
Louisville	2.8

Based on the need for sandbars to be at least 1.5 feet in height with a preference of 3 feet in height for least tern and piping plover nesting and protection from flooding, the difference between bankfull flows and June flows creates sandbars at Louisville that are currently of sufficient height to meet the requirements. North Bend sandbars just meet the minimum requirement, but sandbars on the Platte River above the Loup River are of insufficient height to produce suitable least tern and piping plover nesting habitat.

Evaluating the height of potential sandbars based on sediment transport and bankfull flows only establishes the potential sandbar heights. The sandbars must also be clear of most vegetation, be of sufficient area, and separated from the river banks. Flows that maintain isolation of the sandbars from the banks throughout the summer are an increasingly important component of reproductive success. Sandbars that are not isolated are more accessible to mammalian predators which can decrease nesting success for the already imperiled species. In addition to the deep water that isolates the nesting habitats, least terns need shallow water foraging areas that harbor the minnow species that compose the majority of their diet.

Parham 2007 also estimated the area of sandbar habitat in relation to discharge from aerial photographs of the lower Platte River. The analysis calculated the area of sandbars that were disconnected from the shore and had at least 3.5 acres of exposed sandbar habitat at discharge rates from 0 to 21,000 cfs. The results showed that exposed sandbar habitats suitable to least terns and piping plovers were most common between 4,400 cfs and 9,100 cfs and decreased at lower or higher flows (Figure 26).

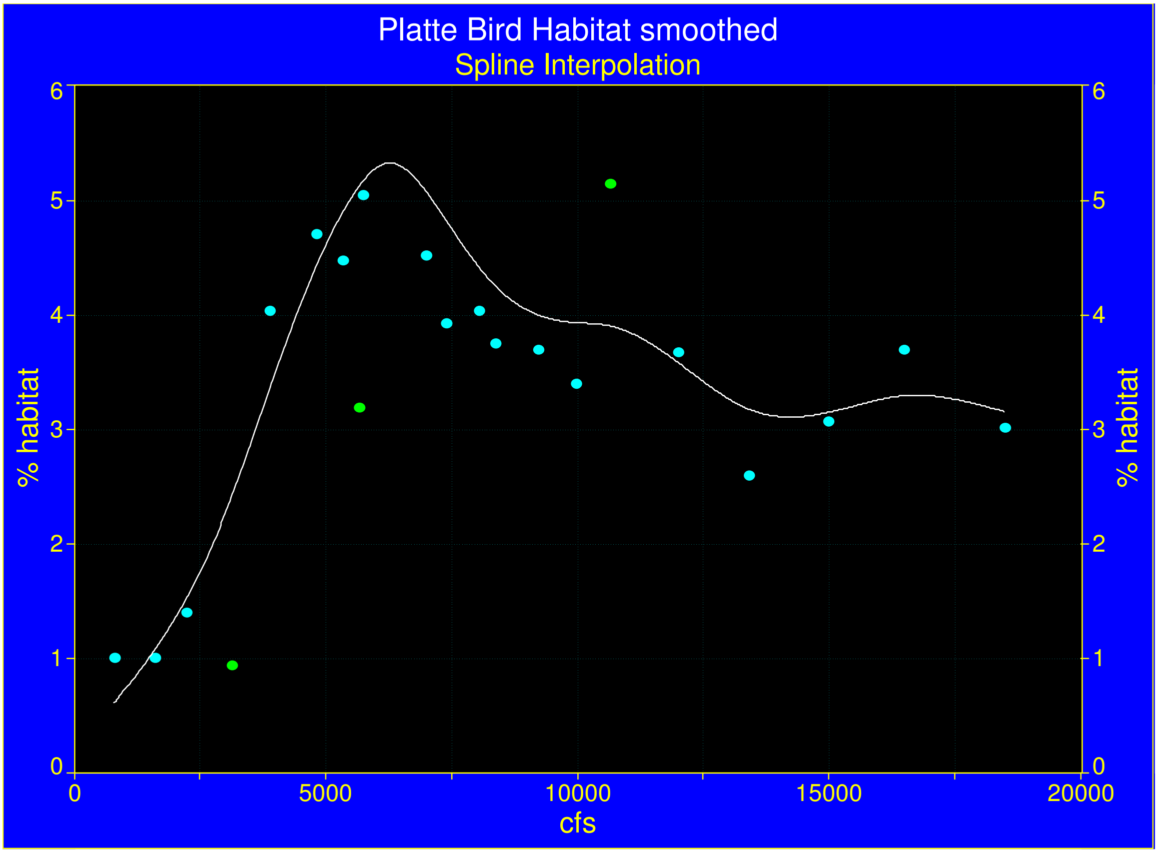


Figure 26: Least tern and piping plover habitat as related to discharge based on GIS reclassification of aerial photos with the criteria of sandbars that were at least 3.58 acres in size, was an exposed sandbar, and was unattached to the bank.

Another component of a successful nesting season for least terns and piping plovers is the length of time the sandbars are exposed without inundation. A good nesting season for least terns and piping plovers with an approximate 60 day period when suitable sandbars are available, and are not inundated by higher flows increases the likelihood that birds will successfully reproduce. Although flooding is possible and does occur throughout the year, least terns and piping have a reproductive strategy that temporally corresponds with the historic hydrograph which maximizes the likelihood that birds will successfully reproduce. These birds typically arrive in May and begin nest initiation in late May to early June as the water level historically peaks and then begins to recede (Figure 27). Alteration of the historic hydrograph, with a reduction of the key high spring flows, means that lower sandbars are more common and thus more susceptible to inundation by subsequent flows. This ultimately results in an increased likelihood of decreased fecundity and further population declines and potentially extirpation of breeding populations.

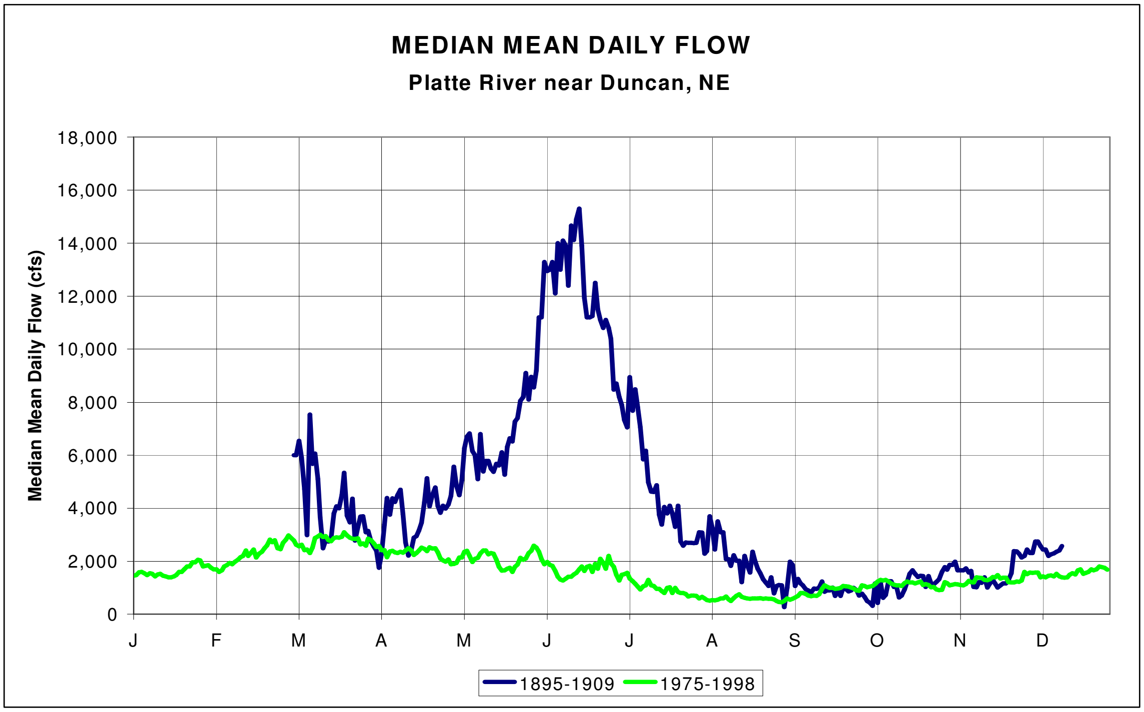


Figure 27: Median mean daily flow in the Platte River at Duncan, Nebraska, in 1895-1909 vs. 1975-98. (Source: USGS gage data, as presented in Platte River FEIS (2006)).

To provide an estimate of the amount of suitable habitat available to least terns and piping plovers of the past 60 days, Parham 2007 combined the results for the estimates of sandbar height and sandbar area into a single metric. To assess if the nest may be inundated during the 60 day nesting period, the highest discharge that had occurred in the previous 1.5 years (bank full flows) was compared with the highest discharge during the 60 day nesting period. If the difference in sandbar height created at the two discharge rates was at least 1 ft, then the nest inundation was considered not to have occurred while if it was less than 1 ft then the nest was considered to be lost to flooding. The 1 ft difference was a conservative estimate to allow for “smoothing” of the sandbar habitat over time and to account of some of the daily variation in flows resulting from the power plant peaking flows observed in the lower Platte River. To estimate the area of habitat available during the 60 day nesting period, a relative area index was created that placed habitat area into one of 4 categories. If the daily flow was between 0 and 399 cfs then the value was 0, between 400 and 3,199 cfs the value was 1, between 3,200 and 4,399 cfs or greater than 9,100 cfs the value was 2 and between 4,400 and 9,100 cfs the value was 3. These values were then averaged for the pervious 60 day period to estimate the area available during the nesting period. To combine the results for the nest inundation estimate with the nest area estimates, the value for each estimate was multiplied together to estimate overall habitat suitability during the last 60 day period. The resulting yearly habitat suitability index ranged from 0 (no habitat) to 180 (maximum habitat), where 186 would be the maximum of 62 possible days of successful non-inundated nest sites times 3, the maximum nest area (Figures 28-30).

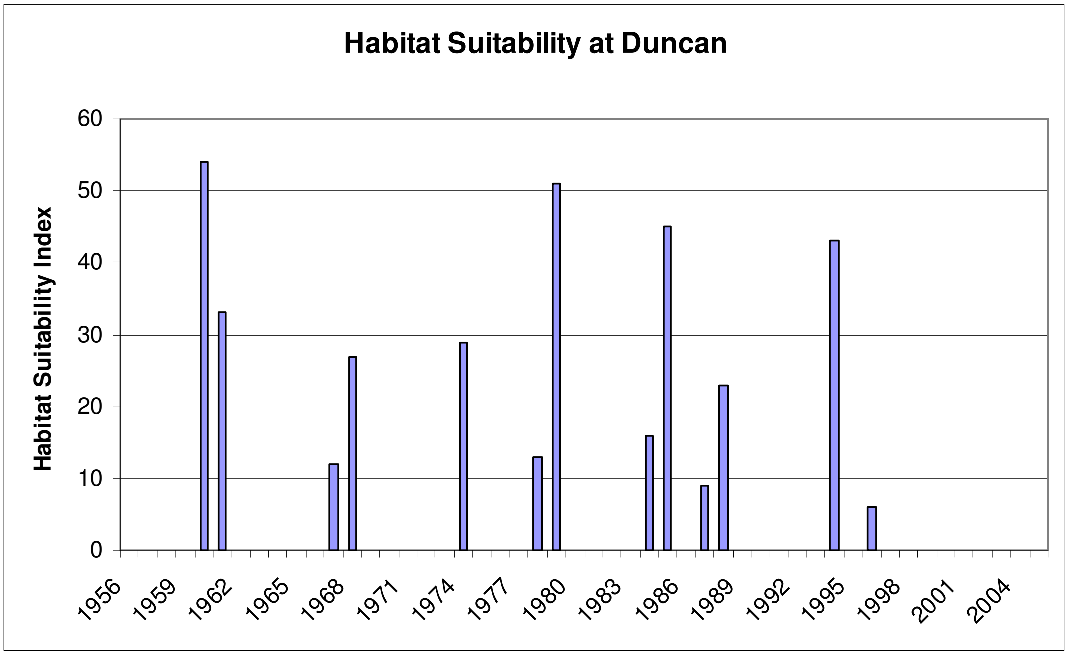


Figure 28: Habitat suitability index for Duncan where higher values reflect the higher quality habitat. Index based on habitat creating flows in the previous 1.5 years and the lack of inundation during the nesting period (based on period of record 1954 – 2005).

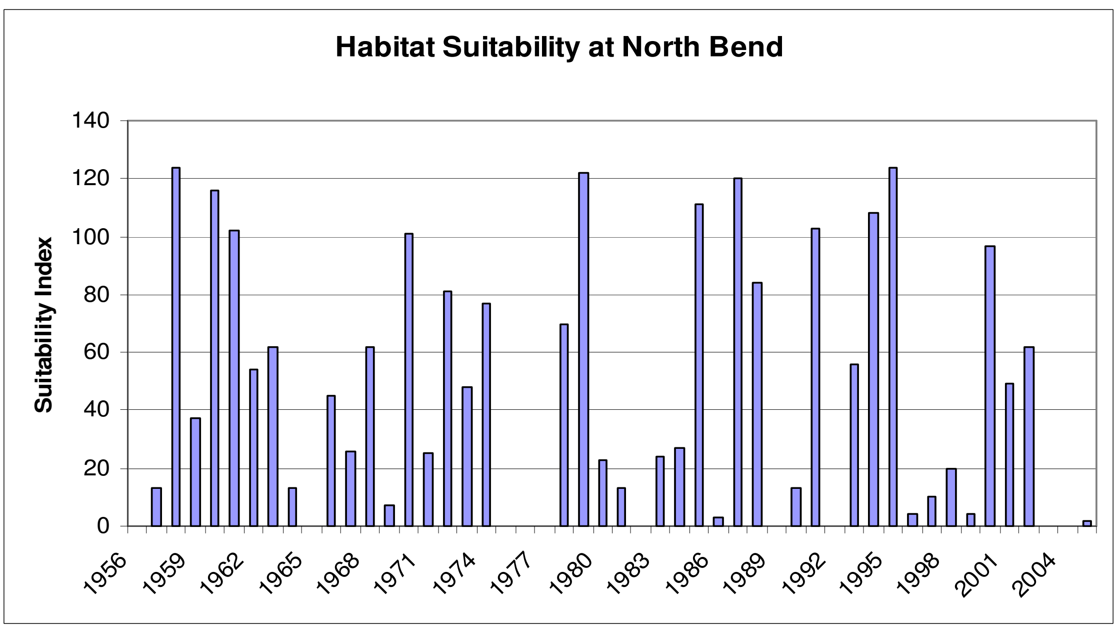


Figure 29: Habitat suitability index for North Bend Gage where higher values reflect the higher quality habitat. Index based on habitat creating flows in the previous 1.5 years and the lack of inundation during the nesting period (based on period of record 1954 – 2005).

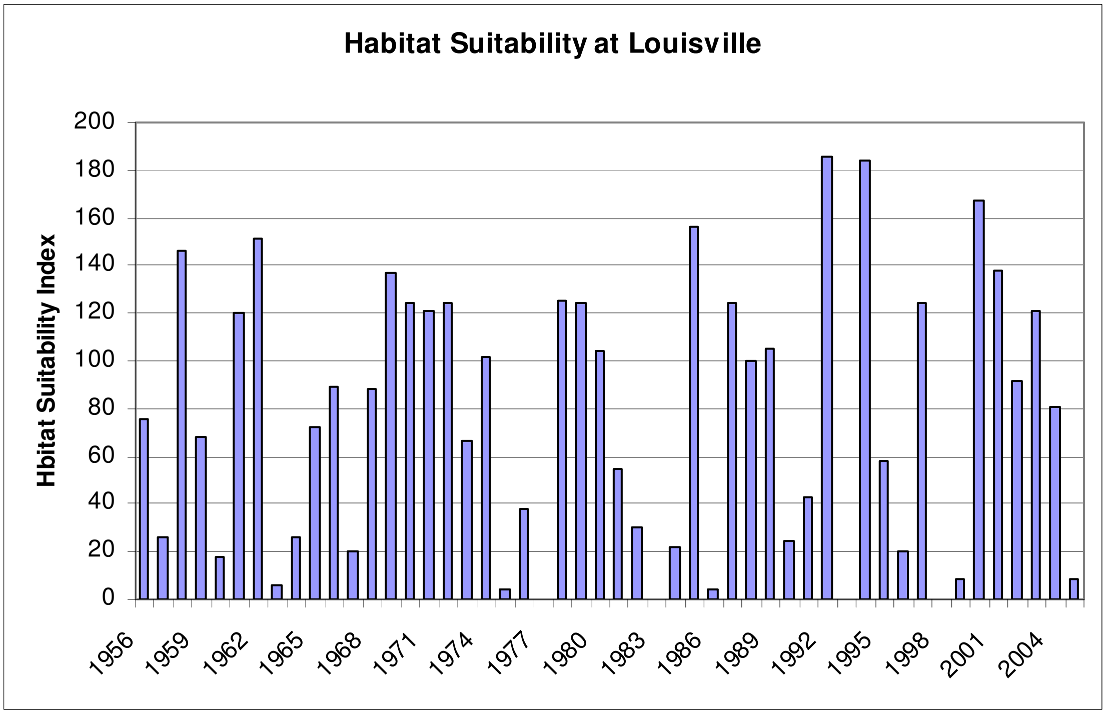


Figure 30: Habitat suitability index for Louisville Gage where higher values reflect the higher quality habitat. Index based on habitat creating flows in the previous 1.5 years and the lack of inundation during the nesting period (based on period of record 1954 – 2005).

The results can be categorized to evaluate the conditions that occurred in the most suitable years for each location. The habitat forming flows as a function of the natural hydrograph are fundamental to building sufficient sandbars that will set the foundation for suitable conditions throughout the nesting season. Table 10 illustrates the average flow events that created sandbar habitat in years of the most habitat suitability. It should be noted that this analysis was done using data from a period when the Platte River was already altered and the derived habitat suitability index should not be construed as representing historic conditions.

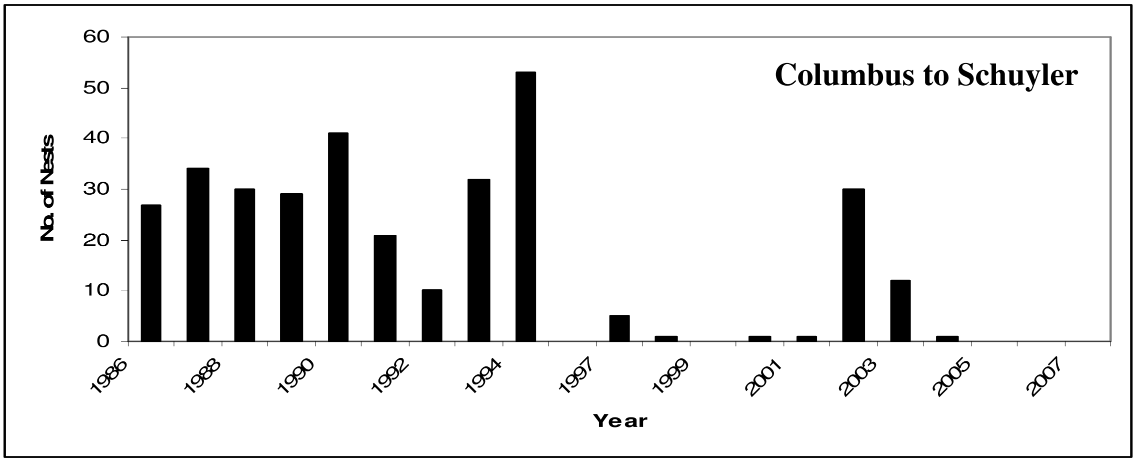
Table 10: Average of the highest flows that occurred within the previous 1.5 years of the years with the most habitat suitability, based on the period of record 1954 – 2005.

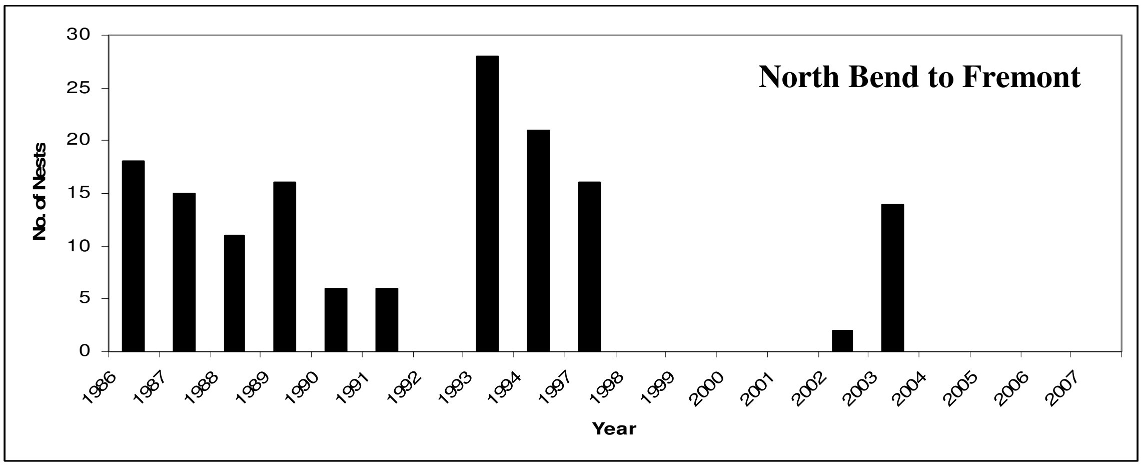
Location	Average Flows (cfs)
Duncan	19,150
North Bend	46,600
Louisville	65,710

These flows are more than double the bankfull flows for Duncan, approximately two times greater than bankfull flows at North Bend and the flows at Louisville are 50% greater than the bankfull flow (Table 8). Flows at very similar levels and their sandbar maintenance effects were described by Sidle and Carlson (1992). They reported a large flood of 32,300 cfs at the North

Bend gage and 60,500 cfs at the Louisville gage which noticeably reduced vegetation on sandbars by 78%. Bankfull flow events are important and occur with more regularity and are important to the system for sandbar habitat, but the high flows in Table 10, which are infrequent, are the flows that created the most suitable habitat. This analysis illustrates the importance of the natural hydrograph and variability inherent in the ecosystem that creates and maintains habitat.

Figures 28-30 illustrate an eastward trend of increasing suitable habitat. The scale for each figure was adjusted for illustration purposes, but the habitat suitability values are comparable between each location. When comparing figures, it is apparent that Louisville has the highest and most consistent level of suitable habitat. Duncan had very few years with suitable habitat, indicating that the flows from the central Platte River are highly degraded and no longer sufficient to create and maintain sandbar habitat. The patterns of available habitat between the different locations are supported when looking at recent trends in bird nesting patterns. Nestin is extremely limited as discussed above upstream from the confluence of the Loup River, including the Duncan area (Figure 31 - 32). Figure 31 illustrates that least terns now nest infrequently on river sandbars and may be extirpated from the river from the Loup River confluence to Schuyler and the Fremont to North Bend segments. Prior to the late 1990’s, least terns were regularly observed nesting on river sites in these segments, but now only regularly nests downstream, primarily the Louisville to Plattsmouth segment. Even in areas with consistent nesting, there is a downward trend in least tern numbers. A similar pattern is seen with piping plovers with declines in use in the upper reaches of the lower Platte River (Figure 32).





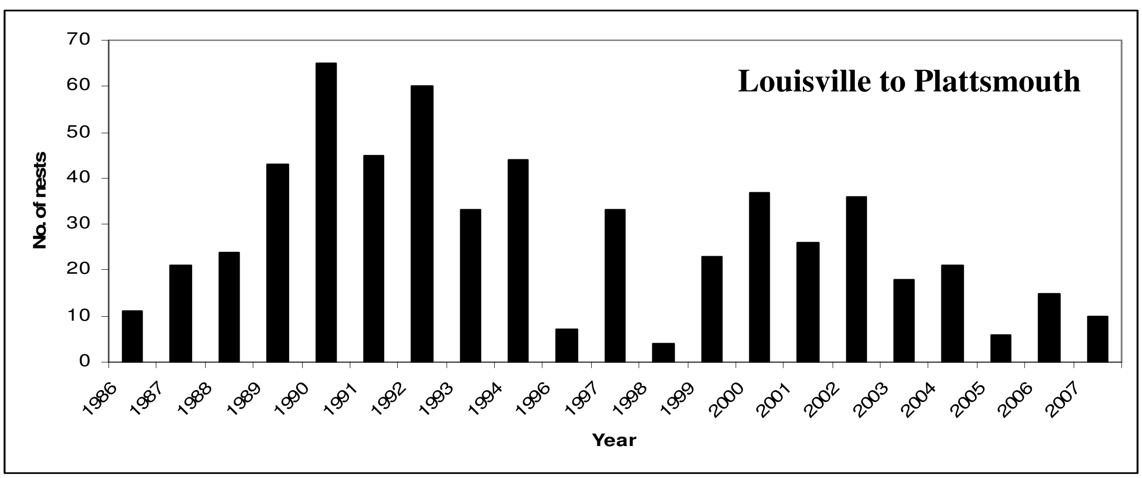
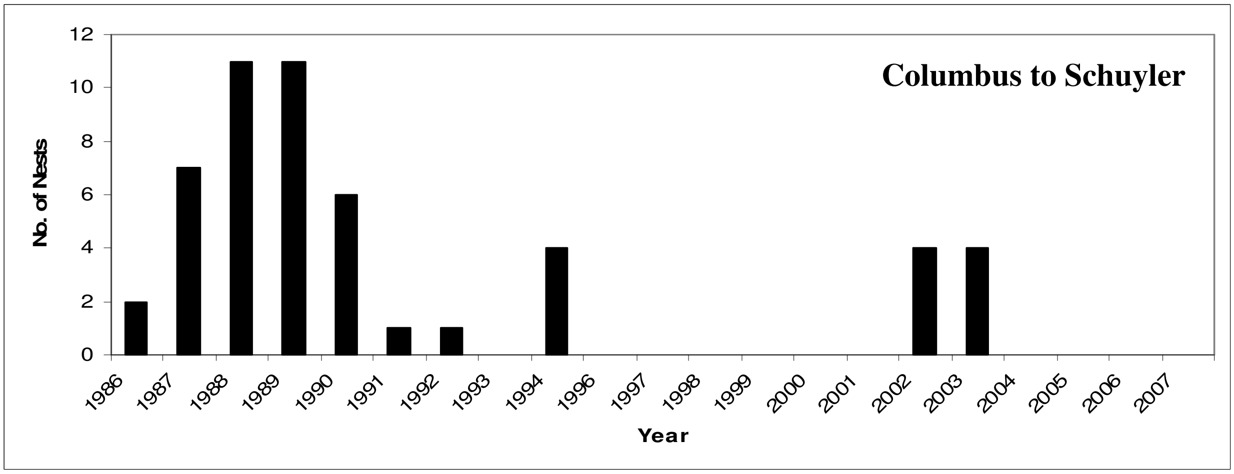
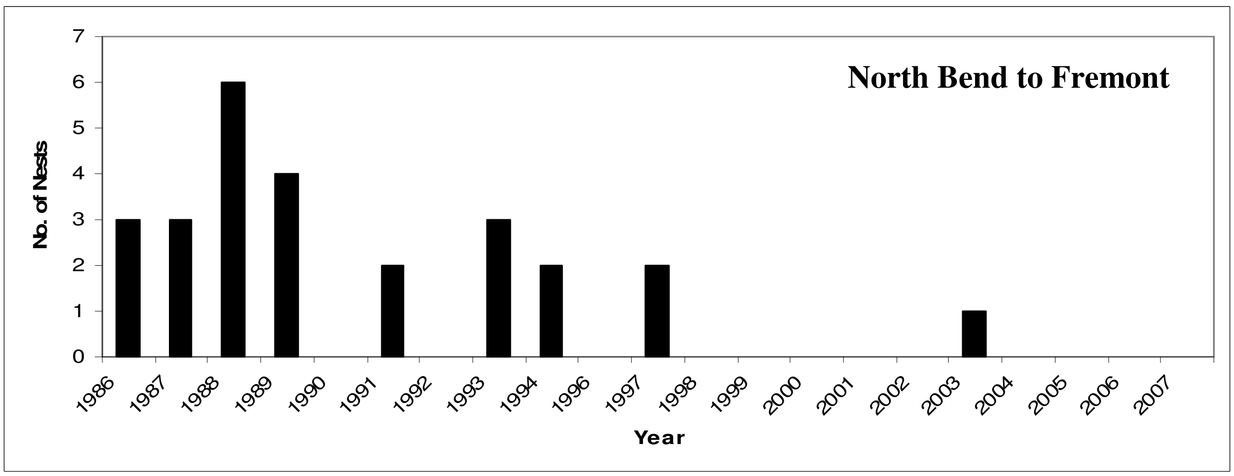


Figure 31. Number of least tern nests from selected river segments recorded during Nebraska Game and Parks Commission annual surveys. Data indicates decline and effectual extirpation of breeding birds on the Platte River in upper segments (Columbus to Schuyler and North Bend to Fremont) resembling declines and extirpation from the Central Platte River. In contrast, breeding birds have been observed on the river in the lower segment (Louisville to Plattsmouth) through 2007 where river function is not as greatly degraded and affected by diversion.





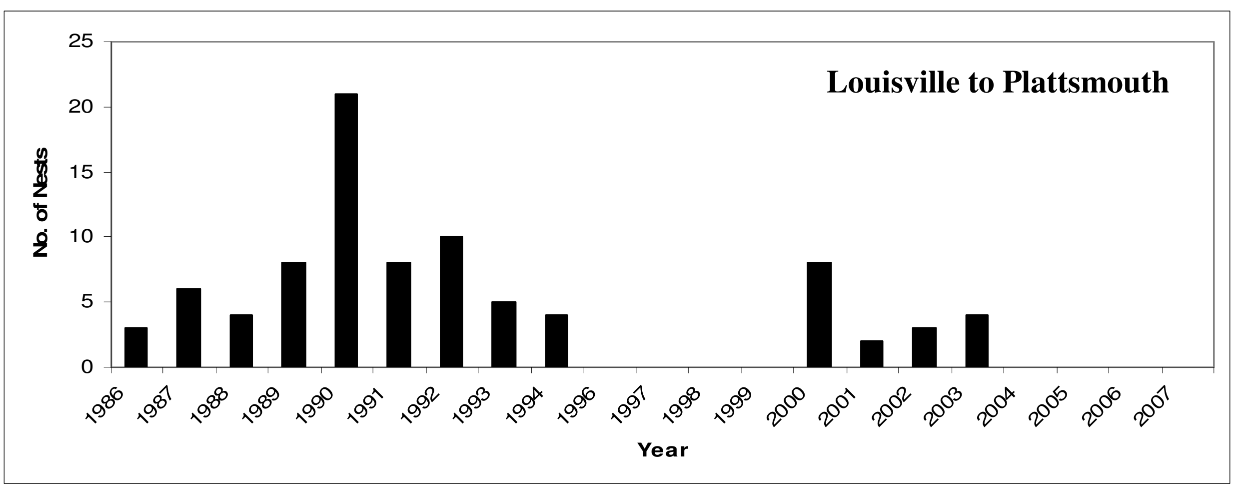


Figure 32: Number of piping plover nests from selected river segments recorded during Nebraska Game and Parks Commission annual surveys. Data indicates decline and effectual extirpation of breeding birds on the Platte River in upper segments (Columbus to Schuyler and North Bend to Fremont). Breeding on lower river segments, such as Louisville to Plattsmouth, is now infrequent.

Throughout the nesting season, least terns forage on small minnow species, therefore the lower Platte River must contain habitat for these smaller fish. Flowing water that separates sandbars from mammalian predators is also important as discussed previously. Current instream flow appropriations were based on the fish community of the Platte River, but did not include the pallid sturgeon. This appropriation as based on several fish that are considered potential forage for least terns. At North Bend, the instream flow appropriation is 1,800 cfs for the entire year. For Louisville, the instream flow appropriation is 3,100 cfs for January, 3,700 cfs for February through July 31, 3,500 cfs for the month of August, 3,200 cfs for September, and 3,700 cfs for October through December. Parham (2007) found that a flow of 2,350 cfs for the lower Platte River resulted in the maximum level of shallow water habitat.

Least terns and piping plovers have very limited available habitat available along Nebraska's rivers when compared with historical distributions. In Nebraska, much of the habitat utilized is inadequate to sustain the populations of least terns and piping plovers. The natural hydrograph of the lower Platte River, with high spring flows followed by lower summer flows, is fundamental to sandbar creation and maintenance. The higher spring flows move the sediment, create and scour sandbars and must be sufficiently higher than summer flows to prevent inundation. Summer flows must provide forage.

Hydrological Discussion as related to Pallid Sturgeon

Currently, the lower Platte River does retain a natural spring rise, although much smaller than historic flows, due to inputs from the Loup and Elkhorn rivers and other tributaries. Information from the Duncan gage (Figure 27) clearly illustrates the historic and reduction of the natural hydrograph. Although not historic, Figure 15 demonstrates the hydrograph at Louisville. This spring rise allows migratory pallid sturgeon to move into the lower Platte River and utilize the scour holes, deep channels and shifting habitat.

Bankfull flows are channel shaping flows that move sediment within the river and scour deeper channels preferred by the pallid sturgeon. Although more subtle than large floods, these more frequent flows make significant contributions to forming habitats suitable for pallid sturgeon.

Peters and Parham (2007) conducted extensive analysis of pallid sturgeon habitat as related to flows in the lower Platte River. They found that in the lower Platte River, pallid sturgeon were most frequently captured in the deepest and swiftest runs of the river. Pallid sturgeon selected areas with a depth greater than 0.8 m with an average depth of approximately 1.6 m and a mean column current velocity of 0.8 m/s (Figures 32 and 33). They appear to target areas with complex microhabitats, as the deep runs where pallid sturgeon were captured were typically within 50 to 100 m of shallow, exposed sandbars.

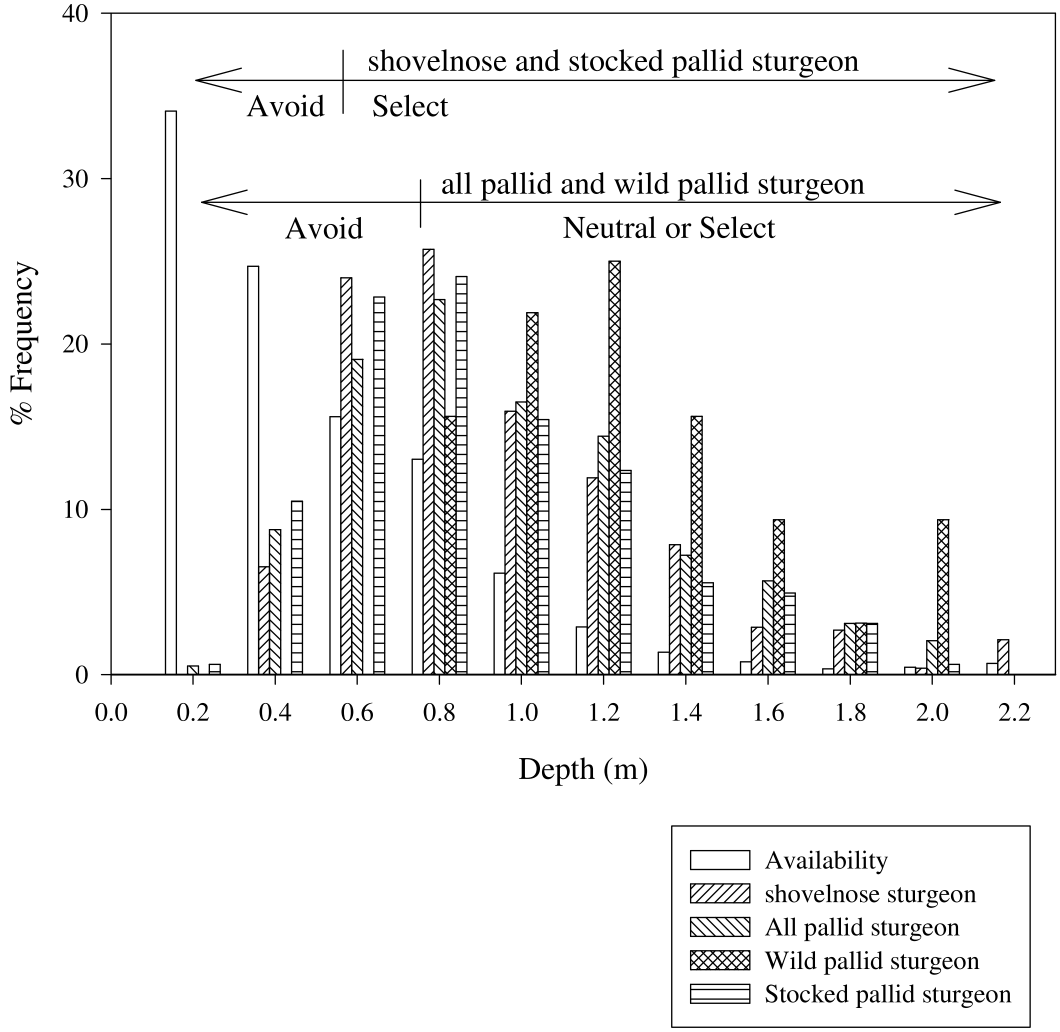


Figure 32: Sturgeon habitat use vs. depth availability in the lower Platte River (Peters and Parham 2007).

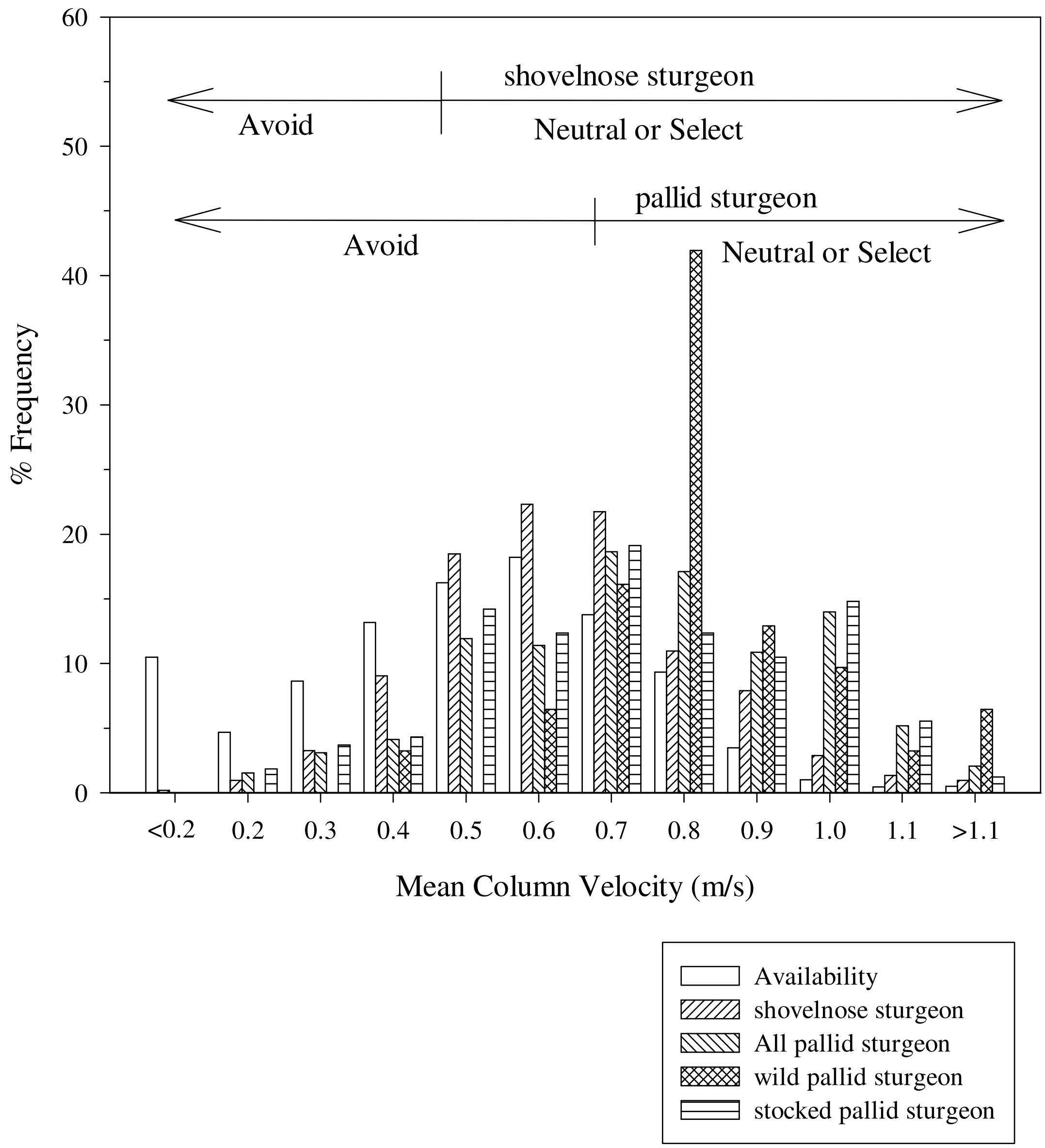


Figure 33: Sturgeon habitat use vs. mean column velocity availability in the lower Platte River (Peters and Parham 2007).

When combining depth and velocity information and their availability at discharge rates for the lower Platte River, they found that habitat availability had a non-linear relationship with discharge (Figure 34), such that small changes in discharge result in significant habitat changes. There was little to no habitat (deep, swift water) at low discharge rates, but increased rapidly starting at 6,000 cfs and reached an asymptote near 9,000 cfs.

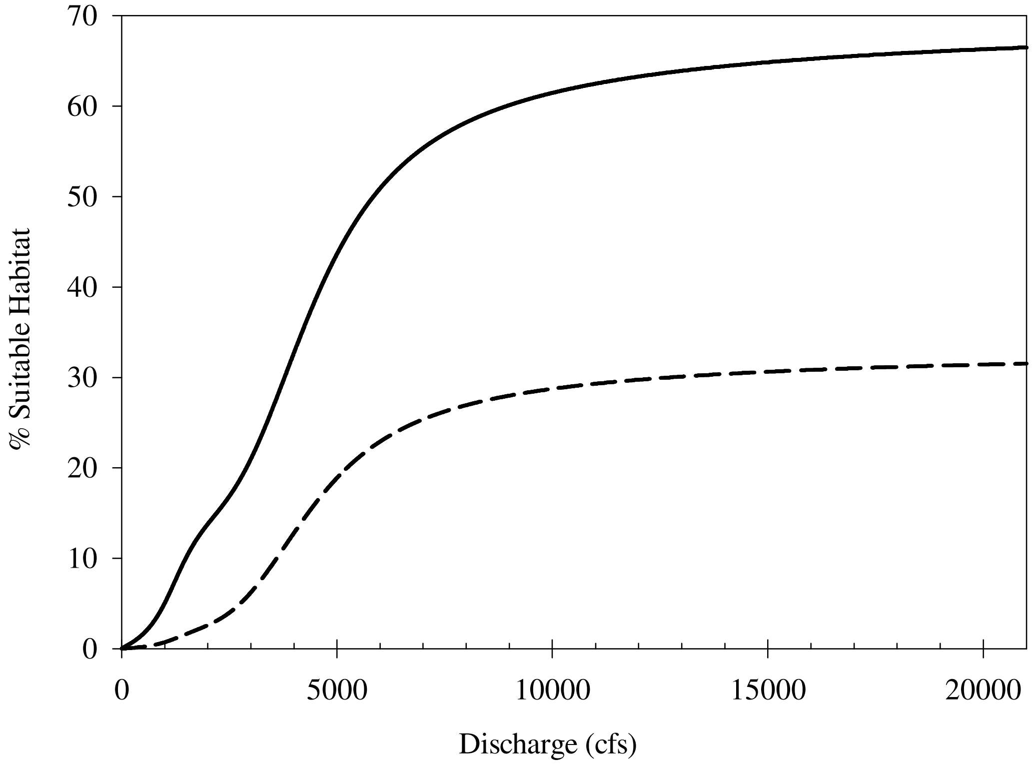


Figure 34: Suitable habitat vs. discharge for the sturgeon in the lower Platte River. The solid line represents shovelnose sturgeon and the dashed line represents pallid sturgeon (Peters and Parham 2007).

Another component of pallid sturgeon habitat is that of habitat connectivity within the channel. The geomorphology of the river has highly variable depths, with deeper channels, shallow areas and sandbars. For pallid sturgeon to be able to utilize the deeper areas of the river, they need to be connected via flowing water of great enough depth for passage. Pallid sturgeon may use deeper holes as refuge as discharge rates drop, but will rapidly become stranded and perish if connectivity is not returned and maintained. According to Peters and Parham (2007), the lower Platte River is generally unconnected at low discharge rates, with a rapid increase in connectivity between 3,200 and 5,600 cfs with 100% connectivity occurring at approximately 8,100 cfs (Figure 35).

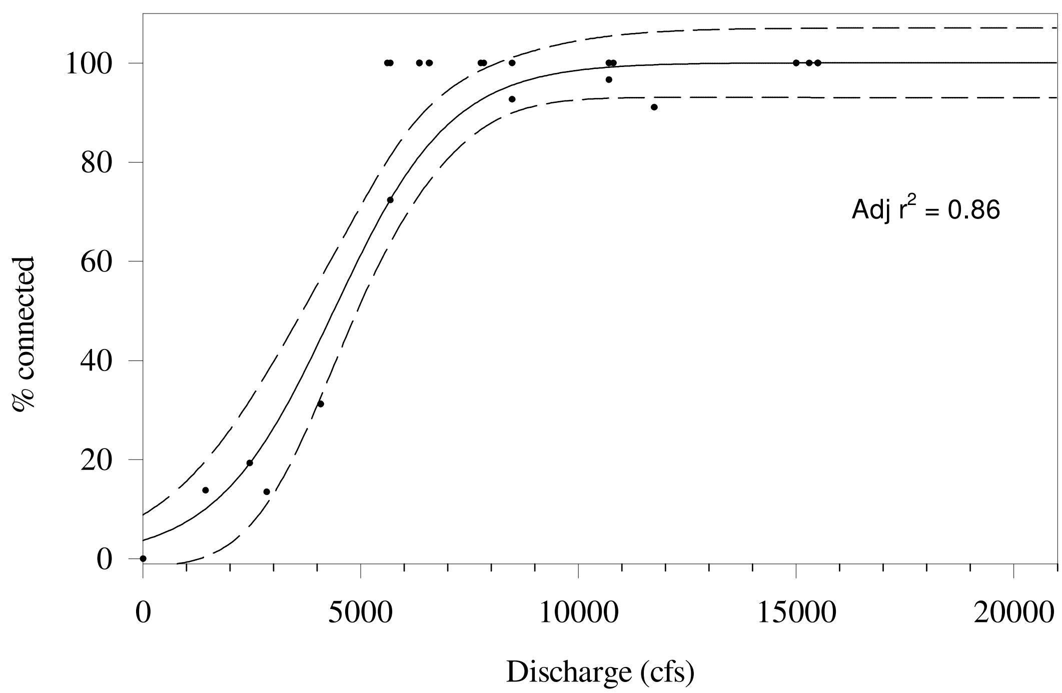


Figure 35: Curve of the best fit for river connectivity vs. discharge for the lower Platte River. The solid line represents the fitted line, the dashed lines are the 95% confidence intervals about the line, and the dots are the observations.

The pallid sturgeon has limited habitat available, but does use the lower Platte River. If the lower Platte River is consistently unconnected in the spring of the year, sturgeon will likely not be able to access habitats available to them in the river which decreases the likelihood of the fish completing a successful spawning run. Likewise, mortality by stranding of genetically important broodstock also decreases the likelihood of species recovery. It is imperative that habitat be available every year for this very rare species, as individual females are likely not all capable of reproducing annually when favorable conditions exist. Keenlyne (1989) concluded that, “because of their low reproductive potential, meeting reproductive needs may be a delicate but crucial strand in the success of sturgeon species, including the pallid sturgeon.” Pallid sturgeon utilize habitats in the lower Platte River at other times of the year, so habitat availability throughout the year is also important.

Opinion

It is the opinion of the Nebraska Game and Parks Commission that there be no additional degradation in magnitude and structure of the hydrograph. Higher flows must be protected from further depletion to a) scour deep channels with swift current which provides habitat for the pallid sturgeon, b) to build and maintain sandbars for least tern and piping plover nesting. Timing and duration of the higher spring flows must be protected for pallid sturgeon spawning cues. Flows need to be sufficient to maintain connectivity during the spawning time of year for pallid sturgeon, so that habitat is available each year for any females that are physically ready for spawning to both migrate upstream to spawn and to safely migrate back downstream to the Missouri River. Summer flows need to be maintained to provide forage for least terns and sandbar isolation. Flows throughout the year must be maintained for pallid sturgeon habitat.

Least Terns and Piping Plovers

As described in the Environmental Baseline Section, current conditions above the Loup River confluence with the Platte River no longer have sufficient flows to create and maintain sandbar habitat, with the exception of a rare flood event. Depletions and diversions upstream have severely reduced potential for this area to host sandbar nesting birds. The lower Platte River between the confluence of the Loup River and the Elkhorn River currently provides questionable habitat, and as seen in the central Platte River, future depletions to this area will eventually eliminate nesting habitat the majority of the time. The lower Platte River downstream of the Elkhorn confluence still appears to have minimal suitable habitat and the flow regime necessary to create and maintain this suitable habitat. Habitat restoration activities above this location may be necessary to ensure continued nesting of least tern and piping plovers.

The remaining semblance of the natural hydrograph is necessary for creation and maintenance of sandbar habitat for nesting least terns and piping plovers. Bank full flows of 39,800 cfs from the confluence with the Elkhorn River to the confluence with the Missouri River and flows of 21,300 cfs from the confluence with the Loup River to the confluence with the Elkhorn River must be maintained.* These flows may occur at any time of the year. Currently, these flows occur approximately every 1.5 years. Near Louisville, current conditions are sufficient, but above the Elkhorn River, flows are just adequate to potentially create new habitat and maintain existing nesting habitat for these species in the lower Platte. This analysis is corroborated by the patterns of least tern and piping plover use in the lower Platte River, which have declined dramatically. The remaining semblance of the natural hydrograph that produces higher flow events are also vital for sandbar creation and maintenance as described above. Therefore, further depletions that reduce the frequency and duration of the bankfull flows and higher flows exacerbate the decline of suitable river nesting habitat in the lower Platte River and jeopardize the continued existence of least terns and piping plovers in Nebraska.

In addition to maintaining the hydrograph and higher flows, there must also be flowing channels during the nesting season that provides refuge and productivity for the smaller fish that least terns use for forage. These flows also provide exposure and separation of sandbars from the bank which is important for reducing predation. Based on the habitat suitability index analysis and maximum shallow water values, the frequency, duration and timing of 5100 cfs in June, 3,350 cfs in July and 2350 cfs in August from the confluence with the Loup River to the confluence with the Elkhorn River must be protected from future depletions. At the North Bend Gage, these flows occur approximately 40%, 35% and 35% of the time respectively.* From the Elkhorn River to the confluence with the Missouri River, the frequency, timing and duration of 7670 cfs in June, 4,840 cfs in July and 3,650 in August must be protected from future depletions. These flows only occur at the Louisville Gage approximately 40%, 50%, and 35% of the time respectively.* Therefore, any further depletions to the lower Platte River system would exacerbate the decline of habitats within these two sections of the river and will jeopardize the continued existence of least terns and piping plovers in Nebraska.

Pallid Sturgeon

As described in the Environmental Baseline, current conditions of the lower Platte River appear to provide minimal habitat for pallid sturgeon and the remaining semblance of the natural hydrograph provides necessary components for spawning. There are records of shovelnose sturgeon as far west as Wyoming in the Platte Basin (Baxter and Simon 1970) and recent records of Lake Sturgeon *(Acipenser fulvescens)* as far west as Columbus (Heritage data 2007). Given the similarities of these species, it is likely that historically the pallid sturgeon utilized available habitat west of Columbus. However, depletions and diversions upstream of the Loup Confluence have severely reduced potential for pallid sturgeon habitat. At this time, there are no records of pallid sturgeon in the lower Platte River west of the Elkhorn confluence, but there are records in the Elkhorn River. Therefore, the following recommendations for the pallid sturgeon are from the Elkhorn River east to the confluence with the Missouri River, but this most eastern section of the lower Platte River is highly dependent on flows from all upstream sources, especially the central Platte River, the Loup River and Elkhorn River as well as the Salt Creek basins.

It is the opinion of the Nebraska Game and Parks Commission that from April 1st through June 30, the current frequency, timing and duration of 8100 cfs must be protected from future depletions in the lower Platte River from the confluence of the Elkhorn River east to the confluence with the Missouri River. At the Louisville gage, this required flow is available approximately 45% of the time from April through June.* At 8100 cfs the lower Platte River channel reaches 100% connectivity within the 95% confidence interval and provides approximately 85% of the maximum available pallid sturgeon habitat (Figures 34 and 35) (Peters and Parham 2007, Parham 2007). According to Figures 14 and 15, the spring rise is typically ending during the month of July and there is a reduction in flows. During this month, pallid sturgeon may still be spawning (Mestl, personal communication 2007), adults need to exit the river and larvae are still drifting. Therefore from July 1 to July 15, the frequency, timing and duration of 7000 cfs and from July 16 to July 31, the frequency, timing and duration of 6000 cfs must be protected from future depletions. These flow occur approximately 27 – 32 % of the time respectively at the Louisville Gage.* There are records of pallid sturgeon using the lower Platte River in times outside of the presumed spawning season, therefore it is important to maintain habitat for pallid sturgeon during the rest of the year. There must be protection of the current frequency, timing and duration of 4950 cfs from the Elkhorn River Confluence to the Missouri River Confluence the rest of the year. At 4950 cfs, 59% of the maximum habitat is available and reaches the upper inflection point (Figure 26). For the period of record from 1954 to 2005, this required summer flow occurs approximately 55% of the time annually at the Louisville Gage.*

The lower Platte River is considered crucial for the survival of the pallid sturgeon in Nebraska, but also for the entire species. "The population of the pallid sturgeon is so low in numbers, and habitat such as the lower Platte River is pivotal in the recovery and management of the species…and the loss of lower Platte River habitat would probably result in a catastrophic reduction in the pallid sturgeon population. (NRC 2005)." Given that an individual pallid sturgeon female may only spawn once every 10 years, and that available habitat is currently only available approximately 27-45% of the time during this crucial period, and 55% of the time the rest of the year, the species are considered to be in jeopardy based on current conditions. Therefore, additional depletions to the action area would jeopardize the continued existence of pallid sturgeon existence in Nebraska.

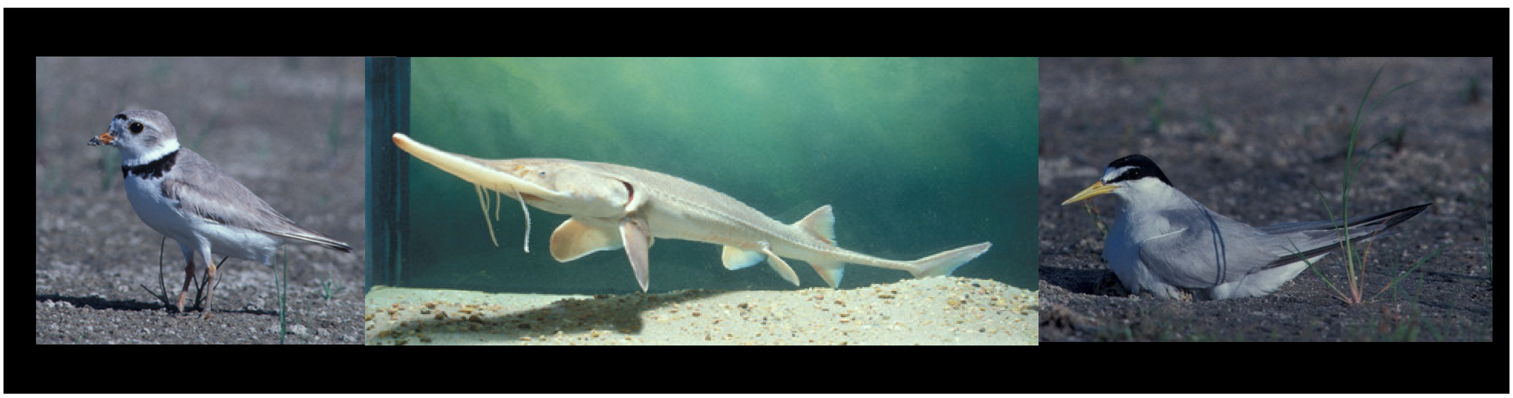
It is the opinion of the Nebraska Game and Parks Commission that there be no additional degradation in magnitude and structure of the hydrograph and that the continued issuance of surface water appropriations by the Nebraska Department of Natural Resources for the action area including the lower Platte River Basin, the Loup River Basin, Elkhorn River Basin and Salt Creek Basin will jeopardize the continued existence of the least tern, the piping plover and pallid sturgeon in Nebraska.

In a letter from the Commission to DNR dated 1999, it was agreed upon that while studies were underway to evaluate pallid sturgeon and sturgeon chub in the lower Platte River, up to 5,000 acre feet of new surface water applications would be considered “no jeopardy.” It is the Commission’s understanding that this agreed upon amount has not yet been fully allocated. With the completion of the agreed upon studies, the disbandment of the Task Force and submission of this Biological Opinion, allocation of the remaining 5,000 acre feet in the action area will also jeopardize the continued existence of the target species in Nebraska.

As mentioned previously, this consultation and biological opinion addresses only the effects of surface water appropriations in the action area on pallid sturgeon, least tern and piping plover. There are additional listed species in the action area, but outside of the lower Platte River that will continue to require individual consultation. Additionally, with new information, this biological opinion is subject to revision.

* Based on period of record 1954 – 2005 (Parham 2007)

Assessment of the Pallid Sturgeon, Least Tern and Piping Plover in the Lower Platte River



Nebraska Game and Parks Commission
Lincoln, Nebraska
December 2008

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"It is now recognized that harnessing of streams and rivers comes at a great cost. Many rivers no longer support socially valued native species or sustain a healthy ecosystems that provide important goods and services" (Poff et al. 1997).

Introduction

The purpose of this report is to evaluate impacts of continued depletions to the lower Platte River on the pallid sturgeon, least tern and piping plover.

This report includes information from a Commission Federal Aid and Sportfish Restoration project which focused on the ecological relationship of two sturgeon species (pallid sturgeon and shovelnose sturgeon) with fish species typical of shifting sand-bed rivers. This study delineated five objectives:

- Objective 1 was to document habitat use, relative habitat preference, and species assemblages associated with adult and juvenile sturgeon in the lower Platte River.
- Objective 2 was to document the phenology and relative abundance of larval recruitment for sturgeon and associated species in the lower Platte River.
- Objective 3 was to determine how changes in river discharge influence habitat use by sturgeon life stages in the lower Platte River.
- Objective 4 was to document the catch of sturgeon by anglers in the lower Platte River.
- Objective 5 was to develop educational materials and management recommendations for the sturgeon fishery in the lower Platte River.

This report also includes information from a report produced from a consortium of Natural Resources Districts and Public Power and Irrigation districts, which investigated the possibilities of funding research on the Platte River to study the pallid sturgeon and sturgeon chub. This committee formally signed an Inter-local Cooperative Agreement for the Pallid Sturgeon and Sturgeon Chub Study of the Lower Platte River (Inter-local Agreement) with the last signatory on October 25, 1999 which formalized the Pallid Sturgeon / Sturgeon Chub Task Force (Task Force). On May 18, 2000, the Task Force approved the funding of a five-year study of pallid sturgeon, sturgeon chub, and associated species in the lower Platte River.

The primary goal of the study funded by the Task Force was to quantitatively describe habitat use by pallid sturgeon and sturgeon chub in the lower Platte River. Additional analyses evaluated the ecological relationships of pallid sturgeon and sturgeon chub, and other fish species typical of shifting sand-bed rivers, as exemplified by the Platte River. This study was done in conjunction with the Federal Aid and Sportfish Restoration project previously described. The Task Force study delineated five objectives:

- Objective 1 was to document habitat use, relative habitat preference, and species assemblages associated with adult and juvenile pallid sturgeon and sturgeon chub in the lower Platte River.
- Objective 2 was to document the phenology and relative abundance of larvae for pallid sturgeon, sturgeon chub and associated species in the lower Platte River.
- Objective 3 was to determine if changes in ambient river habitat conditions influence habitat use by pallid sturgeon and sturgeon chub life stages in the lower Platte River.
- Objective 4 was to document the catch of sturgeon by anglers in the lower Platte River.

- Objective 5 was to develop management recommendations and educational materials to facilitate appropriate recovery efforts for pallid sturgeon and sturgeon chub in the lower Platte River.

Dr. Ed Peters and Dr. Jim Parham with the University of Nebraska - Lincoln were contracted to complete the study which addressed both project objectives. A report on the completed study was submitted to the Task Force and to the Commission in May, 2005. This study was subsequently peer reviewed by numerous professionals in the field of sturgeon ecology, environmental science and statistical evaluations. The peer reviewed was published in the Nebraska Game and Parks Commission Technical Series. Results and figures from the technical series document (Peters and Parham 2008), are referenced throughout this report.

Action Area

This report examines the effects of continued issuance of new water use on the hydrology of the lower Platte River. For the purposes of this report, the lower Platte River is defined as the reach extending from the confluence of the Loup River near Columbus to the mouth of the Platte River (Figure 1). Flows of the lower Platte River are highly dependent on the Loup River Basin, the Elkhorn River Basin and the Salt Creek Basin. Therefore, the action area of this report includes the Loup River Basin, Elkhorn River Basin, Salt Creek Basin and Lower Platte River Basin.

Flows from the Platte River watershed above Columbus are an important component of the lower Platte River, but future depletions to these upstream flows are outside the scope of this consultation and not addressed in this report. The effects of depletions to flows upstream from Columbus are addressed by the Platte River Recovery Implementation Program (Program) implemented by the three Platte River basin states and the U.S. Department of the Interior on January 1, 2007. The Program's primary focus is to improve and protect threatened and endangered species' habitat in the central reach of the Platte River, and to avoid or offset new depletions to flows upstream from Columbus. Federal actions resulting in depletions to the Platte River downstream from Columbus (i.e., in the Loup River, Elkhorn River, Salt Creek and lower Platte River tributary basins) are outside the scope of the Program, and are not provided Endangered Species Act compliance via the U. S. Fish and Wildlife Service Biological Opinion on the effects of the Program issued on June 16, 2006.

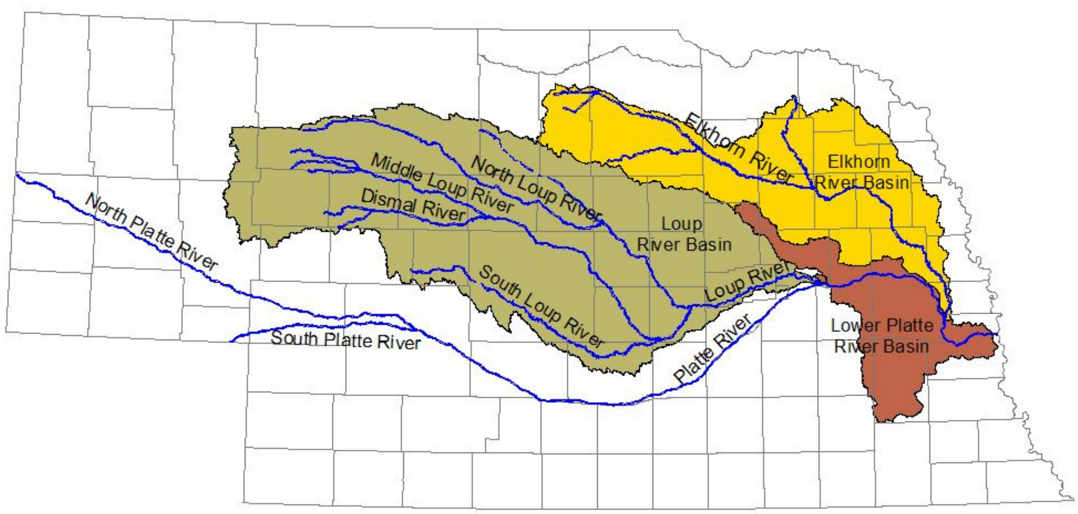

Figure 1: Action area of this Report.

Water in the lower Platte River is utilized for irrigation, municipal use, domestic use and commercial use and as instream flows for biodiversity. Half of the public water supply for the Omaha Metropolitan Area and all of the public water supply for the City of Lincoln is dependent on flows from the lower Platte River recharging the municipal ground water well fields.

Species

State threatened or endangered species in the action area include the interior least tern (*Sternula antillarum athalassos*), piping plover (*Charadrius melodus*), pallid sturgeon (*Scaphirhyncus albus*), sturgeon chub (*Macrhybopsis gelida*), river otter *(Lutra canadensis*), western prairie fringed orchid (*Platanthera praeclara*), lake sturgeon (*Acipenser fulvescens*), blacknose shiner (*Notropis heterolepis*), finescale dace (*Phoxinus neogaeus*), northern redbelly dace (*Phoxinus eos*), American burying beetle (*Nicrophorus americanus*), Salt Creek tiger beetle (*Cicindela nevadica lincolniana*) and small white lady's slipper (*Cypripedium candidum*).

This report only addresses those species which occur in the lower Platte River, not the entire action area. **Specifically, the target species of this report are the interior least tern, piping plover and pallid sturgeon.** The sturgeon chub, river otter and lake sturgeon were not included in this report due to the lack of information regarding specific habitat requirements for these species in the lower Platte River. The western prairie fringed orchid, blacknose shiner, finescale dace, northern redbelly dace, American burying beetle, Salt Creek tiger beetle and small white lady's slipper were not included as target species because they do not occur in the lower Platte River or in habitats in the immediate vicinity of the lower Platte River.

Authority

This Report was prepared as prescribed in rules and regulations of the Nebraska Game and Parks Commission governing the inter-agency consultation process, and under the authority of the Nongame and Endangered Species Conservation Act (Act) §37-807(3). The legislative intent of the Act is, "That it is the policy of this state to conserve species of wildlife for human enjoyment, for scientific purposes, and to insure their perpetuation as viable components of their ecosystems." The Act requires that, "All state agencies shall, in consultation with and with the assistance of the Commission, utilize their authorities in furtherance for the purposes of the act by carrying out programs for the conservation of endangered species and threatened species, by taking such action necessary to insure that actions authorized, funded or carried out by them do not jeopardize the continued existence of such endangered or threatened species or result in the destruction or modification of habitat of such species which is determined by the Commission to be critical." The area of jurisdiction for the Act is the State of Nebraska, so determinations of a species status are based on their occurrence within the state boundary, not the individual species' entire range.

Data and Resources

The biological information and data considered in this Report are the best data currently available. Species records were obtained from a variety of sources and have been incorporated into the Natural Heritage Database using strict standards for species occurrences records. All records were geospatially referenced using Geographic Information Systems (GIS) technology.

A series of research projects performed by the University of Nebraska-Lincoln in conjunction with the Commission produced the habitat use and movement data for a variety of species inhabiting the lower Platte River, including the pallid sturgeon and sturgeon chub. As part of a five-year study of sturgeon ecology conducted by the University of Nebraska-Lincoln, sturgeon habitat use and preference and seasonal movement data were related to flow records in order to develop a habitat connectivity model in the lower Platte River. These studies have been reviewed by specialists in the appropriate fields of study. Platte River flow records were obtained from USGS river gage records.

Hydrological analyses that modeled both normative and extreme flows of the lower Platte River system were conducted by Dr. Parham on contract with the Commission. An analysis of the timing, duration and magnitude of river discharge that creates and sustains nesting habitat for least terns and piping plovers was also completed.

The Commission incorporated biological information, relevant literature and data into the context of the Platte River hydrograph. Specific references are noted, wherever necessary, within the Report and are listed in the reference cited section.

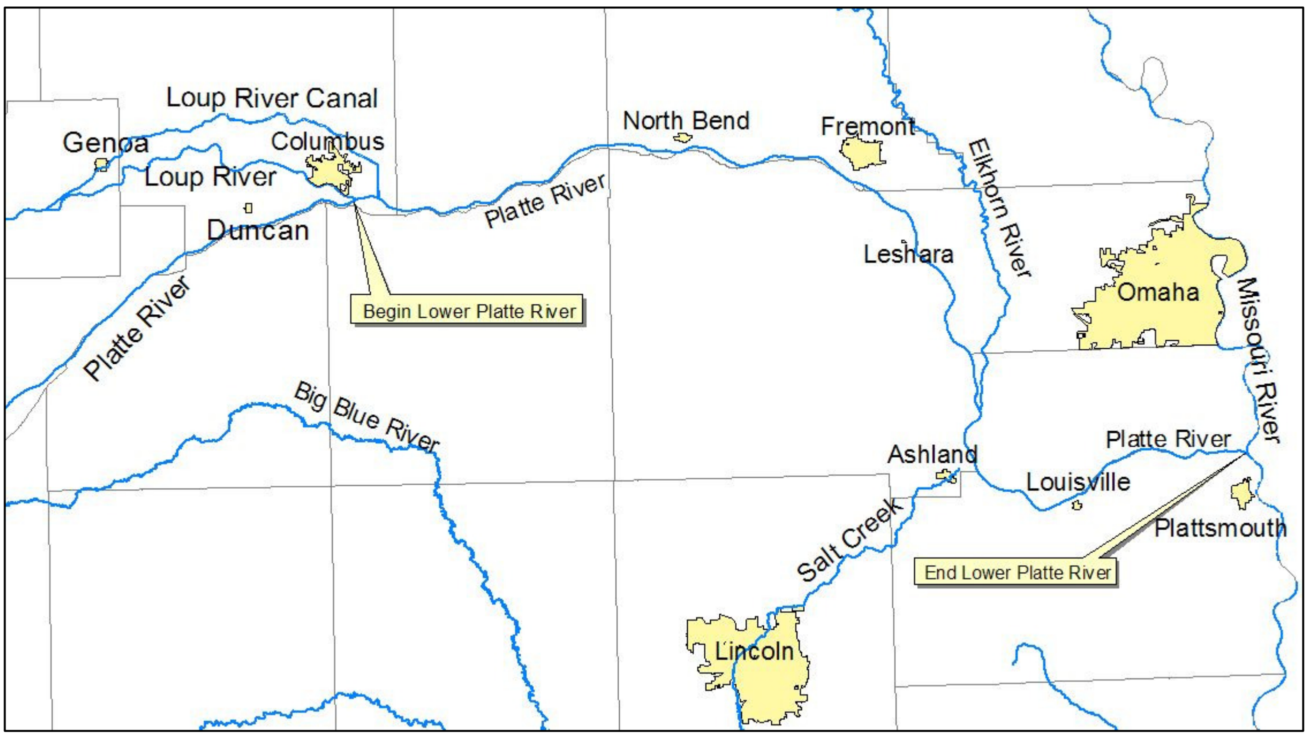

Figure 2: Map of the lower Platte River, large tributaries, population centers and significant landmarks mentioned in this document.

Status of Species

Interior Least Tern (*Sternula antillarum athalassos*)

Least terns are the smallest members of the subfamily Sterninae, family Laridae of the order Charadriiformes. The least tern was previously in the genus *Sterna*, but was recently re-classified by the American Ornithologists' Union Committee on Classification and Nomenclature – North America and placed within the genus *Sternula* (Banks et al. 2006). This bird measures 21-24 cm long with a wingspan of 51 cm. It can be distinguished from other terns by its black crown, white forehead and under parts, pale gray back and wings, and black-tipped yellow-orange bill.

The American Ornithologists' Union (AOU) recognizes three subspecies of the least tern, California (*S. a. browni*), eastern (*S. a. antillarum*), and the interior (*S. a. athalassos*) (American Ornithologists' Union 1957). The California least tern is also listed as endangered in California and is federally endangered. The eastern least tern has received state protection, but is not federally listed. On May 28, 1985, the U.S. Fish and Wildlife Service (Service) designated as an endangered species the population of least tern occurring in the interior of the United States (interior least tern) (50 F.R. 21792). Under Neb. Rev. Stat. § 37-806 any species determined to be threatened or endangered pursuant to the federal Endangered Species Act shall be similarly listed under the Nebraska Nongame and Endangered Species Conservation Act. Unless otherwise indicated, this Report refers to the interior least tern.

Distribution

Historically, the breeding range of the interior least tern extended from Texas to Montana and from eastern Colorado and New Mexico to southern Indiana. This species nested along the Missouri, Mississippi, Colorado, Arkansas, Red, and Rio Grande river systems. All subspecies of the least tern apparently were abundant through the late 1880s (Bent 1963). The interior least tern continues to breed in most of the aforementioned river systems, but its distribution is generally fragmented and restricted to the less altered river segments.

The first historical observation of the least tern in Nebraska was recorded along the Missouri River by the Lewis and Clark expedition of 1804. Prior to settlement by European American, the least tern was apparently a common breeding species on riverine habitat throughout much of Nebraska, including along the Missouri, Platte, Elkhorn, lower Loup, and Niobrara Rivers (Ducey 2000, Bruner et al. 1904, Sharpe et al. 2001). Taylor and Van Vleet (1888) described it as "abundant in June, July and August and breeding in the state," and Bruner et al. (1904) described it as "a common migrant and not a rare breeder." A record of five nests at what is now North Kirkpatrick Wildlife Management Area, York County, discovered by Tout (1902) is the only known nesting record away from riverine systems and their neighboring habitats in Nebraska.

On the Platte River system, least terns have a long record of using an extensive area of the Platte River. Least terns were observed in Platte County in 1857 and east of Ash Hollow, Keith

County, in 1859 (Ducey 2000). In Lincoln County, Tout (1947) described least terns as, "a regular summer resident and breeder on the sandbars of the Platte River and its forks." Tout (1947) noted consistent use of the South Platte River with a colony of 17 nests and several chicks in 1926, and noted similar nesting patterns and locations in 1927. In 1928 Tout (1947) found 18 nests in the same vicinity and in 1929 found 22 nests, all in relatively the same area. Benckeser (1948) found a small colony of six least tern pairs on the South Platte River two miles east of Brule, Keith County, 10 July, 1948.

Along the Platte River south of Lexington, Wycoff (1960) reported finding 35 nesting least terns in 1949, 20 in 1950, 24 in 1953, and 25 in 1954. These birds were nesting on a "low, sandy island not over 75 feet wide, about 200 feet long, and lying nearly a quarter-mile west of the Platte River bridge which is straight south of Lexington, Nebraska."

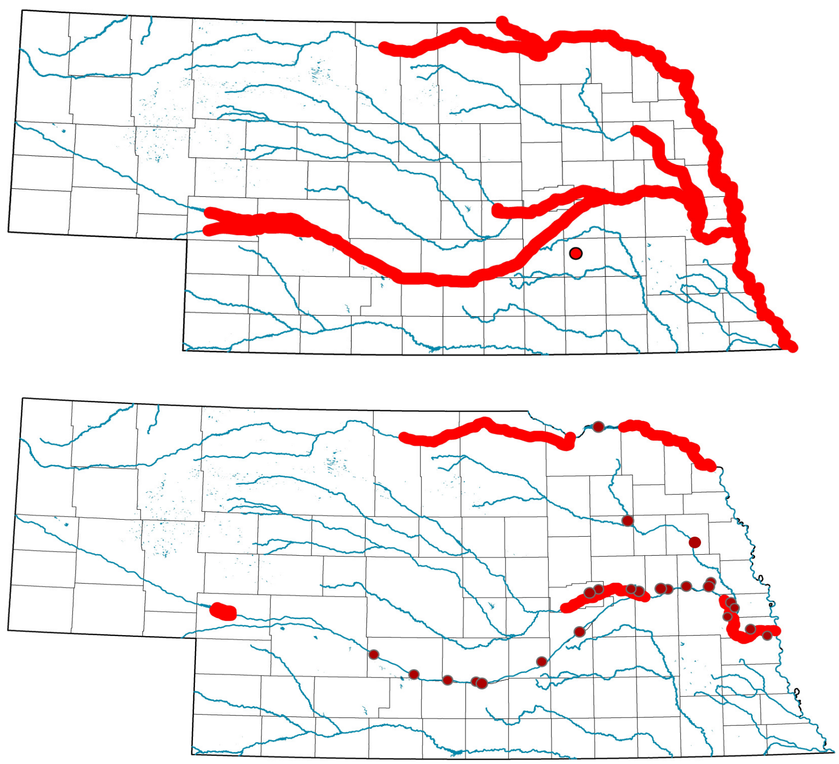

Figure 3. Previous (top) and current (bottom) breeding distribution of the least tern in Nebraska. Modern breeding sites along central Platte, lower Loup and Elkhorn Rivers are primarily limited to sandpits (dark red dots). The exception being a restored riverine site near Gibbon.

The lower Platte River from Columbus to the mouth, lower portions of the Loup River, the lower Niobrara River and a few stretches of the Missouri River below Ft. Randall Dam and Gavins Point Dam are the only river segments in Nebraska that still provide naturally occurring sandbar nesting habitat used by least terns. Because riverine nesting habitat has been severely reduced or eliminated in the central and upper Platte River by water diversions, nesting rarely occurs there; sand and gravel pits adjacent to the river now provide the majority of the nesting habitat.

Additionally, the Loup River has been highly altered in the reach below Genoa with a canal diversion system to a hydropower facility (Figure 3*).

Reproduction

Interior least terns are migratory birds. They spend the winter in South America and typically arrive in Nebraska in May to establishing feeding and nesting territories. They are colonial birds and are often found nesting with piping plovers. Ziewitz et. al (1992) found that least terns initiated nesting on the Platte River from May 19 to June 23, but nest initiation can occur as late as the first two weeks of July (Jorgensen 2007) . Sidle (1992) found that most fledging is completed by July 31.

Least terns nest on sparsely vegetated riverine sandbars, sand and gravel spoil piles, fly-ash disposal sites of power plants, dike fields, reservoir shorelines, wetlands and other artificial habitats such as rooftops. The quality of artificial and human created habitat is discussed later in this document. Colony sites are usually located in open expanses of sand or pebble substrate within the river channel or reservoir shoreline. Least terns prefer sites that are well-drained and well back of the water line. Along the Yellowstone and Mississippi Rivers, least terns choose sites for nesting that were exposed longer above river levels throughout the breeding season than non-nesting habitats (Bacon 1996, Smith and Renken 1991).

Least terns are dependent on ephemeral, early successional habitat (Thompson et al. 1997). Birds select sites that lack vegetative cover (Dirks 1990, Ziewitz et al. 1992), but may nest on sites with up to 30 percent vegetative cover (Schulenberg and Ptacek 1984, Dryer and Dryer 1985, Landin 1985, Rumancik 1985). Without disturbance to remove excess vegetation, nesting habitat becomes unsuitable and the birds will abandon these areas. Water flow and sediment deposition in the river are necessary to maintain least tern nesting habitat. Unconsolidated material such as small stones, gravel, sand, debris, and shells are important components of nesting substrate.

Ziewitz et al. (1992) measured characteristics of nesting habitat of least terns and piping plovers in the central and lower reaches of the Platte River. At the time of this study, most nesting birds were in the lower Platte River. They found that birds nested in areas where the channel was wider with a greater area of sandbars. They recommended that sandbars be at least 3.58 acres in size and that they be 2.99 feet above river level for maximum flooding protection, but should be at least greater than 1.48 feet in height.

A least tern pair will make several shallow nest scrapes in open, gravelly areas, but will only use one for nesting. Both adults will incubate the eggs and will re-nest if a nest is lost, an adaptation to highly variable river conditions. Incubation lasts approximately 21 days. The newly hatched

* References used to develop distribution maps includes Adolf 1998, American Ornithologists' Union 1957, Andrews and Righters 1992, Bent 1962, Bent 1963, Benckeser 1948, Brooking, Bruner 1901, Bruner 1904, Currier et al. 1985, Ducey 1985, Ducey 1988, Ducey 2000, Haecker 1937a, Haecker 1937b, Haecker et al. 1945, Heinemann 1944, Moser 1940, NRC 2005, NOU 1935, NOU 1937, NOU 1938, NOU 1939, NOU 1941, NOU 1944, NOU 1947a, NOU 1947b, NOU 1949, NOU 1950, NOU 1951, Sharp et al 2001, Stiles 1938, Swenk 1925, Swenk 1935, Taylor and Van Vleet 1888, Thompson et al. 1997, Tout 1902, Tout 1933, Tout 1947, Wycoff 1950, Wycoff 1960, Youngworth 1957.

young are weak and helpless, and must be attended to by both adults. Chicks are able to fly about 20-21 days after hatching. They do not become adept at fishing until after migrating from the breeding grounds in the fall (Hardy 1957, Tomkins 1959, Massey 1972, 1974). They remain dependent on their parents for food even after they become capable of flight.

Demographic Parameter Estimates

Least terns are a relatively long lived species. Estimates of survival are variable between life stages. Adult annual survival estimates from all populations range from 0.80 to 0.941 (Renken and Smith 1995, Massey et al. 1992, Thompson et al. 1997). Thompson (1982) estimated mean adult survival along the Texas Coast at 0.853-0.941. Massey et al. (1992) estimated California least tern annual adult survival at 0.88. Renken and Smith (1995) reported mean annual adult survival for least terns on the Mississippi River was 0.85 ± 0.06. Natural longevity can exceed 20 years and the record longevity record is 24 years 1 month (Thompson et al. 1997).

A common estimate of reproductive success, measured as the number of fledglings divided by the number of nests in the colony (fledge ratio), varies among locations and between years. In Nebraska, these estimates range form 0.12 to 1.26. This range of reported fledge ratio is potentially biased by methodology and logistical constraints. Lingle's (1993b) and Kirsh's (1992) work are the only studies in the table below where birds were individually marked, thus overcoming a major source of potential bias (Erwin and Custer 1982). Fledge ratios from these studies range from 0.12 to 0.49. Kirsch's (1992) estimated fledge ratios for birds breeding at sandpits ranged from 0.19 to 0.32.

Table 1. Published estimates of least tern fledge ratios.

YEAR	FLEDGE RATE	LOCATION	SOURCE
1986	0.5	Mississippi River Valley – river sandbars	Smith and Renken 1993
1987	0.7	Mississippi River Valley – river sandbars	Smith and Renken 1993
1988	1.4	Mississippi River Valley – river sandbars	Smith and Renken 1993
1989	0.2	Mississippi River Valley – river sandbars	Smith and Renken 1993
1987	0.19	Lower Platte River – spoil piles	Kirsch 1992
1987	0.12	Lower Platte River – river sandbars	Kirsch 1992
1988	0.16	Lower Platte River – spoil piles	Kirsch 1992
1988	0.29	Lower Platte River – river sandbars	Kirsch 1992
1989	0.38	Lower Platte River – spoil piles	Kirsch 1992
1989	0.31	Lower Platte River – river sandbars	Kirsch 1992
1990	0.32	Lower Platte River – spoil piles	Kirsch 1992
1990	0.19	Lower Platte River – river sandbars	Kirsch 1992
1988-1989	0.49	Central Platte River	Lingle 1993b
1991-2000	0.86	Central Platte River – gravel mines and artificial sandbars	Plettner 2000
1992	0.76	Lower Platte River – protected nests (fenced)	Lackey 1994
1992	0.30	Lower Platte River – unprotected nests	Lackey 1994
1988-2000	0.35	NE - Fort Randall Dam to Niobrara	USACE 1998 and unpubl. data
1988-2000	0.67	NE - Lewis and Clark Lake	USACE 1998 and unpubl. data
1988-2000	0.87	NE - Gavin's Point Dam to Ponca	USACE 1998 and unpubl. data
1988-2000	0.74	NE – Combined Mis. River Adj. to NE	USACE 1998 and unpubl. data
1992-2000	1.26	NE – Lake McConaughy	Peyton and Wilson 2000
1992-2000	0.91	Upper Platte River	Peyton and Wilson 2000
1995	1.27	Lower Mississippi River	Sznell and Woodrey 2003
1996	0.28	Lower Mississippi River	Sznell and Woodrey 2003
1999	0.58	Lower Platte River – gravel mines	Marcus 1999
2000	0.88	Lower Platte River – gravel mines	Marcus 2000
2001	0.67	Lower Platte River – gravel mines	Marcus 2001
2002	1.23	Lower Platte River – gravel mines	Held et al. 2002
2003	1.07	Lower Platte River – gravel mines	Held et al. 2003
2004	0.69	Lower Platte River – gravel mines	Held et al. 2004
2005	0.72	Lower Platte River – gravel mines	Held unpubl. data

Foraging

Interior least terns consume small fish captured from shallow water areas. Foraging habitat along rivers for least terns includes side channels, sloughs, tributaries, shallow-water areas adjacent to sand islands and the main channel (Dugger 1997). They hunt by hovering, searching and diving and catching small fish in their bills. Least terns forage almost exclusively upon small, narrow bodied, schooling fish (Atwood and Kelly 1984, Wilson et al. 1993, Schweitzer and Leslie 1996). Least terns have been shown to feed on *Fundulus*, *Notropis*, *Campostoma*, *Pimephales*, *Cyprinella*, *Morone*, *Dorosoma*, *Lepomis*, and *Carpiodes* species when the appropriate size is available.

The proximity of suitable foraging areas is a factor in reproductive success (Dugger 1997). Areas that appear to be suitable nesting habitat may not be utilized due to the distance to foraging areas. Least terns will forage some distance away from nesting sites, but the cost of travel time and energy expenditure in relation to nesting success is not well known, nor is the distance that birds are traveling to forage. A Nebraska study found that least terns were observed foraging within 328 feet (100 meters) of the colony (Faanes 1983). Another study found that birds nesting at sand and gravel mining sites and other artificial habitats may fly up to 3.2 km to forage at riverine sites (Smith and Renken 1990). However, recent radio telemetry work, conducted on the Missouri River by the Northern Prairie Wildlife Research Center of the U.S. Geological Survey suggests that terns may be moving farther from the colony for foraging than previously published (J. H. Stucker, personal communication 2007).

Evidence suggests that terns forage most efficiently in areas with shallow water, as these areas have higher density and richness of small fish species that compose tern forage when compared to deep-water habitats (Dugger 1997, Tibbs and Galat 1997). Nesting typically coincides with the timing of declining flows in major river systems. As flows decline through the nesting season, nesting and rearing habitat increase as does shallow water for foraging and fish production.

Mortality

Causes of mortality, for both adults and juveniles, range from natural predators to human disturbance. Lingle (1993b) reported that about 53 percent of adult least tern and piping plover deaths along the central Platte River were due to predation, another 33 percent from weather, and 13 percent of adult deaths could be attributed to humans. Adult least terns have been killed under the tires of all-terrain vehicles while incubating nests, in addition to documented deaths from shooting (Lingle 1993b, Smith and Renken 1993).

Flooding is also a cause of mortality. Least tern's nesting habitat is a highly dynamic system, as it is dependent on river flow and sediment deposition. Although their reproductive cycle is in sync with the historic hydrograph of many of Nebraska's major rivers, nests are inundated. Least terns will re-nest if there is sufficient conditions and remaining time in the nesting season.

Artificial and Alternative Habitats

Across their entire range, least terns will nest in locations other than riverine sandbars, but in Nebraska, the quality of these alternative habitats is limited and is not the primary type of habitat used by least terns and piping plovers prior to development. Early nesting records indicate that least terns were utilizing sandbars in the river channel (Figure 3). However, available habitats used by least terns for nesting have changed through time as human development has encroached on breeding areas and natural ecological changes have occurred (Thompson et al. 1997). The distribution patterns and habitats used today began with development along the Platte River. Wycoff's (1960) observations of least terns near Lexington covered 17 years and he remarked,

> "During the years which followed the building of the dams in the hills along the south side of the Platte River, thus insuring a more continuous flow of water, the sandy river bed became covered with sprouting cottonwoods, willows, and many acres of cockleburs and sweet clover. No open places were left for the terns."

The dams mentioned above refer to the water storage reservoirs associated with the Tri-County Irrigation Project that was completed in the early 1940s. During this period, Wycoff (1960) observed least terns (and piping plovers) nesting at sandpits, specifically Kirkpatrick's sandpit. In 1959, most of the least terns in this area were nesting at the Luther sandpit and by 1955 Wycoff (1960) noted that "terns appeared to have completely lost any interest in the old nesting place," referring to the river sandbar where he originally observed least terns nesting.

Least terns use the sand spill piles (sandpits) along the Platte River and its lower tributaries that result from sand and gravel sandpit mining operations as nesting habitat. These sandpits are often found in close proximity to the river, but evidence suggests that these artificial habitats do not provide least terns with the necessary nesting habitat requirements. "Island habitat is critical because nests that are on islands have lower rates of predation than nests on the mainland," (NRC 2005). Lingle (1988) reported that the causes of least tern nest losses varied between natural and artificial habitats. The major cause of nest failure on natural riverine sandbars was flooding, while nest failure at sandpits was the result of predation and abandonment. Sidle and Kirsch (1993) reported that topography of sandpits is much more variable than the flat river sandbars, potentially enhancing adult's risk of predation.

Sandpits and reservoir shorelines offer only a temporary habitat that, without considerable management, do not offer a viable, long-term solution for least tern nesting habitat. Sandpits will become overgrown as the sand mining is completed, unless extensive maintenance is implemented. Other sites are converted to housing developments, which no longer provide nesting habitat. Nests at sandpits are extremely vulnerable to high predation rates (J. Ledwin, USFWS personal communication 2007). Least terns will nest along reservoir shorelines, such as Lake McConaughy, when water levels are sufficiently low. This type of habitat is temporary and use by least terns is relatively low, even with ample habitat in recent years (32 birds in 2005, Lott 2006). Reservoir shorelines are not sustainable habitat as beaches become vegetated when reservoir levels remain low for multiple years, and beaches will disappear when the reservoir refills during a wet cycle.

Continuing Threats

Habitat Loss and Degradation – Changes in natural river hydrology due to channelization, diversion of river flows for irrigation and hydropower production, construction of reservoirs, bank stabilization (rock armoring, revetment, hard points), levees and unnatural, managed river flows have contributed to the elimination of much of the least tern's sandbar nesting habitat (Funk and Robinson 1974, Hallberg et al. 1979, Sandheinrich and Atchison 1986).

Sediment and sediment movement in association with variable discharges are key components of sandbar habitat creation. In much of the least tern's range, sediment has been reduced from flowing water as it settles out in reservoirs. Historical high river flows, which are now tempered, are important to introduce and transport organic material from the floodplain to the river system and support the system's productivity.

Human Disturbance - Human disturbance affects tern productivity in many locations, (Massey and Atwood 1979, Goodrich 1982, Burger 1984, Dryer and Dryer 1985, Dirks and Higgins 1988, Schwalbach 1988, Mayer and Dryer 1990). Many rivers have become the focus of recreational activities, and sandbars, where they exist, are fast becoming the recreational counterpart of coastal beaches. Human presence reduces the bird's reproductive success (Mayer and Dryer 1988, Smith and Renken 1990). Domestic pet disturbance and trampling by grazing cattle are other factors that have contributed to nest loss.

Pollution/Contaminants - Pollutants entering the waterways within and upstream of nesting areas can negatively impact water quality and fish populations in nearby foraging areas. Strip mining, urban and industrial pollutants, and sediments from non-point sources can all degrade water quality and fish habitat, thereby impacting small-fish populations on which least terns depend (Wilbur 1974, Erwin 1983). In addition, because least terns are relatively high on the food chain, they are in a position to bioaccumulate contaminants which may render eggs infertile or otherwise affect reproduction and chick survival (USFWS 1983, Dryer and Dryer 1985).

A 1997 report by the U.S. Fish and Wildlife Service (Allen and Blackford, 1997) concluded that selenium and mercury toxicity may be causing decreased least tern reproduction. The study evaluated concentrations of arsenic, mercury, selenium and organochlorines compounds in interior least tern eggs collected from Montana, North Dakota, South Dakota, Nebraska and Kansas from 1992 -1994. Concentrations of selenium in 20 least tern eggs collected from Nebraska in 1992 averaged 4.32 milligrams per kilogram (mg/kg) dry weight (dw) from the Platte, North Platte and Elkhorn Rivers. Eighteen of the least tern eggs from Nebraska had selenium concentrations above the normal background concentration of 3 mg/kg dry-weight for waterbird eggs (USDOI 1998) and two of these eggs were within a 6-10 mg/kg dry-weight range for decreased egg viability (Hamilton 2004). These concentrations of selenium in least tern eggs are a particular concern as avian species can differ substantially in embryo sensitivity to selenium (Skorupa et al., 1993; Skorupa et al 1998 as cited by USDOI 1998) and least tern sensitivity to selenium toxicity is unknown.

Principal anthropogenic sources of selenium to aquatic ecosystems include coal-fired power plants and irrigation return flows (Schmitt 2002). There are naturally high selenium concentrations in Upper Cretaceous marine and sedimentary bedrock which underlies the lower Platte River (USDOI 1998) and watersheds that drain into the lower Platte River are dominated by irrigated land. However, a low evaporation index for central and eastern Nebraska indicates that a selenium problem due to irrigated lands is unlikely (USDOI 1997). Runoff from cattle feedlots also may contribute selenium releases into the lower Platte River as Se is often used as a feed additive by large livestock operations (Sims 1995).

Disease – Diseases such as West Nile Virus, or other pathogens, have the potential to negatively impact rare species, especially those that are reduced to a small portion of their former range. West Nile Virus has caused several least tern deaths (Ledwin 2007, personal communication, G. Pavelka 2006, personal communication).

Predation - Predation is a significant cause of mortality for least terns. Predators include dogs or coyotes (*Canis latrans*), skunks (*Mephitis spp.*), raccoons (*Procyon lotor*), great-horned owls

(*Bubo virginianus*), American crows (*Corvus brachyrhynchos*), great blue herons (*Ardea herodias*), barred owls (*Strix varia*), minks (*Mustela vison*), American kestrels (*Falco sparverius*), black-billed magpies (*Pica pica*), bull snakes (*Pituophis melanoleucus sayi*), and garter snakes (*Thamnophis spp.*) (Lingle 1993a, Renken and Smith 1995). Predation intensity may vary as a consequence of river flow patterns. Sandbars may not be isolated by water deep, wide of flowing fast enough to deter predators. Local predators may learn of nesting areas and return to them repeatedly. With the loss of much least tern nesting habitat, predation has become a significant factor affecting least tern productivity in many locations (Massey and Atwood 1979, Jenks-Jay 1982). Additionally, sandpits present unique challenges as colonies are not isolated by flowing water and more easily subjected to different predators using adjacent terrestrial habitats.

Recovery Objectives

In 1990, the Service published the *Interior Population of the Least Tern Recovery Plan* (USFWS 1990). That plan includes recovery goals for the least tern along major river systems throughout the species range. Major recovery steps outlined in the plan include: a) determine population trend and habitat requirement; b) protect, enhance, and increase populations during breeding; c) manage reservoir and river water levels to the benefit of the species; d) develop public awareness and implement educational programs about the least tern, and; e) implement law enforcement actions at nesting areas where there are conflicts with high public use.

The recovery plan details conditions necessary for the removal of the least tern from the list of threatened and endangered species. The essential habitat throughout its range needs to be properly protected and managed, and species distribution and population goals need to be reached and maintained for a period of ten years. Specifically, the recovery plan recommends that the following distribution and numbers of adult birds be maintained for ten years:

Missouri River system - 2,100
Lower Mississippi system - 2,200-2,500
Arkansas River system - 1,600
Red River system - 300
Rio Grande River system - 500

The recovery plan also specifies a geographic distribution of these totals within each river system. Within the Missouri River system, the plan calls for 1,120 of the 2,100 adult terns to be distributed in Nebraska, as follows:

Missouri River - 400 (shared with South Dakota on the Missouri River)
Niobrara River - 200
Loup River - 170
Platte River – 750

Current Status

In the late 1980's, Sidle et al. (1988) documented that the Platte River supported approximately 13% of the interior least tern population. Numbers have fluctuated over the years with changing river conditions. The Platte River in Nebraska has accounted for a high portion of the least tern interior population (6.2-13.6 percent) (Kirsch and Sidle 1999, Jones 2001). Focused survey efforts for the entire range of the least tern have only recently been implemented. The first range wide least tern survey was completed in 2005, although least terns were previously counted in the International Piping Plover Census. From the 2005 survey, there were a total of 17,591 least terns counted in 489 colonies across its entire range. Most terns were found in river habitat (89.0%). This number is considerably higher than previous range wide estimates. To meet the recovery goals set in the Recovery Plan, the numbers of birds and geographic distribution mentioned in the previous section need to be maintained over ten years.

Available riverine habitat for least tern nesting has declined dramatically across Nebraska (Figure 3). When looking at the Nebraska population, the Platte River system is clearly important for least terns, with over half of the current population using the Platte River system and associated sandpits (Figure 4). Numbers from the Platte River indicate a decline and now only supports 4.4 percent of the entire least tern population (Lott 2006), which accounts for 7% of the Platte River recovery goal. The Platte River system contributed a total of 588 adults including 53 adults from 2 colonies on the lower Platte River and 328 adults from 13 colonies on sandpits associated with the lower Platte River (Lott 2006). These numbers do not meet the numeric or temporal goals of the U. S. Fish and Wildlife Recovery Plan for the Platte River (750 adults over 10 years).

The long term sustainability of much of the Platte River least tern nesting habitat is questionable, as with the exception of recent breeding at two restored sites near Gibbon, these birds are now extirpated as a breeding species from riverine sites within the central Platte River upstream of the Loup River (NGPC database) (Figure 5). This reduction in habitat is largely due to modifications made to the Platte River’s form and function. The terns and plovers are still present and routinely use the river for foraging, but are primarily utilizing sandpits near the river for nesting and have also taken advantage of low water levels at Lake McConaughy. Sandpits and reservoir shorelines are currently providing temporary habitat, but as mentioned earlier in this document, without intensive management, may accelerate population decline either locally or regionally if birds immigrate to these poor quality sites.

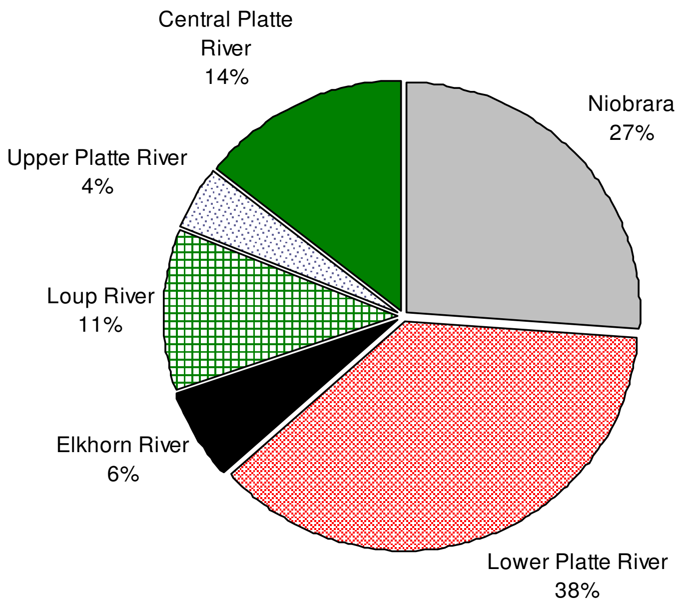

Figure 4: A) Proportion of all least terns recorded in Nebraska occurring on individual river systems (Missouri River excluded) based on 1991, 1995, 2001, and 2005 survey results (Lott 2006, NGPC database). Upper Platte River includes Lake McConaughy and the Missouri River is not considered.

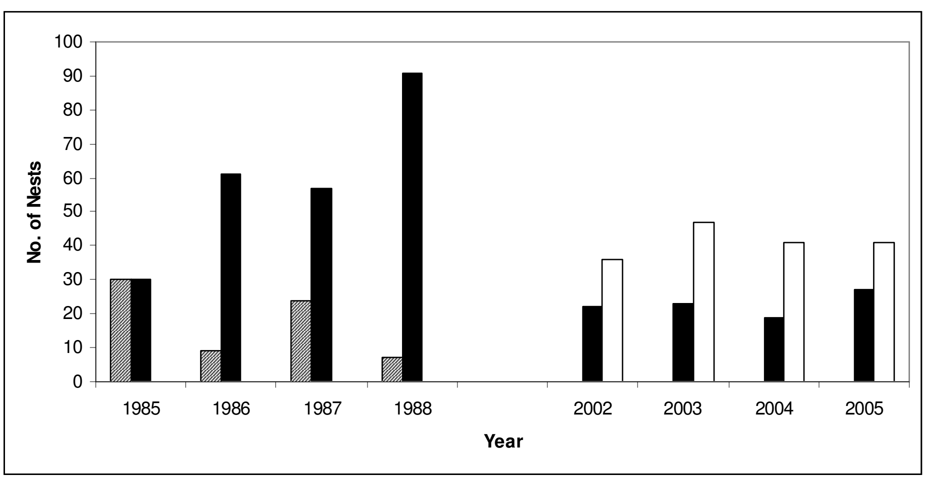

Figure 5: Number of least tern nests recorded at river sandbars (cross-hatched bars), industrial sandpits (black bars), and managed sandpits (white bars) on the central Platte River system from Lexington to Grand Island during two 4-year periods. Graphic shows decline and eventual extirpation of breeding least terns on the river and sole use of sandpits as nesting sites. The majority of nesting least terns in this stretch now occurs at heavily managed sandpits.

Population Viability Analyses

Multiple Population Viability Analyses (PVAs) have been generated for interior populations of least tern and northern Great Plain's populations of piping plovers. PVA's are valuable when used to evaluate different management strategies. As Plissner and Haig (2000) point out, “population viability models do not serve as predictors of minimum viable population sizes, but rather they are useful as tools providing probabilities of relative success for developing and assessing alternative population management strategies.” At the same time, limitations of PVAs must be recognized to prevent uncertainty and misuse (Beissinger and Westphal 1998, Fieberg and Ellner 2000, Reed et al. 1998, McCarthy et al. 2003). PVAs that have been created for these two species have not been validated. This is critical, as several PVAs were discredited once predictions were tested or evaluated (Hitchcock and Gratto-Trevor 1997; Nichols et al. 1980, Ludwig 1998).

Piping Plover (Charadrius melodus)

The piping plover is a migratory shorebird of the subfamily Charadriinae, family Charadriidae, and order Charadriiformes. Inland and coastal breeders have been formally recognized as different subspecies (AOU 1957). Atlantic Coast birds are referred to as *C.m. melodus* and inland birds, including Nebraska breeders, are referred to as *C.m. circumcinctus* (AOU 1957). More recent information, however, suggests subspecific classification may not be valid (Haig and Oring 1988a, Wilcox 1959).

Adult birds weigh between 43 and 63 grams, are 17-18 centimeters (cm) long, and have a wingspan 11.0-12.7 cm long. Both sexes are sand-colored with white undersides, and the legs are orange. During the breeding season, adults develop an orange bill, and a single black forehead band and breast band.

In 1986, the piping plover gained federal and state protection in the United States and is now listed as threatened in the Great Plains region. Under Neb. Rev. Stat. § 37-806 any species determined to be threatened or endangered pursuant to the federal Endangered Species Act shall be similarly listed under the Nebraska Nongame and Endangered Species Conservation Act.

Distribution

Piping plovers are territorial shorebirds that spend three to four months on northern United States and southern Canada breeding sites. Piping plovers historically bred in three areas of North America: Atlantic coastal beaches from Newfoundland to South Carolina, beaches of the Great Lakes, and the northern Great Plains/Prairie region from Alberta to Ontario and south to Nebraska (USFWS 1988). The current distribution is similar, except that plovers nesting in the Great Lakes have almost disappeared (Haig and Oring 1988). The piping plover winters along Gulf Coast beaches and sand/mudflats from Florida into northern Mexico (Laguna Madre). Large numbers of piping plovers winter along the Texas coast (Ferland and Haig 2002, Haig and Plissner 1992, Plissner and Haig 1997).

Prior to recent development, the piping plover was apparently a common breeding species on riverine habitat throughout much of Nebraska, including along the Missouri, Platte, Elkhorn, lower Loup, and Niobrara rivers (Bruner et al. 1904, Ducey 2000, Sharpe et al. 2001) (Figure 6). In addition to riverine habitat, there are several breeding records from the Sandhills, specifically Cherry and Garden Counties from the early 20th Century (Sharpe et al. 2001, Ducey 1988). Three or four pairs of piping plovers nested at Salt Lake, Lancaster County, in 1922 (Pickwell 1925).

On the Platte River, piping plovers were apparently very abundant in the 1860s (Ducey 2000). In Lincoln County, Tout (1947) considered piping plover a "common summer resident and breeder here during some years" where it was found on "sand bars in the bed of the Platte and its north and south forks." Wycoff (1960) noted piping plovers breeding in association with least terns near Lexington, Dawson County in the 1940s and 1950s. Additional breeding records from the Platte River systems prior to 1960 are from Hall, Platte, Douglas, and Cass Counties (Ducey 1988).

Today the piping plover is found on sandbars of the lower Niobrara, lower Platte and portions of the Loup River. In addition to riverine habitat, there are several breeding records from the Sandhills of north central Nebraska from the early 20th Century (Sharpe et al. 2001). Today the piping plover is found on sandbars of the lower Niobrara, lower Platte River and at low densities and a few locations along the Lower Loup River (Figure 6*).

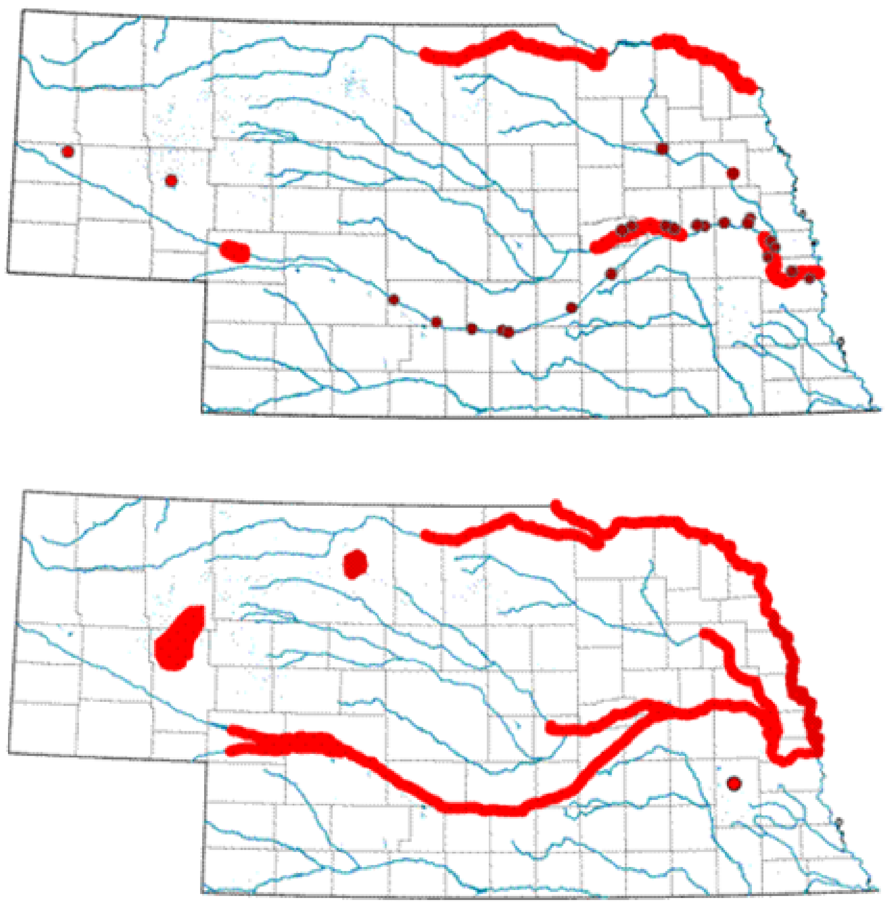

Figure 6: Previous (top) and current (bottom) breeding distribution of the piping plover in Nebraska. Current breeding sites along central Platte, lower Loup and Elkhorn Rivers are primarily limited to sandpits (dark red dots).

* References used to develop distribution map includes Adolf 1998, American Ornithologists' Union 1957, Andrews and Righters 1992, Bent 1962, Benckeser 1948, Bruner 1901, Bruner 1904, Currier et al. 1985, Ducey 1988, Ducey 2000, Haecker et al. 1945, Haig 1992, Heinemann 1944, Moser 1940, Moser and Haecker 1941, Moser 1942, NRC 2005, NOU 1935, NOU 1937, NOU 1938, NOU 1939, NOU 1941, NOU 1944, NOU 1947a, NOU 1947b, NOU 1949, NOU 1950, NOU 1951, Pickwell 1925, Sharp et al 2001, Swenk 1925, Swenk 1935, Taylor and Van Vleet 1888, Thompson et al. 1997, Tout 1902, Tout 1933, Tout 1947, Wycoff 1951, Youngworth 1957.

Reproduction

Piping plovers arrive on breeding areas in late April and early May (Thompson et al. 1997, Sharpe et al. 2001). Adults may return to the same areas in succeeding years (Wilcox 1959, Cairns 1982, Haig and Oring 1988b, Wiens and Cuthbert 1988). Nest initiation varies depending on local conditions and may begin by late April and continue until early July (USACE 1998).

Piping plovers are semi-colonial and are a relatively timid species. Piping plover often nest in association with least terns which are aggressive and mob intruders that enter nesting colonies. Piping plovers likely reap the benefits of early predator detection and reduced predation because of this relationship. Similar associations have been noted between red phalaropes (*Phalaropus fulicarius*), another timid shorebird, and Sabine's Gull (*Xema sabini*), another mobbing larid (Smith et al. 2007).

Piping plovers nest on sparsely vegetated sandbars, aggregate mining spoil piles, and reservoir shorelines. The quality of these human created and temporary nesting habitats is discussed later in this document. Nesting habitats on the Platte, Niobrara, and Missouri rivers typically are dry sandbars located midstream in wide, open channels, with less than 25 percent vegetative cover (Faanes 1983, Schwalbach 1988, Ziewitz et al. 1992). The optimum range for vegetative cover on nesting habitat has been estimated at 0 to 10 percent (Armbruster 1986). Schwalbach (1988) and Ziewitz et al. (1992) suggest that birds select higher nest sites when available and sites away from the water's edge. This suite of habitat conditions provide wide, horizontal visibility; protection from terrestrial predators; isolation from human disturbance; greater distance from avian predator perch sites; and sufficient protection from rises in river levels and flooding when sandbars are of sufficient height (USFWS 2000 and 2003). The absence of any or all of these conditions can negatively impact reproduction.

Ziewitz et al. (1992) measured characteristics of nesting habitat of least terns and piping plovers in the central and lower reaches of the Platte River. At the time of this study, most nesting birds were in the lower Platte River. They found that birds nested in areas where the channel was wider with a greater area of sandbars. They recommended that sandbars be at least 3.58 acres in size and that they be 2.99 feet above river level for maximum flooding protection, but should be at least greater than 1.48 feet in height.

Nests are small scrapes or shallow depressions, frequently lined with small pebbles or shell fragments (USFWS 1988). Both adults actively defend the nesting territory, generally by performing injured-wing feigning display when human or other predator approach nests or chicks (Cairns 1982, Haig 1992). Egg laying typically begins the second or third week of May. Both sexes share incubation responsibilities, which can last for 25 to 31 days (Wilcox 1959, Cairns 1977, Wiens 1986, Haig and Oring 1988a) (USFWS 2000).

Piping plover chicks are precocial, leave the nest almost immediately, and are able to feed themselves within a few hours. Adults will accompany the chicks and lead them to and from foraging locations, provide shelter during inclement weather, and attempt to protect them from predators (Wilcox 1959, Cairns 1982). Most adults raise only one brood of up to four chicks per nesting season. Upon the loss of eggs or newly hatched chicks, a pair may renest up to four times. Renesting efforts characteristically result in fewer than the typical four eggs being produced (Lingle 1988, USFWS 1988).

Nesting is typically complete by July 31 (Sidle 1992) and piping plovers begin fall migration in late July and August (Cairns 1982, Prindiville-Gaines and Ryan 1988).

Demographic Parameter Estimates

Root et al. (1992) estimated mean adult survival in the northern Great Plains at 0.664 ± 0.057 (SE). With additional data, Larson et al. (2000) re-analyzed and revised the earlier estimate to 0.737 ± 0.092. Larson et al. (2000) also estimated juvenile survival to be 0.318. Juvenile survival from the Atlantic Coast is somewhat higher (0.48; Melvin and Gibbs 1996).

Estimates of reproductive success, measured as the number of fledglings divided by the number of nests in the colony (fledge ratios), are variable and range from 0.3 to 1.5 fledglings per pair. In Nebraska, fledge ratio estimates range from 0.37 to 1.93. This range of reported fledge ratios is potentially biased by methodology and logistical constraints. Potential sources of bias include 1) adults are not individually marked, 2) the colony is visited infrequently, and 3) the inability to monitor all young until they fledge (Erwin and Custer 1982) and 4) emigration/immigration of juvenile birds to non-natal colonies.

Table 2. Published estimates of Piping Plover fledge-ratios in Nebraska

YEAR	FLEDGE RATE	LOCATION	SOURCE
1986-1990	0.52	Central Platte River	Lingle 1993b
1991-2000	1.34	Central Platte River – gravel mines and artificial sandbars	Plettner 2000
1992	0.71	Lower Platte River – protected nests (fenced+exclosure)	Lackey 1994
1992	0.44	Lower Platte River – unprotected nests	Lackey 1994
1988-2000	0.37	NE - Fort Randall Dam to Niobrara	USACE 1998 and unpubl. data
1988-2000	0.51	NE - Lewis and Clark Lake	USACE 1998 and unpubl. data
1988-2000	0.75	NE - Gavin's Point Dam to Ponca	USACE 1998 and unpubl. data
1988-2000	0.70	NE – Combined Missouri. River Adj. to NE	USACE 1998 and unpubl. data
1992-2000	1.15	NE – Lake McConaughy	Peyton and Wilson 2000
1992-2000	1.07	Upper Platte River	Peyton and Wilson 2000
1999	0.73	Lower Platte River – gravel mines	Marcus 1999
2000	1.50	Lower Platte River – gravel mines	Marcus 2000
2001	1.93	Lower Platte River – gravel mines	Marcus 2001
2002	1.19	Lower Platte River – gravel mines	Held et al. 2002
2003	0.86	Lower Platte River – gravel mines	Held et al. 2003
2004	0.72	Lower Platte River – gravel mines	Held et al. 2004
2005	0.83	Lower Platte River – gravel mines	Held unpubl. data

Foraging

Piping plovers forage visually for invertebrates in shallow water and associated moist substrates (Cairns 1977, Cuthbert et al. 1999, Whyte 1985). Open, wet, sandy areas provide foraging areas. Along the Platte River, their prey consists primarily of beetles and small soft-bodied invertebrates from the riverine waterline. In addition, they opportunistically take prey from drier sites at sandpits (Lingle 1988).

Artificial and Alternative Habitat

As with least terns, piping plovers will use artificial habitats such as sandpits. The National Research Council (2005) concluded that "sandpits do not provide the full complement of essential elements for tern and plover reproduction, and is not a suitable substitute for riverine nesting habitat." Similarly the U.S. Fish and Wildlife Service (2002) stated that "sandpits are artificial and temporary in nature, not all of the necessary biological and physical features that are essential to the conservation of the species are present at sandpits" and "sandpits do not provide for piping plover recovery in the long term."

One component of piping plover nesting habitat is food resource availability. Catch rates and density of invertebrates, the prey base for piping plovers, is higher for river channel habitat sites than gravel mines (Corn and Armbruster 1993a). They also found that invertebrates are distributed more or less uniformly across riverine foraging habitat, but decline with increasing distance from the water's edge at sand pit locations. Research has found that invertebrate abundance also increased more dramatically over the course of the summer on riverine sites when compared to sand pit sites (Corn and Armbruster 1993a). These patterns of invertebrate occurrence translated into greater foraging activity on river channel habitat sites even when birds nested off the river (Corn and Armbruster 1993b). Lingle (1988) observed banded piping plovers known to be nesting as close as 0.5-mile away on a sandpit site, foraging in riverine habitat.

The issue of forage availability is critical to the survival and reproduction of piping plovers, and is especially critical for chick survival. Chick mortality is correlated with reduced growth rates (Cairns 1982), potentially a result of reduced prey availability. Piping plover chicks studied along the Atlantic coast typically tripled their weight during the first two weeks after hatching; and chicks that failed to achieve at least 60 percent of this weight gain by day 12 were unlikely to survive (USFWS 1996). D. Catlin (personal communication, 2007) found that chicks with slower growth rates spend more time in the pre-fledge state, thus increasing the time they are vulnerable to predators. Inadequate foraging at sandpits sites may limit chick survival.

Piping plovers will also use shorelines of reservoirs when water levels are sufficiently low and will use sandhill lakes. In Nebraska, use of these locations is minimal compared to historical use of riverine sandbars. Lake McConaughy currently provides habitat and piping plover are utilizing the available habitat, but this is a temporary habitat that will be either overgrown or inundated.

Continuing Threats

Habitat Loss and Degradation - Since the early 1900s, habitat alteration and destruction from channelization, irrigation, and the construction of reservoirs on our nation's large river systems constitute the primary reason for the species' decline and current status (USFWS 1988). Bank stabilization via rock armoring, revetment and hard points and levee construction have also altered the river form and corresponding function. Disruption of riverine ecosystem processes by these human activities has resulted in significant piping plover habitat loss. Alterations to the historic hydrograph have subdued the lower Platte River's capacity to build high sandbars and scour existing sandbars which is necessary for successful nesting.

Sediment and sediment transport in association with variable discharges are key components of sandbar habitat creation. In much of the piping plover's range, sediment had been reduced from flowing water as it settles out in reservoirs. In addition, historical high flows, which are now tempered, are important to introduce and transport organic material from the floodplain to the river system. These over bank flows and resulting input of organic material support the system's productivity.

Human Disturbance - Human disturbance affects piping plover productivity (Massey and Atwood 1979, Goodrich 1982, Burger 1984, Dryer and Dryer 1985, Dirks and Higgins 1988, Schwalbach 1988, Mayer and Dryer 1990). Many rivers have become the focus of recreational activities, and sandbars provide popular sandy areas for a variety of activities. Human disturbance, particularly from pedestrians, is frequently the key hurdle facing piping plover chicks and other shorebirds attempting to forage along the waters' edge (Elliot 1999, Fackelmann 1991, Rodgers and Smith 1995).

Carney and Sydeman (1999) conducted a literature review on the effects of human disturbance on nesting colonial waterbirds and found that human presence reduced reproductive success in *Charadriiformes*. Direct losses resulting from human presence include trampling of eggs and chicks under foot, crushing of nests by all-terrain vehicles, as well as predation by dogs. Rodgers and Smith (1997) studied flushing distances and energy expenditure for loafing, foraging, and flushed waterbirds. They concluded availability and access to disturbance-free foraging grounds may be as important as disturbance-free nesting sites.

Pollution/Contaminants - In the northern Great Plains Region, most of the nesting habitat used by the piping plover is surrounded by agriculture and/or urbanization. Proximity to these land uses puts nesting birds at risk of exposure to numerous fertilizers, pesticides, herbicides, and other chemicals found in agricultural and urban environments (Gilliom et al. 2006).

Fannin and Esmoil (1993) found that addled piping plover eggs collected from nests along the Platte River and adjacent sandpits had selenium and mercury concentrations elevated above background. They reported that selenium in particular may be causing embryo mortality without gross embryological defects being observed. They also reported that impacts of contaminants, combined with habitat degradation, may accelerate population declines.

Disease – Piping plovers are susceptible to disease. West Nile has been confirmed in piping plovers and documented as the possible cause of death (USGS 2004). In addition there are potentials for new viruses to have significant impacts on piping plovers because they lack immunity and their populations are low.

Predation - Predation is a significant cause of mortality for piping plovers and includes many of the same predators as least terns. Predators include dogs or coyotes (*Canis latrans*), skunks (*Mephitis spp.*), raccoons (*Procyon lotor*), great-horned owls (*Bubo virginianus*), American crows (*Corvus brachyrhynchos*), great blue herons (*Ardea herodias*), barred owls (*Strix varia*), mink (*Mustela vison*), American kestrels (*Falco sparverius*), black-billed magpies (*Pica pica*), bull snakes (*Pituophis melanoleucus sayi*), and garter snakes (*Thamnophis spp.*) (Lingle (1993a, Renken and Smith 1995). Predation may occur at varying intensity if the river channel is not dynamic such that sandbars are only located in limited areas where predators learn of nesting activities and prey upon colonies annually. Additionally, sandpits present unique challenges as colonies are not isolated by flowing water and more easily subjected to different predators using adjacent terrestrial habitats.

Recovery Plan

The Service finalized a recovery plan for the Great Lakes and Northern Great Plains Piping Plover in 1988 that established a recovery goal for the northern Great Plains piping plover population of 1,300 pairs (USFWS 1988). The recovery plan states that the population must remain stable for a period of at least 15 years. The geographic goals in the recovery plan indicate that 1,300 pairs are to be distributed in the following locations.

Montana - 60 pairs
North Dakota - 650 pairs
 Missouri River - 100 pairs
 Missouri Coteau - 550 pairs
South Dakota -350 pairs
 Missouri River below Gavin's Point - 250 pairs (shared with Nebraska)
 Other Missouri River sites - 75 pairs
 Other sites - 25 pairs
Nebraska - 465 pairs (including 250 pairs shared with South Dakota on the Missouri River)
 Platte River - 140 pairs
 Niobrara River - 50 pairs
 Missouri River - 250 pairs
 Loup River system - 25 pairs
Minnesota - 25 pairs at Lake of the Woods

The above recovery goals include 465 pairs of piping plovers to be maintained over a period of 15 years in Nebraska. The coordinated surveys to date have documented populations below these levels for Nebraska and the Platte River basin.

Current Status

In the late 1980's, the Platte River provided nesting habitat for 9% of the piping plover population of the northern Great Plains (USFWS 1988) with 2,137 to 2,684 adult plovers in the Northern Great Plains/Prairie region, 28 adults in the Great Lakes region, and 1,370 to 1,435 adults along the Atlantic Coast (Haig and Oring 1985) (USFWS 2000). The International Piping Plover Censuses provide the most reliable information on range wide population trends and was conducted in 1991, 1996, 2001 and 2006. These surveys indicate a range wide decline for most years in the northern Great Plains/Prairie Canada population (Ferland and Haig 2002, Haig and Plissner 1992, Plissner and Haig 1997). Preliminary results from the 2006 International Piping Plover Census suggest that the U.S. Great Plains/Canadian Prairie region had 4,700 birds, which could indicate an increase in this population. However, these numbers are not finalized, as data verification is not complete (Elliott-Smith 2007, personal communication). In Nebraska, there were 308 adults counted in 2001, 366 in 1996 and 398 in 1991. The 2006 survey results with 723 adult piping plovers (Jorgensen 2007), is an increase over past years. These results do not meet the numerical and temporal requirements of the recovery plan.

Available sandbar habitat has declined dramatically across Nebraska. As with least terns, piping plovers have made a similar transition from riverine sandbar habitats to sandpits over much of their range in Nebraska (Figure 6). When looking at the Nebraska population, the Platte River system is clearly important for piping plovers, with over half of the current population using the Platte River system and associated sandpits (Figure 7). The long term sustainability of much of the Platte River piping plover nesting habitat is questionable. Two recently restored sites near Gibbon recently provided nesting habitat for piping plovers on the Platte River, but beyond these locations, the piping plover is extirpated as a breeding species within the central Platte River upstream of the Loup River (NGPC database) (Figure 8). This reduction of available nesting habitat is due to modifications made to the Platte River's form and function. The piping plovers are still present and routinely use the river for foraging, but are primarily utilizing sandpits near the river for nesting and have also taken advantage of low water levels at Lake McConaughy. Sandpits and reservoir shorelines are currently providing temporary habitat, but as mentioned earlier in this document, without intensive management, may accelerate population decline either locally or regionally if birds immigrate to these poor quality sites.

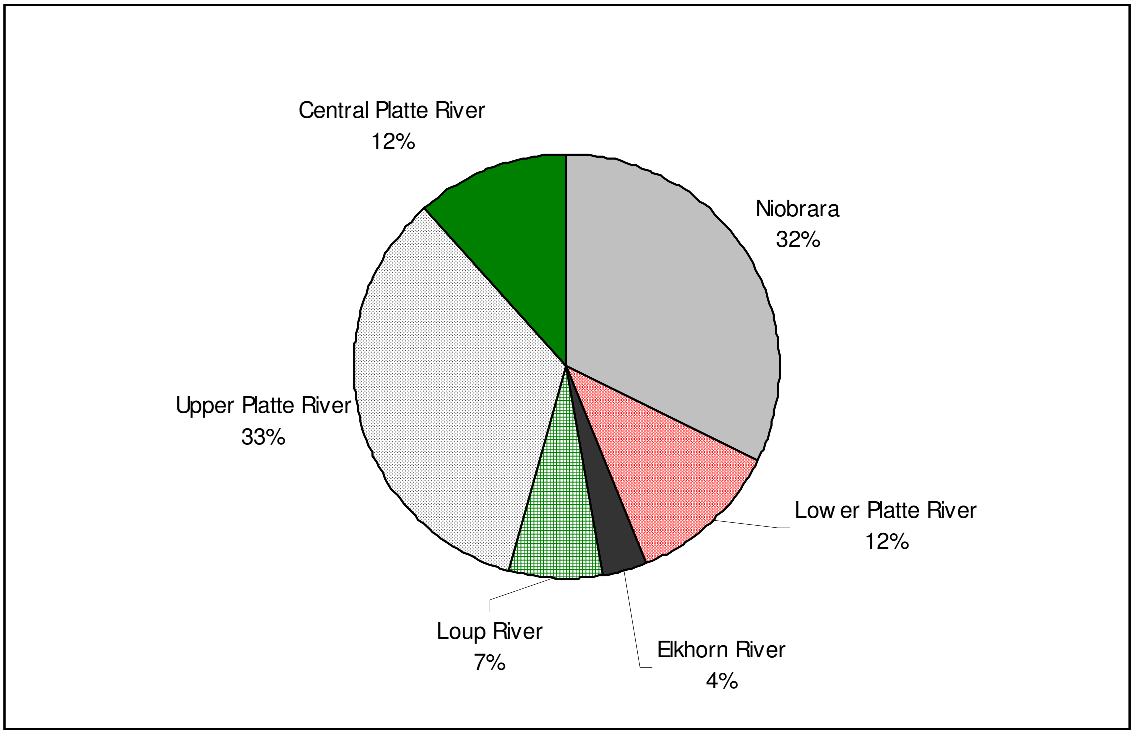

Figure 7: Proportion of all piping plovers recorded in Nebraska occurring on individual river systems (Missouri River excluded) based on 1991, 1996, 2001, and 2006 International Piping Plover Survey results (Ferland and Haig 2002, Plissner and Haig 1992, Plissner and Haig 1997, and NGPC database). Note: Upper Platte River includes Lake McConaughy and the Missouri River is not considered.

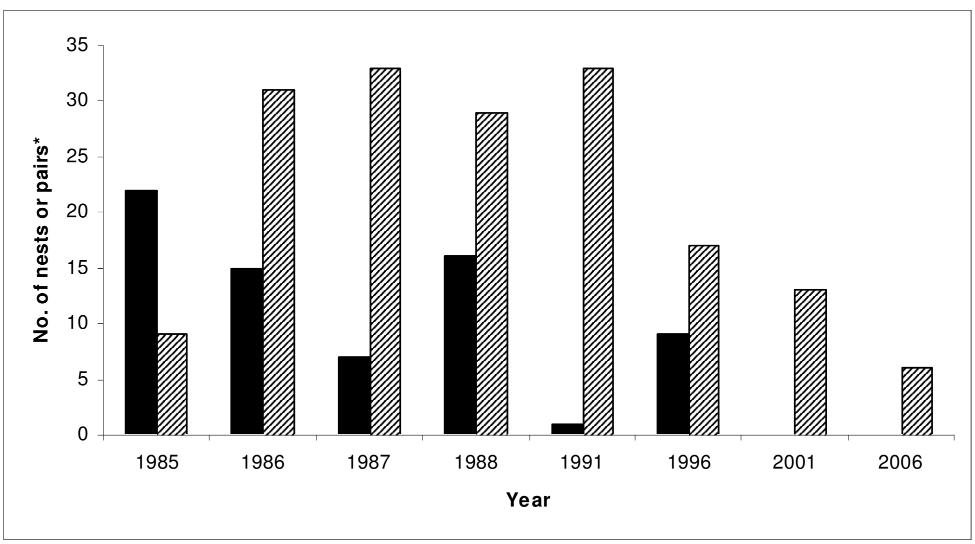

Figure 8: Number of piping plover nests (1985-1988) and number of pairs (1991,1996, 2001, 2006) recorded on river sandbars (black bars) and sandpits (cross-hatched bars) in the central Platte River from Lexington to Grand Island (Lingle 1990, Ferland and Haig 2002, Plissner and Haig 1992, Plissner and Haig 1997, and NGPC database).

Population Viability Analyses

Multiple Population Viability Analyses (PVAs) have been generated for interior populations of least tern and northern Great Plain's populations of piping plovers. PVA's are valuable when used to evaluate different management strategies. As Plissner and Haig (2000) point out, "population viability models do not serve as predictors of minimum viable population sizes, but rather they are useful as tools providing probabilities of relative success for developing and assessing alternative population management strategies." At the same time, limitations of PVAs must be recognized to prevent uncertainty and misuse (Beissinger and Westphal 1998, Fieberg and Ellner 2000, Reed et al. 1998, McCarthy et al. 2003). PVAs that have been created for these two species have not been validated. This is critical, as several PVAs were discredited once predictions were tested or evaluated (Hitchcock and Gratto-Trevor 1997; Nichols et al. 1980, Ludwig 1998).

Pallid Sturgeon (Scaphirhyncus albus)

The pallid sturgeon was federally listed as an endangered species on September 6, 1990 (USFWS 1993). Under Neb. Rev. Stat. § 37-806 any species determined to be threatened or endangered pursuant to the federal Endangered Species Act shall be similarly listed under the Nebraska Nongame and Endangered Species Conservation Act. The pallid sturgeon is an ancient fish species with five rows of scutes that run the entire length of the body. It possesses a spade-like rostrum, dorsoventrally flattened body, and tough skin. The sturgeons' reduced eyes and larger outer barbels are believed to be adaptations for feeding in turbid, sediment-laden waters (Keenlyne 1989). Pallid sturgeon and shovelnose sturgeon are very closely related and very similar in appearance, but genetics have confirmed they are separate species. Pflieger (1975) reported the principal morphologic features distinguishing pallid sturgeon from shovelnose are the relative lack of scutes on the belly. The pallid is typically lighter in color. Barbel length and relative position as well as the relative length of the rostrum also distinguish this species from the shovelnose sturgeon (Bailey and Cross 1954).

Distribution and Habitat

The pallid sturgeon is endemic to the Missouri River, the lower reaches of the Platte, Kansas, and Yellowstone rivers, the Mississippi River below the confluence with the Missouri River, including several major tributaries of the Mississippi such as the Atchafalaya River, Yazoo/Bit Sunflower and St. Francis Rivers (Keenlyne 1989). The pallid sturgeon is believed to once have been fairly abundant before commercial over-harvest and habitat modification. Forbes and Richardson (1905) estimated that pallid sturgeon comprised 1 in 5 river sturgeon collected in the lower Missouri River and Keenelyne (1989) reported that "correspondence and notes of researchers suggest that pallid sturgeon were still fairly common in many parts of the Mississippi and Missouri river systems as late as 1967."

Pallid sturgeon are well adapted to life on the bottom in swift waters of large, turbid, free-flowing rivers (Forbes and Richardson 1905, Kallemeyn 1983, and Gilbraith et al. 1988), with braided channels, dynamic flow patterns, flooding of terrestrial habitats and extensive microhabitat diversity (Mayden and Kuhajda 1997). Prior to management of the Missouri River for navigation, this river ecosystem was in a constant state of change, maintained by a variable dynamic intra- and inter-annual flow regime, ample sediment transport and interactions with the floodplains. The pallid sturgeon, along with many other native species, evolved a life cycle in sync with the ever changing dynamic system of this large river and its tributaries.

Today, these habitats and much of the previously functioning ecosystem have been changed by impoundments and channelization. The deep, high-velocity, single channel of the Missouri River from South Sioux City downstream was engineered for navigation purposes and is severely lacking in available sturgeon habitat. As stated in the Pallid Sturgeon Recovery Plan (USFWS 1993) "destruction and alteration of habitats by human modification of the river system is believed to be the primary cause of declines in reproduction, growth and survival of pallid sturgeon."

Sturgeon are found in deep areas with swift current and turbidity (Bailey and Cross 1954, Erickson 1992), and pallid sturgeon inhabit higher velocity areas than the smaller and sympatric shovelnose sturgeon (Carlson et al. 1985, Bramblett 1996). In the Missouri River in South Dakota, pallid sturgeon most frequently occupy river bottoms where velocity ranges from 0 to 0.73 m/s (Erickson 1992). Other studies in Montana found that pallid sturgeon are most frequently associated with water velocities ranging from 0.46 to 0.96 m/s (Clancey 1990). Bramblett (1996) noted pallid sturgeon occupying bottom velocities ranging from 0.0 to 1.37 m/s. During all seasons, pallid sturgeon used locations of high current velocity (0.5 - 1.5 m/sec) at the channel margin, near sand islands and off the ends of wingdikes, usually over a sand substrate (DeLonay and Rabeni 1998). Parham et al. (2005) found that the upper and lower quartiles of bottom velocity in nets that captured pallid sturgeon were from approximately 0.2 to 0.44 m/s with the median near 0.4 m/s in the lower Platte River. Snook (2001) found that pallid sturgeon were using bottom velocities ranging from 0.17 to 0.97 m/s. Peters and Parham (*2008*) found that pallid sturgeon were most frequently captured in the deepest and swiftest pools, riffles and runs of the Platte River which averaged approximately 0.8 m/s.

Pallid sturgeon have been found using a variety of depths, which could be dependent on local conditions. Hurley (1996) found wild pallid sturgeon using depths between 1.8 and 19.1 m in the middle Mississippi River. In Montana, pallid sturgeon were captured from depths that ranged from 1.2 to 3.7 meters in the summer, but they were captured in deeper waters during winter (Clancey 1990). Other pallid sturgeon collected in the upper Missouri, Yellowstone and Platte rivers were captured in depths ranging from 1 to 7.6 meters (Watson and Stewart 1991, USFWS 1993). Bramblett (1996) found pallid sturgeon in depths ranging from 0.6 to 14.5 meters. Snook (2001) found pallid sturgeon to use depths from 0.15 to 1.89 meters in the lower Platte River, and Swigle (2003) found wild pallid sturgeon using habitat averaging 1.3 m in depth. Peters and Parham (*2008*) found pallids in an average depth of almost 1.6 m in the lower Platte River.

Pallid sturgeon appear to use areas with higher turbidity. Turbidity levels where pallid sturgeon have been found in South Dakota range from 31.3 Nephelometric turbidity units (NTU) to 137.6 NTU (Erickson 1992). Bramblett (1996) found the mean Secchi disc transparency was 7.8 inches at 115 pallid sturgeon locations in the upper Missouri and Yellowstone rivers.

Within large, highly altered river systems, sturgeon select microhabitat areas such as island tips, deep holes near wing bars and other areas where there is a sharp edge in depth such as the downstream end of chutes and in chutes. Snook (2001) found that pallid sturgeon substantially use the downstream edges of alluvial sand bars. It is believed that this habitat gradient provides refugia and/or feeding areas (Sheehan et al. 1998).

Temperature influences pallid sturgeon behavior and habitat use. They have been found in areas where the water temperature ranges from 0° C to 33°C. Swimming ability decreased and mortality increased for some river species below 4° C (Sheehan et al. 1998), so pallid sturgeon at these temperatures seek areas with warmer waters such as downstream island tips, areas below wingdikes, main channel, and the main channel border (Hurley 1996). When temperatures rose above 4° C, pallid sturgeon were restricted to the main channel border and main channel. As temperatures rose to between 10° C and 20° C, pallid sturgeon were increasingly relocated below wingdikes (Hurley 1996).

When evaluating substrates of pallid sturgeon habitat, they showed significant preferences for sandy substrates, and avoided gravel and cobble substrate (Bramblett 1996). Snook (2001) found similar results in the lower Platte River.

Foraging

Food habits of this species range from aquatic invertebrates to fish depending on life stage (Gerrity 2005, Gerrity et al. 2006, Wanner 2006). Carlson et al. (1985) reported that both shovelnose sturgeon and pallid sturgeon have a high incidence of aquatic invertebrates in their diet, but the pallid sturgeon had a greater proportion of fish (mostly *cyprinids*) than did shovelnose. Turbidity is likely a key component of successful foraging for the pallid sturgeon. Modde and Schmulbach (1977) found that pallid sturgeon could be expected to forage efficiently for fish and benthic invertebrates in highly turbid areas. Historically, the turbid environment caused by suspended sediment provided pallid sturgeon with cover while moving from one snag or undercut bank to another. Today in much of the pallid sturgeon's range, the water clarity has increase dramatically. Site-feeding predators such as northern pike and great blue heron may have a competitive advantage over species not equipped by evolution with good eyesight.

Adult pallid sturgeon are primarily piscivorous (Coker 1930, Carlson et al. 1985) and historically were said to rely on large-river minnows as their primary forage. Carlson et al. (1985) determined composition of food categories by volume and frequency of occurrence in the diet of shovelnose sturgeon (n=234), pallid sturgeon (n=9), and presumed hybrids (n=9). Aquatic invertebrates composed most of the diet of shovelnose sturgeon, while larger pallid sturgeon, and presumed hybrids, consumed a greater proportion of fish (mostly cyprinids). Other researchers also reported a higher incidence of fish in the diet of pallid sturgeon than in the diet of shovelnose sturgeon (Cross 1967; Held 1969, Gerrity 2005).

Reproduction and Movement

Pallid sturgeon are generally long-lived, and researchers have estimated pallid sturgeon longevity to be in excess of 40 years (USFWS 1993). Males do not become sexually mature until five to seven years of age, and between 533 – 584 mm TL (Fogle 1961) while females are nine to twelve-years-old before egg development begins and the first spawn may not occur until age thirteen to fifteen or 850 mm FL (Keenlyne and Jenkins 1993). It is suspected that these fish do not spawn annually (Keenlyne and Jenkins 1993).

Pallid sturgeon have been found to have mature gametes during seasons coinciding with natural high river flows (Keenlyne and Jenkins 1993) and likely spawn as early as April in the lower portion of their range and as late as June in the northern portion. In their natural environment, male pallid sturgeon may be capable of spawning annually while it may take up to 10 years between spawning events for females, with an individual female spawning only a few times during a normal life span (Keenlyne and Jenkins 1993). Recent data presented by Dave Herzog (Missouri Department of Conservation), at the pallid sturgeon Recovery Team meeting

September 28 and 29, 2005 held in Lakewood, Co. suggest that pallid sturgeon may spawn over an extended period. This could be individual fish spawning at multiple times or individual pallid sturgeon within a locality spawning at different times.

The rarity of the pallid sturgeon and the habitats they use has made documenting their reproduction and spawning challenging, so limited information is available at this time. Currently, there are multi-state, collaborative efforts to learn basic parameters such as spawning locations, substrate preference, water temperature, and spawning time of year. Another source of general information for pallid sturgeon spawning is the similar shovelnose sturgeon. Given that the pallid and shovelnose sturgeon are known to hybridize, it can be inferred that spawning conditions and associated behaviors must be similar, at least in the highly modified system in existence today (Pflieger 1975).

The spawning cue is likely driven by a number of factors, most of which are tied to high spring flows. These include temperature, turbidity, depth, velocity and changes in water chemistry. Higher flows in the spring cause an a) increase in temperature as water surface area increases relative to its volume; b) increase in turbidity as fine sediment and organic matter are contributed by the floodplain; and c) increases in nutrient cycling through similar mechanisms.

Pallid sturgeon hatcheries have determined that spawning temperatures in the hatchery environment range from 55° to 60° F (12.7° – 15.56° C) (Krentz et al. 2005). The similar species shovelnose sturgeon are documented to spawn late in May through early June in Wisconsin when water temperatures were between 19 and 21°C (Christenson 1975).

The larvae drift downstream from the hatching site (Moyle and Cech 1982, Kynard et al. 2002). After a successful spawn, limited data suggest the downstream drift period for larval pallid sturgeon begins at hatching and continues for up to thirteen days, with a decline after day 8 (Kynard et al. 1998).

The pallid sturgeon is a highly mobile fish. Recent recaptures of stocked fish and telemetry results indicate that the pallid sturgeon is capable of large distance movements in a relatively short amount of time. A sturgeon captured at the confluence of the Platte and Missouri River on November 5, 2002 had been stocked at Boonville, MO on April 25, 2002 nearly 400 river miles away (K. Steffensen, personal communication 2007) and two individuals from this same stocking were captured in the Platte River in 2004 (Peters and Parham *2008*).

It is also believed that sturgeon demonstrate spring spawning migrations. Initiation of pallid sturgeon spawning migrations has been associated with seasonal higher spring flows (Peterman 1977, Zakharyan 1972, Gilbraith et al. 1988) and potentially by rising water temperature (Peters and Parham *2008*). Pallid sturgeon will migrate significant distances prior to spawning, suggesting segregation of spawning sites from home areas. In spring of 2007, two radio tagged, gravid, wild female pallid sturgeon were tracked in the Missouri River adjacent to Nebraska. A series of flow pulses resulting from natural runoff from the James River and Big Sioux River occurred in mid May, at which time both females demonstrated rapid upstream movement, followed by slower downstream movement. The females were recaptured and the field scientists confirmed that they had expelled eggs in the upstream reaches of the lower Missouri River (USGS 2007).

There are observations of both sturgeon species migrating up tributaries of the Missouri River in the spring (Bramblett and White 2001, Peters and Parham 2008). Bramblett and White (2001) found that pallid sturgeon moved upstream into the Yellowstone River from the Missouri River in the spring and downstream again later in the year although pallid sturgeon did use the Yellowstone River in the winter as well. They speculated that long-range spring and summer movements by both shovelnose and pallid sturgeon were associated with spawning activities. Pallid sturgeon in the lower Platte River have demonstrated similar migration patterns in the spring (Peters and Parham 2008) and larval *Scaphirhyncus* have been sampled in the lower Platte River, confirming sturgeon spawning in the lower Platte River (Peters and Parham 2008, Reade 2000, Hofpar 1997).

In recent years, pallid sturgeon populations have been augmented by release of hatchery-reared fish. Since 1994, thousands of juvenile pallid sturgeons have been released. Despite stocking efforts, pallid sturgeon remain rare throughout their range, and low tag return rates have made it difficult to assess the success of the stocking program. Additionally, given the time it takes for pallid sturgeon to reach sexual maturity, it may take decades following stocking for pallid sturgeon to contribute to the population through spawning. It is important to note that in 1997, 401 pallid sturgeon were stocked into the Platte River at the Nebraska Highway 50 bridge. Sturgeon for this stocking were raised at the Blind Pony Fish Hatchery in Missouri and were tagged with external Floy tags (Krentz et al. 2005). In 1998, 84 age-6 pallid sturgeon from the same hatchery were released in the Platte River at Two Rivers State Recreation Area (RM 40) and were tagged with passive integrated transponder (PIT) tags and coded wire tags. Ten of these fish were also implanted with radio transmitters. In 1999, 15-age 7 pallid sturgeon were PIT tagged, coded wire tagged and implanted with radio transmitters and released into the Platte River at Two Rivers State Recreation Area (Snook 2001, Snook et al. 2002a). During a study by Peters and Parham (2008) in the lower Platte River, each pallid sturgeon captured was evaluated, but none of these fish were originally stocked in the Platte River. The pallid sturgeon captured in this study were a mix of both wild and hatchery raised fish released at other locations. This indicates that both wild and stocked sturgeon from the Missouri River are utilizing habitat in the lower Platte River. Telemetry evidence confirms that they are moving into and out of the Platte River from the Missouri River.

Continuing Threats

Habitat Loss - Habitat loss and alteration is believed to be the leading cause of decline of pallid sturgeon and continues to threaten its existence. Once a diverse assemblage of braided channels, sandbars, and backwaters, the Missouri River is now confined via bank stabilization and levee construction within a narrow channel of rather uniform width and swift current from Sioux City, Iowa to Saint Louis, Missouri. Morris et al. (1968) found that channelization of the Missouri River reduced the surface area by approximately 67 percent. Funk and Robinson (1974) calculated that the length of the Missouri River between Rulo, Nebraska, and its mouth (~500 river miles) had been reduced by 8 percent and the water surface area had been reduced by 50 percent following channelization. Six mainstem dams on the Missouri River without fish passage facilities block pallid sturgeon migrations and have inundated historic spawning and nursery areas. The remaining mainstem riverine habitat between dams and downstream of the dams has been further altered by removal of snags, and hypolimnetic (i.e., year-round cold water) releases and an unnatural hydrograph. Similar impacts to the lower Platte River can be seen with reduced high flows and vegetation encroachment.

Sediment and sediment movement in association with variable discharges are key components of habitat creation in large river systems such as the Missouri, Mississippi and Platte rivers. In much of the pallid sturgeon's range, sediment had been reduced from flowing water as it settles out in reservoirs. Historical high flows, which are now tempered, are important to introduce and transport organic material from the floodplain to the river system which maintains turbidity and supports the system's productivity.

Elements of the natural hydrograph (i.e., magnitude, frequency, duration, timing and rate of change) are essential for many life requirements of native large-river fish like the pallid sturgeon and paddlefish. Throughout much of the pallid sturgeon's range, the natural hydrograph has been highly altered. Spring and early summer high flows have been shown to stimulate spawning activities of shovelnose sturgeon. Hesse and Mestl (1993) showed significant negative relationships between indices of river discharges due to flood control actions in the spring and year class development for a number of native fish in the Missouri River. Invertebrate reproduction, secondary productivity and behavioral migration of fish are closely tied to the natural hydrograph (Hesse and Mestl 1993).

Hydropeaking is another modification to the natural hydrograph. The lower Platte River, among other locations, is directly impacted by hydropower peaking operation on a regular basis. Hydropower peaking is the operation of hydropower generating facilities to concentrate power generation into certain timeframes, which in turn results in rapid, large magnitude, sub-daily flow fluctuation in the reach below the generating facility. These flows fluctuations on the river can impact water depth as dramatically as one to two feet during a peaking cycle (Figure 9).

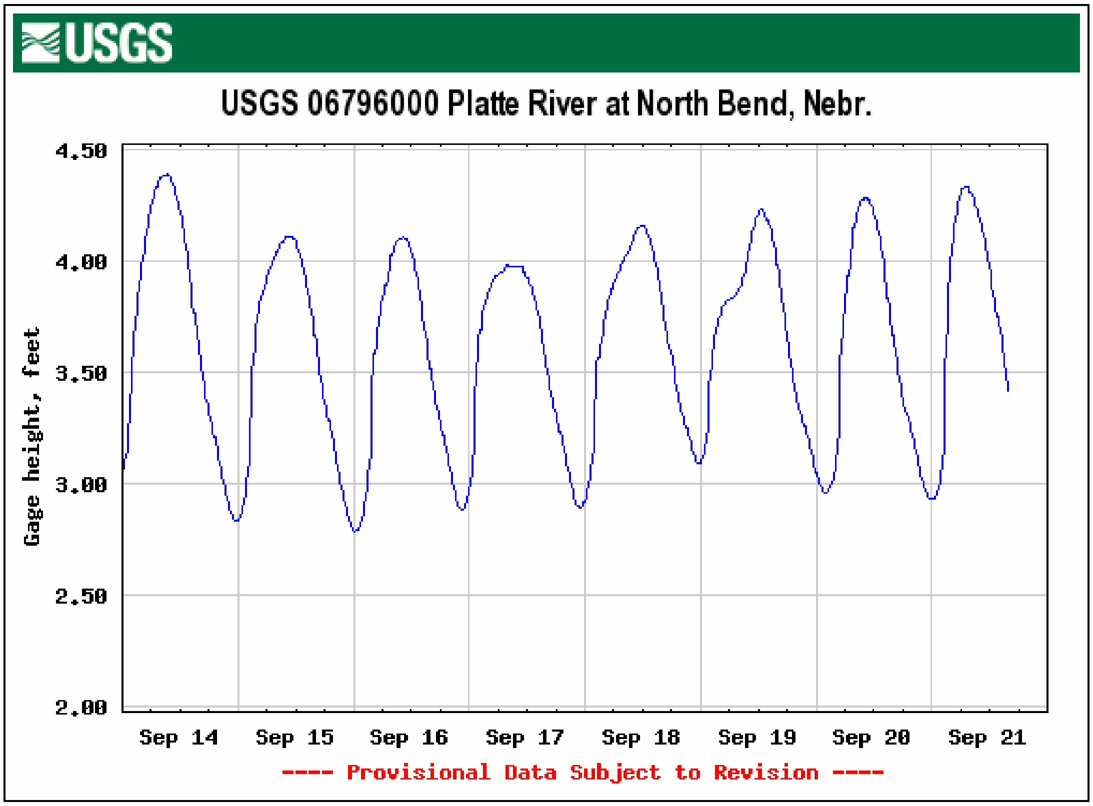

Figure 9: Platte River USGS Gage No 0679600 at North Bend showing fluctuations in gage height September 14-21, 2007, North Bend Gage 7 Day 09-21-07

Commercial Harvest - Sturgeon species, in general, are highly vulnerable to impacts from fishing mortality due to unusual combinations of morphology, habitats and life history characteristics (Boreman 1997). Historically, pallid, shovelnose, and lake sturgeon (*Acipenser fulvescens*) were commercially harvested on the Missouri and Mississippi rivers (Helms 1974). Commercial harvest of sturgeon was documented in the Platte River with 310 lbs of sturgeon taken in 1894 (U. S. Commission of Fish and Fisheries 1898). Five of the 13 states where pallid sturgeon occur, currently allow commercial fishing for shovelnose sturgeon. It is difficult to distinguish between pallid and shovelnose sturgeon, thus accidental commercial harvest is considered a major threat to the pallid sturgeon. However, surveys of anglers by Peters and Parham (*2008*) indicate that approximately 87% of sturgeon anglers can recognize the difference between the two species.

Pollution/Contaminants - Pollution is a likely threat to the pallid sturgeon over much of its range. Various fish-harvest and consumption advisories exist or have existed as a result of manmade pollution from the mouth of the Big Sioux River to the mouth of the Platte River, and from near Kansas City, Missouri, to the mouth of the Mississippi River.

Polychlorinated biphenyls (PCBs), cadmium, mercury, and selenium have been detected at elevated concentrations in tissue of three pallid sturgeon collected from the Missouri River in North Dakota and Nebraska. Detectable concentrations of chlordane, DDT (including its metabolites), and dieldrin were also found. The prolonged egg maturation cycle of the pallid sturgeon, combined with an inclination for certain contaminants to be concentrated in eggs, could make contaminants a likely agent adversely affecting development of eggs and embryos, or survival of fry, thereby reducing reproductive success (Ruelle and Keenlyne 1993).

The exposure and effects of environmental contaminants on pallid sturgeon in the lower Platte River were evaluated by using shovelnose sturgeon as a surrogate species (Schwarz et al., 2006). Gross observations and condition indices seem to indicate that shovelnose sturgeon from the lower Platte River are healthy; however, histological examination of the gonads and reproductive biomarkers revealed potential reproductive impairment as indicated by ovicular atresia, abnormal estrogen to testosterone ratios, and high concentrations of vitellogenin in males. Contaminants detected in shovelnose sturgeon at concentrations of concern included PCBs, selenium, and atrazine. Selenium and total PCBs in shovelnose sturgeon tissues exceeded concentrations known to cause reproductive impairment in some fish species. The pesticide atrazine was detected at elevated concentrations in water and shovelnose sturgeon blood plasma. Although the effects of atrazine exposure to sturgeon species is unknown, research on other fish species indicate that atrazine may be adversely affecting pallid sturgeon health and reproduction by mechanisms that are both direct (endocrine disruption) and indirect (decreased prey base). The report concluded that a piscivorous diet and longer life-span and reproductive cycle likely make pallid sturgeon more susceptible than shovelnose sturgeon to toxins that bioaccumulate and/or cause adverse reproductive effects.

Pallid sturgeon also may be adversely affected by point-source discharges controlled under the National Pollutant Discharge and Elimination System (NPDES). For example, discharges from wastewater treatment plants (WWTPs) can contain endocrine disrupting compounds (EDCs) including natural and synthetic hormones, pharmaceuticals, and detergent breakdown products (Kolpin et al, 2002). Endocrine disruption in fish exposed to WWTP effluent is well documented (Purdom et al., 1994; Routledge et al., 1998; Cheek et al., 2001; Schultz et al., 2003); however, endocrine disruption is not addressed by NPDES permits. In addition, Omaha has a combined sewer system that is incapable of separating storm water run-off and sewage. Each year, Omaha discharges billions of gallons of untreated sewage and storm water into a section of the Missouri River identified as a Recovery Priority Management Area for the pallid sturgeon (Dryer and Sandvol, 1993). Discharges by drinking water treatment plants are also a concern. During a telemetry study in April, 2004, Peters and Parham (2008) documented that pallid sturgeon moved out of the Platte River immediately following a back-flushing operation at the MUD water treatment plant which released an unknown white material into the river. According to NPDES Permit # 000906, MUD is authorized to discharge chemicals in back-flushing operations. Further investigation determined that the facilities' discharges contain several toxic irritants including ferric sulfate, calcium oxide, hydrofluosilicic acid, chlorine, and ammonia. These compounds were not monitored under the existing NPDES Permit.

Hybridization – Hybridization is a phenomenon of which the cause and frequency is unclear. Carlson et al. (1985) first identified that hybridization had occurred between pallid sturgeon and shovelnose sturgeon in the Missouri and middle Mississippi rivers. Suspected hybrids also have been reported in commercial catches from the lower Missouri River (USFWS 1993). In a recent genetic analysis, Tranah et al. (2004) found that pervious assumptions of hybrids based on morphometrics were valid, and that hybrids of pallid sturgeon and shovelnose sturgeon are more pronounced in the middle Mississippi and Atchafalaya Rivers. As referenced in USFWS (1993), Bailey and Cross (1954) did not report hybrids, which may indicate hybridization is a recent phenomenon caused by man-induced reductions in habitat diversity and measurable changes in environmental variables such as turbidity, flow regimes, and substrate type (Carlson et al. 1985). However, Allendorf et al. (2001) suggested that pallid and shovelnose sturgeon in the lower Mississippi River have not evolved reproductive isolation to the same degree as northern populations, which clearly have genetically distinct shovelnose and pallid sturgeon (Tranah et al. 2001, Campton et al. 2000, Heist and Schrey 2006a and b).

Current Status

The distribution of pallid sturgeon stretches 3,515 miles of river through Montana, North Dakota, South Dakota, Nebraska, Iowa, Kansas, Missouri, Illinois, Kentucky, Tennessee, Arkansas, Mississippi and Louisiana (Figure 10). The U.S. Fish and Wildlife Service actively engaged in the recovery of the pallid sturgeon, and has divided its range into six recovery priority management areas (RPMA). The following discusses the current known status of the pallid sturgeon for each reach.

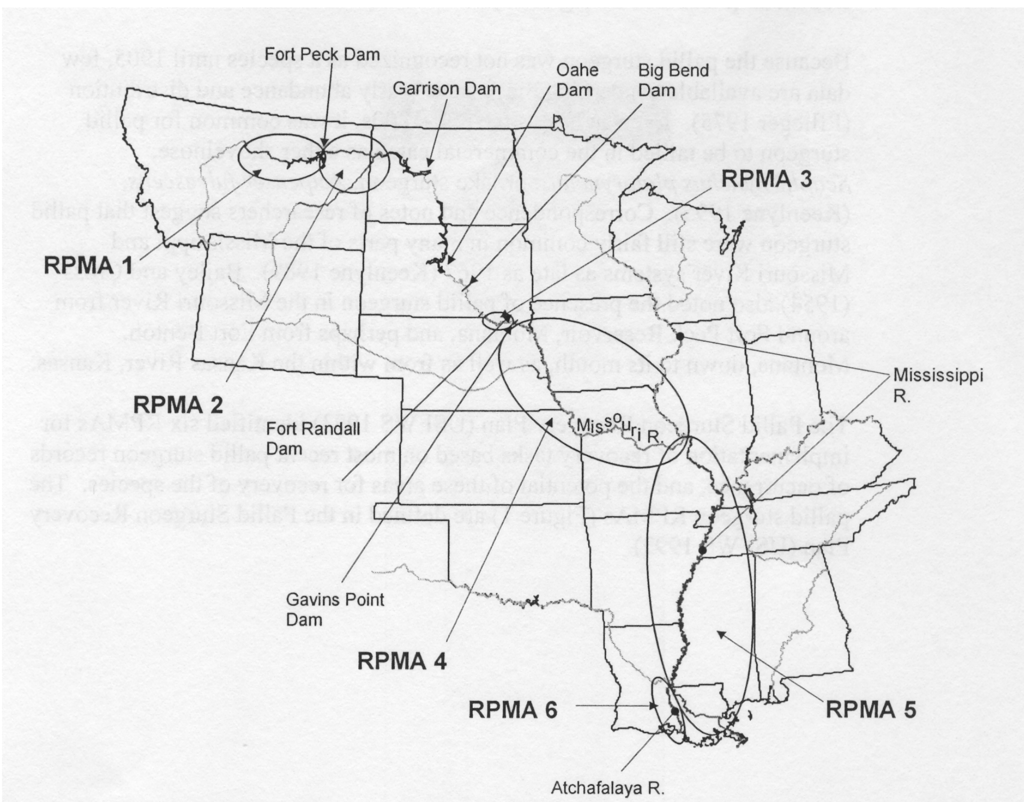

Figure 10: Map depicting Missouri and Mississippi Rivers with major dams identified. Outlined areas (ovals) correspond with approximate location of RPMAs as defined in the Pallid Sturgeon Recovery Plan (USFWS 1993). Map not to scale.

RPMA 1 is the Missouri River from the headwaters of Fort Peck Reservoir upstream to the confluence of the Marias River, Montana (Figure 10). According to the Pallid Sturgeon 5-Year Review, (USFWS 2007), the sturgeon population in this RPMA has remained relatively unchanged with 52 wild adult fish. The lack of smaller pallid sturgeon suggests that spawning, recruitment, or both are severely limited or absent within this reach. This area is sustained with a hatchery and stocking program.

RPMA 2 is the Missouri River below Fort Peck Dam to the headwaters of Lake Sakakawea and the lower Yellowstone River up to the confluence of the Tongue River, Montana. This population continues to decline. Small sturgeon are absent from this reach, suggesting that spawning and recruitment appear to be limited. This reach contains the Yellowstone River, a major tributary documented with the presence of pallid sturgeon. In 2007, Montana fisheries biologists implanted two gravid female pallid sturgeons, with radio tags and followed them. They found that the fish moved up into the Yellowstone River near Fairview and were surrounded by males that were similarly tracked. Upon recapture, they had spawned. Larval nets captured just hatched sturgeon. Additional studies are pending to determine if the larvae captured are pallid or shovelnose sturgeon, but this conclusively documents that sturgeon spawn in the Yellowstone River, and illustrates the importance of major tributaries of the Missouri River and their use as spawning habitat for sturgeon species (Henckel 2007).

RPMA 3 is the Missouri River from 20 miles upstream of the mouth of the Niobrara to Lewis and Clark Lake (Figure 10). No native wild population of pallid sturgeon is known to survive in this area, but there are hatchery stocked fish present. It appears that the population in this reach is surviving and growing. Additionally, two wild pallid sturgeon were caught in the mouth of the Niobrara River in 1964 and 1973 (G. Zuerlein, personal communication 2007).

RPMA 4 is the Missouri River downstream of Gavins Point Dam to the Missouri River/Mississippi River confluence. **This stretch includes the confluence with the Platte River.** Population trends in this stretch are not conclusive, but captures of all size classes indicate that hatchery fish are contributing to the population. There is also evidence of spawning in this reach. Three larval pallid sturgeon were collected in the Lisbon Chute, just off the Missouri River (Krentz 2000). Larval sturgeon that could not be identified to species, were found just below Gavins Point Dam (G. Mestl, personal communication 2007), in the Platte River and Elkhorn River (Hofpar 1997, Reade 2000, Peters and Parham *2008*). In May of 2007, a female pallid sturgeon implanted with a radio transmitter, spawned just upstream of Ponca State Park, in a reach of river that is unchannelized and a second female spawned near Sioux City, Iowa in late April or early May (USGS 2007). A gravid female pallid sturgeon in the lower Platte River exhibited expected spawning migration and downstream movement (Peters and Parham *2008*). However, smaller fish in this reach are of hatchery origin, so it appears that natural recruitment of pallid sturgeon is still limited in RPMA 4 (USFWS 2007).

RPMA 5 extends from the confluence of the Missouri and Mississippi River to the Gulf of Mexico (Figure 10). For this stretch, population trends and status remain unknown. Herzog et al. (2005) documented successful reproduction with the collection of larval pallid sturgeon in this reach. Smaller size classes captured indicate that some level of recruitment is likely occurring in this area.

RPMA 6 is the Atchafalaya system to the Gulf of Mexico. Pallid sturgeon were not documented in this reach until 1991. Hybridization between shovelnose and pallid sturgeon is a problem, and status and trends are not conclusive at this time.

Recovery Plan

Due to the extreme rarity of pallid sturgeon and the large size of its range, capture information is extremely limited at this time. As a result, range wide trends have been difficult to identify and monitor. The pallid sturgeon is a long-lived species, but as a consequence of the relative lack of known recruitment, natural mortality would cause a decline in numbers over time. The magnitude of this effect cannot be calculated at this time, and the success of hatchery programs may compensate to an unknown degree. The recent Pallid Sturgeon 5-year summary and evaluation (USFWS 2007) stated that "previously established down listing criteria are no longer relevant to a potential future down listing as written." Each recovery priority management area is faced with problems beyond just total population numbers and male to female ratios. A self-sustaining population can not be maintained without adequately addressing identified threats. A revision of the recovery plan is suggested.

Environmental Baseline*

The Platte River

The Platte River headwaters are in the Southern Rocky Mountains and the Wyoming Basin. It begins as two rivers: the North Platte River and South Platte River which converge near North Platte, Nebraska. The Platte River extends across Nebraska where it meets the Missouri River near Plattsmouth. This river system drains over 88,803 square miles (Galat et al. 2005). For the purposes of this Report, the lower Platte River is considered to be the area beginning at the confluence of the Platte and Loup rivers near the city of Columbus, Nebraska and extends downstream approximately 162 km to the Missouri River near Plattsmouth.

Historically, this river meandered across the floodplain with wide shallow braided channels and shifting sand and gravel substrates. In pre-settlement times, the flows of the Platte River were highly influenced by snowmelt in the Rockies. In the late spring and early summer, there would be higher discharge from plains snowmelt, interspersed with higher flows associated with rainfall events throughout the warmer months (Figure 11).

Specialized habitats such as backwaters, sloughs, side channels, shoreline and deep water habitats along the edges of sandbars and river banks are examples of the diverse habitat types that occur along the Platte River. These varied features of the river provides year-round habitat for numerous species of plants, invertebrates, amphibians, fish and reptiles. The presence of the existing variety of habitats is a reflection of the highly dynamic hydrology of the Platte River system.

Today diversions and depletions from the system have reduced the flows and tempered flooding and ice flows that would have built high sandbars and maintained the open sandbar habitat, such that very little remains. The Platte River basin was originally dominated by grasslands (Galat et al. 2005, NRC 2005), but today approximately 90% of the land area is used for agricultural production. Irrigated agriculture in the central and lower sub-basins of the Platte River in Nebraska consumes 1,366,400 acre-feet of surface water each year (NRC 2005).

There are five main-stem dams on the North Platte River. These dams alter water temperatures below the dams by releasing colder water and alter the hydrograph. They also reduce sediment transport. According to the Platte River Recovery Implementation Program Final Environmental Impact Statement (USDOI 2006), "Climate and streamflow records indicate that the pronounced reduction in flows in the Central Platte River during the first part of the 20th century occurred while precipitation was above average, again illustrating how construction of large storage and diversion projects can overwhelm the decadal variation in annual precipitation." The bankfull flows have been consistently reduced and when declines in water use above and below major reservoirs are compared, it is evident that water level declines are greater below reservoirs (USDOI 2006). Due to these reduced river flows, much of the Platte River is now narrower with

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* The Environmental Baseline is an analysis of the effects of past and ongoing human and natural factors leading to the current status of the species, its habitat, requirements and ecosystem within the action area. It does not include the effects of the action under review in the consultation.

densely vegetated islands and the diversity of habitats is much reduced.

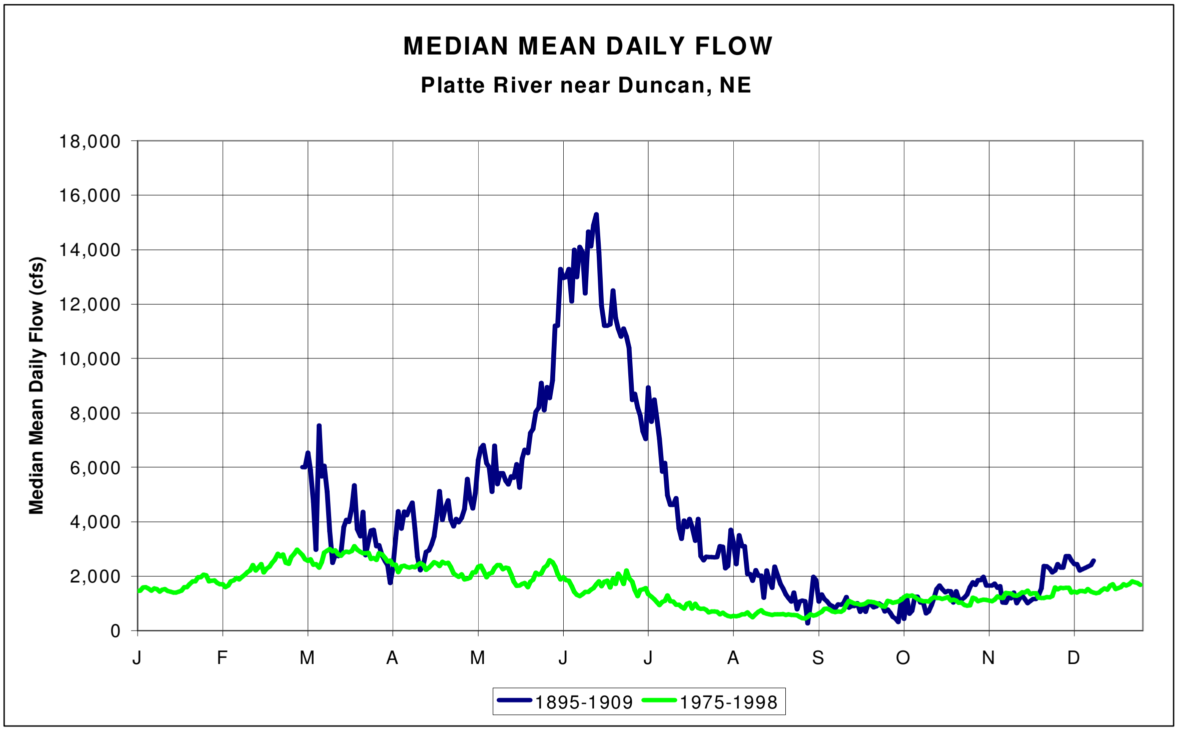


Figure 11: Median mean daily flow in the Platte River at Duncan, Nebraska, in 1895-1909 vs. 1975-98. It should be noted that the record from 1975 – 1998 is considered a wet period of time. (Source: USGS gage data, as presented in Platte River FEIS (USDOI 2006)).

As described in the Introduction Section of this document, water development in the Platte River basin upstream of the Platte River and Loup River confluence is now subject to the provision of the Platte River Recovery Implementation Program (Program). This Environmental Baseline includes the Program, and assumes its continuing existence and implementation including the variations in flows expected to result from the result from the implementation of Program.

The lower Platte River still has some geomorphological characteristics similar to those of the historic Platte River, largely due to the influence from large tributaries. The lower Platte River is a mid-size, shallow, braided river with sandbars and islands. The width in some downstream areas has remained relatively constant with approximately 90 percent of the width remaining (Eschner et al.1983). However, as much as 38.8% of the lower Platte River's high banks have been stabilized (Runge and Harms 2007). Bank stabilization prevents channel evolution and disconnects the floodplain from the stream. Mussetter (2002) reported that along the reach bordered by the Sarpy County levee, a decline of 30-40 percent of stream width had occurred between 1859 and 1985. Land-use changes within the flood plain as well as hydrologic changes are likely both contributing factors in alterations of the active channel.

The lower Platte River's hydrograph and base flow benefit from the influence of the groundwater fed Loup and Elkhorn rivers, which are considered to have some of the most stable flows when compared to rivers worldwide (Bentall 1989). Salt Creek is also a large tributary to the lower

Platte River. The flows from these large tributaries are a key component of the more stable, higher flows, and more natural stream characteristics seen in the lower Platte River, relative to the rest of the Platte River (Figure 12). However, this stretch of river should not be considered unaltered or pristine. It has been highly altered due to decreased base flows, decreased flood events, residential flood control levees, bank stabilization, timber encroachment and other development along its banks over time.

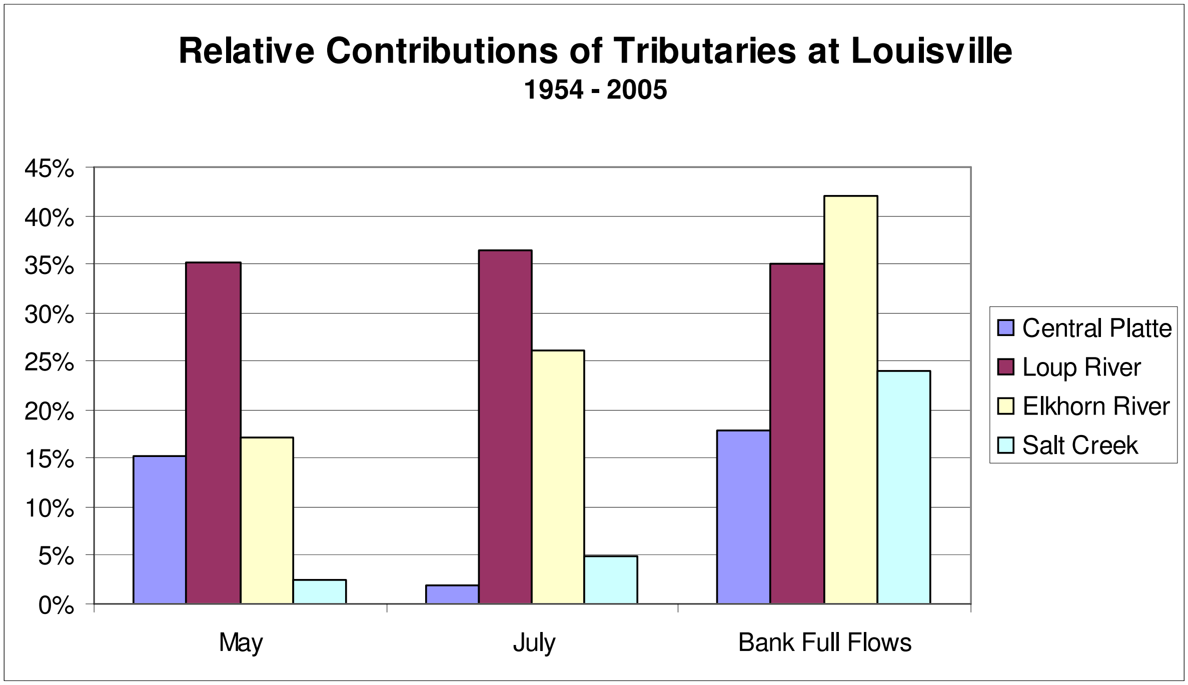


Figure 12: The relative contributions of the larger tributaries to the lower Platte River. May and July statistics were based on the 80% exceedance for the period or record 1954-2005. Bank full flows are based on the 1.5 year return interval peak flows, representing higher flow events.

The flowing water in the lower Platte River and its tributaries originates from several sources, including ground water. Nearly all surface water, which includes streams, lakes, reservoirs and wetlands interact with the groundwater such that depletions to stream flows can affect ground water levels, with the reverse also being true (Winter et al. 1998). Management of only one component of this interconnected system will be met with only partial success as surface and ground water are in continuous interaction.

The lower Platte River has water temperatures that range from near 0 °C in January (Peters et al. 1989) to temperatures over 40 °C recorded in June, July, and August. USGS records document typical pH values of 8.0, alkalinity of 153.5 mg $CaCO_3$/L, nitrate nitrogen of 1.35 mg/L and phosphate phosphorous of 0.73 mg/L (Galat et al. 2005). In summer months, water temperatures increase as discharge decreases.

Statistics

To describe the current status of the lower Platte River, flow statistics were generated from January 1, 1954 to December 31, 2005. These dates contain the longest complete gage record for all gages used in this analysis, which allows for more comparable data sets. This period of record is used consistently throughout the Environmental Baseline to describe current conditions.

The following statistics are based on information in Parham (2007) which provides additional details regarding these statistics. Exceedance tables were used throughout this document. In an exceedance table, low flows are most often exceeded so they have high exceedance probabilities. This table can be interpreted such that a flow that is exceeded 80% of the time is "available" 80% of the time or considered to occur in the 20th percentile of all flows (Parham 2007).

Included in the descriptive statistics is the Coefficient of Dispersion (CD) which characterizes the consistency, timing, and the rate of change of the flow regime, especially focusing on moderate flows. It is calculated as ((25th exceedance percentile – 75th exceedance percentile) / 50th exceedance percentile)). A single value of the CD is not highly significant, but can be used to compare flows between locations or timeframes. Changes in the CD value reflect change in the dispersion of the discharge data which indicates differences or changes in the flow regime. The low to median flow ratio (LMR) also characterizes flow consistency and timing, but focuses on low flows. This index is useful when determining if low flow events are becoming more frequent or more common at certain times of the year. This is the ratio of the 95th exceedance percentile (low flow) to the 50th exceedance percentile (median). The LMR index is not intended to be a measure of base flow in the river, yet it will be highly influenced by changes in base flow. A base flow index, derived using IHA software, is an annual statistic which compares the 7 day minimum flow with the mean annual flow. Minimums and maximums for different time periods and days of zero flow were also generated.

Flow duration curves were created which characterize the magnitude and frequency of the discharge record by plotting the discharge vs. percent of time that a particular discharge was equaled or exceeded. The upper portion of these curves can be interpreted as the flood regime. Steep curves generally denotes flashy floods from rain events, while a flatter upper region of the curve would indicate a steadier source of water such as snowmelt. In the lower region of the curve, low flow patterns are evident. A steady falling line suggests the discharge in the river is controlled by runoff, while flatter lines are low flows sustained throughout the year due to groundwater adding to baseflow or to artificial flow regulation.

Bankfull flows were calculated, which are the peak flows that occur at an interval of 1.5 years in this analysis. Bank full flows can be defined as the flow that "just fills the stream to its banks" (Gordon et al.1992 in Annear et al 2004). The bank full flow moves a significant amount of sediment over time. These flows may move less sediment per event than a large flood, but they occur much more frequently resulting in more overall sediment moved. Rosgen (1996) suggested that a 1.5 – 2 year flood event is typically close to the bankfull discharge, although the frequency of this discharge is specific to each river type. This level of analysis for the lower Platte River has never been evaluated, so for the purposes of this Report, the maximum discharge with a 1.5 year return period was used for estimating the bankfull discharge for the period of record 1954-2005.

Environmental Flow Characteristics (EFC) characterize the magnitude, duration, frequency, timing and rate of change of the discharge record and are descriptive statistics generated by software package Indicators of Hydrologic Alteration (IHA). These characteristics provide information on a wide variety of flow conditions such as the low flows, extreme low flows, high-flow pulses, small floods and large floods. Detailed descriptions of each of these characteristics are available in Parham (2007) or http://www.nature.org.

Duncan and Central Platte Contribution

Evidence of the reduced flows from the central Platte River can be seen at the USGS gage near Duncan (USGS Gage 06774000) which is just upstream of the Loup confluence. Figure 11 illustrates how the hydrograph has changed drastically with development of the Platte River upstream from the Duncan gage. A smaller spring pulse in March followed by a larger pulse in May and June were characteristically observed in records prior to 1910. More recent data suggest a highly altered hydrograph with little to no resemblance to the historic hydrograph.

On an annual basis, the mean discharge for the Platte River near Duncan was 1,867 cfs with a median flow of 1,250 cfs. The difference between the mean and median flows reflected the presence of high flow pulses recorded at the gage. Based on all daily flow recordings for the time period, the flow was greater than 417 cfs 80% of the time. Around 3% of the time the river was at zero flow. The river's discharge was greater than 1,000 cfs for 58% of the days, greater than 5,000 cfs for 6% of the days, and greater than 10,000 cfs for 1% of the days. The maximum flow recorded for the Platte River near Duncan was 23,800 cfs on 7/1/1983. For annual peak flows, the Platte River near Duncan exceeded 4,280 cfs in 8 out of 10 years, 7,000 cfs in 5 out of 10 years, and 13,800 cfs in 2 out of 10 years. The bankfull flows that occur every 1.5 years on average peaked at 7,130.

In terms of monthly median flow rates, the Platte River near Duncan, NE peaked in March (2,365 cfs) and was lowest in August (232 cfs). The river exceeded 1,000 cfs during February, March, and April more than 80% of the time. Figure 13 illustrates the flows that were exceeded 80% of the time. Zero flow days were possible from July until December, but were most frequent in August and September. The coefficient of dispersion (CD) reflected a change in flow characteristics between the winter and spring time period and late summer and fall. The low flow to median flow ratio (LMR) also reflected this pattern suggesting that base flow was missing from the river during the late summer and fall (Table 3).

A description based on the median Environmental Flow Characteristics (EFC) for the middle Platte River near Duncan, NE resulted in the river as having the highest stable flows in March (1,618 cfs) dropping to lows in August (259 cfs) and with little change in discharge between October and January (1,000 cfs to 1,100 cfs). On an annual basis, the base flow was estimated to be 3% of the mean flow. The extreme low flows (less than 10% of annual mean) approached zero flow (1.9 cfs) during an 11 day event around August 25. Approximately 3 in 10 years would experience zero flow. There were 7 high flow pulses lasting 6 days per event. These pulses peaked at 2,650 cfs and occurred most commonly around the end of May. These high flow pulses rose nearly twice as fast as they fell (400 cfs and -233 cfs, respectively). Approximately every other year there was a small flood event that approached a peak of 9,800 cfs lasting 63 days and was centered in mid May. A large flood would peak in late April near 22,500 cfs and last nearly 2 months (54 days) from beginning rise to return to low stable flow conditions and occurred with a 10 year recurrence interval. The flood waters would rise at 1,282 cfs per day and fall more slowly at -560 cfs per day.

The flow duration curve for the Duncan location illustrates a steady declining slope in the beginning of the curve with a sharp decline at the end of the curve (Figure 14). This indicates that inputs to the system are from snowmelt and steadier sources. The sharp decline suggests that water is being lost from the river system which could be either from artificial diversions or from the water returning to groundwater (Parham 2007).

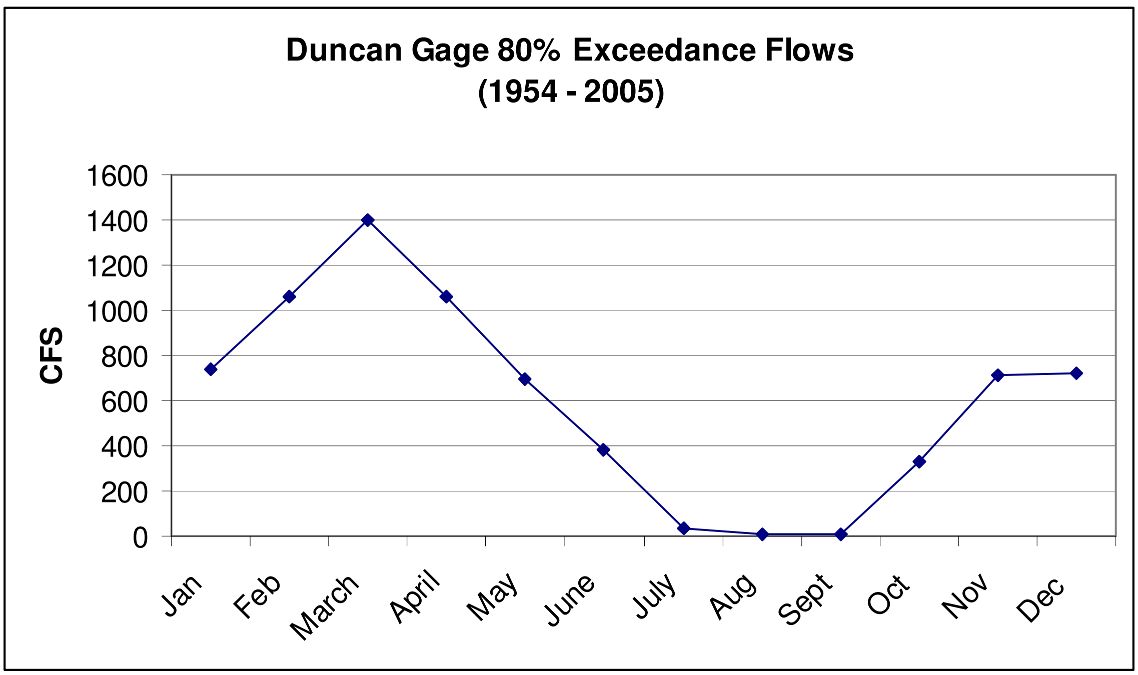


Figure 13: Flows at the Duncan Gage based on the 1954 – 2005 period of record expected to occur 8 out of every 10 years (80% exceedance flows)

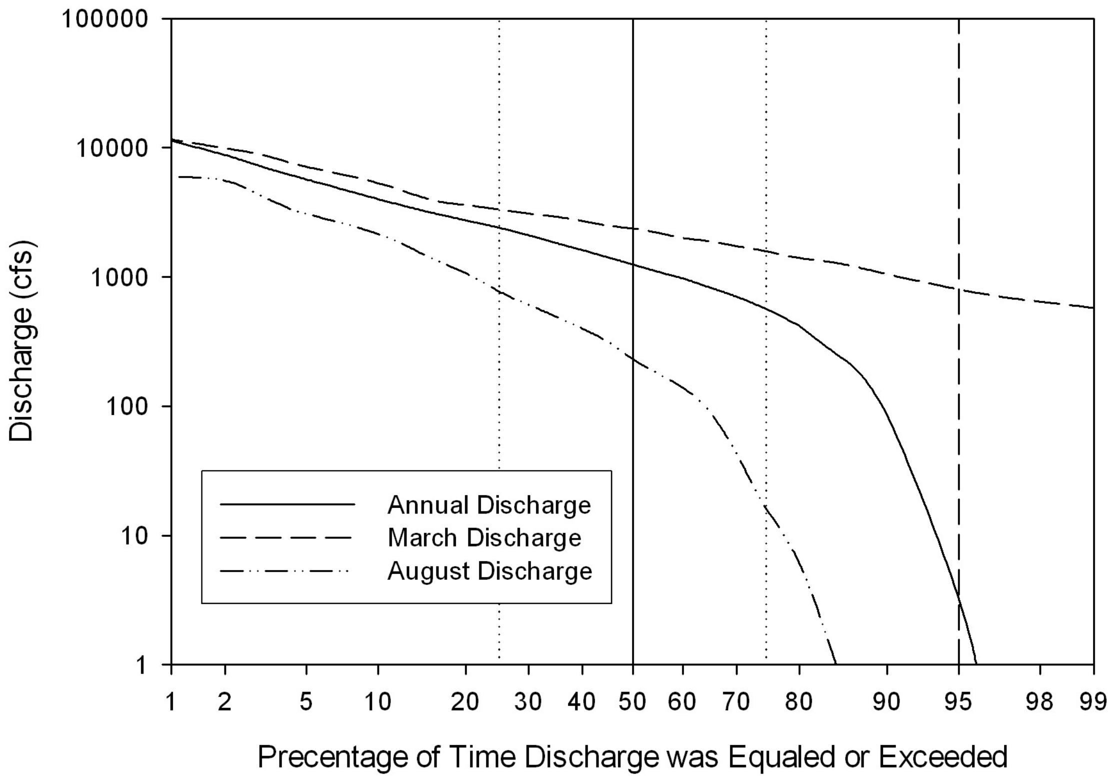


Figure 14: Flow duration curve for the Platte River near Duncan, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. The LMR is based on 95% exceedance discharges / 50% exceedance discharges from Parham 2007.

Table 3: Coefficient of Dispersion (CD) and Low to Median Flow Ratio (LMR) at the Duncan Gage (January 1, 1954 to December 31, 2005).

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
CD	0.96	0.89	0.74	0.87	1.38	2.17	2.6	3.26	3.3	1.57	1.09	0.97
LMR	0.35	0.35	0.34	0.31	0.17	0.04	0	0	0	0	0.1	0.28

Loup River and Loup River Canal Contribution

The Loup River basin is defined as the area of central Nebraska that drains into the Loup River above its confluence with the Platte River. The total basin area includes approximately 15,200 square miles. Major tributaries of the Loup River include Beaver Creek, the Calamus River, the Cedar River, the Dismal River, Mud Creek, the Middle Loup River, the North Loup River, and the South Loup River. Baseflow in the streams in this basin are supplied primarily by ground water discharge with additional contributions from precipitation.

Although the source of water in these streams is relatively consistent, development has impacted Loup Basin flows. There are approximately 15,824 registered wells as of October 1, 2005, and 1,200 surface water appropriations (DNR 2005). The number of new wells and surface water appropriations has grown steadily over the last 20 years, and it is reasonable to expect this trend to continue. The impacts of current water use have not been fully realized due to lag effects. Lag effects are defined as the delayed effect that the consumptive use of water associated with well pumping will have on hydrologically connected stream flow and the associated impact on surface water appropriations (DNR 2005). According to the 2006 DNR Annual Report, the lag impact from depletive ground water wells within the legally defined hydrologically connected aquifer, shows that an additional 95 cubic feet per second of daily depletion can be expected from the basin due to the effect of lag impact from existing wells. In addition to consumptive use, water is being diverted through a series of surface water canals, including the Burwell-Sumter Canal, Farwell Main Canal, Farwell South Canal, Middle Loup Canals, Mirdan Canal, Ord-North Loup Canal, Sargent Canal, Taylor-Ord Canal and the Loup Power Canal.

Flows of the Loup River near Genoa (USGS gage 06793000) are below the intake for the Loup Power Canal, and are therefore influenced by both seasonal changes and power production activities. The median flow for the Loup River was 120 cfs. Based on daily flow recordings, the flow was greater than 28 cfs 80% of the time. The flows were zero about 1% of the time. The river's discharge was greater than 1,000 cfs for 23% of the days, greater than 5,000cfs for 1% of the days and greater than 10,000 cfs for less than 1% of the days. The maximum flow recorded for the Loup River was 70,800 cfs on August 13, 1996. Annual peak flows for the Loup River near Genoa exceeded 6,060 cfs in 8 out of 10 years, 8,880 cfs in 5 out of 10 years, and 16,200 cfs in 2 out of 10 years.

For median monthly flow, the Loup River near Genoa, NE was highest in December (1,000 cfs) and relatively high in January through March (840 to 957 cfs). The median monthly flows for the rest of the year were much lower with the only flow over 100 cfs occurring in April (271 cfs). The lowest median monthly flow occurred in August when median flow average 31 cfs. Zero flow days were possible from July until October, but were most frequent in July and August occurring on average 5% of the time.

The Environmental Flow Characteristics describe a small flood event that would approach 12,500 cfs lasting 23 days and centered in early May. Approximately every ten years a large flood would peak in mid June near 38,600 cfs and last 3 weeks from beginning rise to return to low stable flow conditions. The EFC also described the river as having the highest stable flows in January through March (289 to 204 cfs) with discharge less than 100 cfs the rest of the year with August having the lowest flows (28 cfs). The extreme low flows approached 3 cfs during a 4 days event around August 16. Approximately 1 in 10 years the Loup River near Genoa, NE would experience zero flow. There would be 16.5 high flow pulses lasting 4 days per event. These pulses would peak at 1,064 cfs around mid July. These high flow pulses would rise and fall at a similar rate (264 cfs and -200 cfs, respectively).

The Loup River Power Canal (Canal) returns flows to the Platte River approximately 1-2 miles downstream of the Loup River mouth. Information regarding the Canal is based on the USGS gage 06792500. Most months the median flow was between 1,200 and 1,900 cfs and the Canal withdrew an annual median flow of 1,800 cfs. Flows greater than 3,020 cfs were observed only about 1% of the time. This gage reflects a highly modified system such that EFC characteristics are not appropriate to describe flow conditions, so fewer statistics were generated for this gage.

Contributions of the Loup River System to the lower Platte River can be seen at the gage near North Bend (USGS gage 0679600), which is the first gage site downstream of the Loup River confluence. The annual median flow was 3,630 cfs. The peak median flows occur in April at 5,880 cfs and the lowest monthly median flows were 1,670 cfs. The coefficient of dispersion was generally stable with a value under 1 and the LMR was 0.27 annually. These metrics both suggest a large portion of base flow in this section of the river (Table 4). Monthly flows approaching or exceeding 1,000 cfs were observed in all months greater than 80% of the time, with flows greater than 1,000 cfs 99% of the time in February to June and again in October. On an annual basis, flow of 5,000 cfs occurred more than 30 % of the time and more than 10,000 cfs 5% of the time. The monthly flows exceeded 80 percent of the time are displayed in Figure 15. The maximum flow recorded for the Platte River near North Bend was 82,300 cfs on March 10, 1993. In terms of peak flows, flows greater than 21,000 cfs were observed in approximately 1 out of 2 years and flows greater than 38,000 cfs were seen 1 out of every 5 years on average. The bankfull flows that occur every 1.5 years on average peaked at 21,280.

Based on the Environmental Flow Characteristics (EFC), approximately every ten years a large flood would peak in late April near 64,900 cfs and last nearly 1.5 months (46 days) from beginning rise to return to low stable flow conditions. The EFC described the river as having the highest stable flows in March and April (near 4,300 cfs) dropping to lows in August (1,815 cfs) and with another peak in November (3,545 cfs). On an annual basis, the base flow was estimated to be 19% of the mean flow. The extreme low flows (less than 10% of annual mean) typically occurred 5 times annually for 2 days per event. The lowest of these would be near 858 cfs around August 14. Only approximately once in ten years would the extreme low flows reach 623 cfs. There would be 10 high flow pulses lasting 4 days per event. These pulses would peak at 6,085 cfs around June 20. These high flow pulses would rise nearly twice as fast as they would fall (1,044 cfs and -590 cfs, respectively). Every other year there would be a small flood event that would approach 26,950 cfs lasting 32 days and centered in early June. Approximately every ten years a large flood would peak in late April near 64,900 cfs and last nearly 1.5 months (46 days) from beginning rise to return to low stable flow conditions. The flood waters would rise at 6,244 cfs per day and fall more slowly at -1,686 cfs per day. The Loup River, on average, contributes 34% of the discharge annually for the lower Platte River, (Peters and Parham *2008*).

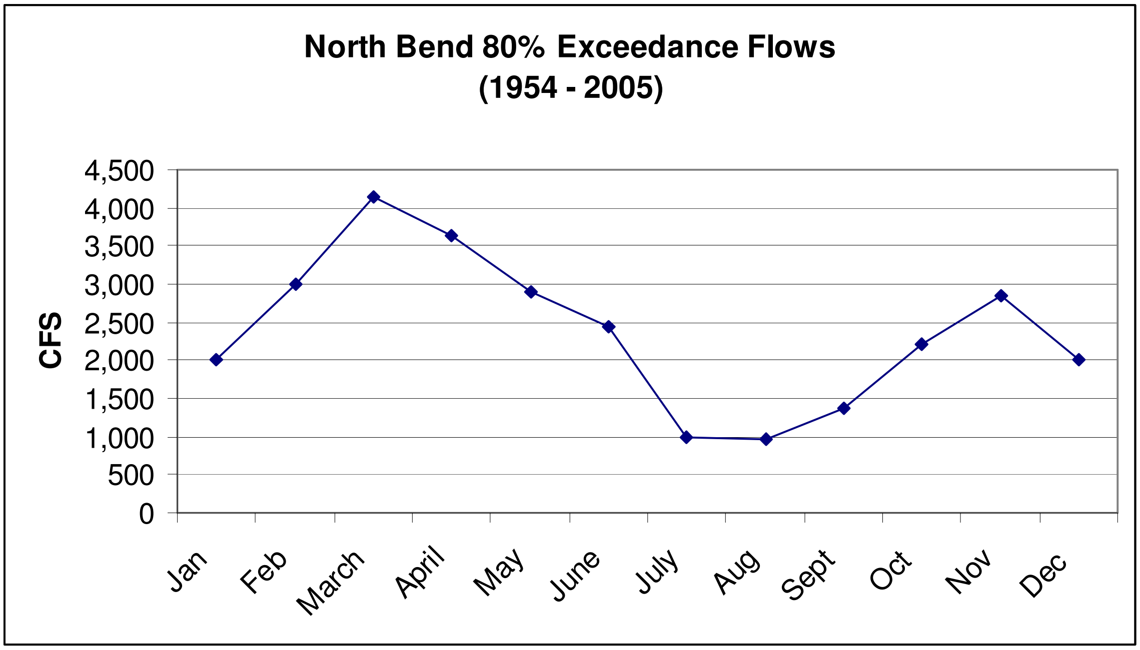


Figure 15: Flows at the North Bend Gage that occur 8 out of 10 years for the period of record from 1954 – 2005 (80% Exceedance Flows).

The flow duration curve for the North Bend location illustrates a steady declining slope in the beginning of the curve (Figure 16). This indicates that inputs to the system are from a steadier source such as snowmelt. The gradual decline in the lower portion of the graphic suggests that the river is sustained throughout the year by groundwater adding to the baseflow.

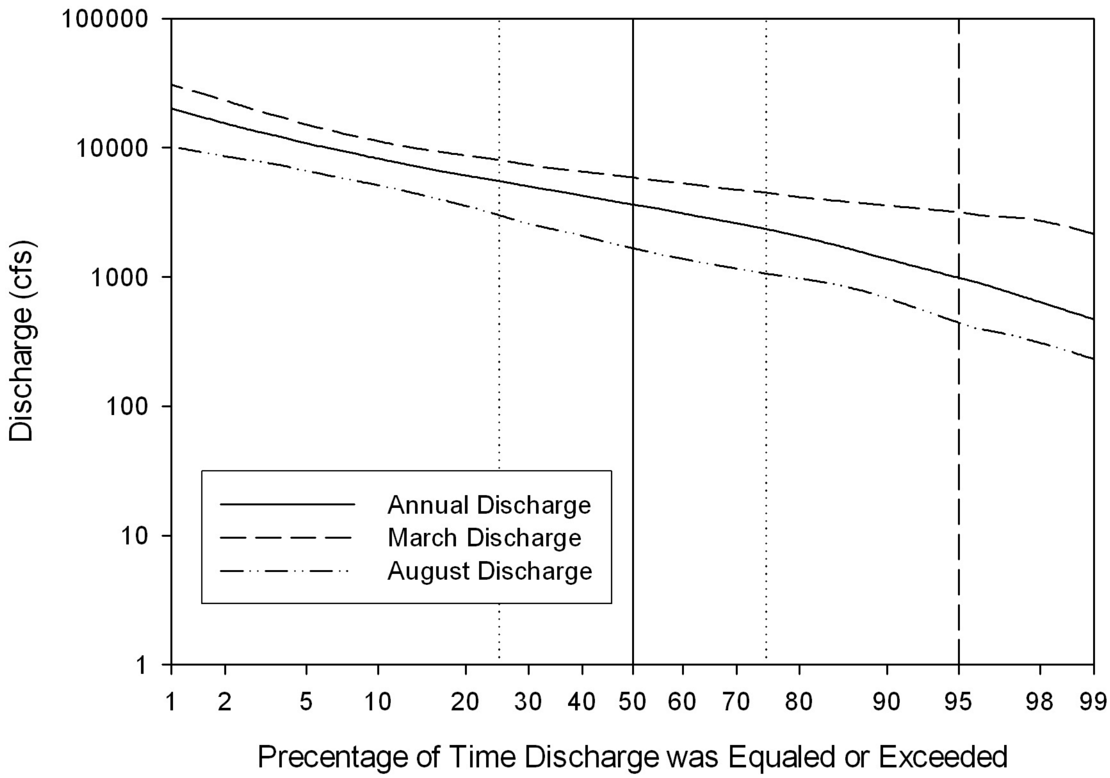


Figure 16: Flow duration curve for the Platte River near North Bend, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR) (Parham 2007).

Table 4: Coefficient of Dispersion (CD) and Low to Median Flow Ratio (LMR) at the North Bend Gage (January 1, 1954 to December 31, 2005).

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
CD	0.77	0.66	0.6	0.6	0.86	1.3	1.3	1.16	0.93	0.73	0.5	0.74
LMR	0.39	0.45	0.54	0.56	0.46	0.4	0.22	0.26	0.37	0.51	0.52	0.32

Impacts of Power Generation on the Loup River System

The Loup Public Power District (LPPD) has a hydropower station near Columbus, Nebraska that utilizes water diverted from the Loup River at Genoa, Nebraska. LPPD has been generating hydropower since March 5, 1937 and holds one of the most senior water rights in the basin. The power generating process is generally a pass through system and under their appropriation, the diversion facilities cannot pass more than 3,500 cubic feet per second. According to an agreement between LPPD and the Commission, LPPD always passes a minimum of 50-100 cfs of Loup River flow past their point of diversion. However, it is relatively rare for flows of 3,500 cfs to be available at their point of diversion (perhaps only 10-20 days in a typical year). Thus, the majority of the year, LPPD is diverting all but 50-100 cfs of the Loup River flow.

Loup Public Power (LPPD) utilizes a form of hydropeaking to generate power, where water is stored and passed through the station into lower-lying watercourses. This leads to frequent, regular alteration between rising and falling flow rates which differs fundamentally from the natural flow regime (Figure 17). Hydropeaking impacts the hydraulics of the system through rapid and significant changes in discharge, velocity and bed stress. It also impacts the chemical and physical water quality as the diurnal cycle of turbidity and temperature is impacted, and the morphology of the river is also altered through changes to the sediment load. The two terms hydrocycling or hydropeaking may have different definitions, but the impacts of frequent fluctuations in the flow regime remain significant to the riverine ecosystem, regardless of the definition used.

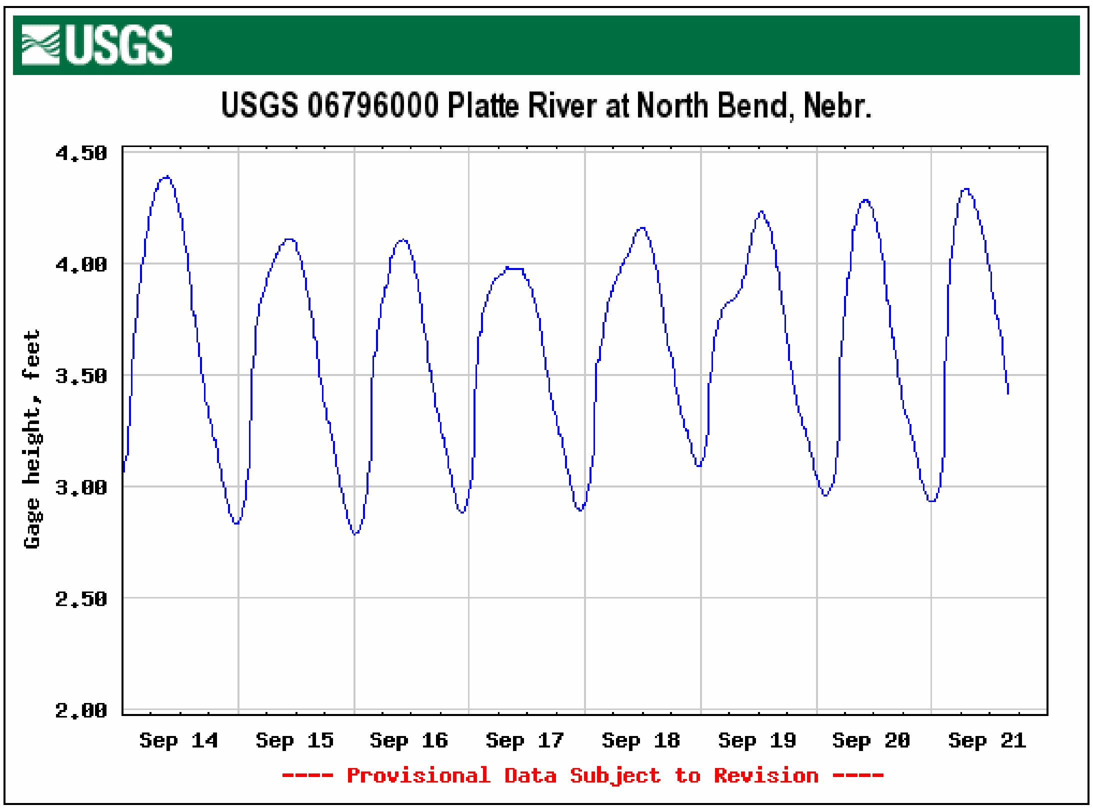


Figure 17: Platte River USGS Gage No 0679600 at North Bend showing fluctuations in gage height September 14-21, 2007, North Bend Gage 7 Day 09-21-07

Research in other river systems affected by hydropeaking clearly describes impacts to various biological resources which are important to the target species of this Report. Aquatic invertebrates, terrestrial invertebrates that use gravel bars, and native fish populations have been documented to be impacted by hydropeaking (Gersich and Brusven 1981, Danks 1991, Cereghino and Lavandier 1998, Cereghino et al. 2002, Van Looy et al. 2007, Troelstrup and Hergenrader 1990, Freeman et al. 2001). The impact of hydropeaking to early life stages of fish is of concerns as they provide forage for least terns and pallid sturgeon. The daily fluctuating hydrograph alternately floods and dewaters areas of the active channel. This rapid fluctuation causes many fish become isolated into disconnected backwaters, pools and channels that are susceptible to water quality changes, susceptibility to disease and increased predation.

The availability of invertebrates supported by moist riverine sandbar habitat is important to piping plovers nesting. Results in the lower Platte River (Peters et al. 1989) indicate that macroinvertebrate colonization and production along hard materials and woody and plant debris was impacted by repeating water level fluctuations as occurs with diel discharges from LPPD hydropeaking activities. As mentioned in the species status section of this document, piping plovers forage visually for invertebrates in very shallow water associated with moist substrates. Evidence suggests that hydropeaking decreases the number of taxa and density of invertebrates in shallow water and that some taxa such as Ephemoptera and Trichoptera are extremely intolerant to the diel fluctuations (Troelstrup and Hergenrader 1990).

Sandbars are fundamental to least tern and piping plover nesting. The practice of hydrocycling raises water levels in a cyclic pattern and potentially inundates areas of sandbars that might otherwise provide tern and plover nesting habitat under an appropriate flow regime.

Hydropeaking may also expedite sandbar erosion. Studies of sand beaches/bars along the Colorado River in Arizona below Glen Canyon Dam suggest that these features are prone to erosional episodes that occur over a matter of hours and are associated with dam operations, including the diurnal hydropeaking of flows (Werrel et al., 1991; Dexter and Cluer 1999).

The hydropower operation also has significant impacts to the amount of sediment that passes down the river, which is an important component of the river ecosystem. Due to the reduced velocity of diverted flow, the suspended sediment carried by the Loup River quickly settles out in LPPD’s canal system, beginning immediately below their headworks along a two-mile-long settling basin. An annual dredging operation removes sediment from the canal system and piles the sediment (mostly medium to fine sand) on adjacent lands.

Elkhorn River

The Elkhorn River is located in northeast and north-central Nebraska and joins the Platte River near Gretna. The Elkhorn River Basin includes approximately 7,000 square miles. Major tributaries to the Elkhorn River include the South and North Forks of the Elkhorn River, Logan Creek and Maple Creek. The flows of the Elkhorn River are largely uncontrolled by reservoirs. Baseflow in this basin is driven by groundwater discharge, with the punctuated spikes in flow by the addition of precipitation. Based on National Wetland Inventory data, there are more than 26,000 acres of wetlands associated with the Elkhorn River (LaGrange 2005).

Portions of this basin are highly developed. There are 12,441 registered ground water wells and 550 surface water appropriations as of October 1, 2005 (DNR 2005). Calculations of the lag effect estimated that an additional 40 cfs of daily depletion will occur in this Basin with no additional wells. Although some areas of this basin have limited potential for additional wells due to the geology of the area, based on current trends, it is reasonable to expect additional ground water and surface water use in the basin.

The Elkhorn River is the second largest tributary of the lower Platte River. On an annual basis, the median flow of the Elkhorn River near Waterloo (USGS gage 06800500) was 861 cfs. Median monthly flows in the Elkhorn River were highest from March to June with the peak in June at 1,620 cfs. Figure 18 displays the flows that were exceeded 80% of the time. The lowest median monthly flow was 524 cfs observed during September. The coefficient of dispersion and LMR (annual value of 0.33) suggested a stable base flow in the Elkhorn River near Waterloo (Table 5). In terms of peak flows, the maximum discharge recorded during the time period of 1954 to 2005 was 44,500 cfs on March 29, 1962. On average, the peak flow that occurred every other year was 14,200 cfs and once out of every five years the peak flow exceeded 23,100 cfs.

The median Environmental Flow Characteristics (EFC) for the lower Elkhorn River near Waterloo, NE described the river as having the highest stable flows in April (1,040 cfs) dropping to lows in September (503 cfs) and not rising substantially until the following March. On an annual basis, the base flow was estimated to be 26% of the mean flow. The extreme low flows (less than 10% of annual mean) typically occur once per year for 5 days. The low flow would be 251 cfs around November 17. Approximately every ten years, the extreme low flows reach 128 cfs. There would be 7 high flow pulses lasting 5 days per event. These pulses would peak at 2,370 cfs around June 21. These high flow pulses would rise nearly twice as fast as they would fall (585 cfs and -282 cfs, respectively). On average, every other year there would be a small flood event that would approach 18,950 cfs lasting 35 days and centered in early June. Approximately every ten years a large flood would peak in early April near 41,000 cfs and last nearly 50 days from beginning rise to return to low stable flow conditions. The flood waters would rise at 4,354 cfs per day and fall more slowly at -1,098 cfs per day.

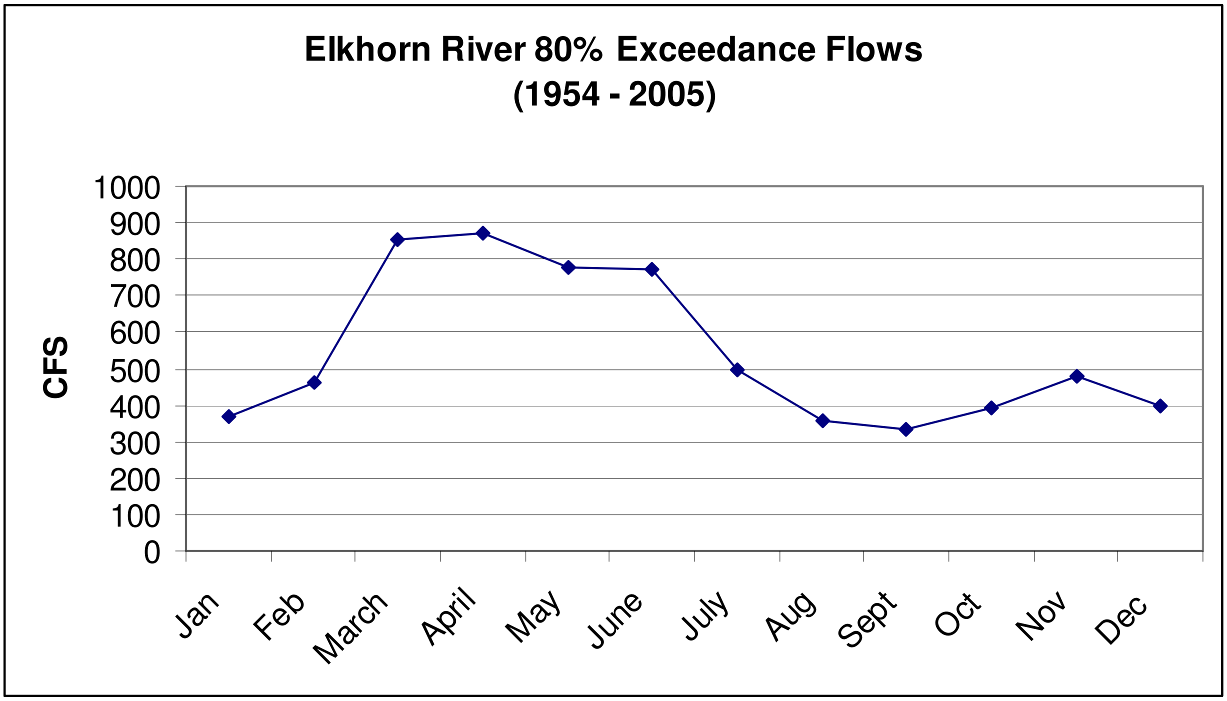


Figure 18: Elkhorn River (Waterloo Gage) flows that occur 8 out of 10 years based on the period of record from 1954 – 2005 (80% exceedance flows).

Table 5: Coefficient of Dispersion (CD) and Low to Median Flow Ratio (LMR) at the Waterloo Gage (January 1, 1954 to December 31, 2005).

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
CD	0.93	1.11	1.09	1.32	1.3	1.59	1.22	0.94	0.98	0.94	0.8	0.83
LMR	0.45	0.33	0.37	0.46	0.34	0.29	0.28	0.33	0.38	0.47	0.46	0.41

Salt Creek

The Salt Creek basin drains 1,645 square mile of southeastern Nebraska, encompassing the City of Lincoln. This basin is highly developed and contains ten flood control structures which create 4,289 surface acres of water and catches many precipitation events that historically contributed to the lower Platte River hydrograph. Salt Creek begins south and west of Lincoln as a meandering stream, but becomes channelized as it wraps through the city. Lincoln also discharges treated sewage water into this creek and all storm water run-off from streets discharge into the system. Major tributaries include the Little Salt Creek, Oak Creek, Wahoo Creek and Rock Creek. This area is dominated by urban development and agriculture. Wetlands associated with Salt Creek are mostly saline; however some freshwater wetlands are also present. A categorization project for the eastern saline wetlands indicated that there were 3,244 acres remaining, but many of these wetlands are highly degraded. The source of the salinity is not understood, but it’s postulated that groundwater inflow passes through a rock formation containing salts deposited by an ancient sea (LaGrange et al. 2003)

Salt Creek is the largest tributary of the lower Platte River that drains into the river from the South. It is much smaller than the Loup or Elkhorn rivers with an annual median flow of 146 cfs at the Greenwood gage (USGS gage 06803555). The flows that are exceeded 80 percent of the time are displayed in Figure 19. Salt Creek near Greenwood had relatively stable flows throughout the year which peaked in March at 208 cfs and fell to a low of 116 cfs in October. The stable flow and large base flow are reflected in the coefficient of dispersion and LMR values during the months (Table 6). June displayed the widest coefficient of dispersion as June flows were likely to be lower or higher than average. In terms of annual peak flows, Salt Creek near Greenwood reached 8,090 cfs in 1 out of 2 years and 20,300 cfs in 1 out of 5 years. The maximum flow recorded during the period between 1954 and 2005 was 37,100 cfs on June 13, 1984.

The median Environmental Flow Characteristics (EFC) for Salt Creek near Greenwood, NE described the river as having relatively stable flows all year ranging from a high of 168 cfs in March to a low of 99 in October. On an annual basis, the base flow was estimated to be 27% of the mean flow. The extreme low flows (less than 10% of annual mean) of 61cfs occurred for 2 days in early October. Only once approximately every ten years would the 1-day minimum flow reach 28 cfs. There would be 12 high flow pulses lasting 3.5 days per event. These pulses would peak at 357 cfs around July 12. These high flow pulses would rise nearly twice as fast as they would fall (140 cfs and -70 cfs, respectively). Every other year there would be a small flood event that would approach 13,230 cfs lasting 22 days and centered in late June. On average, once every ten years a large flood would peak in early July near 33,750 cfs and last nearly 78 days from beginning rise to return to low stable flow conditions. The flood waters would rise at 1,381 cfs per day and fall more slowly at -822 cfs per day.

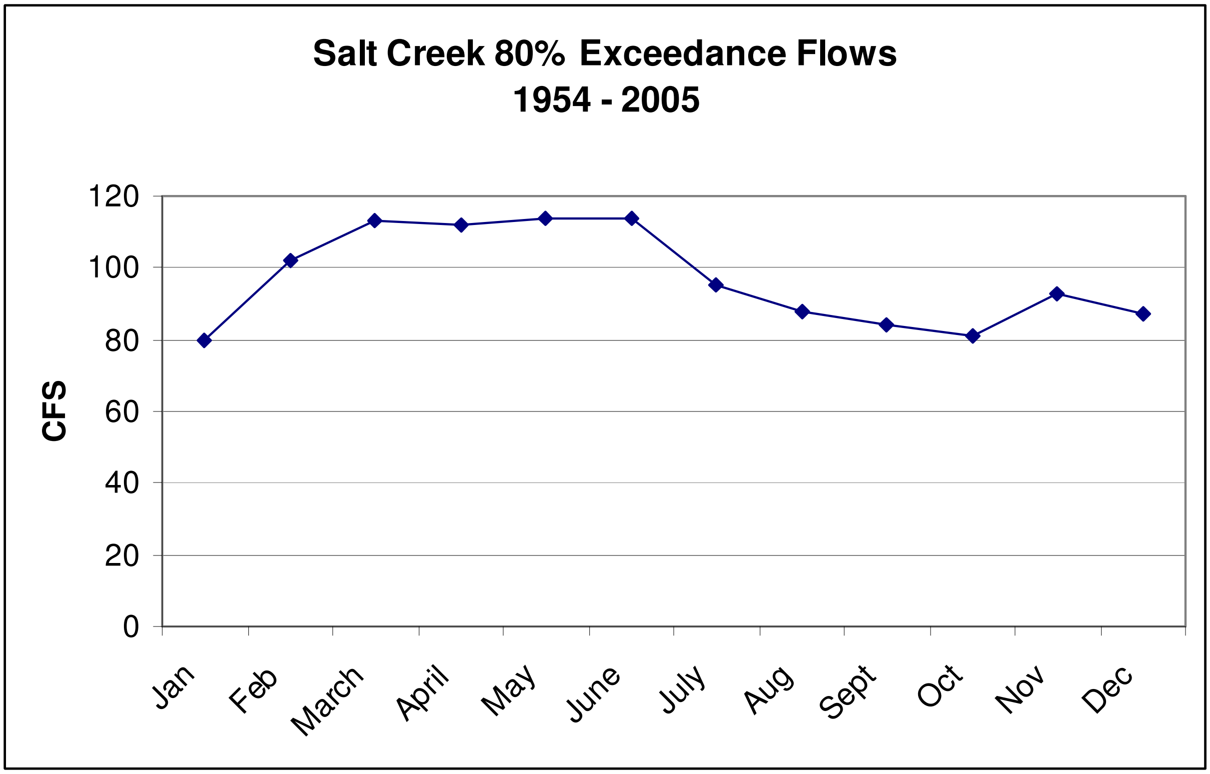


Figure 19: Salt Creek (Greenwood Gage) flows that occur 8 out of 10 years based on the period of record from 1954 – 2005 (80% exceedance flows).

Table 6: Coefficient of Dispersion (CD) and Low to Median Flow Ratio (LMR) at the Greenwood Gage Gage (January 1, 1954 to December 31, 2005).

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
CD	0.83	0.94	1.07	1.27	1.73	1.8	1.24	0.89	0.83	0.83	0.74	0.65
LMR	0.33	0.36	0.36	0.39	0.29	0.32	0.33	0.44	0.41	0.44	0.47	0.43

Cumulative Impact of all Inputs at Louisville

Contributions of flow from all tributaries to the lower Platte River and inputs from groundwater and runoff can be evaluated at the Louisville gage (USGS gage 06805500). The semblance of a natural hydrograph can still be seen at the Louisville gage, especially when compared to the Duncan gage. A spring rise and a late summer low were clearly observed in the monthly flow data (Figures 20-21). The median annual discharge at this gage is 5,230 cfs. Monthly median flows peaked in March at 8,355 cfs and reached their lowest during August at 2,720 cfs. Median monthly flows were greater than 5,912 cfs in March and greater than 1,470 cfs in August 80% of the time. The annual coefficient of dispersion (0.93) and LMR (0.28) values reflected a large baseflow component to discharge. In terms of annual peak flows, the maximum flow recorded was 138,000 cfs on July 25, 1993 (Table 7). The median annual peak flow was 40,800 cfs and in 20% of the years a peak of 54,500 cfs was recorded. The bankfull flows that occur every 1.5

years on average peaked at 39,800.

The median Environmental Flow Characteristics (EFC) for the lower Platte River near Louisville, NE described the river as having the highest stable flows in March (6,360 cfs) dropping to lows in August (2,980 cfs) and rising again to peak in the next March. On an annual basis, the base flow was estimated to be 24% of the mean flow. The extreme low flows (less than 10% of annual mean) typically occur 3 or 4 times for 3.5 days per event. The lowest of these would near 1,320 cfs around August 19. On average, every ten years there would be extreme low flows reach 1,122 cfs. There would be 9 high flow pulses lasting 5 days per event. These pulses would peak at 9,778 cfs around June 25. These high flow pulses would rise nearly twice as fast as they would fall (1,838 cfs and -954 cfs, respectively). Every other year there would be a small flood event that would approach 50,500 cfs lasting 25 days and centered in mid June. Approximately every ten years a large flood would peak in mid May near 114,000 cfs and last nearly 3 months (83 days) from beginning rise to return to low stable flow conditions. The flood waters would rise quickly at 7,926 cfs per day and fall more slowly at -3,506 cfs per day.

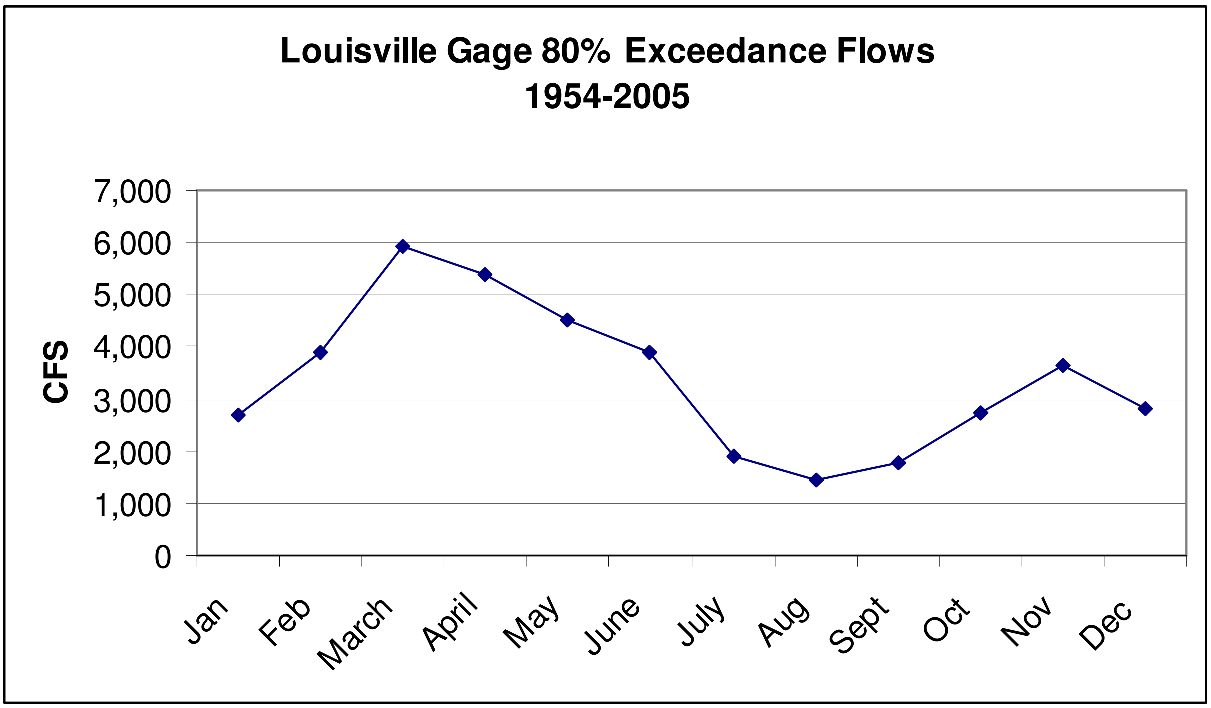


Figure 20: Lower Platte flows at the Louisville Gage that occur 8 out of 10 years based on the period of record from 1954 – 2005 (80% exceedance flows).

Table 7: Coefficient of Dispersion (CD) and Low to Median Flow Ratio (LMR) at the Louisville Gage (January 1, 1954 to December 31, 2005).

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
CD	0.79	0.79	0.65	0.73	0.89	1.24	1.23	1.18	1.01	0.93	0.62	0.73
LMR	0.44	0.47	0.53	0.54	0.38	0.35	0.22	0.28	0.33	0.51	0.54	0.33

The effects of current development and alterations have not been entirely realized at this point in time, and there is anticipated to be less water in the lower Platte River due to the lag effect. The Nebraska Department of Natural Resources has calculated that, "The total calculated depletion at North Bend includes future depletions from the Loup River Basin, and the Platte River Basin and the total calculated future depletion at Louisville includes the future depletions from the Loup River Basin, Elkhorn River Basin and Platte River. The sum of those depletions (i.e., due to lag effects) results in a total depletion in the year 2030 of 110 cfs daily at North Bend and 310 cfs daily at Louisville, if there is no new well development. These estimates are based only on wells within the legally defined hydrologically connected aquifer (DNR 2005).

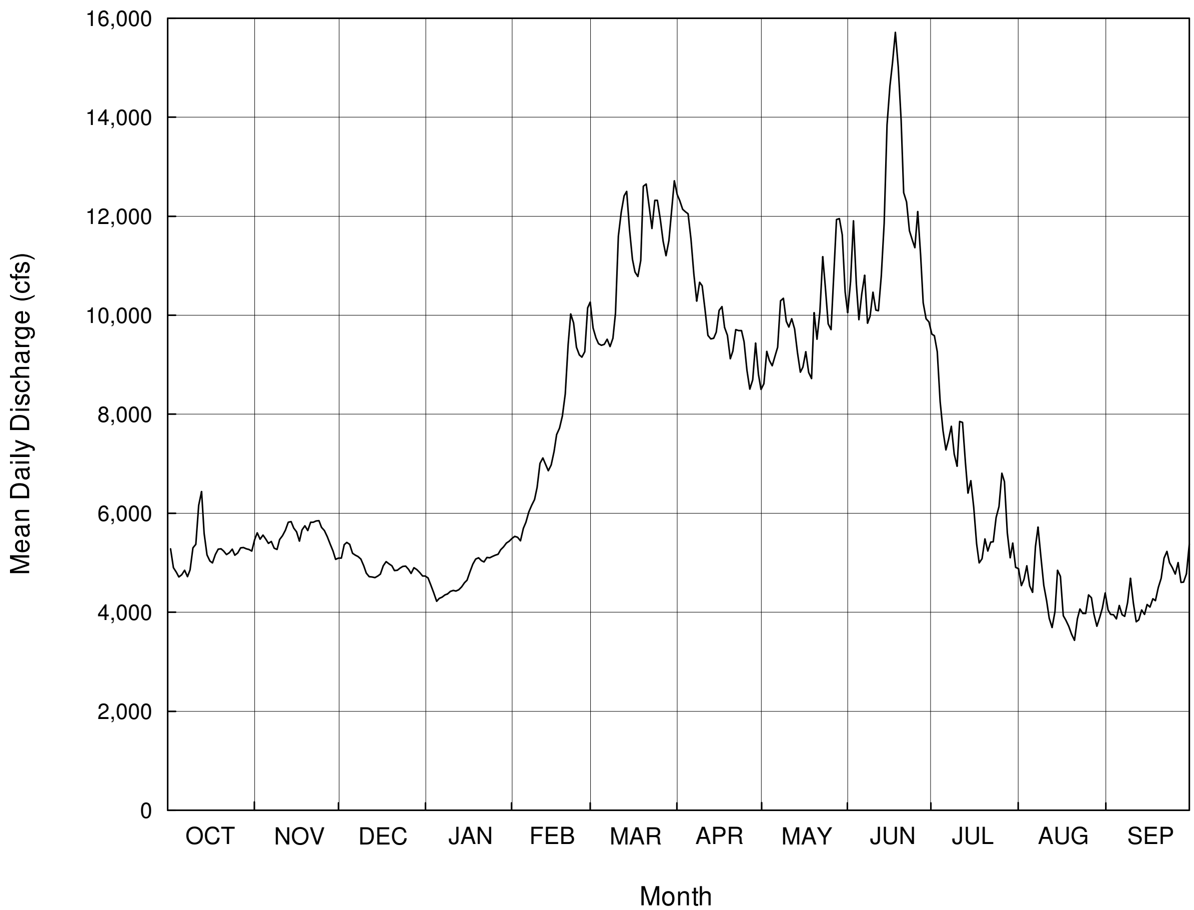


Figure 21: Average annual hydrograph for the Platte River at Louisville (USGS Gage No. 06805500) based on the recorded mean daily flows from 1954 through 2000

(Mussetter Engineering, Inc. January 2002)

The Flow Duration Curve (Figure 22) illustrates a steady declining slope which can be interpreted that inputs are from steady sources such as snowmelt and sustained throughout the year from groundwater.

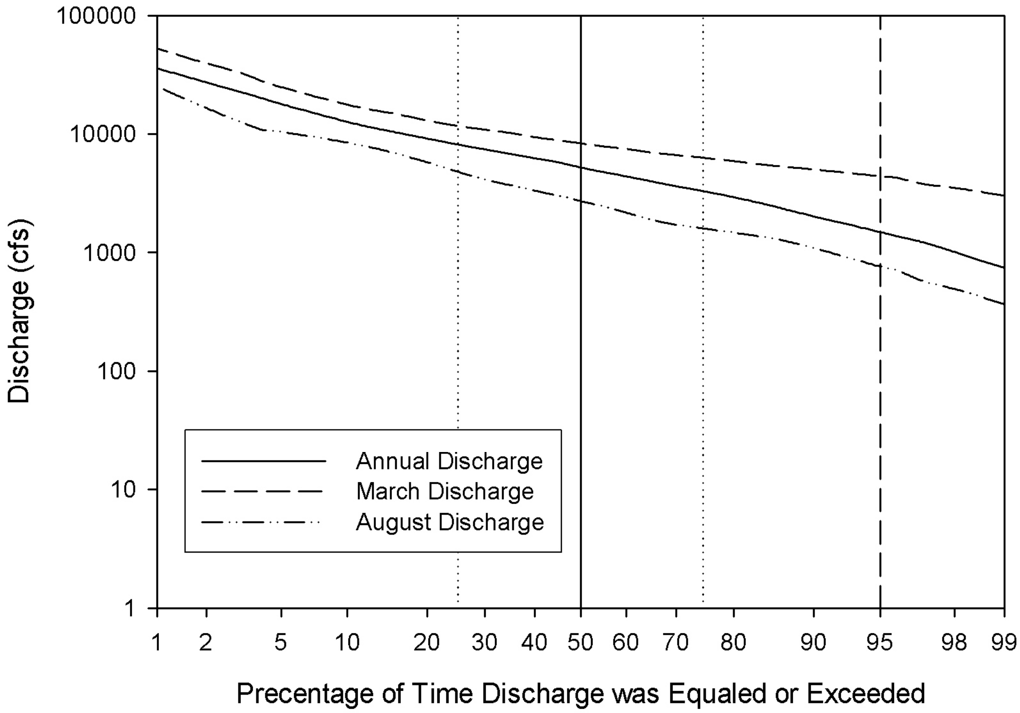


Figure 22: Flow duration curve for the Platte River near Louisville, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR) (Parham 2007).

Least Terns and Piping Plovers in the lower Platte River

Least terns and piping plovers have a reproductive strategy that in Nebraska is dependent upon highly dynamic riverine systems, which results in ephemeral habitat. In years with high flows, nests might be inundated depending on the timing of high flows, but new sandbars would be created. Floods, such as those on the Platte River in 1983 and 1993, scoured existing sandbars, replenished sand, removed vegetation and created new sandbars. In other years, low and average flows provided ideal nesting conditions on exposed sandbars, surrounded by water (Sidle 1992, Kirsch and Sidle 1999). During a drought period, existing sandbars may sustain for a time, but will slowly become vegetated, and will no longer provide adequate quality nesting habitat for terns and plovers.

Historically, several river systems in eastern Nebraska provided substantial habitat that supported large numbers of least terns and piping plovers. Natural variability across a large geographic scale in these systems increased the likelihood that quality habitat was consistently available somewhere in Nebraska. Today, most of Nebraska's major rivers have been altered, and nesting habitat is becoming scarce. When the range of potential habitat becomes limited, the likelihood that these few remaining locations will not have adequate conditions in Nebraska for least tern and piping plover nesting increases. Additionally, the negative impacts of localized stochastic events may be heightened when so few locations for nesting are available.

The Platte River from Keith County to the confluence of the Missouri River has a long record of use by nesting terns and plovers (see species status sections). The historical seasonal and inter-annual flow variation within the framework of a shallow, braided river with sandy and gravel substrate was an ideal combination for creating least tern and piping plover nesting habitat. The Platte River has been altered and the natural dynamics that recreate the ephemeral habitat that least terns and piping plovers depend on has been diminished and eliminated in some areas.

The lower Platte River still has least terns and piping plovers nesting on sandbars in the lower Platte River, due to the remaining semblance of the natural hydrograph in portions of the lower Platte River. This stretch of the Platte River benefits from flow and sediment contributions of the Loup River, Elkhorn River and Salt Creek, and the remaining inputs from the central Platte River which when combined with flows from the much reduced central Platte River's reach, are now the foundation of the hydrograph as we see it today. As such, while substantial water resource development has significantly altered the hydrograph of the lower Platte River, it continues to retain a semblance of the seasonal and interanual flow patterns with higher spring flows.

Since 1987, the Commission has coordinated a least tern and piping plover survey along the lower Platte River from Columbus to Plattsmouth that includes both the river and sandpits. Data from these surveys suggests least tern numbers, overall, have remained relatively stable when including both river and sandpit use during this 20 year period on the lower Platte River, but that Piping Plovers have declined (Figure 23-24).

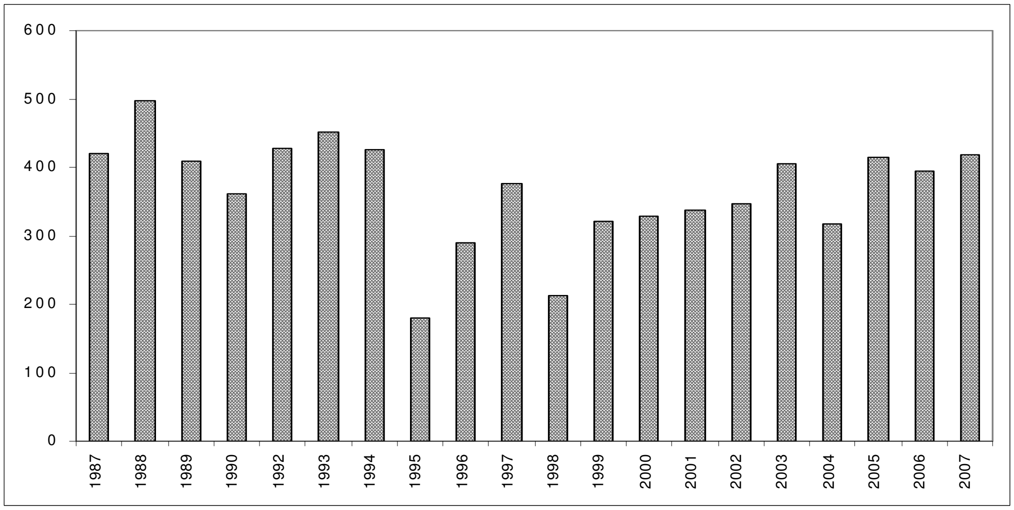


Figure 23. Total nesting least tern population of the lower Platte River, including nesting at both sandpits and riverine sites.

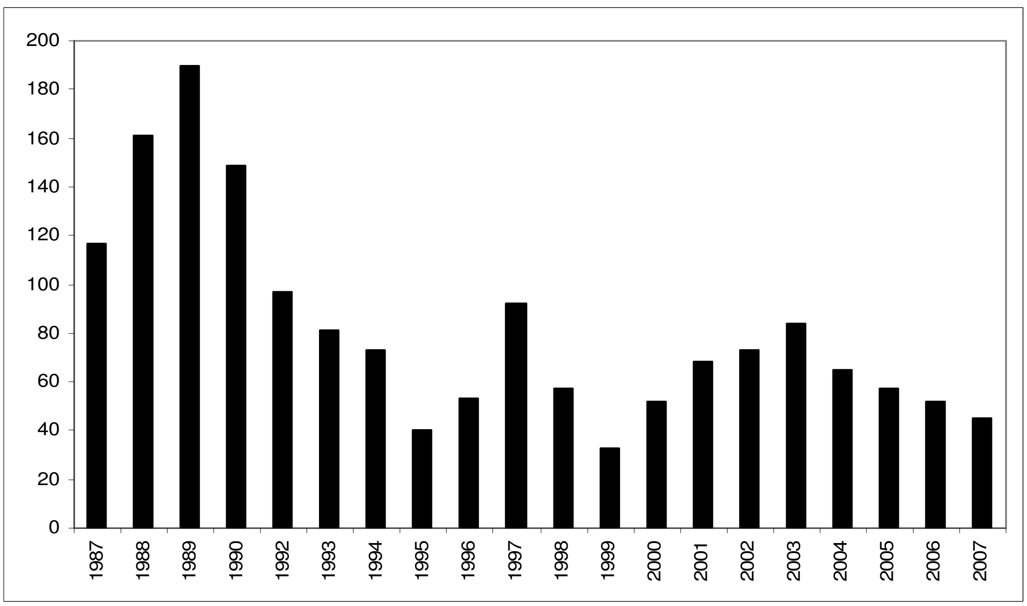


Figure 24: Total nesting piping plover population of the lower Platte River including nesting at both sandpits and riverine sites.

While there is some semblance of a natural hydrograph, the lower Platte River has been altered and the evidence can be seen in least tern and piping plover trends. It is well established that when riverine sites disappear, least terns and piping plovers nest in alternate locations, but in Nebraska the alternate options are limited and suboptimal. The change in nesting locations from riverine to sandpit exemplifies the altered hydrologic regime and declining habitat. As described in the Species Status Section, the central Platte River no longer supports significant riverine nesting. In this area, the least terns and piping plovers nest primarily in suboptimal sandpits and reservoir shorelines. The gradual relocation of birds from the river sandbars to sandpits is beginning to be seen in the lower Platte River (Figures 25-28). Continued depletions to the lower Platte River basin will exacerbate the decline of riverine habitat, and this transfer of nesting birds to suboptimal sandpits will likely increase.

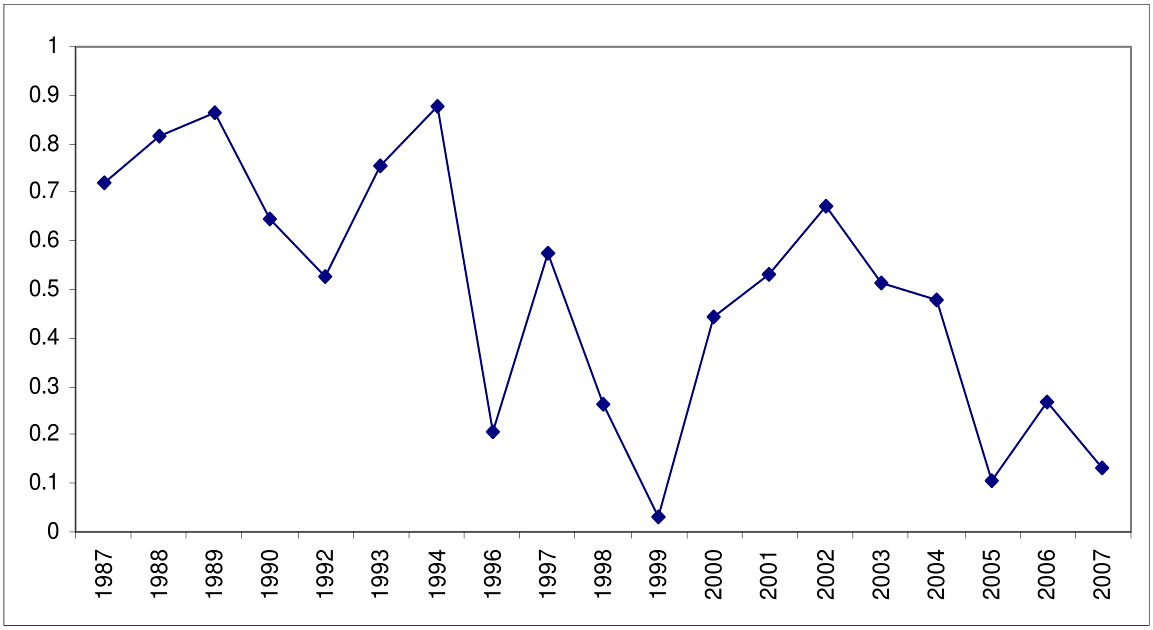


Figure 25: Percentage of piping plovers nesting on the river compared to total nesting locations, including both sandpits and riverine sites in the lower Platte River.

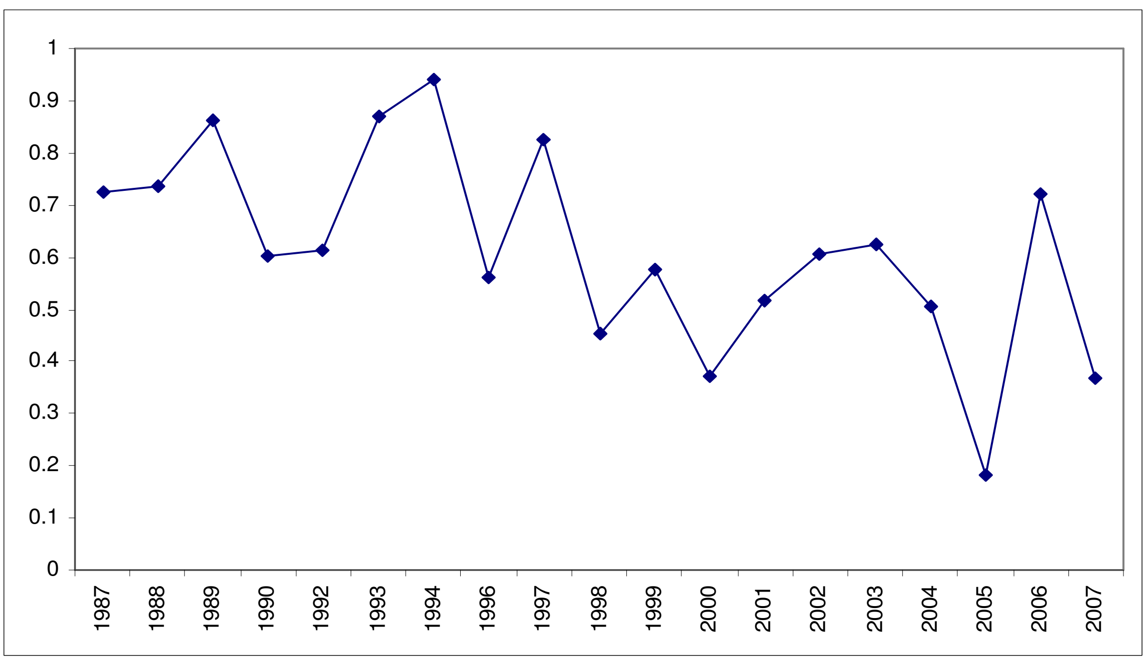


Figure 26: Percentage of least tern nesting on river sites compared to the total (both riverine and sandpit sites) lower Platte River nesting population.

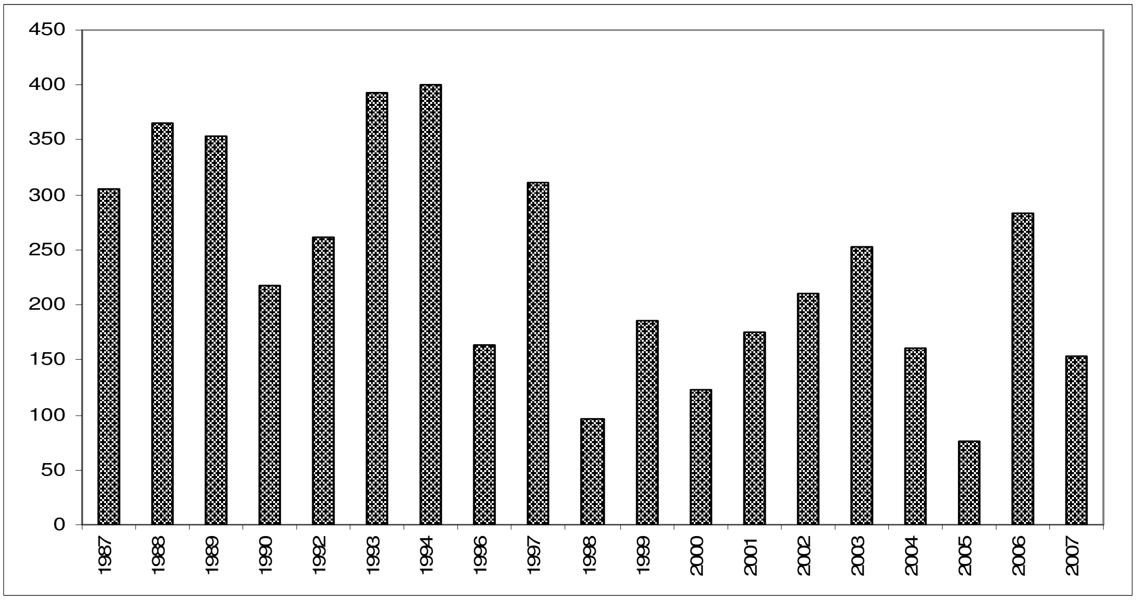


Figure 27: Number of adult least terns nesting on sandbars in the lower Platte River.

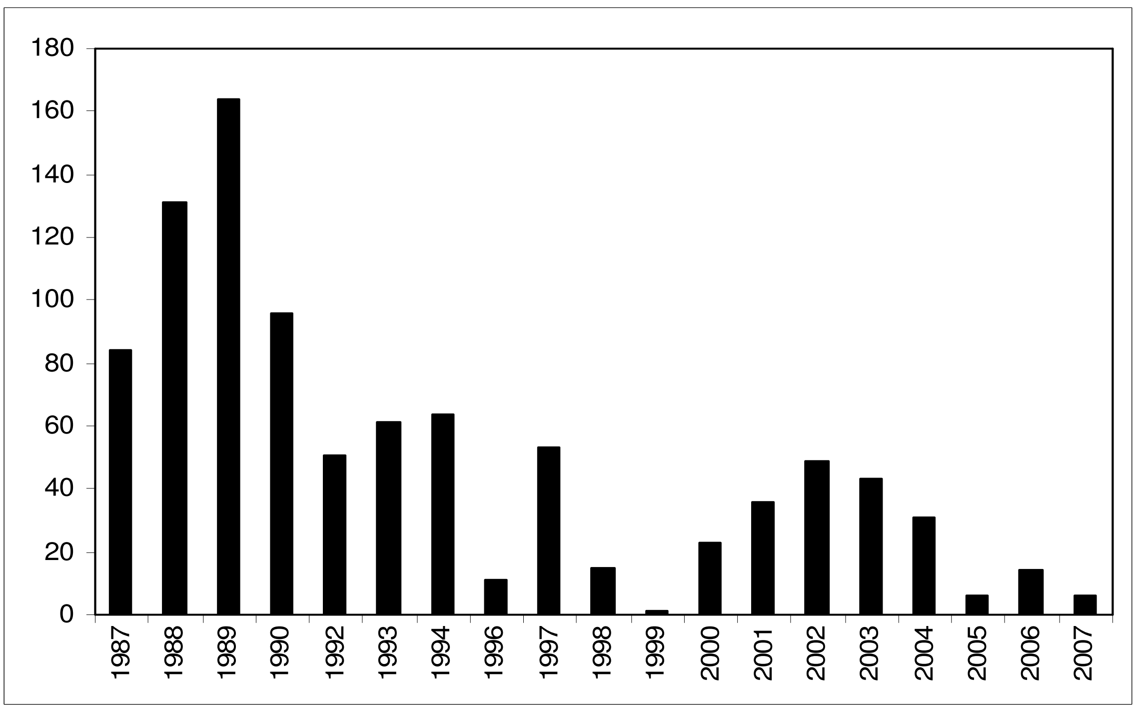


Figure 28: Adult piping plovers using sandbars in the lower Platte River.

These two bird species have limited riverine habitat available in Nebraska, and maintaining the little habitat that remains, is critical. The lower Platte River provides valuable nesting habitat for least terns and piping plovers. In a system that has been highly degraded, with limited available habitat, an area that has 38% of the least terns nesting in Nebraska and 12% of the piping plovers of Nebraska is important and necessary to maintain for the recovery of these species (Figure 29).

A

B

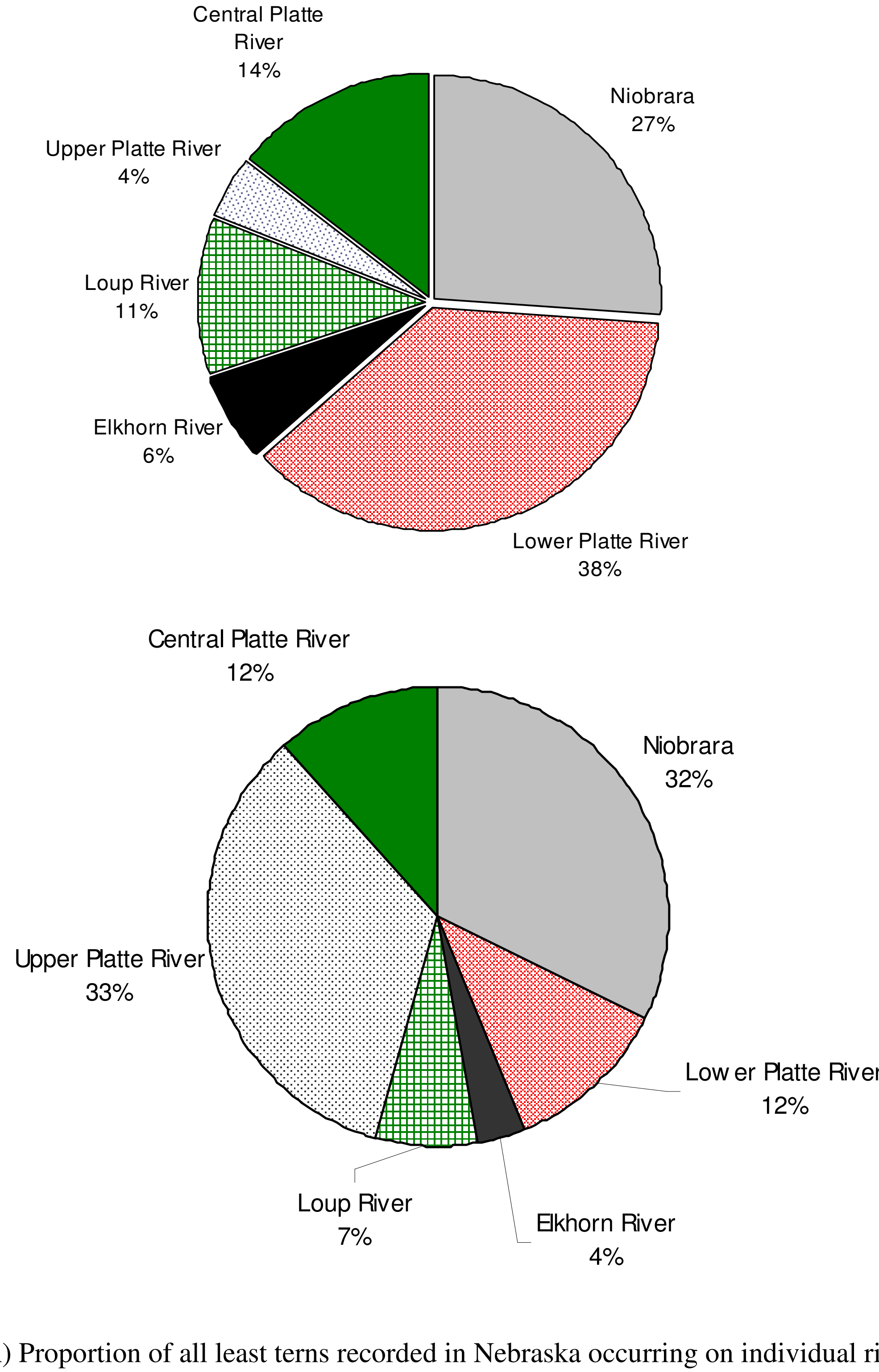


Figure 29: A) Proportion of all least terns recorded in Nebraska occurring on individual river systems (Missouri River excluded) based on 1991, 1995, 2001, and 2005 survey results (Lott 2006, NGPC database). B) Proportion of all piping plovers recorded in Nebraska occurring on individual river systems (Missouri River excluded) based on 1991, 1996, 2001, and 2006 International Piping Plover Survey results (Ferland and Haig 2002, Plissner and Haig 1992, Plissner and Haig 1997, and NGPC database). Note: Upper Platte River includes Lake McConaughy and the Missouri River is not considered.

Pallid Sturgeon in the lower Platte River

The pallid sturgeon is an ancient fish species that has adapted over time to the dynamics of large riverine systems. As stated in the Species Section, scientists are just beginning to understand much of the natural history of this elusive, rare species. The pallid sturgeon depends on deeper, turbid waters with higher velocity. Within large river ecosystems, the pallid sturgeon likely uses braided channels and took advantage of the irregular flow patterns which creates extensive microhabitat diversity. This species is capable of moving large distances, so it is likely that historically it would move to areas of suitable habitat within the matrix of habitats that composed the Missouri and Mississippi rivers and their major tributaries. This large fish is influenced by many factors including temperature and velocity when selecting microhabitats.

Within the degraded middle section of the pallid sturgeon range, the lower Platte River contains the most remaining intact habitat in terms of hydrology and physical habitat, even though those characteristics have declined significantly (NRC 2005). The Platte River is the only tributary below Gavins Point Dam that originates in the Rocky Mountains and delivers runoff from mountain snowmelt to the lower basin. The stretch of the lower Platte River benefits from flow and sediment contributions of the Loup River, Elkhorn River and Salt Creek, and the remaining inputs from the central Platte River which when combined with flows from the much reduced central Platte River's reach, are now the foundation of the hydrograph as we see it today. As such, while substantial water resource development has significantly altered the hydrograph of the lower Platte River, it continues to retain a semblance of the seasonal and inter-annual flow patterns with higher spring flows.

Evidence suggests that the pallid sturgeon, much like its close relative the shovelnose sturgeon, utilize the Platte River at various times of the year (Snook 2001; Peters and Parham 2008). In 1894 commercial fisherman reported harvesting 810 lbs of sturgeon in the Platte River and 7,136 lbs of sturgeon in the Missouri River bordering Nebraska (U. S. Commission of Fish and Fisheries 1898). These records indicate that sturgeon species were abundant and supported commercial fishing. Since the pallid sturgeon were not recognized as a separate species until 1905 (Pflieger 1975), it is reasonable to assume that catch statistics for 1894 included pallid sturgeon.

It is difficult to quantify how many pallid sturgeon are using the lower Platte River, but Peters and Parham (2008) estimated that there are 23,000 to 69,000 shovelnose sturgeon in the lower Platte River. Low catch rates of pallid sturgeon make these types of estimates difficult, but the use by the closely related shovelnose sturgeon illustrate the importance of the lower Platte River to sturgeon species. The relative density of the Platte River population can also be estimated when comparing catch rates between Platte River work and the extensive Missouri River sampling. Peters and Parham (2008) in 2004 captured 6 hatchery reared pallid sturgeon in the lower Platte River while Krentz et al. (2005) had a total of 91 recaptures from all of the RPMA 4, meaning that there was 1 recapture for every 2.1 miles of river in the Platte River and 1 recapture per 8.8 miles of Missouri River. Although population estimates are difficult to achieve, "the importance of the lower Platte River for pallid sturgeon has been documented," (Snook et al. 2002b, Swigle 2003).

Peters and Parham (2008) conducted extensive analysis of pallid sturgeon habitat as related to flows in the lower Platte River. They found that in the lower Platte River, pallid sturgeon were most frequently captured in the deepest and swiftest runs of the river. Pallid sturgeon selected areas with a depth greater than 0.8 m (2.6 ft) with an average depth of approximately 1.6 m (5.3 ft) and a mean column current velocity of 0.8 m/s (2.6 ft/s). Pallid sturgeon appear to target areas with complex microhabitats as the deep runs where they were captured were typically within 50 to 100 m (164 – 328.1 ft) of shallow and exposed sandbars. Pallid sturgeon were captured when water temperatures were between 10ºC and 17ºC (50°- 62°F). These temperatures coincide with the temperatures reported for sturgeon spawning in a hatchery environment.

The lower Platte River may be one of the few locations in which pallid sturgeon spawn as it still retains habitat characteristics that researchers typically associate with sturgeon spawning (USFWS 2007). These characteristics include sandy substrate, shallow areas for foraging in addition to deeper areas, velocity, temperature, a seasonal hydrograph with appropriate depths and connectivity.

Sediment concentrations of the lower Platte River are comparable to other locations where spawning has been confirmed. Suspended solids concentrations in the lower Platte River increase three- to four-fold during the spring. Sediment concentrations during spring average about 1,100 to 1,500 milligrams/liter (mg/l) (USGS, Louisville gage 1972 to 1976), which is higher than that of the Missouri River at Omaha. These springtime sediment concentrations are equivalent to those found in the Yellowstone River, where other pallid sturgeon populations are concentrated and spawning has been documented. The high flows during spring and early summer deliver about 80 percent of the total annual amount of suspended sediment in the lower Platte River. The high sediment load and discharge produces in-channel fish habitats (i.e. sandbars, backwaters, and pools) in the lower Platte River that are lacking or in extremely short supply in the channelized Missouri River.

Documented pallid sturgeon behavior make a strong argument that pallid sturgeon are using the lower Platte River for spawning. On May 3, 2001 a wild female pallid sturgeon with late-stage eggs was captured in the lower Platte River near Louisville (Peters and Parham *2008*). This female sturgeon was implanted with a transmitter and tracked. The female remained in the general vicinity of Louisville until May 24. Until May 29, this fish moved at an average rate of 150 m/d, while from May 29 to June 9, 2001 it moved at an average downstream rate of 1,940 m/d until it entered the Missouri River. This movement pattern is consistent with a spawning migration (Bramblett and White 2001, USGS 2007).

The most compelling argument for pallid sturgeon spawning, is the fact that larval sturgeon less than one day old have been sampled in the lower Platte River and have been captured in multiple years during May and June. As a part of the Peters and Parham study (2008), larval sturgeon were caught on May 23, 2001 just prior to the time that the female mentioned above moved downstream. The larvae collected from this study were determined to be *Scaphirhyncus*, but the specific species could not be determined as larval *Scaphirhyncus* must be greater than 1 inch (25.4 mm in length) to visually determine the species. Larval sturgeon were caught at several different locations, and in all but one case were associated with an increase in water temperature.

Between 2000 and 2004, 11 sturgeon larvae were collected between May 15 and June 9. Reade (2000) collected three sturgeon larvae on May 26, 1999 and June 23 and 24, 1998. In addition, Hofpar (1997) collected one sturgeon larva on June 10, 1996 near Fremont, NE (RM 57). This confirms that sturgeon (although the larvae could be either shovelnose or pallid) are spawning as far upstream as the US Highway 6 bridge and Fremont. Given that pallid sturgeon and shovelnose are known to hybridize, it is assumed that spawning conditions and requirements are similar. Therefore, it is highly likely that the lower Platte River has suitable conditions and habitat for pallid sturgeon spawning.

In addition to the presence of larval sturgeon, documented angler catch records of pallid sturgeon indicate higher use in the lower Platte River of pallid sturgeon in the spring (Heritage Data 2007), within the period (April through June) in which pallid sturgeon are believed to spawn. These captures also tend to occur during higher than average flow conditions within that period. From 1979 through 2001, 19 of the 23 captures of pallid sturgeon in the Platte or Missouri rivers near the Platte River confluence occurred during April, May, and June; the remaining occurrences were in July and September of 1999. Eighty seven percent of the occurrences correspond with years when flows in the lower Platte River were above normal for the recent period (Louisville gauge, 1970 to 2001). Since 2001, 15 additional pallid sturgeons were captured in the Lower Platte River (Peters and Parham 2008). Thirteen of the 15 were captured in April and May with one capture in July and one in September. Spring high flow conditions are particularly important for pallid sturgeon, as these conditions are believed to act as a cue to staging and spawning behavior. In 2007, a pallid sturgeon was captured near the Highway 50 Bridge on October 9th (T. Barada, personal communication 2007). These capture records suggest that the Platte River may be used for reproduction, the critical link to continued species persistence and recovery, but is also used at other times of the year.

Larval pallid sturgeon are rarely captured, and in most areas of this its range, there is limited evidence of recruitment of young pallid sturgeon into the population. RPMA 4, which contains the Platte River confluence, does have juvenile pallid sturgeon surviving and limited evidence of successful spawning, which is not the case in other stretches of the pallid sturgeon range. The pallid sturgeon population in the upper portion of the species range exhibits little or no recruitment, and the population in the lower portion of the range has hybridization with shovelnose sturgeon. The middle section of the species range, which contains the Platte River has great potential for maintaining the continued existence, and eventual recovery of this species.

Another important component of habitat for pallid sturgeon in the lower Platte River, is the level of connectivity of potential habitat. "The spatial and temporal availability of connectivity between habitats plays an important role for the life cycle of riverine fishes," (Schumtz et al. 2000) and habitat connectivity influences fitness at the level of individual fishes and at the population level (Schiemer 2000). The impediment of spring migrations, or spawning runs, due to the inability of pallid sturgeon to navigate through the river and access potential spawing sites limits reproduction and spawning activity (Wildhaber et al. 2007). A lack of habitat connectivity has been identified as preventing reproduction and natural recruitment of another sturgeon species as it disrupts sturgeon migration and spawning behavior (USFWS 2006).

Potential habitat in the lower Platte River occurs within a matrix of various depths and velocities throughout the lower Platte River when there is adequate flow. This essentially creates a maze through which pallid sturgeon must successfully navigate up and back down prior to falling flows. For the pallid sturgeon to be able to utilize areas of suitable habitat, the river must be suitably connected for the sturgeon to access the habitat and move through the system. It is imperative for spawning sturgeon, that at certain times of the year they are able to move and seek out spawning habitat and also have sufficient flows to navigate out of the lower Platte. It is also important for larvae which drift for days following hatching. Peters (2007) found that the lower Platte River is more connected for pallid sturgeon movement in the spring, and is fully connected approximately 45% of the time near Louisville, but only connected 25% of the time near North Bend.

Discussion and Conclusions

Although the lower Platte River retains most geomorphological characteristics of the historic Platte River, the system is highly altered and the necessary forces that have maintained these characteristics over centuries have been tempered by land-use development and utilization of the water resource. Least terns, piping plovers and pallid sturgeon each have adaptations suited for the highly dynamic system of the Platte River and have strategies that take advantage of, and depend on, the habitats created through a complex interaction of flows, sediment, geomorphology, habitat connectivity and climate that varies seasonally (Figure 30).

Habitat forming flows are a key driver of the lower Platte River's riparian ecosystem and are critical to maintain the physical, chemical and biological functions essential to this ecosystem. Poff et al. (1997) noted, Different habitat features are created and maintained within a river system by a wide range of flows. It is this "predictable diversity of habitat types that has promoted the evolution of species that exploit the habitat mosaic created and maintained by hydrologic variability," with corresponding effects on species distribution, species abundance, and ecosystem function. "Human alteration of the flow regime, changes the established pattern of natural hydrologic variation and disturbance, thereby altering habitat dynamics and creating new conditions to which the native biota may be poorly adapted."

Habitat forming flows are higher flows which sort and transport sediments; move bed material; uproot and dislodge submerged, emergent and streamside vegetation; influence structural stability of stream banks; and prevent vegetation encroachment into the active channel (IFC 2002, Murphy et al. 2004, NRC 2005). Without these flows, 1) associated wetlands are no longer maintained, 2) water tables in the immediate vicinity are not recharged, 3) sandbars and channel areas are not inundated and scoured, 4) sediment collects on bars and channel edges, which causes lowering and narrowing of the stream banks, 5) side channels and backwaters become disconnected and may fill in, 6) tributary confluences aggrade and push out into the main channel and 7) the ratio of pools to riffles is altered (Moriswa 1968; Platts 1979; Leopold and Emmett 1983; Hill et al. 1991 in Annear et al. 2005). Reduction in the frequency, timing, duration and magnitude of the annual and inter-annual hydrograph causes the long-term, and continued, deterioration of the habitats relied upon by the least tern, piping plover and pallid sturgeon (NRC 2005, USDOI 2006). It is these high flows that move sediment in the river which scour out deep channels, that create habitat for pallid sturgeon and deposit and clear sandbars that become nesting areas for least terns and piping plovers. The dynamic interaction of flows and sediment is controlled by the range of hydrologic conditions, and results in the availability of quality habitat for these target species shifting locations from year to year.

Habitat forming flows are not easily defined since flows with varied magnitudes have a multitude of impacts and effects. One important habitat forming flow is called bank full flows and is defined as the flow that "just fills the stream to its banks" (Gordon et al.1992 in Annear et al 2004). A more conventional definition of bankfull discharge is:

> "The bank full flow corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders and generally doing the work that results in

average morphological characteristics of channels" (Dunne and Leopold 1978 in Rosgen 1996).

This bank full flow could essentially be considered the dominant discharge as it moves the most sediment over time. These flows may move less sediment per event than a large flood, but they occur much more frequently resulting in more overall sediment moved. Rosgen (1996) suggested that a 1.5 – 2 year flood event is typically close to the bankfull discharge, although the frequency of this discharge is specific to each river type. This level of analysis for the lower Platte River has never been evaluated, so for the purposes of this Report, the maximum discharge with a 1.5 year return period was used for estimating the bankfull discharge for the period of record 1954-2005.

An additional important habitat forming flow occurs when large floods over top the banks of the river. Flows of this magnitude are important for creating habitat above the bank full level and exchanging nutrients and materials between the channel and the flood plain. This nutrient exchange is a key component of a healthy ecosystem and heavily influences the base of the aquatic food chain. Habitats such as high sandbars and deep channels were rapidly created by historical high water events prior to impoundment and diversions affecting the lower Platte River.

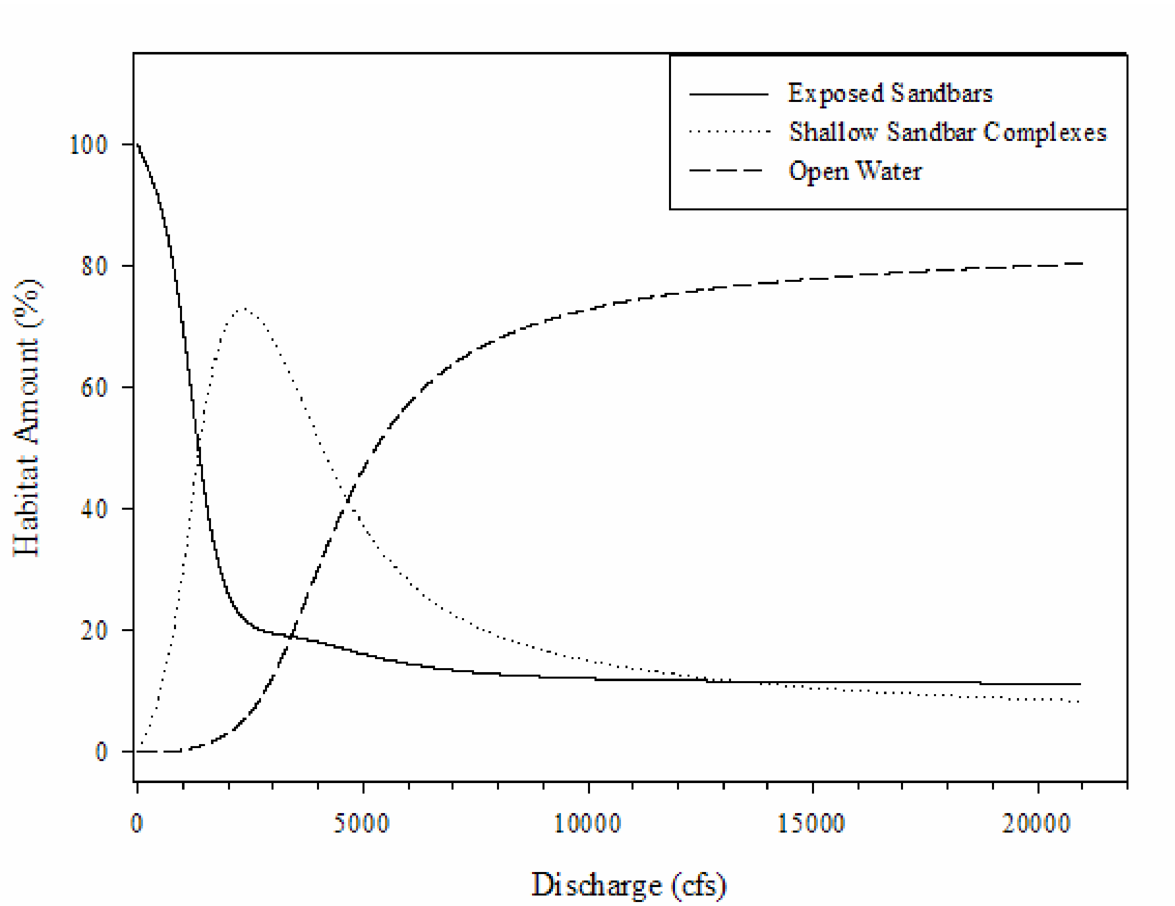


Figure 30: The simultaneously adjusted curves for the habitat type vs. river discharge (Peters and Parham *2008*).

Hydrologic Discussion as related to Least Terns and Piping Plovers

Least terns and piping plovers require sandbars with minimal vegetation cover for nesting. The creation and maintenance of these sandbars are dependent on a series of flow events that continually reduce and eliminate vegetation, and create sandbars of sufficient area and height to avoid nest inundation. To further understand this relationship, the following analyses were utilized which incorporate lower Platte River hydrology, substrate, aerial photography and least tern and piping plover biology.

Sandbar creating flows range from bankfull discharges to large flood events. Large flood events occur infrequently, but cause significant change in the appearance of the river channel in a relatively short amount of time, will potentially build large sandbars. These flows that overtop banks inundate the floodplain and introduce nutrients back into the system. Sidle et al. (1992) reported a large flood of 32,300 cfs on June 1, 1990 at the North Bend gage and 60,500 cfs at the Louisville gage. This flood reduced vegetation by 78% on sandbars. They reported trees floating down the river. Floods of this magnitude are important, as the health of a riverine and riparian ecosystem is related to large, infrequent events such as these.

Bankfull flows peak at lower discharge rates but occur more frequently than large floods and therefore have a significant effect on observed habitat conditions in the river. Bankfull flows (assumed to equal to the peak discharge with a 1.5 year return period in subsequent analyses) can be estimated from USGS gage records at various points along the lower Platte River. Although bank full flows maximize sediment movement within the channel given their frequency over time, these flows accomplish very little nutrient exchange and habitat creation over the bank full level. However, changes in response to larger flood events (assumed to be a 1 in 10 year peak discharge in subsequent analyses) are more difficult to estimate as the dynamics of overbank flows are highly variable and poorly understood for the lower Platte River. Additionally, the subsequent analysis regarding bankfull discharges are likely conservative as most analyses of bankfull events and sediment movement are focused on streams with harder substrate. The Platte River is a warm water river with a shifting sand bed. It rapidly "smoothes" habitat created by high flow events so high flow disturbance levels must be frequent and/or must be of significant magnitude to cause needed sediment movement for channel habitat maintenance.

Frequencies of high flows are also important for vegetation maintenance. Flows that overtop sandbars and reduce seasonal and woody vegetation are essential in maintaining sandbar habitat used by nesting least terns and piping plovers in the lower Platte River. In the absence of these higher flows, sandbars are colonized quickly by fast growing species such as cottonwood trees and willows. Cottonwood trees are a fast growing species and can grow 10 meters in four years (Putnam et al. 1960). Peters and Parham (2008) found that once a woody island was established, there was no correlation between moderate flows and the amount of woody island vegetation, meaning that flows as high as 21,000 cfs are not sufficient to remove this vegetation.

The Platte River also requires sediment (primarily sand) which is essentially the building material of sandbar habitats for the target species, as well as the host of other native species that live in association with the river. The quantity and type of sediment carried by a river has a significant effect on the shape and character of the river corridor and, in turn, impact habitat parameters important to the target species (USDOI 2006). The volume of flow and the available supply of sediment determine the volume of sediment that can be transported. A reduction in flow or sediment supply resulting from storage reservoirs and water diversions produces a corresponding reduction in sediment transport capacity (USDOI 2006). Abrupt changes in river flow also impact sediment transport, creating areas of erosion or deposition. The Platte River flow is changed by water diversions and canal returns, causing sediment to be deposited on the channel bed (aggradation) in some reaches and eroded (degradation) from other reaches (USDOI 2006).

Least terns and piping plovers demonstrate selection for sandbars which not only have minimal vegetation, but that also have suitable area and are of sufficient height to avoid inundation during the nesting season. Ziewitz et al. (1992) measured characteristics of nesting habitat of least terns and piping plovers in the central and lower reaches of the Platte River. They found that birds nested in areas where the channel was wide with a greater area of sandbars. They recommended that sandbars be at least 3.58 acres in size and 3.0 feet above river stage for maximum flooding protection, but should be at least greater than 1.5 feet in height.

The following analyses evaluate the relationship between various discharge levels and the characteristics of sandbars available during least tern and piping plover nesting seasons. These analyses are based on USGS gage records and include gage locations near Duncan, North Bend and Louisville. Duncan is outside of the action area of this report, but this location provides a useful comparison for an area where the hydrologic regime typically no longer supports least tern and piping plover nesting.

Least terns and piping plovers have very similar nesting cycles that approximately coincides temporally. For the following analyses, their nesting requirements were combined into one criterion. Each species migrates into Nebraska in spring based on climate conditions. The birds must then find sandbars, establish nest sites and complete courtship. The nests must be prepared and the eggs laid and incubated. Once the young hatch, the adults continue to provide care until the chicks are fully fledged. The timing necessary for the entire process to be completed is variable depending on weather conditions and other factors. All of these activities must be completed without inundation of the sandbar. If one flow event overtops the sandbar, that nesting attempt fails, and depending on conditions the birds may attempt to re-nest.

Although flooding is possible and does occur throughout the year, least terns and piping plovers have a reproductive strategy that temporally corresponds with the historic hydrograph which maximizes the likelihood that birds will successfully reproduce. These birds typically arrive in late April or early May and begin nest initiation in May and June as the water level historically peaks and then begins to recede (Figure 31). Alteration of the historic hydrograph, with a reduction of the key high spring flows, means that lower sandbars are more common and thus more susceptible to inundation by subsequent flows. This reduction in high spring flows ultimately results in an increased likelihood of decreased fecundity and further population declines and potentially extirpation of breeding populations.

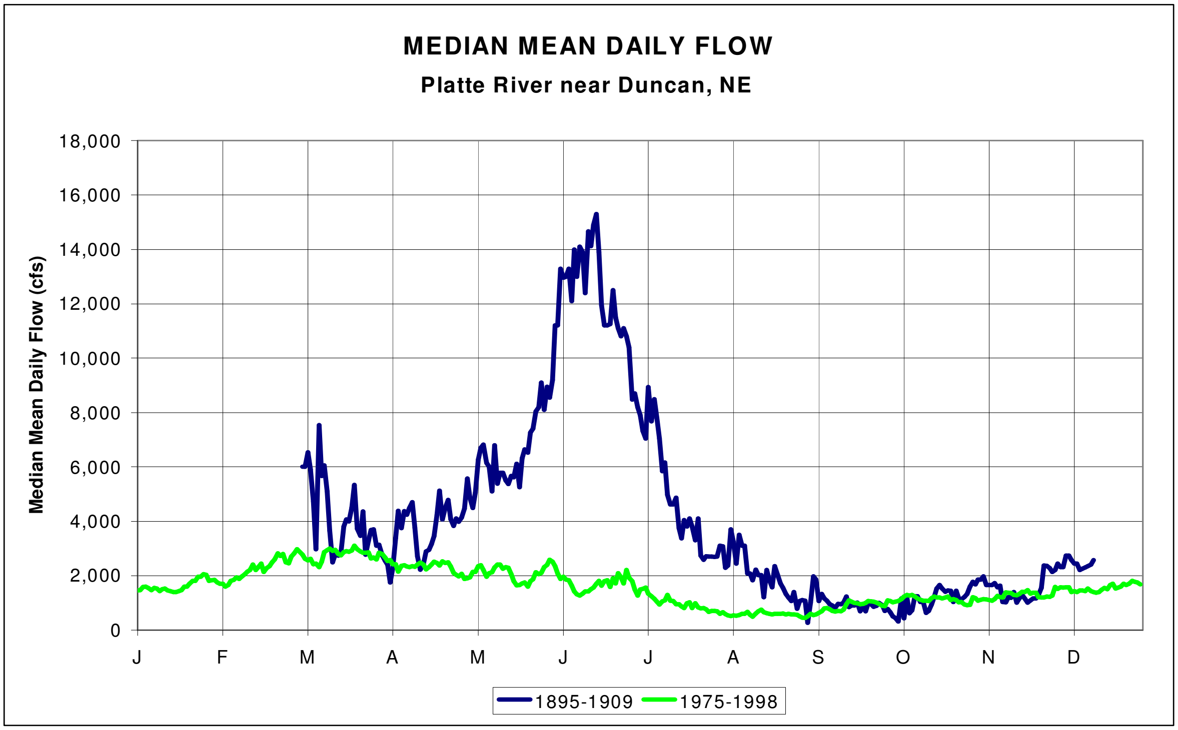


Figure 31: Median mean daily flow in the Platte River at Duncan, Nebraska, in 1895-1909 vs. 1975-98. It should be noted that the record from 1975 – 1998 is considered a wet period of time. (Source: USGS gage data, as presented in Platte River FEIS (USDOI 2006)).

For the following analyses, the *breeding season* was considered to begin on May 1 and continue until August 31. Nesting activities may occur outside of this window, depending on conditions, but this timeframe encompasses the majority of the nesting activity in Nebraska (Jorgensen 2007, Sidle 1992, Ziewitz et al. 1992). To complete all the activities involved in successfully fledging young, the following analyses assumes that least terns and piping plovers need approximately 60 days (Aron 2005, Haig 1992, Thompson et al. 1997). This 60 day window is termed the *nesting period* in the following analyses. The first nesting period date is June 30, which encompasses the previous 60 days starting on May 1. The nesting periods are a 60 day moving window within the breeding season. Therefore, throughout the four month breeding season, there are 63 potential breeding periods.

Sandbar Height

Mussetter Engineering, Inc. (2002) calculated the channel characteristics and sediment transport capabilities over a wide range of flows for the lower Platte River in the vicinity of the mouth of the Elkhorn River. Among channel characteristics modeled, an estimate of hydraulic depth was provided for nine main river transects over the range of discharges between 200 and 151,000 cfs. Parham (2007) averaged the channel depth in relation to discharge information from the nine transects and developed an equation from a line that was fit to the data using curve-fitting software.

Based on this equation, the height of a sandbar created at a given discharge was assumed to be approximately the water surface elevation as the water will deposit sand nearly to the surface of the water. As the water levels drop after high flows, sandbars are exposed. Therefore the observed height of a sandbar was assumed to be the difference between water surface elevations estimated at the various higher discharges. For example, a discharge of 39,800 cfs (bankfull discharge at Louisville) would create channel depths of 4.9 ft. and conversely depositing sand in some areas resulting in shallow sandbars nearly reaching the water surface. If the June discharge after that bankfull flow event was approximately 7,180 cfs then the channel depths would now be approximately 2.1 feet. This would provide an estimated height of exposed sandbars to be 2.8 ft or the difference between water surface elevations at the two discharges. Table 8 shows the estimated bankfull flow, median June flows, and their respective channel depths for three main river gages. Table 9 shows the estimated sandbar heights at these sites.

Table 8: Flow profiles for bankfull discharge (a 1.5 year return using IHA software) for three USGS stream gages, median June discharge from period of record (1954 – 2005) and depths at the corresponding discharges (Parham 2007).

	1.5 year return (cfs)	Depth (ft) at 1.5 year return	Median June Discharge (cfs)	Depth (ft) at June Median Discharge
Duncan	7,130	2.1	1,265	0.9
North Bend	21,280	3.6	4,080	1.6
Louisville	39,800	4.9	7,180	2.1

Table 9: Sand bar height for three Platte River gage locations based on the difference between bankfull discharge and median June discharge at three Platte River gage locations. June was selected for illustration as this is when nest initiation begins and as flows recede, nest inundation is less likely (Parham 2007).

	Sandbar Height (ft)
Duncan	1.2
North Bend	2.0
Louisville	2.8

Based on the need for sandbars to be at least 1.5 feet in height with a preference of 3 feet in height for least tern and piping plover nesting and protection from flooding, the difference between bankfull flows and June flows creates sandbars at Louisville that are currently of sufficient height to meet the requirements. North Bend sandbars are over the minimum requirement, but do not reach the preferred level and sandbars on the Platte River above the Loup River are of insufficient height to produce suitable least tern and piping plover nesting habitat.

Habitat Quantity

Evaluating the height of potential sandbars based on sediment transport and bankfull flows only estimates potential sandbar heights. Sandbars must also have low amounts of vegetative coverage for nesting. Reproductive success is much more likely when sandbars of sufficient area and be separated from the river banks. Flows that maintain isolation of the sandbars from the banks throughout the summer are an important component of reproductive success. Sandbars that are not isolated are more accessible to mammalian predators which can decrease nesting success for the already imperiled species. In addition to the isolation that deep water provides, least terns need shallow water foraging areas that harbor the small fish species that compose the majority of their diet.

Parham (2007) estimated the available area of isolated sandbar habitat in relation to discharge from aerial photographs of the lower Platte River. The analysis, termed *habitat quantity*, used criteria that sandbars needed to be at least 3.58 acres in size (Ziewitz et al. 1992) have minimal vegetation and be isolated from the shore line. Sandbars that met the above criteria were most common between 4,400 cfs and 9,100 cfs and decreased at lower or higher flows (Figure 32). At lower flows, sandbars were no longer isolated from the banks while at higher flows, sandbars became inundated. The range between 4,400 cfs and 9,100 cfs establishes the intermediate flows where sandbars with the above necessary characteristics for least tern and piping plovers are most likely to exist in the lower Platte River. The maximum amount of large disconnected sandbar habitat was observed around 5,480 cfs (Figure 32). Overall, sandbar habitat identified in this model, at the most was only 6% - 7% of the overall habitat in the lower Platte River. Fifty percent of the habitat was available (approximately 3.5%) between discharges of 3,910 cfs and 11,900 cfs.

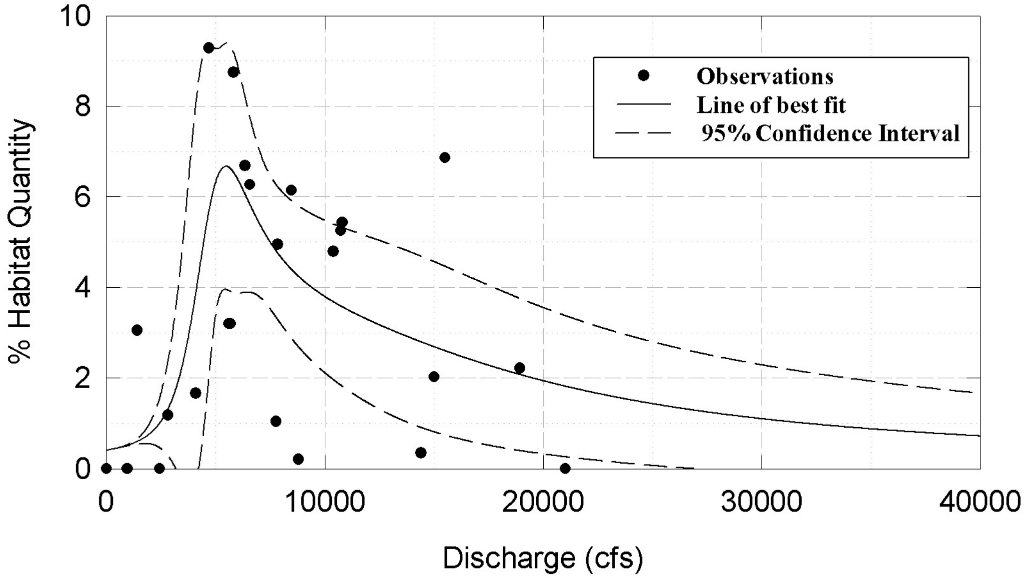


Figure 32: Modeled relationship between discharge (cfs) and percent habitat quantity for the lower Platte River. Habitat for Least Terns and Piping Plovers is defined as large, exposed sandbars that were disconnected from the shoreline (Parham 2007).

This relationship between the discharge and amount of large, isolated available sandbars is especially important during the least tern and piping plover breeding season. For each day during the breeding season, the percent habitat quantity available was calculated from the daily mean flow discharge. The average available habitat for the 60 day nesting period, rounded to the nearest whole value, was used as an estimate of overall percent habitat quantity, or habitat available during that nesting period. These values were averaged over the entire breeding season to compare available habitat between locations (Figure 33).

Duncan consistently has the least habitat available, while Louisville consistently has the most habitat available during the least tern and piping plover nesting season. This result is reasonable given the locations of the gage stations relative to influences from the major tributaries along the lower Platte River and current state of the central Platte River.

Habitat Quality Analysis

The previous analyses have addressed only the physical characteristics of sandbar in relation to discharges in the lower Platte River, but have not specifically addressed the likelihood of inundation during the least tern and piping plover nesting season. As mentioned previously, a nesting period of 60 days with suitable sandbars available, which are not inundated by higher flows, increases the likelihood that birds will successfully reproduce. The next analysis, termed *habitat quality* (Parham 2007) examined the probability of nest inundation.

For each year, during each 60 day nesting period, the highest discharge that had occurred in the previous 1.5 years (bank full flows which created sandbars) was compared with the highest discharge during that 60 day nesting period (Parham 2007). Sandbar heights were calculated using the methods described in the *Sandbar Height* section of this document. If the difference in sandbar height created at the two discharge rates was at least 1.5 ft, then the nest inundation was considered not to have occurred, while if it was less than 1.5 ft then the nest was considered to be lost to flooding. This difference was a conservative estimate to allow for "smoothing" of the sandbar habitat over time and to account of some of the daily variation in flows resulting from the power plant peaking flows observed in the lower Platte River. This 1.5 foot interval is also recommended in Ziewitz et al. (1992). Additionally, least terns and piping plovers nest on dry sandbars and do not place nests on moist substrates (Thompson et al. 1997, Haig 1992). If nest inundation occurred at any point during the nesting period, that entire period was deemed no quality habitat and given a 0 value. This model assumes re-nesting so after an inundation event, the birds may begin re-nesting the following day. If inundation did not occur, that nesting period was given a value of 1. For each year, the sum of the 63 breeding periods was tallied and the percent of the total number of nesting periods during each breeding season was calculated (Figure 34).

A Similar pattern is seen as with habitat quantity. Duncan consistently has a greater likelihood of nest inundation, while downstream sites more consistently have more breeding periods without inundation, which increases the likelihood that least terns and piping plovers would be able to successfully nest.

Habitat Suitability

Suitable habitat needs to take into account all the variables that were used to calculate *habitat quality* and *habitat quantity*. To calculate the value of suitable habitat, the value for habitat quality (0 or 1 for each 60 day nesting period) was multiplied by the value for habitat quantity (0 – 6% total river area) for suitable habitat. The average of all the nesting periods was calculated for each breeding season (Figures 35-37). Louisville consistently has higher values of suitable habitat, North Bend intermediate values and Duncan consistently had lower values of suitable habitat.

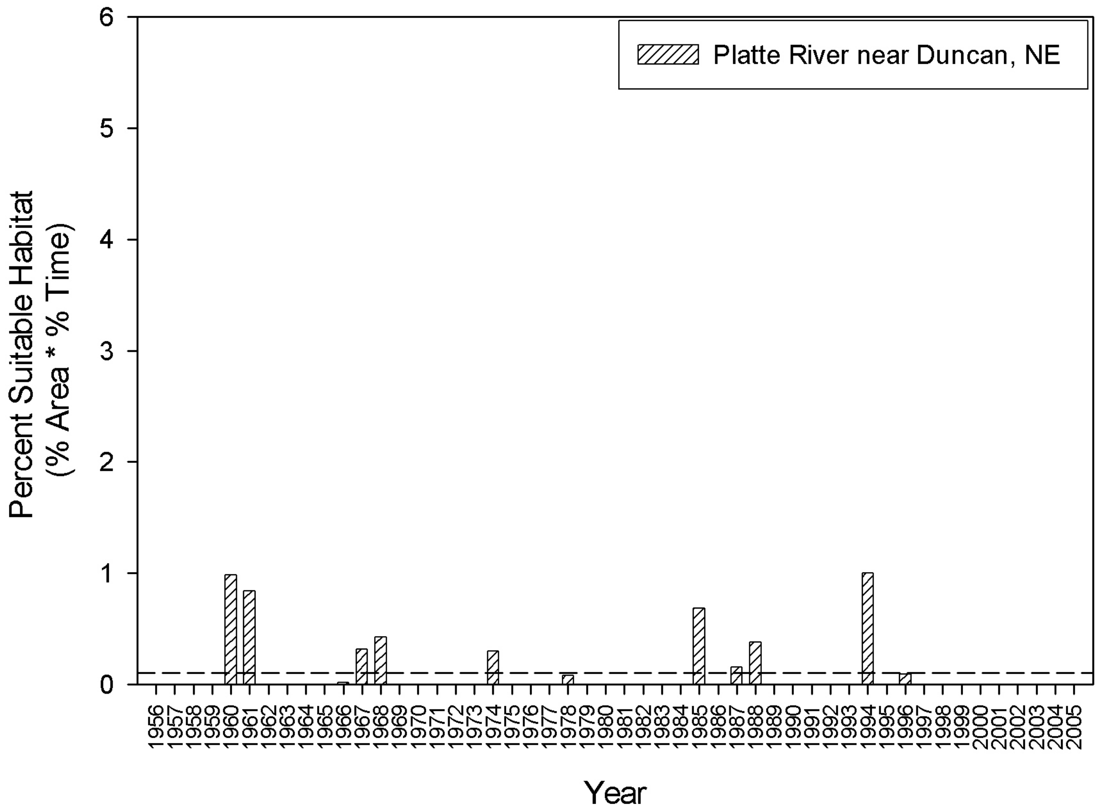


Figure 35: Suitable habitat estimates for the Platte River near Duncan, NE. The bars represent the average amount of suitable habitat within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005 (Parham 2007).

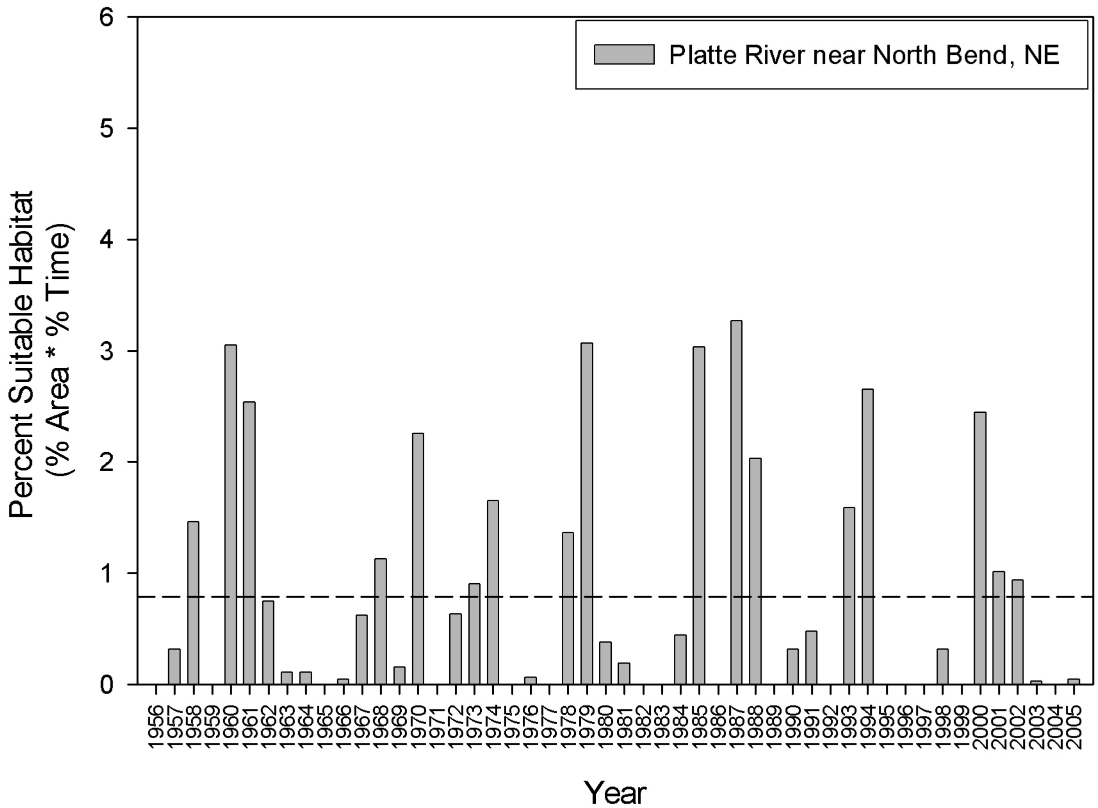


Figure 36: Suitable habitat estimates for the Platte River near North Bend, NE. The bars represent the average amount of suitable habitat within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005 (Parham 2007).

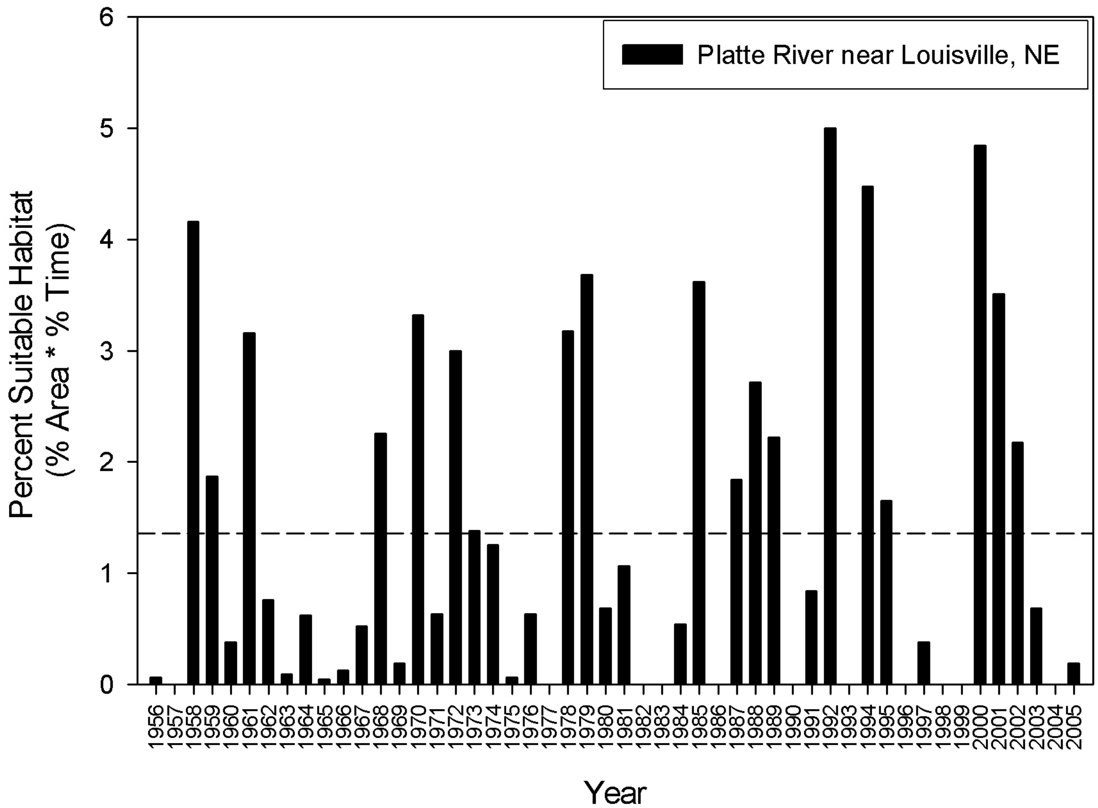


Figure 37: Suitable habitat estimates for the Platte River near Louisville, NE. The bars represent the average amount of suitable habitat within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005 (Parham 2007).

The results provide a method to compare the quality of suitable habitat between sites and conditions between years within the context of previous years' flow conditions. Low values represent years when there was some habitat available, but flows from the previous 1.5 years may not have produced sufficiently high sandbars leading to nest inundation during some of the least tern and piping plover nesting season, or sandbars may be smaller in area which would limit the number of breeding pairs which could use the sandbar, or flows may have not been sufficient enough to isolate sandbars from the banks. High values represent years where flows from previous 1.5 years created/maintained sandbars that were likely not inundated during the nesting period and that were of sufficient area and were isolated. In summary, low values indicate years when conditions were not favorable for successful fledging of least tern and piping plover chicks, while high values indicate years when successful fledging is much more likely.

Favorable Years

The results of the habitat suitability analysis provides the context of which years (1956 - 2005) were *favorable years*, such that they had the appropriate sequence of flow conditions to produce sandbars where successful reproduction of least terns and piping plovers was most probable. Identifying favorable years allows characterization of the flow conditions that occurred during, and previous to, the years with the most suitable potential sandbar habitat. Each gage location was considered separately when identifying favorable years. Separation by gage location is necessary when describing flow conditions as locations used in this analysis have different flow regimes due to tributary influences. The average 1.5 year maximum discharge (bankfull flow) and average monthly flow statistics were calculated from this data set, providing an estimate of flow characteristics for favorable years.

Favorable years were based on the top third of year with some value of suitable habitat (non zero years) (Parham 2007). The locations are different and have different habitat suitable values. The average suitable habitat score at Duncan was 0.88, at North Bend the average score was 2.51 and at Louisville the average score was 3.61. Given the difference, each location has a different minimum suitable habitat score that determined favorable years (Table 10 and 11). It should be noted that this analysis was done using data from a period when the Platte River was already altered and the derived habitat suitability values should not be construed as representing historic conditions. Therefore, comparisons between locations should be done with the understanding that a favorable year at Duncan would not necessarily be favorable years at Louisville. These results characterize the discharge conditions in the "best years" for sandbar creation for least terns and piping plover breeding at each site.

Table 10: Results for 1.5 year flood discharge characteristics for favorable years near the three Platte River gages (Parham 2007).

	Platte River near Duncan, NE	Platte River near North Bend, NE	Platte River near Louisville, NE
Number of non-zero years	12	34	39
Number of years in top 1/3	4	11	13
Maximum yearly suitable score	1.00	3.27	5.00
Average yearly suitable score	0.88	2.51	3.61
Minimum yearly suitable score	0.68	1.59	2.25
Maximum 1.5 year flood discharge (cfs)	22,900	82,300	138,000
Average 1.5 year flood discharge (cfs)	19,804	54,182	79,805
Minimum 1.5 year flood discharge (cfs)	15,317	30,267	39,700

Table 11: Monthly average discharge characteristics during breeding season for favorable years near the three Platte River gages. Minimum suitable habitat score criteria for a month was from Table 10.

Site Name & Suitable Habitat Minimum	Month	Maximum Monthly Discharge (cfs)	Average Monthly Discharge (cfs)	Minimum Monthly Discharge (cfs)	Average Percent Suitable Habitat	Number of Months ≥ Min Score
Platte River near Duncan, NE Suitable Habitat (≥ 0.68)	May	3,990	1,535	763	0.85	2
	June	3,377	1,710	523	1.09	3
	July	1,582	662	215	1.06	3
	August	1,388	572	182	0.91	3
Platte River near North Bend, NE Suitable Habitat (≥ 1.59)	May	10,114	5,129	3,001	4.45	9
	June	10,319	4,686	2,095	4.21	11
	July	9,465	3,921	1,248	3.15	11
	August	4,559	2,042	870	2.33	7
Platte River near Louisville, NE Suitable Habitat (≥ 2.25)	May	10,174	6,943	4,879	5.03	8
	June	12,779	5,575	3,041	4.90	10
	July	13,129	5,191	2,217	3.83	12
	August	8,841	3,811	1,911	3.67	8

The results reflect the need for high flows during the preceding 1.5 years to scour vegetation from sandbars and deposit new sandbars. Average peak flows were large in the Louisville (79,805 cfs) and at North Bend (54,182 cfs) reaches and much smaller in the Duncan reach (19,804 cfs). The large flow volumes at North Bend and Louisville provide substantial sediment transport capabilities. Minimum peak flows near Louisville and North Bend were larger than the maximum peak flows near Duncan. This suggests that peak flows from the central Platte River are not high enough to create suitable sandbar habitats for terns and plovers.

Flows at very similar levels and their sandbar maintenance effects were described by Sidle et al. (1992). They reported a large flood of 32,300 cfs at the North Bend gage and 60,500 cfs at the Louisville gage which noticeably reduced vegetation on sandbars by 78%. Bankfull flow events are important and occur with more regularity and are important to the system for sandbar habitat, but the high flows in Table 10, which are infrequent (Figure 38), are the flows that created the most suitable habitat. This analysis illustrates the importance of the natural hydrograph and variability inherent in the ecosystem that creates and maintains habitat.

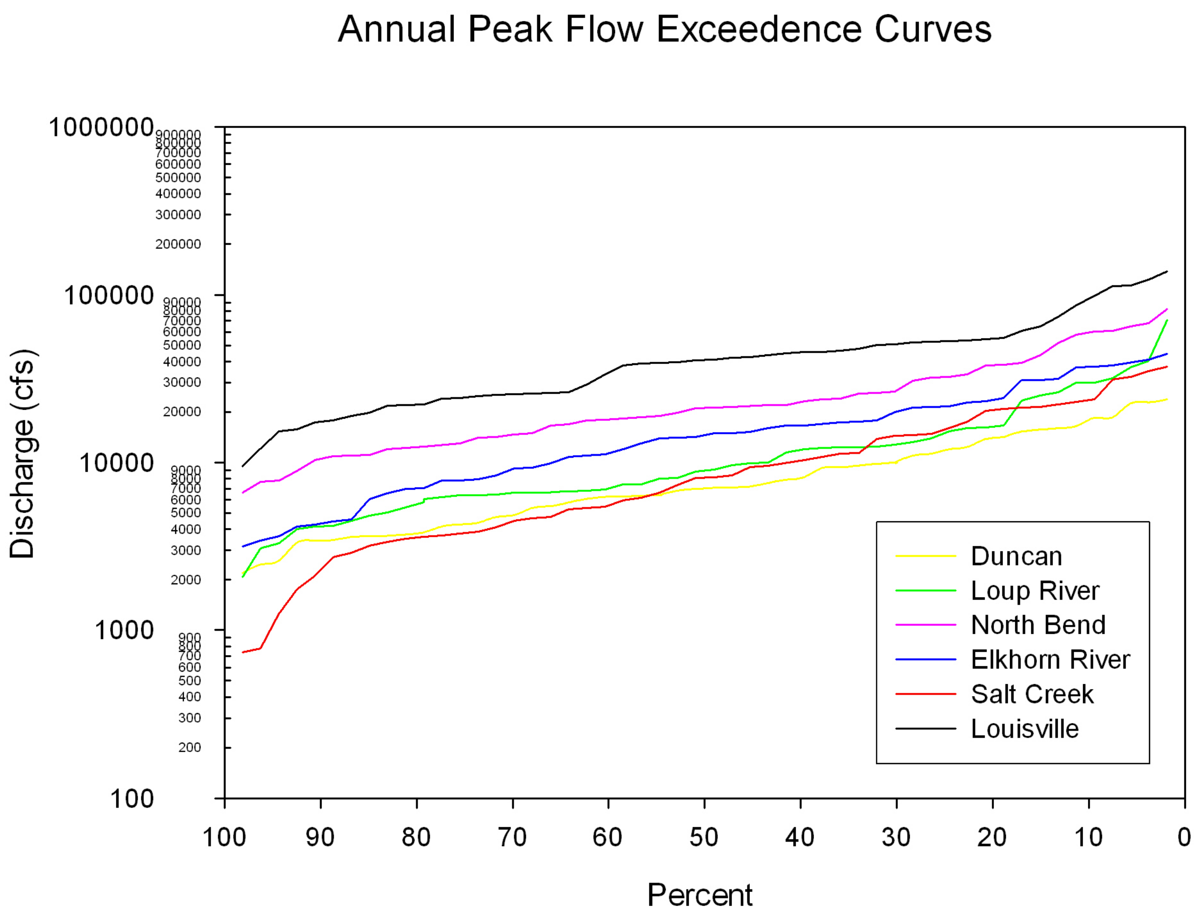


Figure 38: Exceedance values for annual peak flows for gages located along the lower Platte River and along the main tributaries to the lower Platte River (Parham 2007).

Visual inspection of the relationship between peak flows, summer flows, and suitable habitat resulted in the observation of two patterns (Figures 39-41). First, in summers with mean flows substantially higher than average, little suitable habitat was observed (see year 1983 at all sites) suggesting that high summer flows were high enough to eliminate most suitable habitat. Summer mean flows near or slightly below 5,480 cfs resulted in the maximum amount of suitable habitat. This was a result of the maximum available habitat reaching a peak at 5,480 cfs (Figure 32). Second, the majority of higher suitable habitat years occurred in years with high peak flows.

The models in this analysis were based on sandbars of 1.5 feet in height above discharge levels. However, sandbars that were 3.0 ft above the water surface elevation were reported to be selected most often by terns and plovers on the lower Platte River (Ziewitz et al., 1992). Based on the maximum available habitat discharge, the peak flows necessary to create sandbars 3.0 feet in height can be calculated termed *threshold peak flows*. Based on 5,480 cfs (discharge with maximum available habitat termed *threshold summer flows)*, and the peak flows needed to create sandbars 3.0 in height. The peak flow necessary for 3.0 foot sandbars with summer flows of 5,480 cfs was 38,170 cfs for the entire stretch of the lower Platte River.

When plotting a line at the threshold peak flow, a pattern became apparent. When comparing the threshold peak flow to years with suitable habitat greater than 2%, a peak flow of at least 38,170 cfs was observed in 7 of 9 years at North Bend and in 14 of 15 years at Louisville. Overall, 21 out of 24 (88%) of those years had a peak flow of at least 38,170 cfs. Peak flows near Duncan never reached the 38,170 cfs threshold and no years of suitable habitat greater than 2% were observed. When comparing the threshold peak flow to years with suitable habitat between 1% and 2% similar pattern exists. At all sites combined, 9 of 13 (69%) years had a peak flow greater than 38,170 cfs. Conversely, when comparing the threshold peak flow to years with 0% habitat suitability, 18 of 65 (28%) had flows greater than 38,170 cfs.

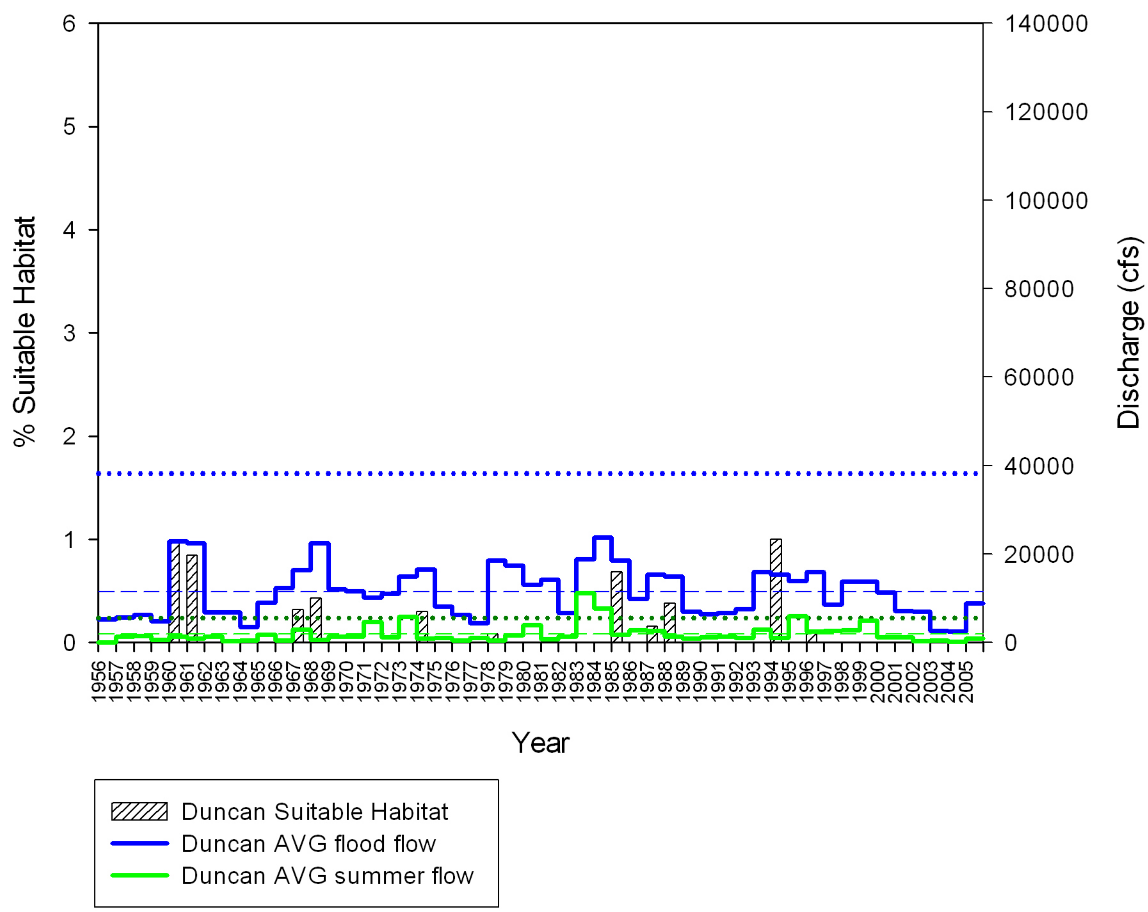


Figure 39: A comparison of average peak flows, average summer flows (May to August), and suitable habitat for the Platte River near Duncan, NE. The dashed lines represent the average flow for the period of record (blue for peak flows and green for summer flows). The green dotted line represents the threshold summer flow of 5,480 cfs and the blue dotted line represents the threshold peak flow of 38,170 cfs (Parham 2007).

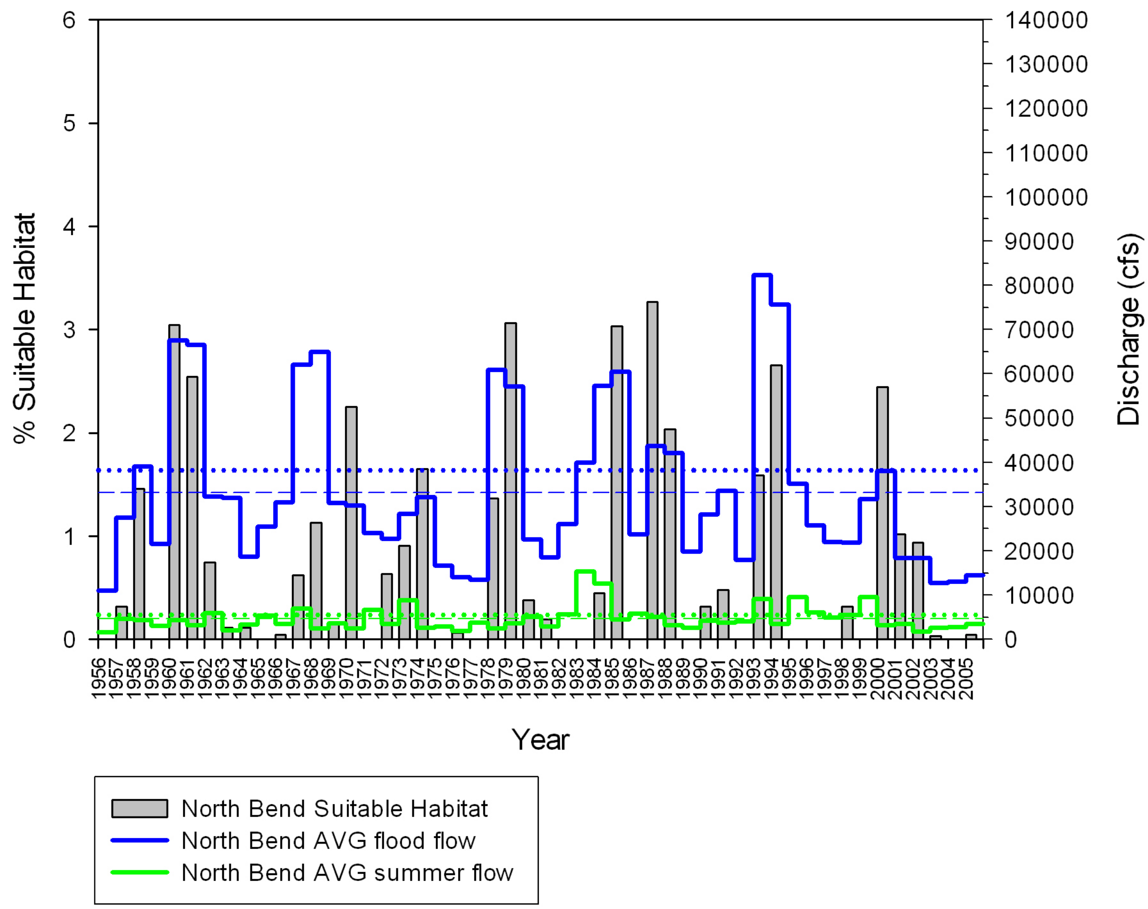


Figure 40: A comparison of average peak flows, average summer flows (May to August), and suitable habitat for the Platte River near North Bend, NE. The dashed lines represent the average flow for the period of record (blue for peak flows and green for summer flows). The green dotted line represents the threshold summer flow of 5,480 cfs and the blue dotted line represents the threshold peak flow of 38,170 cfs (Parham 2007).

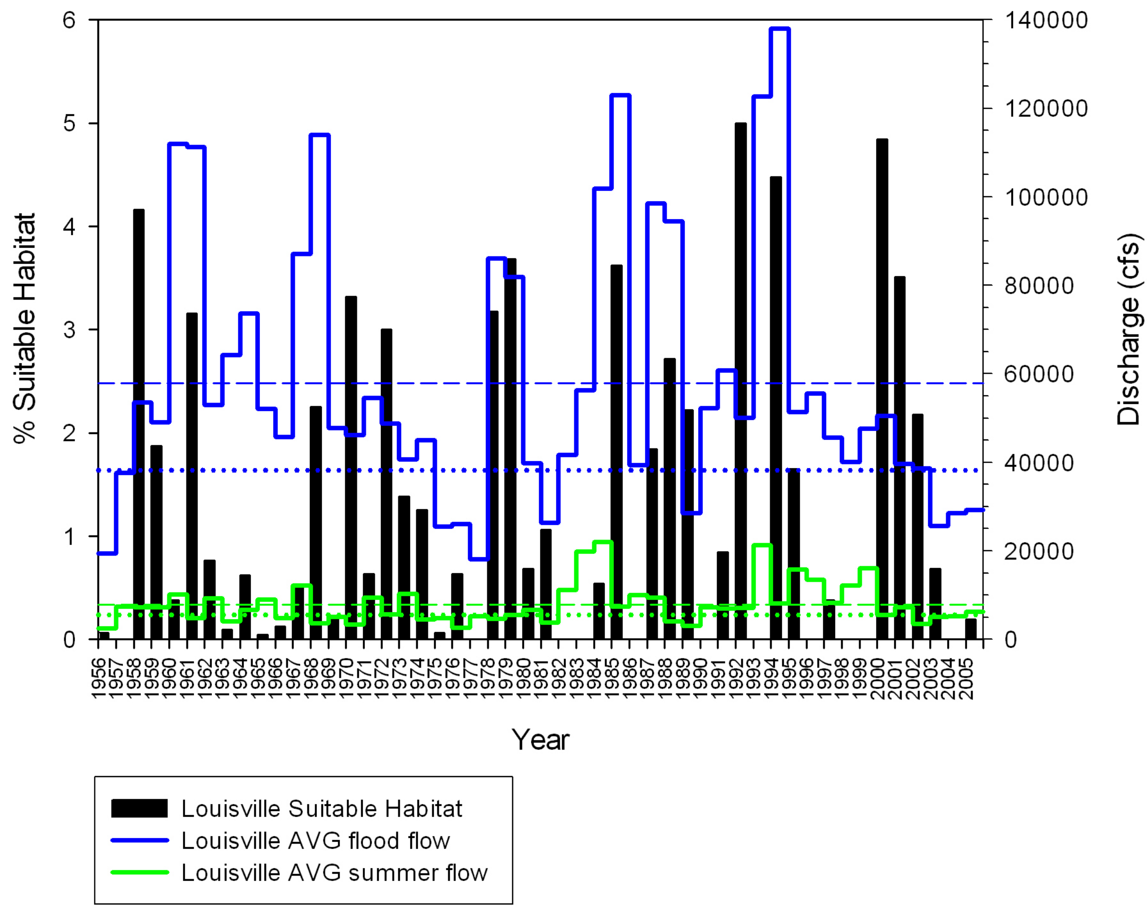


Figure 41: A comparison of average peak flows, average summer flows (May to August), and suitable habitat for the Platte River near Louisville, NE. The dashed lines represent the average flow for the period of record (blue for peak flows and green for summer flows). The green dotted line represents the threshold summer flow of 5,480 cfs and the blue dotted line represents the threshold peak flow of 38,170 cfs (Parham 2007).

Each analysis, habitat quantity, habitat quality, habitat suitability and favorable years illustrate an eastward trend of increasing acceptable habitat. When comparing figures, it is apparent that Louisville has the highest and most consistent level of habitat. Duncan had very few years with habitat, indicating that the flows in the central Platte River are highly degraded and are no longer sufficient to create and maintain sandbar habitat.

The patterns of available habitat between the different locations are supported when looking at recent trends in bird nesting patterns. Nesting is extremely limited as discussed above upstream from the confluence of the Loup River, including the Duncan area (Figures 42-43). Figure 42 illustrates that least terns now nest infrequently on river sandbars and may be extirpated from the river from the Loup River confluence to Schuyler and from the Fremont to North Bend segments. Data indicate declines of breeding birds on the Platte River in upper segments (Columbus to Schuyler and North Bend to Fremont) resembling declines and extirpation from the Central Platte River. In contrast, breeding birds have been observed on the river in the lower segment (Louisville to Plattsmouth) through 2007 where river function is not as greatly degraded and affected by diversion. Prior to the late 1990's, least terns were regularly observed nesting in all three of these segments, but in recent years only regularly nest downstream, primarily in the Louisville to Plattsmouth segment. Even in areas with consistent nesting, there is a downward trend in least tern numbers. A similar pattern is seen in piping plovers with declines in use in the upper reaches of the lower Platte River (Figure 43). Data indicate declines of breeding birds on the Platte River in upper segments (Columbus to Schuyler and North Bend to Fremont). Breeding on lower river segments, such as Louisville to Plattsmouth, is now infrequent.

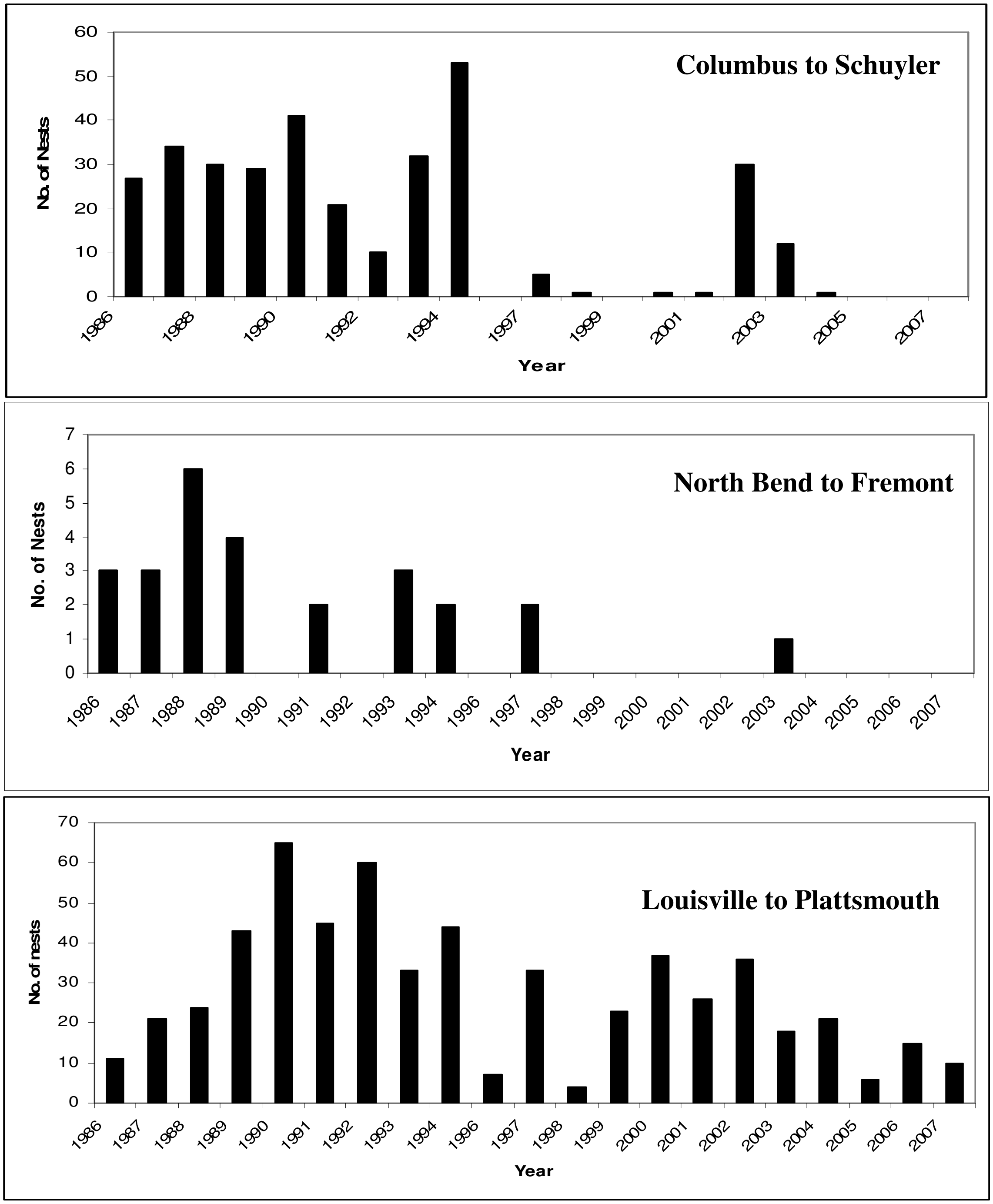
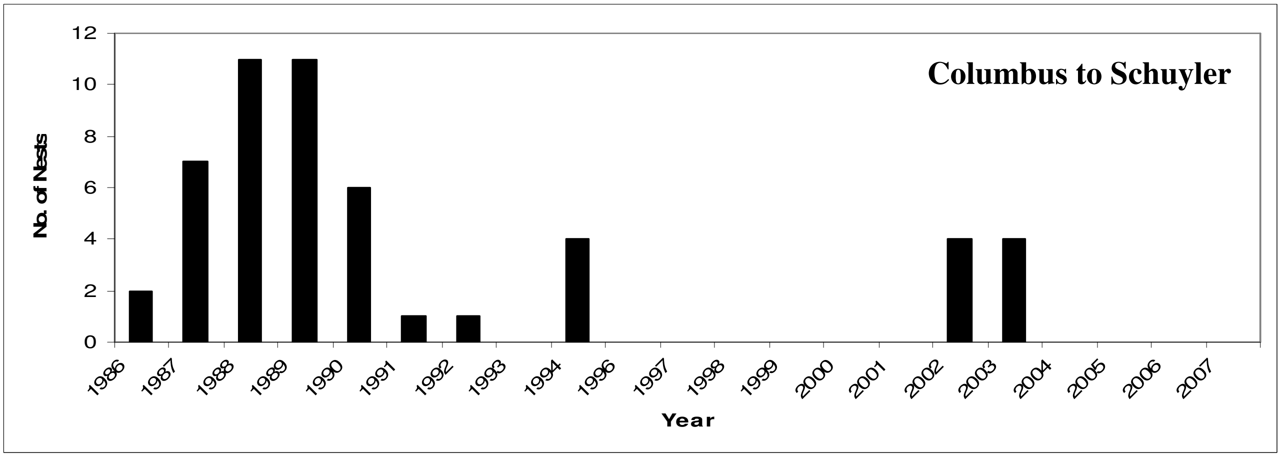
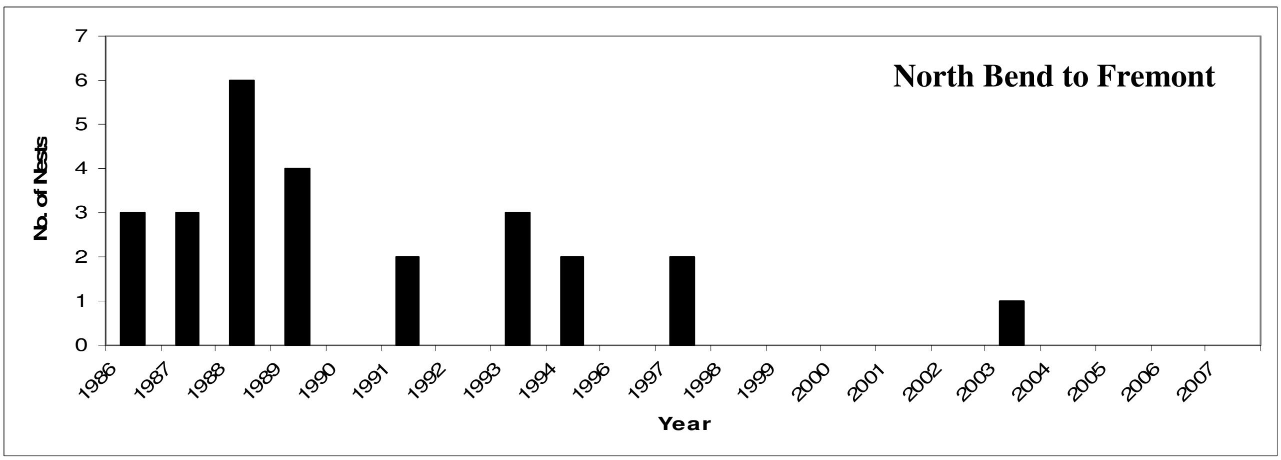


Figure 42: Number of least tern nests from selected river segments recorded during Nebraska Game and Parks Commission annual surveys. Surveys were not completed in 1995.





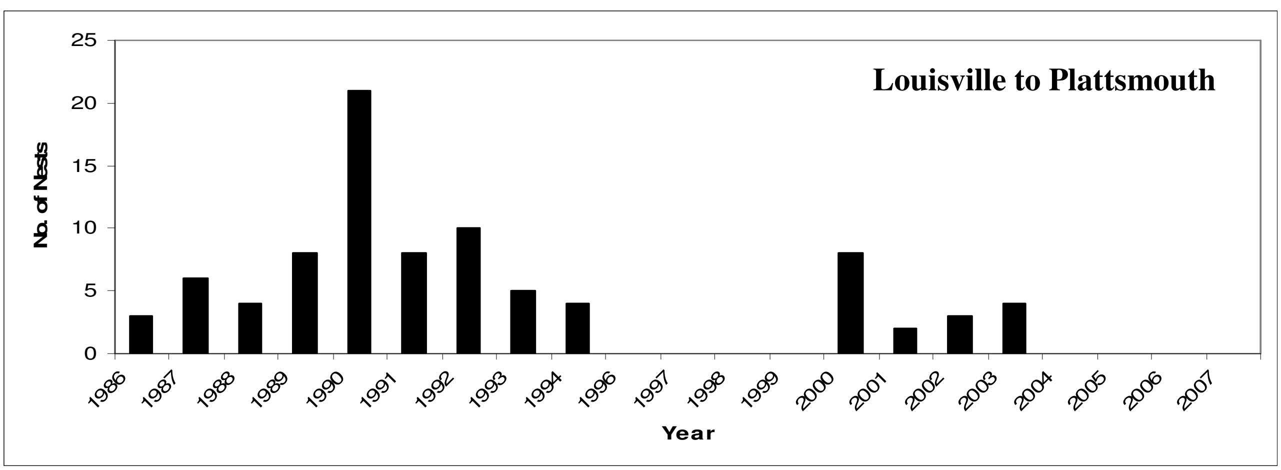


Figure 43: Number of piping plover nests from selected river segments recorded during Nebraska Game and Parks Commission annual surveys. Surveys were not completed in 1995.

Throughout the nesting season, least terns forage on small fish species, therefore the lower Platte River must contain habitat for these smaller fish. Flowing water that separates sandbars from mammalian predators is also important as discussed previously. Current Commission instream flow appropriations were based on the fish community of the Platte River, but did not include the pallid sturgeon. However, these instream flow appropriations do include several fish that are also considered potential forage for least terns. At North Bend, the instream flow appropriation is 1,800 cfs for the entire year. For Louisville, the instream flow appropriation is 3,100 cfs for January, 3,700 cfs for February through July 31, 3,500 cfs for the month of August, 3,200 cfs for September, and 3,700 cfs for October through December. Parham (2007) found that a flow of 2,350 cfs for the lower Platte River resulted in the maximum level of shallow water habitat.

Least terns and piping plovers have very limited habitat along Nebraska's rivers when compared with historical distributions. In Nebraska, much of the habitat utilized is inadequate to sustain the populations of least terns and piping plovers. The natural hydrograph of the lower Platte River, with high spring flows followed by lower summer flows, is fundamental to sandbar creation and maintenance. The higher spring flows move the sediment, create and scour sandbars and must be sufficiently higher than summer flows to prevent inundation. Summer flows must support forage, and isolate sandbars from the banks.

Hydrological Discussion as related to Pallid Sturgeon

Currently, the lower Platte River does retain a natural spring rise, although much smaller than historic flows, due to inputs from the Loup and Elkhorn rivers and other tributaries. Information from the Duncan gage (Figure 31) clearly illustrates the historic, natural and reduced hydrograph. Although not historic, Figure 22 demonstrates the hydrograph at Louisville. This spring rise allows migratory pallid sturgeon to move into the lower Platte River in the spring and utilize the scour holes, deep channels and shifting habitat.

Bankfull flows are channel shaping flows that move sediment within the river and scour deeper channels preferred by the pallid sturgeon. Although more subtle than large floods, these more frequent flows make significant contributions to sediment movement and forming habitats suitable for pallid sturgeon (Dunne and Leopold 1978 in Rosgen 1996).

Peters and Parham *(*2008) conducted extensive analysis of pallid sturgeon habitat as related to flows in the lower Platte River. They found that in the lower Platte River, pallid sturgeon were most frequently captured in the deepest and swiftest runs of the river. Pallid sturgeon selected areas with a depth greater than 0.8 m with an average depth of approximately 1.6 m and a mean column current velocity of 0.8 m/s (Figures 44-45). They appear to seek areas with complex microhabitats, as the deep runs where pallid sturgeon were captured were typically within 50 to 100 m of shallow, exposed sandbars.

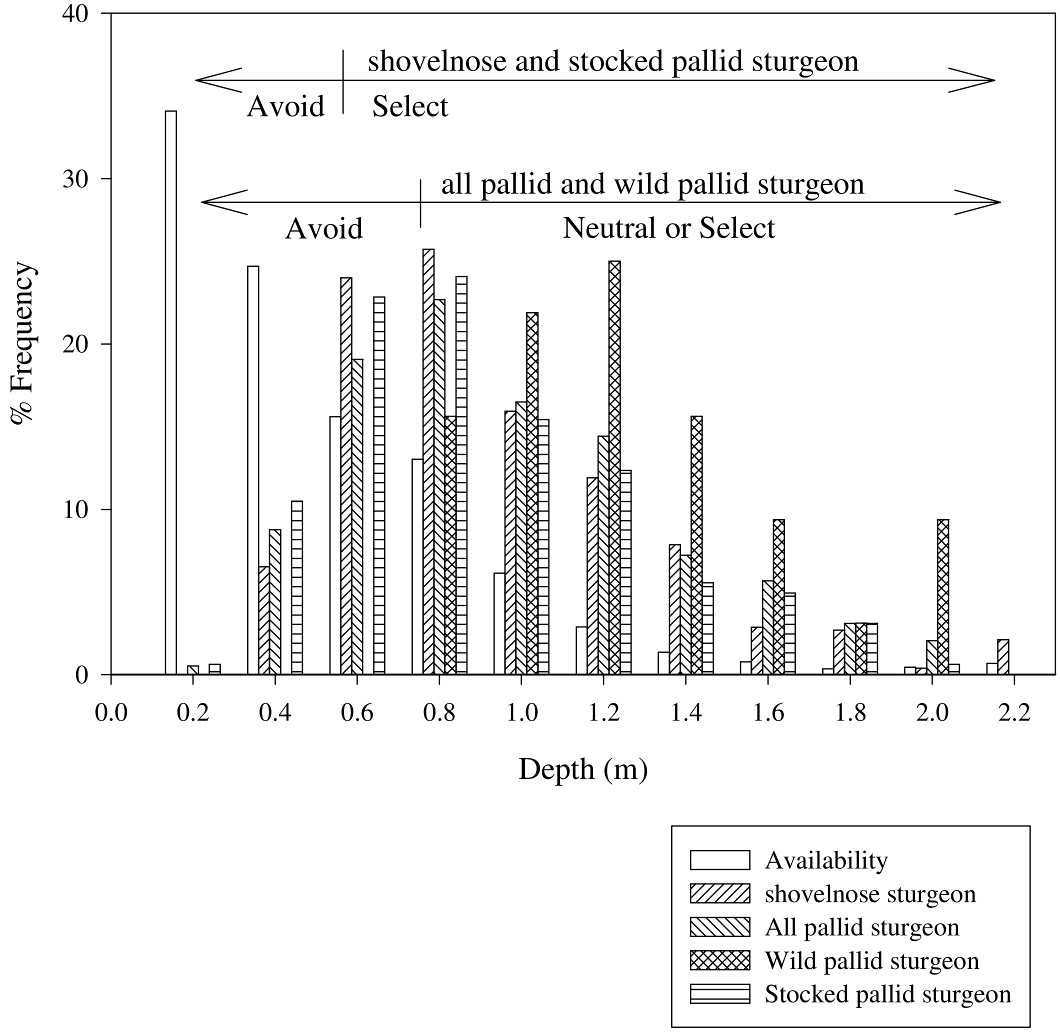


Figure 44: Sturgeon habitat use vs. depth availability in the lower Platte River (Peters and Parham 2008).

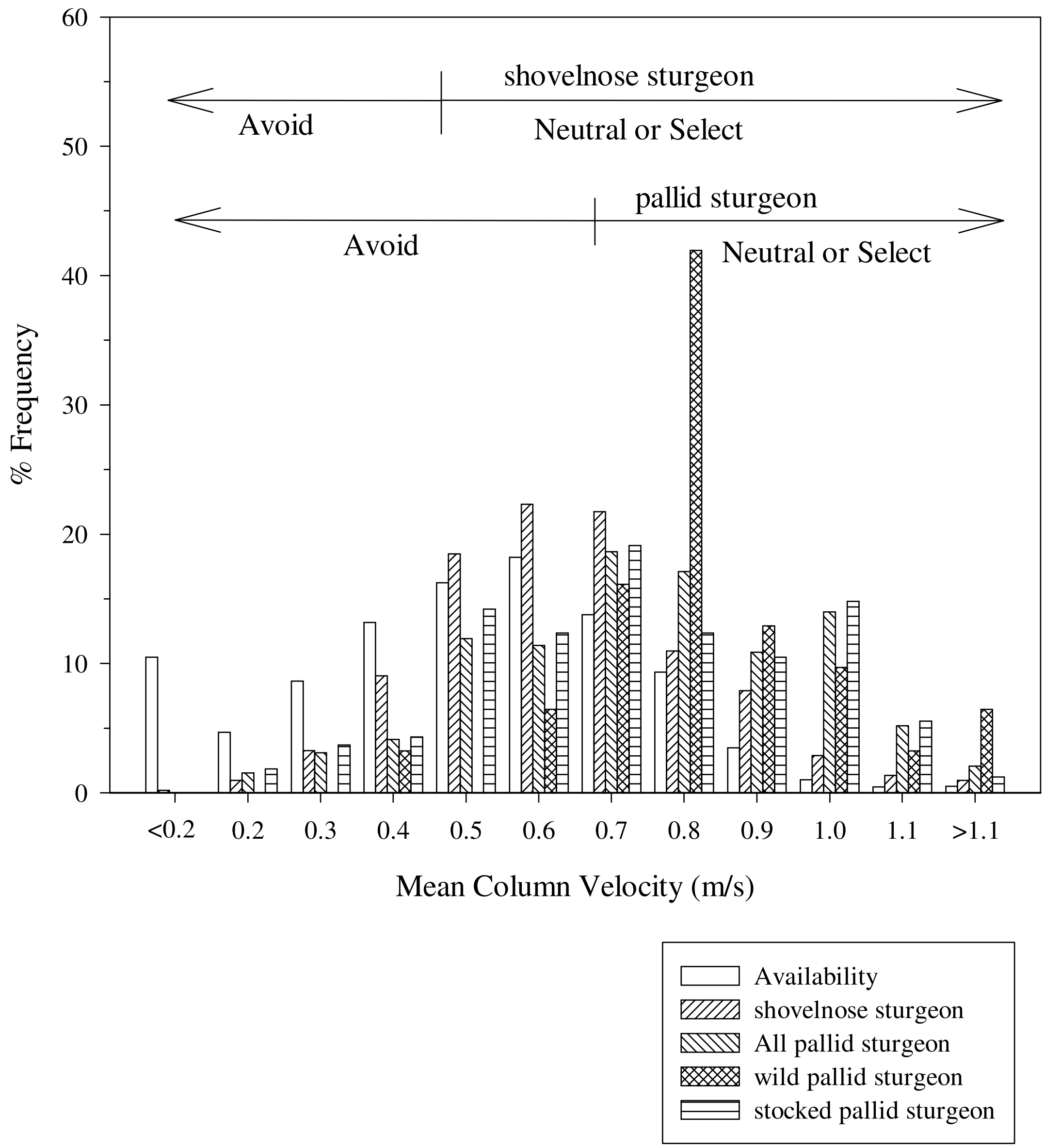


Figure 45: Sturgeon habitat use vs. mean column velocity availability in the lower Platte River (Peters and Parham 2008).

When combining depth and velocity information and their availability at discharge rates for the lower Platte River, they found that habitat availability had a non-linear relationship with discharge (Figure 46), such that small changes in discharge result in significant habitat changes. There was little to no habitat (deep, swift water) at low discharge rates, but increased rapidly starting at 6,000 cfs and reached an asymptote near 9,000 cfs. This relationship also illustrates even under high flow conditions; there is a maximum of 30% of the Platte River which is deep water habitat that the pallid sturgeon utilize.

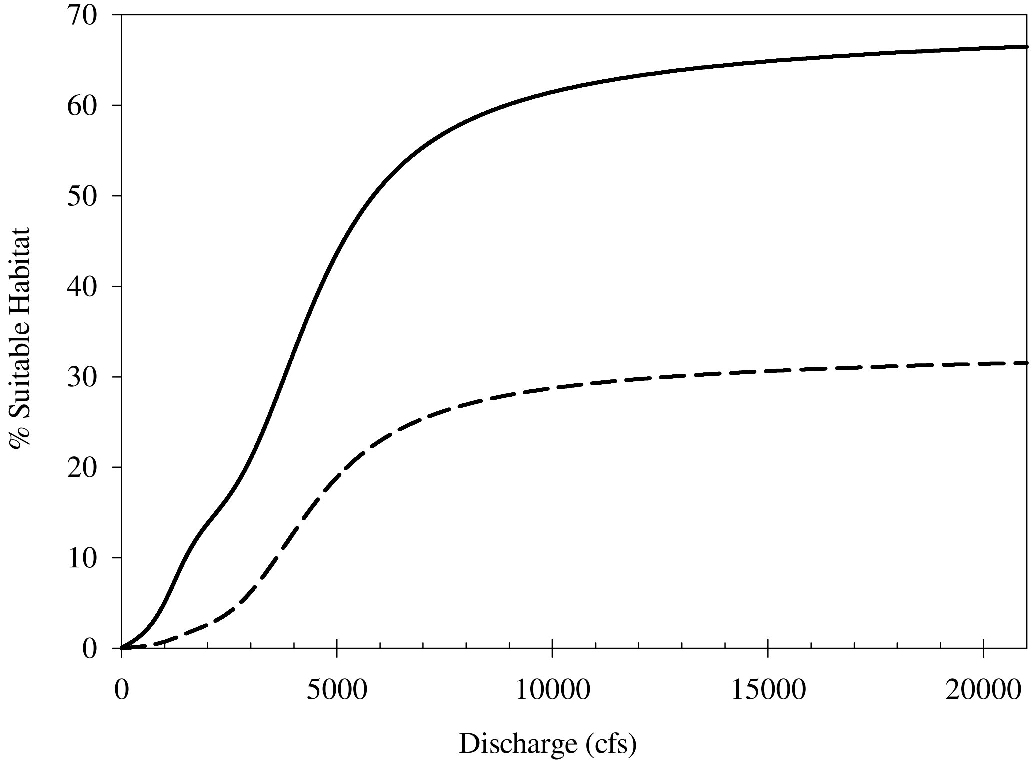


Figure 46: Suitable habitat vs. discharge for the sturgeon in the lower Platte River. The solid line represents shovelnose sturgeon and the dashed line represents pallid sturgeon (Peters and Parham 2008).

Another component of pallid sturgeon habitat is that of habitat connectivity within the channel. The spatial and temporal availability and connectivity between important habitats is critical in the life cycle of riverine fishes (Schumtz et al 2000) and define the fitness at the level of individual fishes and at the population level (Schiemer 2000). The geomorphology of the river has highly variable depths, with deeper channels, shallow areas and sandbars. The pallid sturgeon utilize the deeper areas of the channel, and these areas of potential habitat are essentially patches within a matrix of geomorphological features. This matrix is similar to a maze through which pallid sturgeon must successfully navigate up and back down prior to falling flows. These areas of potential habitat of the river need to be connected via flowing water of great enough depth for passage, essentially creating a path for the pallid sturgeon to navigate through the river. The relationship between increasing discharge the transition to mostly open water habitats can be see in Figure 30, such that in terms of pallid sturgeon habitat, the lower Platte River is most connected at higher discharges. Pallid sturgeon may use deeper holes as refuge when discharge rates drop, but will rapidly become stranded and perish if connectivity is not returned and maintained. According to Peters and Parham (2008), the lower Platte River is generally unconnected at low discharge rates, with a rapid increase in connectivity between 3,200 and 5,600 cfs with 100% connectivity occurring at approximately 8,100 cfs (Figure 47).

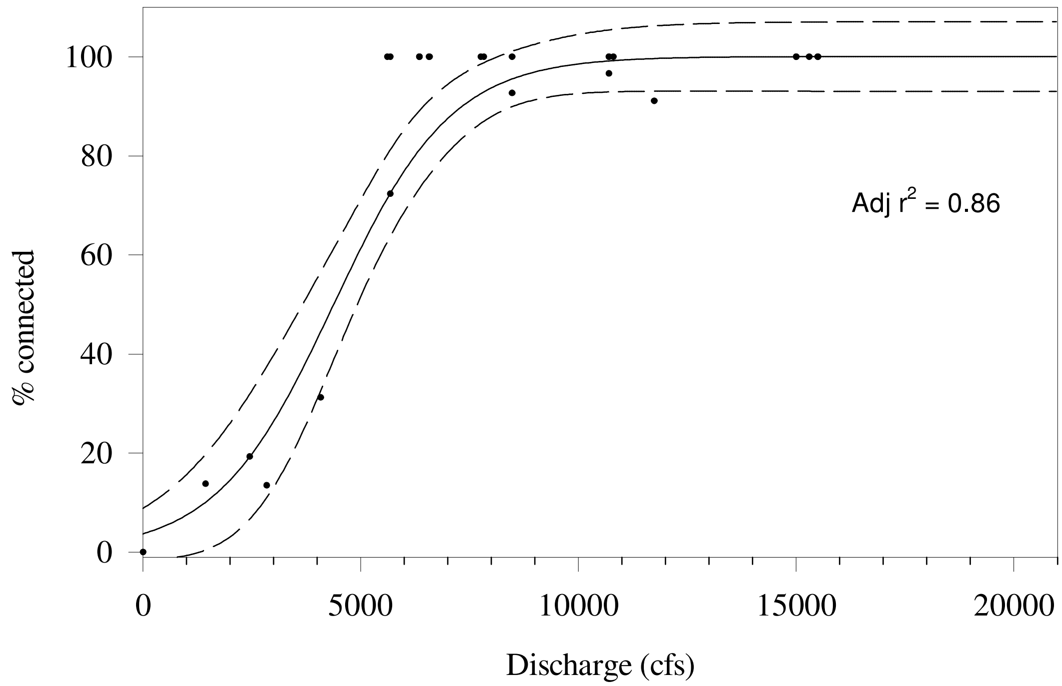


Figure 47: Curve of the best fit for river connectivity vs. discharge for the lower Platte River. The solid line represents the fitted line, the dashed lines are the 95% confidence intervals about the line, and the dots are the observations.

Shovelnose sturgeon migration both up and downstream seem to coincide with periods of high river connectivity and changes in water temperature (Peters and Parham 2008). Given the similarities of the shovelnose and pallid sturgeon, it is reasonable to assume that pallid sturgeon demonstrate similar migrations during periods of high river connectivity (Figures 48-51).

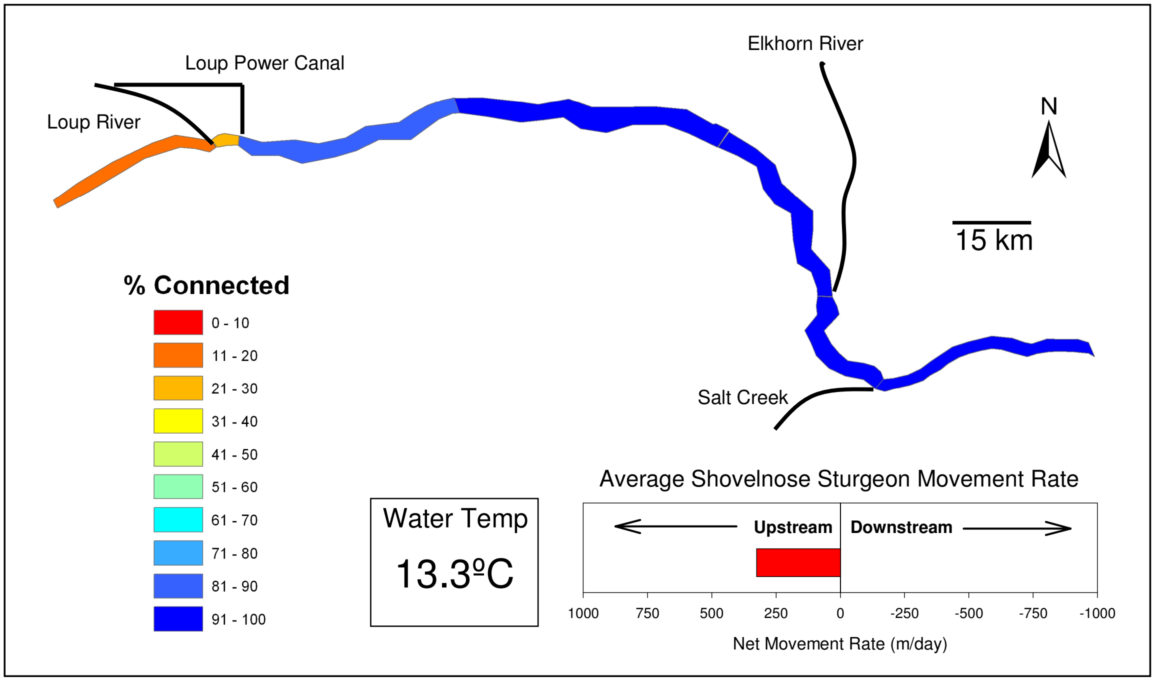


Figure 48: River connectivity for average monthly conditions in April for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement (Peters and Parham 2008).

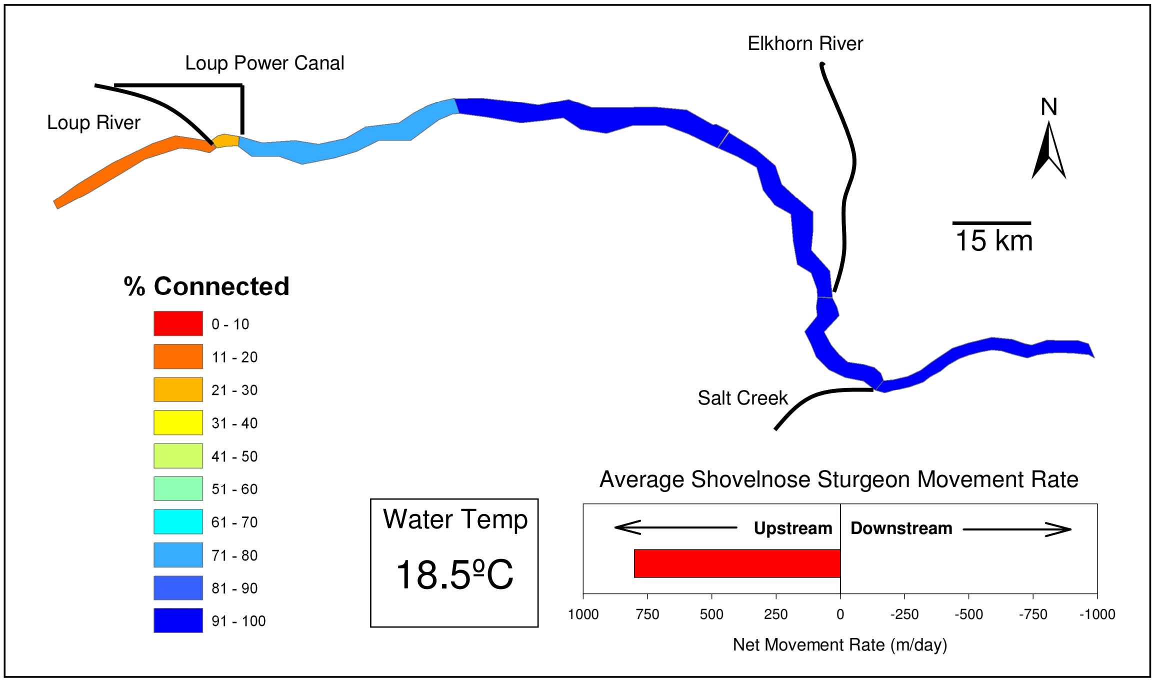


Figure 49: River connectivity for average monthly conditions in May for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement (Peters and Parham 2008).

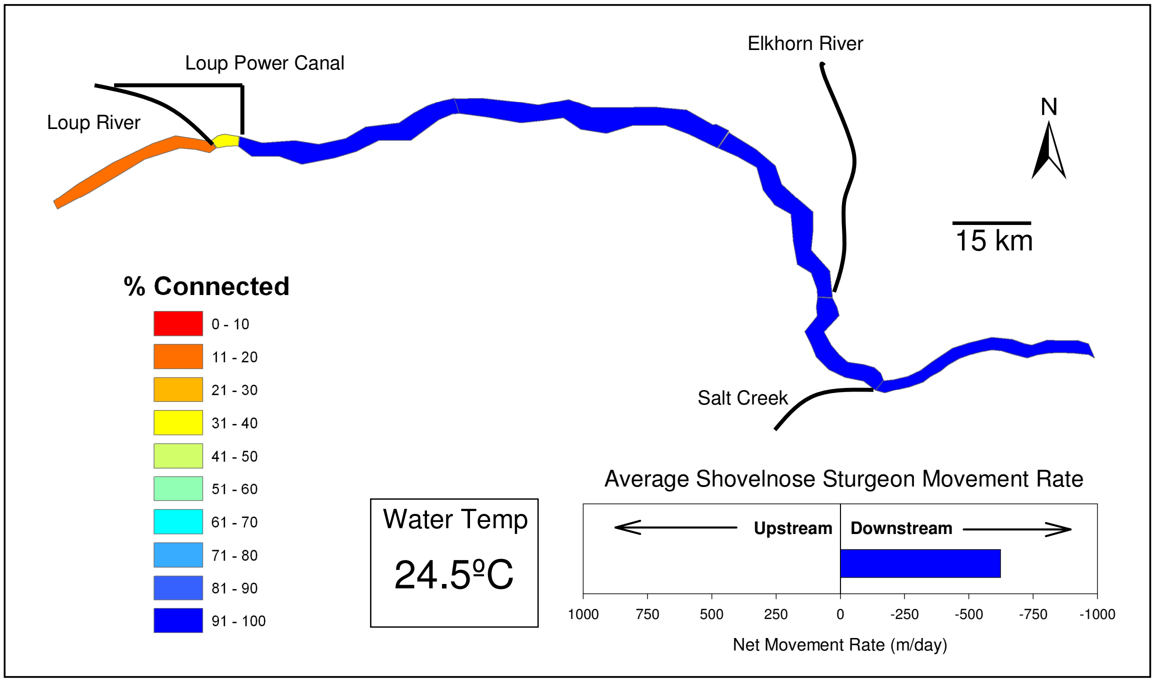


Figure 50: River connectivity for average monthly conditions in June for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement (Peters and Parham 2008).

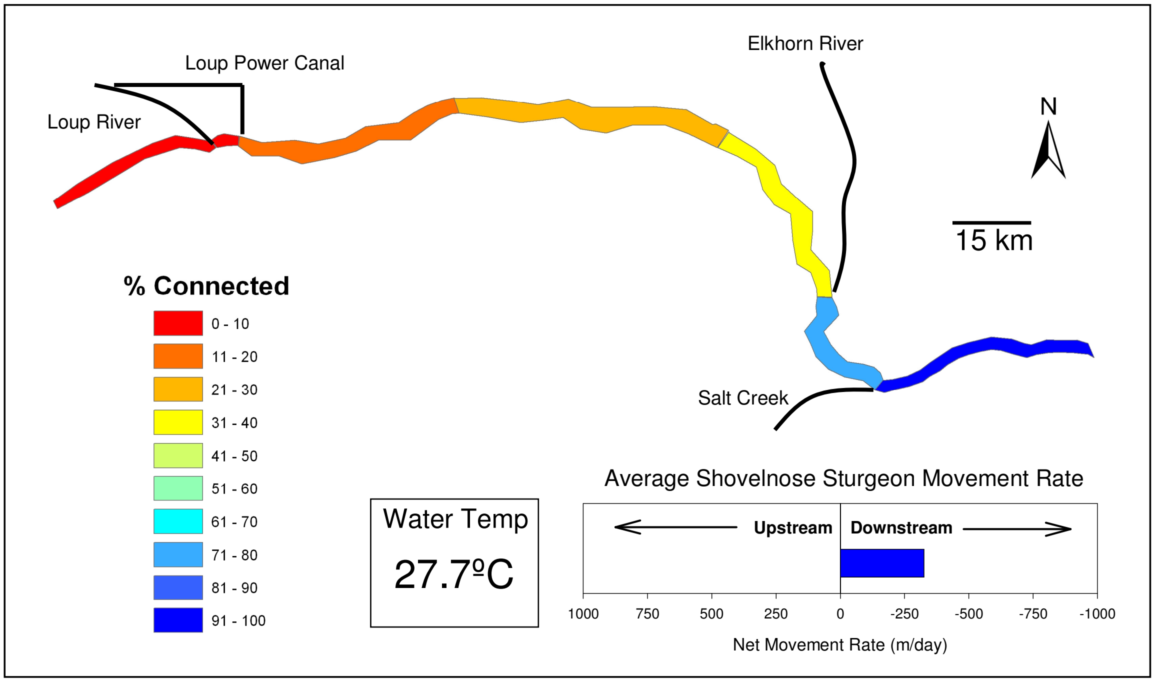


Figure 51: River connectivity for average monthly conditions in July for sections of the lower Platte River associated with USGS gage sites. Additional information includes average monthly water temperature and average shovelnose sturgeon movement (Peters and Parham 2008).

Clearly, river connectivity is important for sturgeon migration. If the lower Platte River is consistently unconnected in the spring of the year, sturgeon will likely not be able to access habitats available to them in the river which decreases the likelihood of the fish completing a successful spawning run. A spring rise allows migratory sturgeon to move through the river to potential spawning sites. Likewise, mortality by stranding of genetically important broodstock also decreases the likelihood of species recovery. It is imperative that habitat be available every year for this very rare species, as individual females are likely not all capable of reproducing annually when favorable conditions exist. Keenlyne (1989) concluded that, "because of their low reproductive potential, meeting reproductive needs may be a delicate but crucial strand in the success of sturgeon species, including the pallid sturgeon." Pallid sturgeon utilize habitats in the lower Platte River at other times of the year, so habitat availability throughout the year is also important.

Conclusions

New water use should be required to offset their impact to the lower Platte River such that there is no new depletions or degradation in magnitude and structure of the hydrograph for which threatened and endangered species in the lower Platte River depend. Higher flows must be protected from further depletion to a) scour deep channels with swift current which provides habitat for the pallid sturgeon, b) build and maintain sandbars for least tern and piping plover nesting. Timing and duration of the higher spring flows must be protected for pallid sturgeon spawning cues. Flows need to be sufficient to maintain connectivity during the spawning time of year for pallid sturgeon, so that habitat is available each year for any females that are physically ready for spawning to both migrate upstream to spawn and to safely migrate back downstream to the Missouri River. It is important that summer flows be maintained to provide forage for least terns and to insure sandbar isolation for both least tern and piping plover nesting. Flows throughout the year must be maintained for pallid sturgeon habitat.

Least Terns and Piping Plovers

As described in the Environmental Baseline Section, the lower Platte River between the confluence of the Loup River and the Elkhorn River currently provides questionable habitat, and as seen in the central Platte River, future depletions to this area will eventually eliminate nesting habitat the majority of the time. The lower Platte River downstream of the Elkhorn confluence still appears to have minimal suitable habitat and the flow regime necessary to create and maintain this suitable habitat.

The remaining semblance of the natural hydrograph is necessary for creation and maintenance of sandbar habitat for nesting least terns and piping plovers. Flows of at least 38,170 cfs are necessary at regular intervals for sandbar creation and maintenance.* These flows may occur at any time of the year. Currently, these peak flows are exceeded approximately 60% of the time at Louisville and 20% of the time at North Bend annually. Near Louisville, current conditions are sufficient, but above the Elkhorn River, flows are mediocre regarding potential to create new habitat and maintain existing nesting habitat for these species in the lower Platte. This analysis is corroborated by the patterns of least tern and piping plover use in the lower Platte River, which have declined and a general pattern of more consistent nesting downstream is evident. The remaining semblance of the natural hydrograph that produces higher flow events are also vital for sandbar creation and maintenance as described above. Therefore, further depletions that reduce the frequency and duration of these peak flows exacerbate the decline of suitable river nesting habitat in the lower Platte River and jeopardize the continued existence of least terns and piping plovers in Nebraska.

In addition to maintaining the hydrograph and higher habitat forming flows, there must also be flowing channels during the nesting season that provides refuge and productivity for the smaller fish that least terns use for forage. These flows also provide exposure and separation of sandbars from the bank which is important for reducing predation. Based on the favorable year analysis and maximum shallow water values, the frequency, duration and timing of 4,686 cfs in June, 3,921 cfs in July and 2,350 cfs in August from the confluence with the Loup River to the confluence with the Elkhorn River must be protected from future depletions. At the North Bend

Gage, these flows are exceeded approximately 45%, 27% and 35% of the time respectively.* From the Elkhorn River to the confluence with the Missouri River, the frequency, timing and duration of 5,575 cfs in June, 5,191 cfs in July and 3,811 cfs in August must be protected from future depletions. These flows are exceeded at the Louisville Gage approximately 63%, 40%, and 35% of the time respectively.* Therefore, any further depletions to the lower Platte River system would exacerbate the decline of habitats within these two sections of the river and will jeopardize the continued existence of least terns and piping plovers in Nebraska.

Maintaining the existing hydrograph in the lower Platte River will not address the recovery of least terns and piping plovers. Habitat restoration activities such as flow augmentation and sandbar maintenance may be necessary to ensure continued nesting of least tern and piping plovers in the lower Platte River.

Pallid Sturgeon

As described in the Environmental Baseline, current conditions of the lower Platte River appear to provide minimal habitat for pallid sturgeon and the remaining semblance of the natural hydrograph provides necessary components for spawning. There are records of shovelnose sturgeon as far west as Wyoming in the Platte Basin (Baxter and Simon 1970) and recent records of Lake Sturgeon *(Acipenser fulvescens)* as far west as Columbus (Heritage Data 2007). Given the similarities of these species, it is likely that historically the pallid sturgeon utilized available habitat west of Columbus. However, depletions and diversions upstream of the Loup confluence have severely reduced the potential for pallid sturgeon habitat. At this time, there are no records of pallid sturgeon in the lower Platte River west of the Elkhorn confluence, but there are records in the Elkhorn River. Therefore, the following recommendations for pallid sturgeon are from the Elkhorn River east to the confluence with the Missouri River, but this most eastern section of the lower Platte River is highly dependent on flows from all upstream sources, especially the central Platte River, the Loup River and Elkhorn River as well as the Salt Creek basins.

The information and analysis presented in this document indicates that from April 1st through June 30, the current frequency, timing and duration of 8,100 cfs must be protected from future depletions in the lower Platte River from the confluence of the Elkhorn River east to the confluence with the Missouri River. At the Louisville gage, this required flow is available approximately 45% of the time from April through June.* At 8,100 cfs the lower Platte River channel reaches 100% connectivity within the 95% confidence interval and provides approximately 85% of the maximum available pallid sturgeon habitat (Figures 34 and 35) (Peters and Parham *2008*, Parham 2007). According to Figures 14 and 15, the spring rise is typically ending during the month of July and there is a reduction in flows. During this month, pallid sturgeon may still be spawning (G. Mestl, personal communication 2007), adults need to exit the river and larvae are still drifting. Therefore from July 1 to July 15, the current frequency, timing and duration of 7,000 cfs and from July 16 to July 31, the frequency, timing and duration of 6,000 cfs must be protected from future depletions. These flow occur approximately 27 – 32 % of the time respectively at the Louisville Gage.* There are records of pallid sturgeon using the lower Platte River in times outside of the presumed spawning season, therefore it is important to maintain habitat for pallid sturgeon during the rest of the year. There must be protection of the current frequency, timing and duration of 4,950 cfs of the lower Platte River from the Elkhorn

River Confluence to the Missouri River Confluence the rest of the year. At 4,950 cfs, 59% of the maximum habitat is available and reaches the upper inflection point (Figure 26). For the period of record from 1954 to 2005, this required summer flow occurs approximately 55% of the time annually at the Louisville Gage.*

The lower Platte River is considered crucial for the survival of pallid sturgeon in Nebraska, and also for the species across its entire range. "The population of the pallid sturgeon is so low in numbers, that the lower Platte River is pivotal in the recovery and management of the species…and the loss of lower Platte River habitat would probably result in a catastrophic reduction in the pallid sturgeon population," (NRC 2005). Given that an individual pallid sturgeon female may only spawn once every 10 years, and that available habitat is currently only available approximately 27-45% of the time during this crucial period, and 55% of the time the rest of the year, the species are considered to be in jeopardy based on current conditions. Therefore, additional depletions to the action area would jeopardize the continued existence of pallid sturgeon in Nebraska.

In conclusion, there must be no additional depletions or degradation in magnitude and structure of the existing hydrograph. New water uses for the area including the lower Platte River Basin, the Loup River Basin, Elkhorn River Basin and Salt Creek Basin will degrade the magnitude and structure of the existing hydrograph which is necessary for least tern, the piping plover and pallid sturgeon in Nebraska.

* Based on period of record 1954 – 2005 (Parham 2007)

APPENDIX B

Independent Reviews of Peters and Parham (2008), Parham (2007), and the NGPC BO (2007)

Refer to attached CD

24 September 2008

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The following is my review of the Peters and Parham report: Ecology and Management of Sturgeon in the Lower Platte River, Nebraska, Edward J. Peters and James E. Parham, Nebraska Technical Series No. 18, Nebraska Game and Parks Commission, Lincoln, Nebraska, Draft 2007 A contribution of Federal Aid in Sport Fish Restoration, Project F-141-R, Nebraska

My comments are organized as follows. Page numbers are listed; following page numbers is text cut and pasted from the Peters and Parham report in Times New Roman font. My comments follow and are in Arial font.

Pg. 28.

Pallid sturgeon or shovelnose sturgeon that weighed at least 300 grams were deemed sufficiently large enough to hold a transmitter.

What was radio weight as a percentage of fish body weight?

There was no specific temperature restriction for implanting transmitters in shovelnose sturgeon, but most were implanted at temperatures below 25 °C.

What percentage of the year is avoided by staying below 25 C? What is the maximum temperature of the Platte River?

Trammel nets consist of three panels of netting suspended from a float line and a single or double lead line.

Could catch rates of benthic fishes vary between single-and double lead lines?

Pg 29.

The trawl design was a modified otter trawl and it was used primarily in water over 1.0 m deep.

How was the net modified? Describe net dimensions, mesh size.

Pg. 30.

Radio telemetry information used to evaluate habitat use was obtained exclusively from airboat surveys, while movement data came from all three contact methods (shore, boat and aircraft). Sturgeons were located by triangulating the radio signal using a directional loop antenna. Final locations were typically accomplished by removing the antenna from the receiver to find the strongest signal.

Were fish located from a boat or by wading or both? Was there any danger of spooking the fish and causing it change location? Why were fish locations not determined by triangulation from shore? This avoids possibly spooking the fish, and habitat data can be collected at the fish's location following triangulation. In a shallow river like the Platte, I could see where a lot of maneuvering about over the fish to determine its location could actually cause the fish to move, probably to deeper water.

To estimate the available habitat in the river, we used transect data gathered by the NGPC during a previous Instream Flow Incremental Methodology (IFIM) study (NGPC 1993a, b). These data included measurements of depth and mean column velocity measured at points along several transect lines from three different localities under differing discharge conditions.

How well do these data represent habitat availability in the study area?

Define "several" transect lines and "differing discharge conditions". When were these data collected? What was the discharge when the data were collected? What was the sample size? Does this data produce a distribution of habitat availability at all different discharges? My point is that if these data were taken in limited locations during certain flow conditions, they may not adequately represent the habitat that was available at all locations where radio relocations were made, or under all of the flow conditions during which relocations were made. If this is true, comparing use to availability is like comparing apples to oranges.

Depth and mean column velocity was analyzed using a bivariate table with four categories of depth and four categories of mean column velocity. First, the distribution of the habitats sampled was determined by tabulating the number of samples for each cell in the table, and then calculating the percent frequency of each cell in the table. Gear selection of the depth and velocity combinations was determined by dividing the percent frequency of occurrence in each cell with the percent frequency of the habitat availability for that cell. The gear selection was normalized by dividing each cell value by the sum of all cell values. These values were standardized to a scale of 0 to 1 by dividing each cell value by the largest cell value (Bovee and Milhous 1978, Peters et al. 1989). In cases where undefined numbers would result in division by zero, the value was replaced with a zero.

I don’t follow—this is not written clearly enough for me to replicate how the bivariate tables with normalized sampling effort (e.g., Table 2.29) are calculated based on this description. Perhaps a more concrete example would help.

Page 33.

Figure 2.2c. Map of the locations of drifted gill net runs attempting to capture sturgeon and associated species in the lower Platte River. Match lines with other map sections of the lower Platte River are denoted by number and dashed lines.

Legend indicates trammel nets, caption indicates gill nets.

Page 38.

Trotlines were used when the water temperature was below 16 °C and were most commonly used in the spring of the year (Table 2.7).

It is mentioned several times that trotlines were used during periods of cooler water temperatures but I don’t see anywhere that explains why this was done.

Page 86

Pallid sturgeon are typically grey colored hunch-backed fishes with five rows of bony scutes that have been found in the lower Mississippi River and Missouri River upstream to the Great Falls in Montana.

As far as I know, the farthest upstream observation of pallid sturgeon on the Missouri River comes from near Ft. Benton, Montana, which is perhaps 40 km below the Great Falls. They were also found upstream in the Yellowstone River as far as the mouth of the Tongue River. Fishes of Montana 1971 C.J.D. Brown.

Page 86.

Historically, pallid sturgeon were more abundant in the main stem and major tributaries of the Missouri and Mississippi Rivers than they are currently.

Is there any historical data for the Platte River? Were they ever abundant there? How far upstream did they go? Was this always marginal habitat or has there been a major reduction in a significant population? Were pallid sturgeon resident in the Platte River or transients or migrants from the Missouri River? Some of this would help place this study in context. Perhaps many of these questions cannot be answered, but the authors could explain that.

Page 87, paragraph 2.

When a Pallid sturgeon was captured,

Pallid should not be capitalized.

The same habitat data were not collected on the 590 mm pallid sturgeon captured on 23 July 2004 by the Statewide inventory crew because they used different measurement methodologies. This fish was not scanned for a PIT tag.

I don't follow; was this fish not implanted with a transmitter because it was not scanned for a PIT, and therefore habitat use data were not collected? Clarify.

Pallid sturgeon 621, a female (880 mm, 2.45 kg),

I don't think there is anything in the methods that describes how sex was determined.

Figure 4.2.

This figure indicates that two pallids were captured in the Elkhorn River. By anglers? I don't see where the implications of this are discussed?

Page 88.

Table 4.1. Capture information for pallid sturgeon caught by this study and by the Nebraska stream fisheries inventory (*) in the Platte River between 3 May 2001 and 25 September 2004.

It may be easier to interpret if location column used river miles instead of local landmarks. Only those very familiar with the study area can interpret local landmarks easily.

Difficult to tie paragraphs on individual pallid sturgeon to Table 4.1 because paragraphs identify fish primarily by transmitter number and transmitter number not listed in Table 4.1.

Of 15 pallids, 7 were wild fish? Are the implications of this interpreted?

Paragraphs on individual pallid sturgeon and aerial photos are OK, but I think movement patterns are easier to discern using graphs (Date on x-axis and River mile on Y-axis). These graphs display time, distance and direction of movement better than dots on an aerial photo.

All the pallid sturgeon implanted during April 2004 apparently moved out of the Platte River by 15 April 2004 during the time when a back-flushing operation at the Metropolitan Utilities District (MUD) water treatment plant released a white material into the river.

This is rather shocking. Is there any more information available on the cause of the release or the identity of the white material?

Page 89.

Is this recap data analyzed for implications on the stocking program and natural reproduction? How do these growth rates compare to other reported growth rates or to expectations? Is there other research on this in the adjacent Missouri River? It appears that Platter River pallid sturgeon are closely tied to the Missouri River pallid sturgeon, therefore research on Missouri River pallid sturgeon has implications for the Platte River.

While these depths are not considered deep for the Missouri River, over 90% of the lower Platte River is less that 60 cm deep with an average depth of 26 cm (Peters et al. 1989).

This is probably true, but depths change with discharge and location on the longitudinal profile. If availability of depths was not quantified at the same time as when sturgeon were captured, you may not be able to directly relate depth at capture to depths available. This relates to my comment above about the quantification of available habitat on page 30. The authors have not clearly made the case that the data that quantifies habitat availability is comparable and representative of all the capture and relocation data.

Our capture of pallid sturgeon began after the water temperature reached approximately 10 °C and stopped after it reached 17 °C (Table 4.3). Pallid sturgeon were captured in water with relatively high dissolved oxygen, high conductivity readings and a range of turbidities. These water quality variables may reflect the spring time water conditions when pallid sturgeon are moving in the Platte River or **may be actively selected by the fish.** At this time it is not possible to differentiate from the data gathered.

How do fish select for water chemistry variables? In order to select for water quality there must be different water quality conditions available to them. If they are captured in the Platte River in spring, these are simply the water quality conditions that occur then. They can't go elsewhere to select different water quality conditions unless the Missouri is different at this time. Is the Missouri different at this time? Or they would have to move very far upstream on the Platte or downstream. They can use different depths or current velocities by moving to a deeper or faster run, but how do they use different conductivities for example? The fish simply occur in whatever the ambient water chemistry conditions are present in their range. Higher conductivities simply coincide with when fish were captured—the fish probably didn't select for higher conductivities.

Page 90.

nets catching pallid sturgeon and in nets not containing pallid sturgeon using Mann-Whitney t-test on ranks were not observed for the variables of depth ($p = 0.98$), mean column velocity ($p = 0.56$), bottom velocity ($p = 0.90$), dissolved oxygen ($p = 0.44$), specific conductivity ($p = 0.74$), total suspended solids ($p = 0.94$) or daily mean discharge ($p = 0.95$). The only variable to show a difference in use was temperature ($p = 0.02$). The pairwise comparisons showed that nets where fish were caught had lower median temperatures (median = 13.4 °C) than either all nets (median = 24.6 °C) or nets without pallid sturgeon (median = 24.6 °C).

It seems that what may be really driving this is season. I gather from this report that pallid sturgeon are only in the Platte River in spring. Any difference in habitat conditions when pallid sturgeon were caught and when pallid sturgeon were not caught would be due to the seasonal differences in habitat. Catch is confounded with season and habitat changes with season. Also, since habitats were not randomly sampled, but targeted for deep and swift habitats, you would not expect differences in depth or velocity. I suppose I am asking these limitations to be expressed more explicitly. It seems that these analyses imply that there was a random sampling design.

It may be useful to characterize and compare overall river conditions when pallid sturgeon occur in the Platte (spring) to when they don't occur in the Platte. Why do they move in and why do they move out?

Habitat Analysis (TROTLINES):

This analysis is similar, but may have been limited to spring gear sets, which would be appropriate for comparing catches and non-catch gear sets.

The pallid sturgeon's selection for sandy substrates is probably related to their turbidity selection.

See Bramblett and White 2001 for an alternative hypothesis: The differences in substrate use we observed may be related to food habits of the two species. Pallid sturgeon include fishes in their diet (Carlson et al. 1985), whereas shovelnose sturgeon are benthic invertivores (Barnickol and Starret 1951; Hoopes 1960; Held 1969; Helms 1974; Modde and Schmulbach 1977; Megargle 1997). We speculate that prey fishes may be easier for pallid sturgeon to capture over sand than over larger substrate. Because cobble and gravel substrate generally has higher benthic insect production than shifting, sandy substrate (Hynes 1970; Junk et al. 1989; Allan 1995), shovelnose sturgeon may find more food over cobble and gravel substrate. Perhaps smaller pallid sturgeon include more insects in their diet, which could explain the greater use of larger substrates by pallid sturgeon less than 5 kg (Erickson 1992).

Page 94

Pallid sturgeon that use the Platte River appear to be mobile animals. Up to the year 2004 evidence pointed toward a conclusion that they may only be using the Platte River during the spring and early summer.

Page 96.

General movement. Was there any attempt to correlate entry into the Platte with discharge? How about outmigration from the Platte? Do you have enough evidence to speculate on cues? Is there any correlation with discharge? Could discharge on the Platte be an important cue for movement into the Platte and initiation of spawning?
What is limiting this population? In Montana, we suspect that larval pallid sturgeon are drifting downstream into the headwaters of reservoirs. Larval pallids drift for around 11-17 days (Braaten et al. 2008. North American Journal of Fisheries Management 28:808–826). If the sturgeon are spawning in the lower Platte, where do you suspect that 11-17 days of drift may put the larvae (240 to 530 km)?

Page 98

Indexes of condition for fish fall into two main types, the Fulton condition factors (K) and relative weight (Wr) (Anderson and Neumann 1996). The value of K is computed by multiplying the weight of a fish in grams (W) by 100,000 and dividing this product by the length of the fish in millimeters cubed (L3). Relative weight values compare the weight of an individual fish of a given length to a standard weight for fish of that same length as calculated from a regression equation developed for that species. Carlander (1969) summarized K values for many species including pallid sturgeon. However, the values he listed were calculated using total lengths (K(TL)) rather than the fork length measurements we typically use to measure pallid sturgeon today. More recently, Quist et al. (1999) developed standard weight equations for shovelnose sturgeon that has allowed use of this method of assessing condition to be used for the management and evaluation of shovelnose sturgeon population health. However, at this time, there are no published standard weight equations for evaluation of pallid sturgeon condition. Shuman et al. (2006) developed proportional stock density and relative stock density criteria for pallid sturgeon, but did not develop standard weight equations. So, as yet there are no standard criteria by which the well-being of pallid sturgeon captured in the Platte River can be judged

Is it possible to convert from total length to fork length; does anyone have a database measures of both? What it you used Quist’s shovelnose standard weight equations? Both species have similar morphology. Might be worth a try?

Page 103.

Drifted gill nets were generally run through areas that were expected to have sturgeon.

Whereas I agree that authors have learned a lot about where sturgeon occur in the Platte, one must be cautious about interpreting habitat use when data are collected in a non-random fashion. Inference about selection is not valid for the whole river, but only among those areas "expected to have sturgeon." I would defer this to a statistician, but I think it violates some assumptions about random sampling and inference. Having said that, I think it is worthwhile data to present as descriptive, rather than probabilistic data.

Were gill and trammel nets monofilament or multifilament?

Page 106.

Table 5.6.

I refer to my comments above about pallid sturgeon and water quality variables. Pallid sturgeon showed a significant difference in temperature because they are captured primarily in spring. Shovelnose sturgeon did not show a significant difference in temperature because they are captured all year.

Page 110.

Substrate containing sand was used extensively by shovelnose sturgeon. Shovelnose sturgeon were observed over sand substrate during 96% of all observations (Table 5.25). Use of substrate containing gravel accounted for 3.5% of all observations. Shovelnose sturgeon rarely (<1%) used silt substrate.

It would be informative to acknowledge that the Platte is primarily sand. It's not as though the shovelnose are actively selecting for a rare substrate. Wouldn't shovelnose sturgeon have a hard time being found over anything but sand in the Platte?

Page 110.

Substrate use by shovelnose sturgeon is often noted as being sandy (Quist et al. 1999) and the Platte River observations fit that description well.

However shovelnose sturgeon may prefer gravel and cobble substrates if such substrates are available (Bramblett and White 2001). In Montana, shovelnose sturgeon are common in upstream reaches of the Yellowstone and Missouri rivers where sand is rare and gravel/cobble predominates, and in downstream reaches where sand is dominant.

Page 114.

Shoal chubs were the most common species and red shiners were only the fourth most common species. Chubs in general made up 42% of the catch in the 3/8th inch seines near sturgeon, where chubs made up only 14 % of the catch in all other ¾th inch seines.

Was there a difference in depth, velocity, season or otherwise between general seining and seining near shovelnose sturgeon?

Page 122

Pulsed gastric lavage (PGL) was developed by Foster (1977) and has been used successfully on many species. Hofpar (1997) used gastric lavage on shovelnose sturgeon in the Platte River and Brosse et al. (2002) used it on Siberian sturgeon.

Check this Montana State University MS thesis for another diet study on shovelnose sturgeon. Temporal variation in diet and food selection of shovelnose sturgeon in the Missouri River above Fort Peck Reservoir, Montana, Megargle, Douglas J. (Douglas John), Pub date: 1997. N378.M4729

To evaluate abundance of macroinvertebrate taxa in the Platte River, the organisms drifting in the area were collected using 0.5 mm mesh nets set to collect larval fish (see Chapter 8 for details). These samples were considered to be representative of the invertebrate taxa which would be most available to sturgeon and other fish species when they settle to the substrate in areas of slow current and eddies where the fish feed.

I'm not convinced that drift samples are reflective of availability to benthic feeders such as shovelnose sturgeon. I think the composition of the drift varies temporally due to emergence, etc. However, I assume the benthos is where shovelnose sturgeon feed. Shovelnose sturgeon may not feed in eddies or slow current--the authors present much data to indicate that shovelnose sturgeon do not use areas of slow current. Moreover, drifting invertebrates may not settle out, but rather emerge as adults.

Page 123.

No mention of drift results in text.

Page 128

Additionally, depth and mean column velocity was analyzed using a bivariate table with four categories of depth and four categories of mean column velocity. First, utilization of the habitat was determined by tabulating the number of captures for each cell in the table, and then calculating the percent frequency of each cell in the table. Selection of the depth and velocity combinations was determined by dividing the percent frequency of occurrence in each cell with the percent frequency of the sampling effort for that cell (see sampling chapter for data on percent frequency of the sampling effort). The habitat selection was normalized by dividing each cell value by the sum of all cell values. These values were standardized to a scale of 0 to 1 by dividing each cell value by the largest cell value (Bovee and Milhous 1978, Peters et al. 1989). In cases where undefined numbers would result in division by zero, the value was replaced with a zero.

I'm not familiar with this technique; what does the statistician think? These bivariate tables seem a bit hard to interpret. There are many steps involved; tabulating captures, calculating percent frequency, dividing percent frequency catch by percent frequency effort, normalizing, and standardizing. It makes intuitive sense, but I can't follow it and replicate it.

Also, the authors don't seem to help us interpret the results, which seem a bit misleading. For example in table 5.5, the cells with velocity 0.30 and depth <0.30, 0.30-0.60, and >0.90 all have a 1.00 for a score—yet only 0.6%, 3.8%, and 0.6% of shovelnose sturgeon were captured there. In contrast, the cell with velocity 0.30-0.60 and depth 0.30-0.60 gets a smaller normalized score of 0.65, yet 39.5% of all observations were in this cell. How do you interpret Table 5.5? It looks like shovelnose sturgeon really like slow water—is this true, or an artifact of slow water not being sampled often, but catching a few fish there? Tables 5.3 and 5.4 suggest different interpretations—shovelnose sturgeons are most often captured in moderate current velocities and depths from 0.30 to 0.90 m.
We know that sampling was not done systematically or randomly, but rather:

"Realizing that much of the sampling effort for this study was intentionally aimed at capturing the rare pallid sturgeon and sturgeon chub, it is important to understand that the sampling strategy was not a random or stratified random sampling design where samples were collected in proportion to their availability in the river. As stated earlier, previous studies had intensively sampled shallow water and shoreline habitats (Peters et al. 1989, Peters and Holland 1994, Yu 1996) and few sturgeon or sturgeon chubs were captured. Most of the different gears used were deployed near or in the deeper or swifter sections of the river."

However, this bivariate table analysis brought to the level of "normalized selected habitats" almost seems to imply randomizations, or at least doesn't work well when samples were not randomized. If habitats had been sampled randomly, I suspect the result would be that more shallow water habitats would have been sampled, yet perhaps catch of sturgeon would not have increased very much, and normalized scores for slow, sahllow waters would have decreased to more accurately represent habitat use. Again, I refer to Table 5.5 by way of example. The highest normalized selected habitat values in that table are for habitats where hardly any fish were captured. It seems that perhaps one should just admit that sampling was not randomized or systematic, and just present percent use tables, such as Table 5.4. However, the fact that Table 5.5 has high normalized selected habitat values for water <0.30 m/s does bring into the question the following assumption:

"Previous studies (Peters et al. 1989, Peters and Holland 1994, Yu 1996) intensively sampled shallow water habitats and shoreline habitats in the lower Platte River between 1986 and 1995 and the results suggested that pallid sturgeon, shovelnose sturgeon or sturgeon chub do not use shallow water or shoreline habitats extensively. In addition, other studies on sturgeon and shovelnose pallid (Hofpar 1997, Snook et al. 2002) indicated that much of our sampling effort should be focused in the deepest and swiftest sections of the river."

It is difficult to spend a lot of time and money sampling habitats where you don't think the fish occur, but sometimes zeros are very important also. This is a judgment call, the authors chose not to sample randomly based on previous experience and limited time and money. I will not second guess this call, but it leaves them vulnerable to this type of artifact.

Another issue that tends to makes habitat use hard to grasp is the presentation of results separately by gear type. I know different gears cannot be compared directly, but at some point, all of the information gathered with all of the gears in all of the habitats needs to be summarized, synthesized, and interpreted for overall inference from this study as well as from the literature. For example, percent use by trawl and percent use by seine-are these ever put together and interpreted together? This report is chocked full of information, almost to point of overload. Perhaps readability and comprehension would be better served by placing many of the tables and intermediate raw data into appendices.

Page 129

it seems that we are seeing a trend similar to those documented by Cross and Moss (1987) and Pflieger and Grace (1987).

Please describe trend mentioned here, otherwise we have to look up these papers.

Page 130

One of the primary habitat characteristics noted for sturgeon chub is their apparent dependence on turbid water (Stewart 1981, Werdon 1992). Turbidity at sites where sturgeon chub sampled during this project ranged from 70 to 130 NTU which was typical for the lower Platte River during the study period from 2000 to 2004, but these values are considerably lower than the 500 JTU values reported by Werdon (1992) from the Powder River, WY.

It can be tricky to interpret turbidity data because it changes quite a bit temporally while the fish remain in the area. For example, even the Powder River has periods of low turbidity, yet the sturgeon chub remain in the river. The fish can't really select for this variable, they just take what comes down the river.

Page 133.

Table 7.5. Number of shoal chub captured in combined depth and velocity categories during trawl sampling in the lower Platte River, Nebraska.

Why are all depths > 1 m lumped? Table 7.3 suggest that shoal chubs are found at depths around a meter, but found less often at depths greater than 1.45 meters. Tables 7.5 and 7.6 sort of suggest that the deeper the better. Couldn't you divide the **maximum** depth by 4; this would achieve equal-sized bins.

Table 7.6 appears twice?

Page 140

This pattern of increasing density downstream agrees, in general, with that found by Yu (1996), except that in 1992 he also found high densities of silver chub (1.25/100m2) at Columbus, NE. In contrast, Yu (1996) generally found densities of silver chubs along the Clarks to Louisville length of the Platte River to be below 0.5/100m2.

It would help those readers not familiar with the study area if river kilometers were used instead of or in addition to place names.

Table 8.2. Sturgeon larvae only collected at 3 lowermost river sites; care to speculate or mention that these fish probably drift into the Missouri R since they drift for 9-14 days? Could place in context by citing Kynard's and Braatens work.

Braaten et al. 2008. North American Journal of Fisheries Management 28:808–826

Abstract.—The drift dynamics of larval shovelnose sturgeon Scaphirhynchus platorynchus (1, 2, 6, and 10 d posthatch [dph]) and pallid sturgeon S. albus (1, 2, 5, 9, 11, and 17 dph) were examined in a natural side channel of the Missouri River to quantify the vertical drift location of larvae in the water column, determine the drift velocity of larvae relative to water velocity, and simulate the cumulative distance (km) drifted by larvae during ontogenetic development. Larvae were released at the side-channel inlet and sampled at points 100, 500, 900, and 1,300 m downstream. Larvae drifted primarily near the riverbed, as 58–79% of recaptured shovelnose sturgeon and 63–89% of recaptured pallid sturgeon were sampled in the lower 0.5 m of the water column. The transition from the drifting to the benthic life stage was initiated at 6 dph (mean length, 15.6 mm) for shovelnose sturgeon and at 11–17 dph (mean length, 18.1–20.3 mm) for pallid sturgeon. Across ages, the drift rates of larval shovelnose sturgeon averaged 0.09–0.16 m/s slower than the mean water column velocity. The drift rates of pallid sturgeon were similar to or slightly slower (0.03–0.07 m/s) than the mean water column velocity for 1–11-dph larvae. Conversely, 17-dph larval pallid sturgeon dispersed downstream at a much slower rate (mean, 0.20 m/s slower than the mean water column velocity) owing to their transition to benthic habitats. Drift simulations indicated that the average larval shovelnose sturgeon may drift from 94 to 250 km and the average larval pallid sturgeon may drift from 245 to 530 km, depending on water velocity. Differences in larval drift dynamics between species provide a possible explanation for differences in recruitment between shovelnose sturgeon and pallid sturgeon in the upper Missouri River.

Kynard, B., E. Parker, D. Pugh, and T. Parker. *In press* . Effect of Water Temperature, Water Velocity, and Swimming Height on Dispersal Distance of Pallid Sturgeon Early Life Stages. Proceedings of AFS Symposium on Pallid Sturgeon.

Kynard B.; Henyey E.; Horgan M. : Ontogenetic Behavior, Migration, and Social Behavior of Pallid Sturgeon, Scaphirhynchus albus, and Shovelnose Sturgeon, S. platorynchus, with Notes on the Adaptive Significance of Body Color

Environmental Biology of Fishes, Volume 63, Number 4, April 2002, pp. 389-403(15)

Abstract: We conducted laboratory studies on the ontogenetic behavior of free embryos (first life interval after hatching) and larvae (first feeding interval) of pallid and shovelnose sturgeon. Migration styles of both species were similar for timing of migration (initiation by embryos on day 0 after hatching and cessation by larvae on days 12–13 at 236–243 cumulative temperature degree units), migration distance (about 13 km), life interval when most distance was moved (embryo), and diel behavior of embryos (diurnal). However, the species differed for two behaviors: movement characteristics of embryos (peak movement rate of pallid sturgeon was only one-half the peak rate of shovelnose sturgeon, but pallid sturgeon continued the lower rate for twice as long) and diel behavior of larvae (pallid sturgeon were diurnal and shovelnose sturgeon were nocturnal). Thus, the species used different methods to move the same distance. Migrating as poorly developed embryos suggests a migration style to avoid predation at the spawning site, but moving from spawning habitat to rearing habitat before first feeding could also be important. Migrants of both species preferred bright habitat (high illumination intensity and white substrate), a behavioral preference that may characterize the migrants of many species of sturgeon. Both species were remarkably similar for swimming height above the bottom by age, and day 7 and older migrants may swim far above the bottom and move far downstream. A migration of 12 or 13 days will probably not distribute larvae throughout the population's range, so an older life interval likely initiates a second longer downstream migration (2-step migration). By day 2, individuals of both species were a black-tail phenotype (light grey body with a black-tail that moved conspicuously during swimming). Aggregation behavior suggests that black-tail is a visual signal used for group cohesion.

Table 8.2 and elsewhere in Chapter 8. Are larval flathead chubs (*Platygobio gracilis*) distinguished (or distinguishable) from Macrhybopsis?

Table 8.6. Fathead misspelled.

Page 181. These graphs suggest that more habitat is available during the spring and fall of the year than during the summer for shovelnose sturgeon. Over the last 50 to 70 years of record, from these gage records, it appears that there has been little suitable habitat for pallid sturgeon in lower Platte River during the summer season.

Isn't this corroborated to a large extent by your catch data? Moreover, because few sturgeon were captured during fall, doesn't this suggest that other factors such as thermograph and hydrograph, turbidity, photoperiod, or spawning condition, etc. are operating.

Page 182-183. Conclusion is logical, well summarized and well-written.

Page 200

We recommend continuation of telemetry efforts for pallid sturgeon in the lower Platte River to be a very prudent emphasis of continuing research. Any future studies in the Platte River should be coordinated with the efforts of USGS researchers that are using telemetry technology that allows depth and water temperature to be monitored during critical phases of the sturgeon's life cycle. Work in the Platte River could provide excellent opportunities to locate spawning sites for pallid sturgeon and then to monitor the fate of larval and juvenile life stages. It will also allow the evaluation of sturgeon stocking programs as these fish develop into adults.

Do we know what effect transmitter implantation has on spawning success of adult pallid sturgeon? At some point, I think we need to stop "studying these fish to death" and leave them alone to spawn. I have no issue with telemetering a portion of stocked fish, but wild fish need a chance to be wild fish so as to possibly achieve some natural reproduction.

Page 200

We recommend that the reactions of pallid sturgeon to water discharges from a variety of sources, especially those related to water treatment facilities, be developed to evaluate the effects on pallid sturgeon populations and life histories.

Yes, but first and foremost, I recommend that potentially harmful or disrupted discharges be minimized or eliminated.

Page 201.

We recommend that chub populations on the lower Platte River be monitored as indicators of habitat changes that may be linked to the habitats needed by sturgeon species.

I like this idea. The benefit of this is that you leave the sturgeon alone to some extent and gather ecological information on the r-selected species that can withstand intensive monitoring.

We recommend a continuation of larval and juvenile fish sampling in coordination with the ongoing efforts on the Missouri River. A potential benefit from this coordinated effort would be the ability to compare sturgeon spawning success in the relatively natural instream habitats of the Platte River with that of the highly modified Missouri River. This comparison may aid in understanding the early life history dynamics limiting the overall recovery efforts for pallid sturgeon (Quist et al. 2005).

I think it is important to consider the two rivers as a single, connected ecosystem. It is important to understand the fate of sturgeon larvae spawned in the Platte and subsequently drifting down in to the Missouri. What becomes of them? What habitat and food resources awaits them as they cease drifting and begin to feed actively? This could, as we suspect in the upper basin, be a bottleneck for pallid sturgeon recruitment.

Summary of review.

This document summarizes a vast amount of data. It is well-written for the most part; I have pointed out specific areas that were hard for me to understand. Yet, perhaps comprehension is hindered because of its bulk; perhaps some data could be placed in appendices to make it easier to read. Moreover, there appears to be no overall executive summary or abstracts or conclusions for each chapter with the exception of Chapter 9. Summaries and conclusions sections would enhance compression of this vast document.

Introductory sections (e.g. for Chapter 4) do not seem to place the problems in clear focus. Some of this is necessarily speculatory, and may be beyond the scope of the written objectives, but would help distill the situation. For example, in Chapter 4, has there been a decline of pallid sturgeon in the Platte River, what may have led to the decline, and what is the relationship between the Platte River and Missouri River pallid sturgeon stocks? What are the implications of larval pallid sturgeon drift? Why are shovelnose sturgeon more common than pallid sturgeon? What limits this population?

The major methodological concern I have relates to characterizing habitat availability and the normalized selected habitats analysis. It is not clear how well the IFIM transects characterize availability. Habitats were not sampled randomly, yet the normalized selected habitats analysis seems to assume that they were, which generates potentially misleading results (i.e., normalized selected habitat tables). Other potential issues involve the implication that fish select for water chemistry variables, that macroinvertebrate drift samples represent benthic macroinvertebrate availability.

Review of:

Peters, E.J. and Parham, J.E. (2007 - draft). Ecology and Management of Sturgeon in the Lower Platte River, Nebraska. Nebraska Technical Series No.18. Nebraska Game and Parks Commission, Lincoln, Nebraska.

Prepared By:

Richard M. Engeman, Ph.D.

October 31, 2008

General Comments
I had reviewed an earlier version of a similar report, and as with that version, I was asked to review this draft report from a statistical perspective. I have a number of comments to make, but I do not dismiss that this report is a compilation of a large multi-year, geographically dispersed effort carried out by many dedicated people. As before, my personal objective for the review is to help insure maximal value from that effort through clear and valid presentation and interpretation of the data collected from that effort.

I will focus on:

1. Clarity in description of experimental designs, methods, analyses, and inferences, with each of these elements building blocks for the validity and clarity of the succeeding ones.

2. Appropriateness of study designs for meeting objectives.

3. Appropriateness of analytical methods, given the study designs and the data collected.

4. Appropriateness of the inferences, given the above and the experimental results.

One general observation is that the organization and clarity of the report is much better. It is much more readable and understandable. Many of my recommendations for the previous draft were incorporated into this one. Also, many were not.

As with any field study involving animals, there are often situations that challenge the best of experimental designs, and I try not to be too critical of things outside the investigator’s control. However, the inferences derived from analyzing those data must still be appropriate, justified, and valid.

The report is organized by chapter and I organize my comments accordingly. Each comment will directly refer to specific lines or sections within the chapter under discussion.

One general trend in the report is that an objective would appear to be satisfied through a statistical description. However, statistical tests would often also be applied. This may seem strange coming from a statistician, but unnecessary statistical tests can distract from the message. Just because the data are such that a statistical test can be applied does not mean it should be applied, unless that is useful for meeting the objectives. If one knows that he is dealing with apples and oranges to begin with, a statistical test saying they are different does not add much information, but does open the process to scrutiny concerning the validity of the procedures applied. It seems that a statistical description of the entities known to be different provides the reader with appropriate and sufficient information. There are several places in the report where I will question why statistical tests were done when it was known in advance that the things being compared were different. Given that they were known to be different, it would be more directly informative to the reader to have a thorough description of each.

Although improved from the earlier draft I reviewed, I still found numerous places where statistical methodology was incorrectly described, incorrectly applied, or invalid. There are also places where analyses were conducted, but without justification.

Chapter 1: General Introduction

Examination of the objectives on page 20 reinforces the comments made about only applying statistical tests if they are necessary. Most of the objectives state "… was to document …" and only occasionally imply a comparison would be needed.

The chapter itself is a good introduction.

Chapter 2: Overview of field methods, catch and a comparison of gear effort.

The presentation of the information in this chapter is much improved from the earlier draft I saw. Not only can the reader much better understand the equipment and methods, but the organization of the information adds much clarity to the report as compared to the earlier draft. There still are a number of areas needing attention in this chapter.

<u>P 30, Gear Comparisons</u>: the gear descriptions state that different gear types are constructed differently and used to sample different habitats. I think it is valuable to describe and summarize what each gear type was sampling. I see nothing in the report that indicates a need to make statistical comparisons among gear types and habitat variables.

<u>P 30, Gear comparisons</u>: For technical correctness minor changes are needed in the sentence beginning “First the median and 25% and 75% values ….” Instead of 25% and 75%, it should read “25th and 75th percentiles.”

<u>P 30, Gear comparisons: “Depth and mean column velocity was [it should be “were”] analyzed using a bivariate table with four categories of depth and four categories of mean column velocity”</u>: Why were the data categorized? What were the categories? These are basic questions that need to be explained in the methods.

<u>P30, Gear comparisons, the rest of the page beginning with “Gear selection of the depth…”</u>: This is difficult to follow what was done, and even more difficult to follow why. It seems the data manipulations lead further from reality, including situations with a potential division by zero. In the cases of division by zero, a zero was substituted. Typically, division by zero is considered to be an infinite value, so I would need to see a solid justification for substituting zero for infinity. Most of all, I would like to see why any of this is needed.

<u>P31, Gear comparisons, last paragraph</u>: Again, why do these tests need to be carried out? What were the groups for which the means were being compared? Given that the described statistical tests were applied, were there any inherent comparisons of particular interest? I would think that would be the case. If so, linear contrasts would be a much preferable method for comparing group means. Lastly, the Kruskal-Wallis test is a one-way layout, but it is not an analysis of variance. The test does not compare means, as stated.

<u>P31, Results and Discussion, first two full paragraphs in second column coupled with Tables 2.5 and 2.6</u>: The paragraphs refer to the results in Table 2.5 and 2.6. The last line of the tables inappropriately combines fish capture data from multiple methods to form average values. The averages incorporate varying sampling efforts between different sampling methods. Thus, for one month or

year to show a different average value from another month or year could be entirely due to the relative sampling efforts from the different methods instead of any trends among years. The last line of the tables and all references to them should be deleted.

<u>P54, first paragraph</u>: A minor point, it is less redundant and reads better to change "The bivariate analyses…" to "The analysis …"

<u>P54, second column</u>: The paragraphs in this column provide good descriptions of what the various gears sampled. In the middle of it are the results of the various pairwise comparisons, which only serve to distract from the informative. I don't see any application for the information from those tests, whether differences are found or not. Therefore, I recommend deletion of the following portions from this section:

> "…pairwise comparisons showed most gears sampled different velocities on average." (By the way, most tests apparently were Kruskal-Wallis tests, so average velocities were not compared)
>
> "…seines were different from all other gear types and trammel nets were different from trotlines and shovelnose sturgeon tracking."
>
> "…most gear types were different with the exception of drifted gill nets, seines, and trawls were not different, and drifted trammel nets were not different from trawls and shovelnose sturgeon tracking."

<u>P55</u>: The paragraphs at the top of p 55 continue more of the same issue described for p 54. I recommend deletion of the following portions:

> "…most gear types were different with the exception of drifted gill nets, drifted trammel nets, and seines, and trotlines and trawls." (Note, even if this was useful, it would be very unclear)
>
> "…drifted trammel nets and drifted gill nets were different from shovelnose sturgeon tracking, trotlines, and seines. Trawls were different than trotlines and shovelnose sturgeon tracking."

<u>Tables 2.23, 2.26, 2.30, 2.34, 2.38, 2.42</u>: Although the headings are probably understood, it is still more technically correct to change the column headings "25%" and "75%" to "25%tile" and "75%tile."

<u>General comment on Results and Discussion section</u>: For the most part, I found I could enjoy reading the section and get a good picture of the situation, as long as it didn't involve the series of unnecessary pairwise tests. Statistical testing often seemed unnecessary and convoluted, and in some instances as indicated above,

the data seemed transformed away from reality. Moreover, I don’t see a use for the test results beyond what is provided by the adequate descriptive statistics.

Chapter 3: Ambient river habitat conditions in the lower Platte River, Nebraska

<u>PP72 – 73, Substrate section</u>: For all sites but the Salt Creek Site in this section, the second paragraph presents the results of more pairwise multiple comparison procedures. However, no such procedures are described in the methods section. Therefore, I have no means to evaluate whether the procedure was appropriate and applied correctly. I would also like to know how the information from these tests would be used - before the next-to-last paragraph of the chapter.

<u>P80, next-to-last paragraph</u>: Again, there is reference to an undescribed analytical procedure. Also, if the test is maintained, it would be better to remove the word “significantly.”

Chapter 4: Habitat use, movement and population characteristics of pallid sturgeon in the lower Platte River

General comment: I like the general description approach up through most of page 89.

P89, Habitat analysis, last line: The sentence beginning "Differences between the mean habitat…" is incorrect. The Mann-Whitney test does not compare means. It compares whether two samples of observations come from the same distribution.

P90, 2nd line: The phrase "…using Mann-Whitney t-test …" is incorrect. The Mann-Whitney test is not a t-test. It is a non-parametric test, and as stated above, it does not compare means as a t-test does.

P90, 9th line of text: Delete "The pairwise comparisons showed the" and begin the sentence with "Nets where …"

P90, statistical comparisons in second column: The comparisons are confounded with year and therefore not valid. That is, any effect you show cannot be determined whether it was due to the effect tested or to due to the different sampling regimens among years. Note that the same problems exist in this paragraph concerning incorrect descriptions of what the Mann-Whitney test is comparing. I consider that a moot point because the analyses as constructed should not even be conducted. The only way I could see to make comparisons would be to restrict analyses to only 2004 data. As indicated in that section of text, sample sizes are very small, making inferences tenuous. Therefore, it would be wisest to just stick with the descriptive statistics.

P92, first full paragraph: Change the word "truncated" to "restricted."

P92, last paragraph: Shouldn't "… 1 of 1 gill nets …" be "… 1 of 1 gill net …"?

P93, 1st line: Insert "caught" so it reads "Of the 15 pallid sturgeon caught…"

P98, 1st 3 lines: The sentence beginning "The relationship …" is incorrect. A correct phrasing option would be "A linear relationship between length and K(FL) was not detected…" I don't see what would be done with this information anyhow. If that can't be answered, it would be better to leave it out.

P98, first paragraph: Delete the word "significant" in general.

Chapter 5: Habitat use, movement and population characteristics of shovelnose sturgeon in the lower Platte River

P102, first paragraph under Habitat Use: The assumption characterized in the sentence “For telemetry data, each random observation was considered to be independent even when gathered on the same fish on different days” is inappropriate. They are not independent and should not be assumed to be so. Alternative methods should be considered. The only way this assumption would not damage the inferential strength from the analyses would be if sample sizes for all fish were the same or nearly the same.

P102, first paragraph under Habitat Use, last line: The text “25% and 75% values ….” should be replaced “25th and 75th percentiles.”

P102, the paragraph under Associated Species: It is stated “We considered that those species which were captured more frequently with the shovelnose sturgeon to be more highly associated than those which were less frequently captured with shovelnose sturgeon.” This assumption is only true to a degree. The relative availability of the other species must be considered to truly assess what species are associated with shovelnose sturgeon.

P103, top of first column: The phrase “… to calculate daily movements …” is more correct written as “… to calculate average daily movements …”

P103, Population Density paragraph, specific comment: Refine the text “…radio tagged shovelnose sturgeon at a location” to “…radio-tagged shovelnose sturgeon known to be at a location”

P103, Population Density paragraph, specific comment: Instead of “25% and 75% percentile”, it should read “25th and 75th percentiles.” What is the justification for considering the 25th and 75th percentiles as lower and upper bounds instead of any other percentile levels?

P103, Population Density paragraph, general comments: The calculation for shovelnose sturgeon density appears to assume that all river habitats are equally likely to hold shovelnose sturgeon. The data were obtained by placing capture devices at sites perceived as optimal sturgeon habitat. Therefore, this density estimate is likely to be biased high.

P103, 2nd column, last paragraph: Remove the text “pairwise comparisons showed that.” Begin the clause with “fish were…”

Tables 5.1, 5.6, 5.11, 5.16, 5.24: As before, it is more technically correct to change the column headings “25%” and “75%” to “25%tile” and “75%tile.”

<u>P108, 2nd column, last line</u>: What was the median number of surveys among the sturgeon?

<u>P118, 2nd column, top section</u>: As indicated above, I believe these estimates are likely to be biased high.

Chapter 6: Food habits of shovelnose sturgeon in the lower Platte River

P122, 2nd column, last paragraph of methods: Change “significance” to “a difference.”

P123, entire page: remove the word “significant.”

Chapter 7: Habitat use and population characteristics by chub species (sturgeon chub, shoal chub, silver chub and flathead chub) in the lower Platte River

P128, 2nd column, Habitat Use 2nd paragraph: As for the same analyses "described" in chapter 2, the methods and justifications are obtuse and I restate the issues. Again, it is difficult to follow what was done, and even more difficult to follow why. It seems the data manipulations lead further from reality, including situations with a potential division by zero. In the cases of division by zero, a zero was substituted. Typically, division by zero is considered to be an infinite value, so I would need to see a solid justification for substituting zero for infinity. Most of all, I would like to see why any of this is needed.

P128, 2nd column, Population Density paragraph: I believe this might be an index of density, and possibly reliable, but I don't believe it is an estimate of density. It is unknown what proportion of the populations in the sampled areas are represented by the numbers of fish captured at each trawl run. Also, this method for estimating density assumes the sampling sites are random samples of the river, which they are not.

P129, Results and Discussion, 1st line: Change "at" to "from."

P124, 140, Length-Weight sections: Delete the word "significant."

P135, 140, 142, Population Density sections: As indicated above, the values are at best indices of density, not estimates.

P142, Reproductive Status section, 1st line: It states that 16 flathead chubs had their gender determined, with 4 females and 8 males. What were the other 4?

Chapter 8: Phenology and relative abundance of larval fishes in the lower Platte River

P144, column 1, last paragraph: The sampling description is awkward, and it is difficult to determine exactly what the procedures were. What is meant by regular sampling? What is meant by "time for regular sampling" – time of day, time of month? Was this time randomized each month? If so, then it can't be "regular" sampling.

P148, 157: The photographs are not labeled with a figure number for reference in the text.

Chapter 9: Creel survey in the lower Platte River

I only have one minor comment for this chapter.

P173, last paragraph, 2nd line: Remove the word “past.”

Chapter 10: GIS models of habitat type availability, river connectivity, and discharge in the lower Platte River

I have many problems with this chapter concerning the description and application of the modeling procedures. I raised many of the same questions when I reviewed the earlier draft, and they don't seem to be addressed in this version

I find this chapter very difficult to follow and evaluate. Not enough information is given on methods or rationale to evaluate the procedures. I cannot deduce the path that led to the results. I will highlight the problems below. Many are repeated for each modeling effort.

<u>P175, last paragraph</u>: What is the meaning of the sentence "To develop the relationships between habitat quantity and discharge, the curve of best fit was solved for the data using Table Curve 2D 5.01 (Systat 2002)"? It says "The selection of the most appropriate curve followed methods outlined in the curve fitting software." What were the curve fitting methods? Given the results, it has to be a nonlinear model fitting procedure. Usually, there is a reason for considering a particular functional form, especially when the forms end up being as nonlinear and complex as those given in the results. What candidate model forms were considered going into the model selection process, and what was the rationale? Is this a black box approach where the data is thrown into a program and a model somehow emerges? Was the adjusted r-square the only criteria for model selection? If so, that would tend to result in over-parameterized models. Usually, model selection procedures such as Akaike's Information Criterion (commonly referred to simply as AIC) are applied, where reductions in residual variation are rewarded, while increases in parameterization are penalized. How were the equations "adjusted" together in a spreadsheet to total 100% discharge rates?

<u>P176, last paragraph</u>: Explain why the four habitat variables were compared using a t-test, with only those showing a difference used in habitat selection analysis. What is considered to be a "statistical difference?" If it's $p < 0.05$, then why is that a suitable criterion?

<u>P178, first paragraph</u>: What chi-squared test was used? The test statistics from many statistical tests are distributed as a chi-square. What test was used to compare habitat use to availability? Was it a goodness of fit test? What data points were actually used in the test? My same comments as above apply to the curve fitting.

<u>P180, 2nd column</u>: What was the basis for even considering these equations? They are very complex and nonlinear. I would expect that the parameters in the equations would relate to a real world interpretation (functional model). Otherwise, why would such models be considered and, where did they come from? How do variables such as depth and velocity relate to the equations?

P181, both columns: My same comments as above apply to these models also.

P181, 2nd paragraph: I can't determine what was done to "simultaneously correct" the curves. I also cannot tell how these curves were subsequently applied.

P181, 3rd paragraph: Remove the word "significant."

P181, 4th paragraph: What exactly is the procedure with the data "…records from the radio-tracking studies on shovelnose and pallid sturgeon were grouped into even sized bins and compared to habitat availability in the transect data"? I cannot follow what was done. What are the even sized bins? How subjective was the size of the bins? What is chi-square selectivity analysis?

P181, general: It seems that most of what is stated so far in the chapter was already indicated from the previous empirical results. In my mind, manufacture of a series of not-well-explained equations serves to detract from the clarity of the results.

P182, 1st paragraph: Same comments on the modeling as above.

P183, last paragraph: Typo "fo ster" should be "foster."

P193, fig 10.17: The fitted model seems to indicate systematic error around a discharge of 5000cfs.

Chapter 11: Management recommendations for sturgeons and chub populations in the lower Platte River

I only have one minor comment, a typo.

<u>P201, Chapter 5 Recommendations, last line first paragraph</u>: Typo “that” should be “than.”

My Conclusions

I recognize that considerable effort went into compiling the data and writing this report. The purpose of a critical review like this is to identify weaknesses so that they may be corrected or improved. I was a reviewer for an earlier draft and find this version a substantial improvement. However, I also found a number of areas where the experimental methods were not clearly described; quantitative methods were not described, or were incorrect or inappropriately applied; or rationales for the methods were not readily discerned. Chapters 2 and 10 are in particular need of attention, with chapters 4, 5, and 7 also in need of attention. All of these issues can detract from the credibility of the final messages. I believe the authors were immersed into the study to such a depth that their impressions are, by and large, correct. I would like to see a more solid foundation in analytical methods and inferences to support their conclusions. I am willing to answer questions as I can about my review.

D R A F T
COMPILED PEER REVIEW OF ALL REQUESTED REPORTS

January 2, 2009

Jaron J. Bromm, Esq.
Fennemore Craig, P.C.
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Denver, Colorado 80203

Subject: Transmittal of compiled peer review of hydraulic, hydrologic, and geomorphologic aspects of:

(I.) "Chapter 10 - GIS Models of Habitat Type Availability, River Connectivity, and Discharge in the Lower Platte River," contained in the 2007 report, *Ecology and Management of Sturgeon in the lower Platte River, Nebraska, Draft No. 1,* (Ecology Report) Nebraska Technical Series No. 18, by E. Peters and J. Parham,

(II.) Chapter 1, in the 2007 report, *Hydrologic Analysis of the Lower Platte River from 1954-2004 with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon*, by J.E. Parham, Bishop Museum, Honolulu, HI (Hydrologic Analysis Report),

(III.) "Chapter 11 - Management Recommendations for Sturgeon and Chub Populations in the Lower Platte River," from *Ecology and Management of Sturgeon in the Lower Platte River, Nebraska, Draft No. 1* (Ecology Report) Nebraska Technical Series No. 18, 2007, by E. Peters and J. Parham, and

(IV.) DRAFT Biological Opinion (DBO), October 19, 2007, by Nebraska Game and Parks Commission.

Dear Mr. Bromm,

At the request of the Lower Platte Basin Coalition of Proponents of Sound Science for Lower Platte River (Coalition), HDR Engineering, Inc. has completed a peer review of the four subject reports. Only the hydrologic, hydraulic and geomorphologic (channel dynamics) aspects of the reports are reviewed, and only for the "study reach," defined as the reach from the confluence with the Loup to the confluence with the Missouri (p. 1-1, Hydrologic Analysis Report). After a brief section that compares the 2007 and 2005 DRAFT Ecology Reports, separate sections describing the results of the peer review of the above four documents are provided.

COMPARISON OF 2007 DRAFT ECOLOGY REPORT WITH 2005 DRAFT PREVIOUSLY REVIEWED BY PARSONS/EA

Chapter 10 of the subject Ecology Report has the same title and overall layout and content as Chapter 9 of the earlier, 2005 Draft Ecology Report and Chapter 11 of the 2007 report has the same title and

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overall layout and content as Chapter 11 of the earlier 2005 Draft Ecology Report. The earlier report was peer-reviewed in 2005 by Parsons Water & Infrastructure and EA Engineering, Science, and Technology, Inc. Parsons' and EA's combined peer reviews of Chapter 9 and relevant portions of Chapter 11 of the 2005 report were submitted to Mr. Kirk Nelson at the Nebraska Game and Parks Commission on August 9, 2005. Copies of that letter are available on request. No NGPC acknowledgement of, or responses to, the letter were subsequently received by Parsons or EA. The latest versions of the Ecology Report made no reference to the Parsons/EA peer review nor did it appear that the review had been provided to the authors.

The Parsons/EA letter also included a list of over 50 questions about the earlier report that they hoped would be addressed by the authors, either by directly responding to Parsons/EA or by addressing them in the next version. Despite not having access to the authors to answer the questions, the Parsons/EA letter included several general comments and observations.

A side-by-side comparison of the two drafts (Ch. 9 from 2005 and Ch. 10 from 2007) reveals that even though somewhat reorganized and including two new figures, virtually no new information is contained in the 2007 draft. The management recommendations found in Chapter 11 of the 2007 report are similar to, but more detailed than, the Parsons/EA peer review of Chapter 11 of the 2005 report.

The DBO begins (p. 2) by stating that the 2005 studies were "peer reviewed by numerous professionals in the field of sturgeon ecology, environmental science and statistical evaluations." Part of the report, primarily Ch. 10 in the 2008 version and Ch. 9 in the 2005 version, addressed fields of hydrology, hydraulics and geomorphology, which are the root of the final Opinion written by the NGPC. Yet there is no mention that the earlier studies (and presumably the 2007 Ecology Study and Biological Opinion) were peer reviewed by professionals from either discipline. It is concluded that the earlier Parsons/EA review and the current HDR peer review reports are evidently the only available peer reviews by professionals in the critical disciplinary fields that became the foundational technical basis for the BO.

Thus, the questions and observations transmitted to Mr. Nelson in 2005 remain unanswered. In addition to the content of HDR's review below, the Coalition is advised to consider including the Parsons/EA letter as a relevant part of the peer review of the Ecology Report. The Coalition is also advised to treat the absence of NGPC's response to the earlier questions and comments as a continuing objection to sharing of scientific information among all stakeholders which would be consistent with the Coalition's and NGPC's sound science objective.

I. AND II. REVIEW OF 2007 DRAFT ECOLOGY REPORT AND 2007 HYDROLOGIC ANALYSIS REPORT

The following 13 subsections provide lists of HDR comments considered to be the primary hydrologic, hydraulic and geomorphologic flaws in Chapter 10 of the recent version of the Ecology Report and in Chapter 1 of the Hydrologic Analysis Report. The comments on these two reports are combined in this section because they are companion reports, developed concurrently and having essentially the same objectives. Defects 1 though 10 generally address the Ecology Report, and 11 through 13 are more applicable to the Hydrologic Analysis Report, although both are mentioned throughout.

Fundamental Defect 1. The Investigators do not Appear to be Trained in Geomorphology

1. The qualifications of the authors of the Ecology Report to practice in the fields of geomorphology, hydrology and fluvial hydraulics are not provided. Numerous evidences strongly suggest that the analyses in the two reports were not performed by someone trained in these fields. The flaws disclosed below also reveal that conclusions are made that are not only incompatible with standard literature but also contradict facts and findings in other peer-reviewed, published studies of physical processes in the lower Platte River.

2. The primary interpretation of the aerial photos, which are a significant portion of the data utilized in the reports, was performed by a technician, probably a GIS technician. That person's qualifications in hydrologic and geomorphic assessments are not stated, but as shown in several locations below, decisions were made by the technician during his or her work that reveal that the person lacked training in hydrology, geomorphology and fluvial hydraulics.

3. Almost all of the sections below, and items described within each, demonstrate that it is easy to conclude that a qualified fluvial hydrologist/geomorphologist did not participate in the data collection, analysis, interpretations, conclusions, or recommendations for management. Among other flaws described below, this clear absence of necessary and sufficient qualifications of the technician to interpret 20,000 ft imagery, and the decision to use 20,000 ft imagery as anything close to being acceptable to propose rigid management of future river flows should be considered as a primary cause for the Coalition to disallow the findings.

Fundamental Defect 2. Channel Morphology Is Not a Singular Function of Discharge

1. The study design and draft reports place total reliance on the assumption that the relationship between in-stream habitat, as defined by hydraulic parameters, and discharge rate is "singular." A singular relationships in nature is one that can have only one outcome (habitat) for each discharge. This is not consistent with the body of knowledge of morphologic channel-forming processes of braided rivers. The error made is that the authors assume that the channel geometry and braided morphology of the study area on any given day can be described by, and more importantly, predicted by a single parameter, the daily discharge rate that happens to be flowing through the area that day.

2. Nothing in the body of knowledge on geomorphology suggests that river morphology for a braided river at any point in time is a function of just the daily discharge that happens to be flowing through any segment on any given day. By stating that future flows must be regulated to match flow rates on particular days when habitat existed, the authors reveal the deficiency in understanding this point. Instead of being singular, stream geometry is the time-dependent result of many other

factors, particularly antecedent conditions leading up to the day when an observed flow is passing through the reach. The morphology (and habitat) at any cross-section or within any reach is categorically not the result of the discharge that day *as implied throughout the subject reports, including the Opinion*. A channel shaped by fluvial processes can experience the same morphology for a wide range of discharge rates, and any single flow rate can pass through a variety of geometries.

3. The report also places emphasis on an implied, singular relationship between discharge and channel geometry, and similarly assumes that the cross-sectional geometry can be described by, and predicted by, one parameter, daily discharge. While rigid-bed hydraulics supports this, the science of fluvial hydraulics does not. It should also be noted, as described in more detail below, that universally-accepted relationships between discharge and channel geometry parameters (depth, width, area) for either fixed or mobile bed channels were not applied in developing the relationships, yet the literature is amply supplied with models and methods of studying river mechanics using these broadly accepted, and widely applied techniques. The investigators lack of training in these fields probably kept them from adopting standard technologies.

4. Instead of being governed by a single discharge passing on any given day, standard literature on rivers in general, and on the Platte and lower Platte in particular, is unanimous in proving that the channel morphology is formed and maintained by the “dominant” or “effective” discharge. These are similar terms describing that flow rate, or range of flow rates, which transport the greatest amount of sediment, and logically shape it. For braided rivers, these ARE NOT the bankfull flow or 1.5-yr flood rates!

5. Marlette and Walker (1968) studied the channel-shaping processes at the Missouri River confluence with the lower Platte (the fact that their publication was peer-reviewed is extremely relevant), and the USGS and others (USGS 1981 &1983; HDR 1983; Parsons 2003) have supported the principles of effective discharge as being fully applicable in defining channel geometry throughout the Platte and lower Platte River. Yet the Ecology Report fails to cite these investigations or apply the standard methods and principles adopted by other scientists in relating channel shape with the discharge hydrograph. Instead, the assumption is made that both habitat and channel geometry are formed by, can be described by, and can be predicted by, a single measure (the serendipitous daily discharge passing by on any given day). It is further assumed by the report authors that this relationship is singular, and that the singular relationships can be best and adequately described on the basis of statistical curve-fitting (Systat 2002) versus physical-process analysis and analogs.

6. Even stage-discharge relationships used by USGS and others to convert river stage (a measure of depth) to discharge are non-singular, frequently requiring adjustments to keep up with the morphologic changes. The histories of required shifts in the stage discharge curves at rating stations in the study area are available from the USGS.

Fundamental Defect 3. The Relationships Derived Cannot be Used to Predict Habitat Change due to Changes in Discharge

1. Paragraph 1 on p. 174 concludes by saying the two models developed by the authors allow one to "view quantity and accessibility of instream habitats with respect to *changes* [emphasis added] in river discharge." It is implied by this statement that the tools would be useful in assessing habitat impacts if discharge on some day of a future year is different than the discharge rate observed during this study. The validity of the tools to provide useful information for flows observed during the study is questioned, but the claim that the tools can predict "changes in" morphology or habitat is particularly inappropriate in light of the non-singularity principle. Even if it is assumed for discussion purposes that the relationships are accurate, they can only provide measures of habitat availability as functions of discharge on a day when daily discharge matches the data value *and when all other antecedent conditions have been duplicated leading up to that particular date*. It needs to be stressed again that the derived relationships are not useful in predicting impacts of changes in discharge, because the relationship between morphology and discharge is not singular.

2. Habitat observed on any given day is not simply the result of flow that day. Principles of fluvial geomorphology state that the channel form (and hydraulics) are the result of short- and long-term antecedent conditions leading up to the date of observation. It cannot be concluded that the difference between the habitat values at two different discharges represents the impact on the habitat if the flow was changed somehow by an amount equal to that difference. The report's derived statistical relationships show the values of quantity and accessibility during specific occasions of discharge, each of which incorporated very different antecedent conditions (time of year, temperature, impact of previous flows leading up to the measurements, etc.) that resulted in the conditions measured. It cannot be concluded that a change in discharge from value A to value B on those same dates would result in quantities of habitat or accessibilities equal to those measured under different antecedent conditions occurring for discharges A and B.

3. The relationships developed in the report at best "connect the dots" between discharge values for highly variable antecedent conditions, but it would be unscientific to conclude that the relationships can predict the quantity and accessibility of habitat if discharge value A is changed to discharge value B on any given day for which value A was previously observed. Events leading up to the habitat that existed under discharge A for prediction of habitat at discharge value B (i.e. a *change* from A to B), with the exception of the flow rate, would need to be identical to those producing habitat at previously-observed discharge value B, which probably occurred on a different time of year and under different antecedent and ambient conditions. This failure to recognize the non-singularity of these processes has resulted in costly development of a tool that has no predictive utility whatsoever for use by the managers of these resources.

Fundamental Defect 4. 20,000 ft Imagery cannot possibly be used for Management Decisions

1. It is questioned whether any legitimate scientific study, particularly with recommendations that the results be used for flow management, can be conducted and results quantified, from 20,000 ft over 103 miles of river with five habitat land-use classification groupings. In describing the use of this high-altitude data, the authors note that exposed sandbars were areas that "appeared to be" above water, and that open water was defined by water "too deep to see the bottom." This important, strictly "visual" and highly subjective classification was done by a single research technician and checked by a single supervisor, which leaves much open to questioning its scientific value. Scientific analysis requires that results and interpretations can be objectively replicated, which would not be possible under these subjective conditions.

2. Further, there is no reference to standard imagery classification literature, nor any mention of ground-truthing of the classification method applied by the technician. The literature on applications of GIS methods for classification of land uses requires that ground-truthing be performed particularly before any attempt is made to propose that management decisions be made using the results. To illustrate the importance of this missing element, the land use classification method applied by CALMIT for the COHYST project had stringent requirements for ground-truth validation through several available methods that do not require that the GIS technician observe or monitor the sites on dates of the imagery. These alternate methods were used and proved that the classification met standard requirements. The entire COHYST project should, and would be rejected by the scientific community without this validation.

3. A standard for studies involving GIS-related interpretation of imagery and classification of land uses, especially in cases where the results may be used in making management decisions, should be validated by sampling of a portion of the remotely-viewed area to test the accuracy of the classifications. There was no indication that this had been done. Because time cannot be reversed, other sources of channel conditions under various discharge rates such as USGS streamflow measurement notes could have, and should have, been researched.

4. The NGPC transect data were used to define "quality" of the habitat for only open water and shallow sandbar complexes. This means that the entire investigation and conclusions drawn for the other three habitat classifications relied completely on the technician's interpretation of imagery at 20,000 ft. Stated another way, three-fifths of the data and interpretations are too subjective to be relied upon. Yet the study conclusions and recommendations for management infer that the results for all habitat types are equally valid.

Fundamental Defect 5. Highly Relevant Literature by Other Investigators Disagrees with the Ecology Report Findings

1. Probably one of the most relevant, scientific studies of physical processes related to sand bars and braiding of the lower Platte was conducted and published after peer review by a University of Kearney professor (Smith 1971). No mention of his work is made in the report, nor are the results of the studies consistent with his findings. His work was done by detailed observations made in the

river, not at 20,000 ft. In fact, no mention of actual on-site observations of habitat or ability to replicate results are made in the reports reviewed, which violates all standards for scientific investigations.

2. Among other inconsistencies of the remotely-sensed information with on-site studies by Smith, the description of Figure 10.1 on p. 175 of Ch. 10, showing development and then dissection of transverse bars over the span of time depicted in the figure, is identical to the processes described by Smith but not referenced in the reports. A number of inconsistencies of the Ecology Report with Smith's scientific findings are described in some of the remaining discussions of other flaws below.

Fundamental Defect 6. With the Exception of the Mouth, the Hydrology, Hydraulics and Morphology of the Study Reach is Not Consistent with the Hydrology, Hydraulics and Morphology Identified as Favorable Sturgeon Habitat

1. A key conclusion of the study is that sturgeon prefer deep, swift water (Ch. 10, p. 183). Numerous citations in both reports describe the lower Platte as braided, where adverse morphology shifts like those alleged to have occurred in the central Platte "have yet to occur in the lower Platte" (p. 1-1, Hydrologic Analysis Report). Earlier in the Ecology Report, page 178, the lower Platte is described as a "shallow, sandbed" river. This preference of sturgeon for "deep and swift flow" is not characteristic of braided streams, and most scientists familiar with the lower Platte would be surprised to hear it being characterized historically or now as a deep, swift river. The aerial photos on pages. 85 and 179 of the report illustrate this point. Inconsistencies regarding preferences for deep, swift water contrasted with known lower Platte characteristics occur at other locations in the Ecology Report and Draft Biological Opinion.

2. The data for habitat (Fig 10.14) suggest at best that less than 50 percent of the lower Platte is suitable for shovelnose sturgeon and only 20% is suitable for pallid sturgeon for any flow less than about 6,000 cfs. The historical mean and median daily flow in the lower Platte at Louisville are 6,939 cfs and 6,170 cfs, which implies that if only 20% or the reach is suitable for pallid sturgeon, it would be 20% suitable only about half the time. This doesn't seem to support the allegation that this is acceptable habitat.

3. A cursory review of Chapters 4 and 5 in the Ecology Report suggests that little use of the lower Platte by pallid sturgeon occurs above the confluence with the Elkhorn River (p. 86 and others). It is also noted that pallid sturgeon entry to the Kansas River at its mouth is documented only during floods. It could be concluded from this that the study should probably have been restricted to the reach below the confluence with the Elkhorn, or perhaps only at or near the mouth of the Platte, with special and perhaps more-detailed focus (lower altitude flights, lower flows, more on-ground truthing) of habitat availability and suitability in this reach. Extending the study upstream to Duncan, and making management recommendations for the entire segment below Duncan, seems to be overreaching. These statements about the reach above the Loup are inconsistent with the finding on p. 183 that the natural spring rise in discharge, which the authors describe as being "provided by

the Loup and Elkhorn Rivers," and conclude that these headwater sources allow the migratory movements.

4. Attempts to fortify the presupposition that the lower Platte is, or should be converted into, pallid sturgeon habitat is further refuted in the last paragraph on p. 181 of the description of the habitat suitability model that over the last 50 to 70 years there has been little suitable habitat for this species during the summer season. The conclusion on p. 182 of Ch. 10 that open water habitats "are the primary habitats for sturgeon," especially pallid, and the previous conclusion on p. 181 about the last 50 to 70 years, do not appear to be consistent with the entire thesis of the study that the Platte from Duncan downstream is suitable habitat or that it should be managed for use by this species.

5. The National Research Council report (2005) contains several conclusions such as the preference of sturgeon for "large turbid rivers" that refute the Ch. 10 conclusions about the suitability of the study reach from the confluence with the Loup to the confluence with the Missouri. See also Fundamental Defect No. 13 below.

Fundamental Defect 7. The Tools are Not Applicable to Terns and Plovers and Not Transferable to Other Rivers

1. The conclusion on p. 182 of Ch. 10 that the study results can "obviously" be extended to predicting suitable habitat for plovers or least terms is neither obvious nor consistent with fluvial geomorphologic principles. Nothing in the data or study methods established a link between the daily discharge and the physical process of sand bar formation and desiccation. Both, in fact are known to be functions of the effective discharge and other factors such as antecedent conditions and vegetative encroachment. Further, like channel geometry parameters, the relationship between sandbar complexes and daily discharge is not singular, and any suggestion that it is linked to a single discharge value is unprecedented in the literature.

2. There is no scientific validity to conclude, as is done on p. 182 of Ch. 10, that a model that relies on one technician's interpretation of 20,000 ft imagery for the lower Platte is transferable to other rivers. Most literature on river morphology is a "contrast of rivers," filled with case studies showing differences rather than commonalities. HDR respectfully doubts that a single case could be found in the literature where statistical best-fit equations like the ones in this report were applied by any respected scientist or practitioner to any river other than the river of origin. This point also speaks to Fundamental Defect No. 1, adding reasonable basis to challenge the authors' knowledge of transferability of results of geomorphologic and hydrologic studies.

Fundamental Defect 8. Connectivity "Data" for Low Discharge Events is Incorrectly Interpreted, Inconsistent with Literature, and Biased to High Flows (see also No. 10 below)

1. The report defines connectivity as a condition where each cross-section was classified with five percent or more (25m) of the width as open water, but with the uncertainty of all remotely-sensed

classifications, and based on the altitude of the imagery used, it would be easy to miss an otherwise-connected system. Close examination of Fig. 10.6 shows that the low percent connectivity values for low flows was almost entirely the result of two unconnected reaches, classified as connected, being separated by segments classified as shallow complexes. With the scant data and high-altitude problem, misinterpretation of the imagery might have significantly biased the results.

2. To illustrate, the photo for 1,400 cfs in Figure 10.6 has the connectivity terminating at the right bank near the center of the photo, but the braid along which open water was classified from the left continues across the floodway toward another open-water-classified braid, yet the observer did not consider the crossing to be open water. Another crossing just west of where the open water class terminated is considerably wider, so it is reasonable that it would not be particularly deep. But the braid that crosses between the two open-water segments is as narrow as the braids that were classified as open water in the same photo. If the two segments classified as open water in this photo are actually connected, the percent connectivity in this figure alone would increase from around 60 percent to nearly 100 percent.

3. A key concern is that because this classification is largely based on one person's interpretation of 20,000 ft remote imagery, and if the technician was not a geomorphologist, a serious bias could be present for lower discharges where the classification would be subject to the highest probable error. It is not apparent from this photo why the narrow braid crossing the channel east of the terminus would not allow migration at the same flow rate if the equally-narrow segments at both ends would allow migration. If a 25m "buffer" on lateral interpretation of open water areas was considered important, then a longitudinal "buffer" should also have been applied to prevent classification of an otherwise uniform and continuous braid into two separate classes.

4. Because the report concludes that only two percent of the shallow sandbar complexes are useable by pallid sturgeon, a different approach to the entire assessment should have been considered focusing largely on transect data versus 20,000 ft imagery. Because the open water classification appears to be the primary factor in assessing needs of these species, a single-focus assessment of open water data, including the IFIM transects and appropriate actual streamflow measurements or other available hydraulic measurement data, could provide improved equations defining the hydraulic geometry of the lower Platte, most-likely over a significantly larger range of discharge rates. For example, the actual percent of any transect or any of hundreds of streamflow measurement records that provide a combination of both the minimum depth and velocity for either species could be entered into a standard log-linear regression analysis against discharge (see Fundamental Defect No. 9 discussion below). Experience has shown that this could have a high coefficient of determination.

5. As a generalization, principles of geomorphology and fluvial hydraulics in a homogeneous system would suggest that if suitable habitat conditions exist at any transect for any given flow, similar conditions would prevail at all nearby transects. More important, if conditions didn't exist in a reach between segments with suitable conditions, all that is often needed is a little time before the conditions could exist (Smith 1971). The principle here is that the river's morphology is shaped by

its flow and sediment transport characteristics, resulting in relatively constant morphology and channel geometry at least in a regional sense. This of course disregards local controls or other factors that force one transect to have different morphology than another, which occurs, but any such variations would likely be regional rather than local, and temporary rather than permanent.

6. While the flow in any braid at some point may spread and widen into multiple "non-connected" braids with shallower water, there is no physical basis for concluding from the imagery alone, especially by an untrained GIS technician, that a braid with suitable migration aspects like the right-bank braid shown in Fig. 10.6 for 1,400 cfs, which clearly does not break into several braids, would not continue to provide passage across the channel to the next downstream open water location, which in the 1,400 cfs example described in item 2 is actually a continuation of the same braid.

7. Snapshots in time (the aerial photos) do not address the time-variability of a braided stream. Nor do transects taken at considerable distances apart capture the transient physical processes of transport of sediments and macro forms moving past and between the transects. With further regard to Fig. 10.6, this "snapshot in time" problem raises another potentially serious misconception evident with the report. Even if the segment of the braid between the two unconnected open water segments in fact did not meet the requirements for migration at the point in time that the photo was taken, the shape and depth of the connecting channel is not fixed, and could easily change to match the braid at both ends within hours of the photograph. In fact, this would be more probable than concluding that a braid would maintain different hydraulic geometries along the same braid for any appreciable length of time.

8. The snapshot in time and spaced transect analysis in the report fails to recognize the highly-mobile, transitioning and reshaping of the channels in this braided river. Based on this and earlier comments, all conclusions about connectivity where similar interpretations of unconnected, open-water segments of the same braid from aerial imagery should be disregarded. In addition, locations where a single braid "appeared" to branch into "lesser" braids would not be sufficient data to conclude that, or ignore the high probability that, one of the branches wasn't about to morph into the same geometry as the braid leading to it (see Smith 1971). Whether a sturgeon would wait for a short time while changes occurred is a biological question. Temperature is one factor noted in the report as triggering migration, but has the possibility been studied that the species can detect bed material transport in some fashion that causes them to migrate, and perhaps pause for a time in order to sense or follow the most-rapidly-changing and most accessible routes in a braided stream?

9. As a minimum, and based on the above hypothesis that the species is selective, the analysis should be conducted on the basis of the existence of "suitable" water depth and velocity at *any point in the transect*, rather than requiring the average depth to exceed 0.5 m. The streamflow measurement data described earlier might be helpful in supplementing the IFIM data for this analysis.

10. The investigators assume or allege that fish would not likely move through the shallow sandbar complexes during low flow if the open water area at any snapshot in time was less than 5 percent of

the average river width. This "buffer" appears to have been arbitrarily selected, as no data regarding use by any of the species of a 25 m or smaller single channel is referenced at this point in the report. Smith (1971) performed detailed studies of physical processes of formation of transverse bars and braiding in the lower Platte. One of his key conclusions is that during low flow, the remaining flow "*rapidly dissects the shallow transverse sandbar complexes and becomes confined to one or more meandering (his term) main thalweg channels.*" A braid, even if correctly classified as shallow complex from a 20,000 ft viewpoint, could easily change to an open water braid a few minutes or a few hours later. This rapid dynamic aspect of the morphology of this braided river is disregarded by the investigators. Instead, singularity is incorrectly presumed with no allowance that a less-than-ideal braid could become a highly-traversable braid a few minutes or hours later.

11. In one observation, Smith reports that when flow dropped to 520 cfs, flow was quickly confined to a single meandering braid. Smith doesn't provide the single-braid dimensions, but it does not appear reasonable to assume that if open water, as defined in the report, dropped to less than a 25 m width, then the water depth and velocity in the single braid would fall below the presumed or actual minimum thresholds of use by the species, preventing passage.

12. The requirement of 50 m of width over 0.5 m deep to classify as "open water" from the IFIM transects means that a 10 m wide braid with 2 m of depth and possibly moderately-high velocity would be classified as a "shallow sandbar" complex with little or no habitat. Data are not provided, but the typical braid or anabranch in this reach would not likely be 50 m wide, and though several braids could have local depths of 0.5 m or more, it may not have a full 50 m of width with depths of 0.5 ft or more. Based on this, there could be a significant percentage of suitable depth and velocity during low flow in the braided segments of the river, and the arbitrary 50 m rule may be resulting in understating the magnitude of the "open water" classification, which is critical to the validity of the equations developed and the overall conclusions of the report regarding "suitable" habitat.

13. The IFIM transect data was only available for discharges of 1,181 to 6,767 cfs, covering only about the lower third of the discharge range represented in Tables 10.1 and 10.2. It is not clear how the final equations and graphs shown later in the report were extrapolated to include flows up through 21,000 cfs. This suggests that any conclusions that were based on the IFIM data should be revised to reflect that they are be applicable only through the range of discharges represented by the IFIM data. Similarly, the portions of the curves that are based completely on the 20,000 ft imagery should be separately analyzed and interpreted due to, and in light of, the extreme uncertainty inherent in remotely sensing the data used in developing them.

14. Smith's investigations suggest that during low flow, the remaining flow, whether considered "low" or not, would concentrate into a single meander, possibly providing the depth and velocities preferred by the species, but not developing a full 50 m wide channel with 0.5 ft of depth everywhere over this width. At low flow, the far right channel in Figure 10.3 might be flowing more than a meter deep (presumably preferred for a pallid sturgeon) and about 20 m wide, yet would not classify as open water or 'quality' habitat due to the 50 m rule. As with the 5 percent

buffer applied to the shallow sandbar complexes, it is suggested that the analysis be repeated by omitting the 50 m rule on open water, for the benefit of the reader and sound science.

15. The literature supports the fact that deep, possibly high velocity channels occur in the lower Platte. Smith found that the average ratio of total wetted-surface channel width to the maximum depth in any transect is 97.6. This means that for a typical transect with 600 m of channel width, the maximum depth of any braid in an average transect, by this ratio, would typically be over 6 m deep. Stated another way, the full width of the bed would need to be less than 50 m to reduce the maximum depth of any braid to 0.5 m or less. This is obviously an over-extrapolation of Smith's ratio, because he found the widths of channel to fall between 450 and 600 m, but his data suggests that the rule requiring 0.5 m of depth over a full 50 m of width may be extremely conservative if the truth is that any channel having a depth of 0.8 m or greater somewhere in the transect is preferred by the species.

16. Smith also reported that during low summer discharges, depths seldom exceeded a few tens of cm except where the thalweg flows against cohesive, vegetated banks, where depths of 2 m were common (like the right bank in Fig. 10.4 mentioned earlier). He observed that as discharge decreases, dissection of sand bar surface areas commences because the total flow is insufficiently strong to maintain active sediment transport over the entire bar surface and that during severely low flow, the flow dissects the bars and becomes confined to one or more channels. As noted earlier, a flow of only 520 cfs monitored by Smith resulted in the flow being confined to the single meandering bar-mouth channel. He further found that variations in depth and velocity over even short distances are both "characteristic and frequent," which lends credence to earlier concerns over us of widely-spaced transects.

17. Because suitable habitat existed on a given day at one location in one transect, there is no physical justification for concluding that this would not prevail throughout, assuming a reasonable level of geomorphic homogeneity of individual braids and given Smith's observations. The 20,000-ft images used would not likely be able to provide proof that any single, continuous braid, on any date when the 25 m buffer was applied, was in fact impassible.

Fundamental Defect 9. Standard Industry Methods of Describing Hydraulic Geometry were Available but not Applied

1. The authors don't suggest that the physical geometry described in the equations as functions of discharge rates are "formed" by the discharge, so the equations are versions (albeit poor) of what the literature describes as equations for "hydraulic geometry." These provide estimates of various channel dimensions (and reach percentages) as a function of the discharge rate flowing at any moment in the channel. Typical parameters of hydraulic geometry are highly related to discharge in fixed-bed streams, but less reliable in most mobile bed streams. The standard relationships of regression models for hydraulic geometry as related to discharge rate, Q, take the form, $V = aQ^b$, $D = cQ^d$, $W = eQ^f$, $A = gQ^h$, etc., where V, D, W and A are representations of the velocity, depth,

width and cross-section area for the given discharge, and the rest of the terms are regression constants. As shown below, these are not arbitrary models selected by a statistical computer program, but instead have a basis in physics (i.e. the continuity equation). A study by someone trained in channel geometry analysis would at least mention these standards of practice.

2. Validity of any set of hydraulic geometry equations, whether of the standard form or those used in the report, depends on whether the system is in a state of quasi-equilibrium. They are most applicable in moderately static morphologic settings, such as rigid-bed meandering streams, and they are least applicable in unstable, mobile-bed systems such as braided streams. Because data at different transects were applied at different times, and because different discharges appear to have been applied to the same transect on different dates, the disequilibrium of the braided segments may account for the variance in the regression equations. The report lacks substantiation that the river's hydraulic geometry is static or that the relationships are singular.

3. Considerably more data exists than the IFIM data that could have been acquired and analyzed in reaching the conclusions about hydraulic geometry for this study. In particular, the lateral distribution of velocities and depths, and the cross-sectional areas of flow, including distributions of these parameters in various sub-channels, are available in the form of streamflow measurement records by the DNR and USGS. Though it is common to disregard uses of this data on the basis that the data are at bridges or other artificially-altered transects, this is a misnomer because many of the measurements are taken by wading the stream, often at considerable distances from the constrictions, or at natural cross sections or on days when the wetted-width is less than the bridge length. These data may have been particularly beneficial in refining the conclusions about the discharge ranges described in the report as "transitional."

4. The authors' analysis resulted in fitting a number of non-standard, non-linear relationships to the data. Relationships such as the "Lorentzian cumulative" curve, "natural logarithm of x rationals" curve, "logistic dose response peak" curve, and miscellaneous others, were applied. Although these reportedly gave the "best fit" to the data, they are unprecedented in hydraulics, hydrology and geomorphology.

5. But the primary concern with these is that none come close to being physical-process based. Standard methods for curve fitting in hydraulics employ distinctly different, peer-approved, physical-process-based models. For example, stage-discharge and hydraulic geometry equations have a physical basis, generally following either known theoretical or empirical relationships such as Manning's equation, $Q = 1.486/n(AR^{2/3}S^{1/2})$ or first order power equations (log-linear forms) such as $Q = Kd^a$, where Q is discharge, d is depth, K and "a" are coefficients of regression, and stage is $d + gh_0$. Hydraulic geometry relationships $W = aQ^b$, $D = pQ^q$, and $V=mQ^n$ are based on the fact that discharge, $Q = WDV$, so Q is known to be physically proportional to each of the three measures of width, depth and velocity. Hence, a relationship like $W = aQ^b$ is physical-process based.

6. Expanding on the above comment for one parameter in particular, namely the channel wetted top width, standard hydraulic literature states that the relationship between water surface area (the product of water top width and reach length) and discharge (Eq. 10.3 and Fig. 10.10) should be adequately described by the standard hydraulic geometry form, $W = aQ^b$, or an explanation provided as to why it was not applied. Using terms in the report, this translates to $y/L = ax^b$, where y is the "open water" (is this the area?), x is discharge, L is reach length (a constant), and "a" and "b" are regression coefficients. Assuming that reach length for the data in Fig. 10.10 is a constant, multiplying all variable widths by a constant length is known to introduce a possible spurious correlation (all widths were multiplied by the same length) and should be removed from the data, allowing a log-linear plot of top width versus discharge, which should either fit the standard hydraulic geometry relationship or an explanation must be provided as to why the relationship does not concur in light of the fact that water width is known to be proportional to discharge.

7. USGS and DWR stream flow measurements are available at the gauging stations, and could easily have been used to establish and expand the range of all the channel geometry relationships. The official streamflow rating curves are also excellent sources of the depth versus discharge relationship, but are not included in the report or data. The form of equation used, "logistic dose response peak" for this parameter has no physical or empirical basis or precedent for explaining the relationship between depth and discharge.

8. None of the physical analogs described allow separation of open water and water-covered shallow sandbar areas, but the data for these areas could have been summed and divided by reach lengths to arrive at total water surface top widths, average depths, and average velocities, and then compared with the streamflow measurement data sheets, the rating curves, or properly-derived, standard channel geometry relationships.

Fundamental Defect 10. High-Discharge Bias is Evident in Setting Flow Rates Required for Connectivity

1. Several statements conclude that a flow of 8,000 cfs is needed to provide migratory pathways, since "at this level connectivity approaches 100%" (p. 183). But this statement is not supported by the data points, which show that at 8,000 cfs connectivity is well beyond the 100% point. It appears that this conclusion was derived by first plotting the actual data on Fig. 10.17, then ignoring the data and instead using the best fit curve, and then using only the curve to arrive at the 8,000 cfs value. The data in Table 10.4 and the graph in Figure 10.17 both show that 100% connectivity occurs at 5,610 cfs, as well as at eight other flow rates between 5,610 and 8,000 cfs. The data also suggest that 100% connectivity could have occurred a lower flow rates. The authors' conclusion regarding 8,000 cfs is not supported by the data, and bias for higher flows is suggested. Another unscientific note in the report states, "more water is better."

2. Rating curves on the Platte are known to be very flat once the water level rises out of the braided channels. If this occurs around 3,000 cfs, why wouldn't the percent of open water also become

relatively constant at around 3,000 cfs, instead of continuing to increase to the higher value of 8,000 cfs indicated on Fig. 10.10? Is this possibly an artifact of the 50 m rule rather than a physical phenomenon?

3. To illustrate this flattening of rating curves, the current stage-discharge curve for the Platte River at Louisville, USGS ID 05805500, was acquired by HDR from the USGS. For the subject range of flows, the current curve shows the following stages and changes in stage for discharges between 2,000 and 10,000 cfs. As shown in the table, the incremental increase in stage for each 2,000 cfs increase in flows decreases geometrically as flow rate goes up. The change of only 0.4 ft in stage per 2,000 cfs increase in flows for flows above 6,000 cfs would cause almost indiscernible increases in wetted-widths.

Flow Rate, cfs	Gauge Height, ft	Change from Previous Rate, ft
200*	1.5	N/A
2,000	2.7	1.2
4,000	3.4	0.7
6,000	3.9	0.5
8,000	4.3	0.4
10,000	4.7	0.4

*Lowest rated discharge

4. For undisclosed reasons, the analysis of connectivity, the charts showing the results and the prognosis regarding future development and target flows in the lower Platte are all provided in monthly values, but connectivity has to occur daily, or else there would be no opportunity for migration. The Opinion clearly requires this condition. A conclusion that an average monthly discharge of 6,000 cfs would not assure connectivity, for example, implies that the flow every day must equal 6,000 unless the authors are suggesting that the species would wait (possibly for extended periods) for the opportunity on lower-flow days to pass on above-average days. A 30-day month with 29 days of 1000 cfs and one day with 151,000 cfs is improbable, but would have an average flow of 6,000 cfs and there would be no connectivity during 29 days. What if during some month, say June, there were 10 to 20 consecutive days (either on average or in any given year) when the flow would be below the 100-percent connectivity level? In other words, average monthly discharge rates do not give sufficient information to respond to issues about, or predict, habitat availability or jeopardy. Daily flow-duration data and persistence analysis of day-to-day flow rates should have been used instead of this coarse method.

5. Page 1-9 of the Hydrologic Analysis Report describes March and June as having the most frequent flood occurrences in the study reach. Using the same two months, the latest daily discharge records (1954 through 2007) at Louisville were downloaded to review the historical mean monthly flow rates. They show, for example, that the flows in March average 10,800 cfs, with average monthly flow less than 6,000 cfs in 7 of the 54 years, with some monthly averages less than 5,000 cfs; and less than 8,000 cfs in 18 of the 54 years (one-third of the time). Average monthly flows during June

were also below 6,000 cfs in 18 of the 54 years, with three years with flows less than 3,000 cfs, and less than 8,000 cfs in nearly half (26) of the 54 years.

6. The authors' description of the insufficiency of 6,000 cfs to provide connectivity and their derivation of the 8,000 cfs amount imply that mean monthly flows of 8,000 cfs would presumably be needed every day of every migration period in every year for success of the species. Table 1.9 shows that an annual flow at Louisville of 6,000 cfs has a 43 percent exceedance rate, and 8,000 cfs has only a 26 percent exceedance rate. Stated another way, flow in the river at Louisville has been less that 6,000 cfs more than half the time (57 percent of the time) and less than 8,000 cfs 74 percent of the time.

7. The flow record does not support this claim of 8,000 cfs as being sufficiently frequent over the period of record to have allowed annual or even frequent migration, nor does it advocate managing the river to provide these flow magnitudes even during parts of the year, yet the Opinion disregards this fact.

8. Among other troubling uncertainties, the authors state that they do not even know whether connectivity for migration is linked to reproduction (p. 183, paragraph 5), yet high levels of connectivity are deemed important to the species and will likely be requested in any final management recommendations. This statement by the authors leaves open the question of whether connectivity is relevant, and whether any management to create connectivity is scientifically sound. Management of a stream's hydrology for protection of species in jeopardy or in threatened condition should not be suggested when a basic biological process such as reproduction is undetermined.

Fundamental Defect 11. Several Analyses and Allegations in the Hydrologic Analysis Report are Flawed

1. With regard to the alleged insufficiency of 6,000 cfs to provide connectivity and the implied requirement of 8,000 cfs for migration, the Hydrologic Analysis Report (2007) contains summary information on flow-duration analyses performed by the authors. Table 1.9 in that report shows flow exceedance percentages for monthly and "annual" daily discharge values. It is not made clear whether the column called "annual" is an average of all the individual years' data sets or a proper *period-of-record* flow-duration table. Assuming that it is a period-of-record versus "annual" table, it shows that a daily discharge of 6,000 cfs at Louisville (annual column) was equaled or exceeded only 43 percent of time.

2. The current (2007) USGS flow-duration statistics for Louisville show that the flow rates with 10%, 50% and 90% period-of-record exceedance percentages are 12,700 cfs, 5,200 cfs, and 2,030 cfs, respectively, which match the "annual" values in Table 1.9 (the authors used an earlier data set) but do not match the graph in Fig. 1.8. Values used in plotting the graph are not discussed.

3. The USGS website shows that the North Bend flow frequencies are considerably less than those at Louisville. The flows are 8,150, 3,620, and 1,400 cfs respectively for the 10-, 50- and 90-percent exceedances, which reasonably agree with Table 1.6 but not Fig. 1.5. It is not easy to read the scales of the graph in Figs. 1.5 (North Bend) and 1.8 (Louisville), but the graphs appear to be consistently higher than the USGS-reported values. A more relevant point is that mandated flows of 8,000 or even 6,000 cfs are nearly impossible to expect to occur at North Bend for all or even parts of the year, and similarly difficult to expect at Louisville.

4. Although not provided in the report, the USGS website shows that the mean daily flows for the entire periods of record at Louisville and North Bend through water year 2007 were 6,939 cfs and 4,500 cfs, respectively, both of which are considerably below the 8,000 cfs value alleged as being needed for connectivity. Because the lower Platte "still retains its characteristic combination of braided channels and shifting sandbars" (p. 1-1, Hydrologic Analysis Report), these flow rates and volumes have either been adequate during recorded times to meet the species' needs or nature has been deficient in meeting the needs.

5. Suggestions of increasing the volumes or re-allocating the time-distribution of the flows are not warranted by any facts in either report. The annual volume of water passing the gauges is the product of these average annual daily flow values times 365 days. By no means is there sufficient flow in the river, by any management method, to raise these averages to 8,000 cfs, and altering the natural distribution of these flows (which are extremely variable) is not justified by any scientific data provided.

6. The discussion of bankfull flows on p. 1-7 of the Hydrologic Analysis Report reflects adherence by the authors to a long-standing predisposition to erroneous characterizations of channel forming discharge rates throughout the Platte River. The citations on p. 1-7 to Rosgen's report and Dunne and Leopold's definition of bankfull discharge are contextually inaccurate, as neither applies to braided rivers. Nor does the next paragraph regarding effective discharge accurately characterize the effective or dominant discharge for braided rivers like the lower Platte. Studies by numerous investigators (HDR 1983, Marlette and Walker 1968, Smith 1971, U.S.G.S. 1981 and 1983) reveal that bankfull flows for braided rivers are nearly impossible to ascertain due to the absence of clearly-defined inner and outer banks, and that equating the flow that would fill the braided corridor from the far left floodplain level to the far right floodplain level with the flow required for channel maintenance extremely overstates the channel-forming flows. Among other evidences, refer to the in-the-field findings by Smith described in Fundamental Defects No. 5 and 8 above, where it was shown that low flows have a significant role in reshaping the sediments in the lower Platte.

7. The same discussion of bankfull flows states that the authors did not perform hydraulic assessments from the IFIM data or USGS streamflow measurement data, but instead crudely estimated bankfull discharges by equating the flow with the 1.5-yr event. Again, the alleged "supporting citations" (Rosgen and Annable) for making this assumption are not valid for braided rivers.

8. Table 1.17 provides the authors' estimates of bankfull flows for the six USGS gauges at and below Duncan, evidently based on peak flow frequency analyses. The values given are presumably the 1.5-yr flood events (this assumption was clearly confirmed in the DBO). The next column in the table is titled, "Duration (days)" which is not at all clear. The 1.5-yr event does not have an associated duration, nor would gauged peak instantaneous flows match the rate exactly, so the durations given for the bankfull flow rates listed are vague. One uncommon but documented error by untrained individuals is that it is assumed that the 1.5 year event can be selected somehow from daily discharge records, which are associated with identifiable durations. It cannot be assumed or concluded that this error occurred, but an independent, Weibull-based frequency analysis of 55-years of USGS peak flow records at the Louisville gauge shows that the 1.5-yr flood would be around 34,000 cfs, not 39,800 cfs as reported in the table.

9. Finally, and most egregious, the effective discharges in the lower Platte were documented by Marlette and Walker (1968). As proof that equating the bankfull flow or even the 1.5-yr flood in a braided river with the effective discharge seriously overstates the effective discharge, Marlette and Walker found that the effective discharge at North Bend is 8,000 cfs, yet Table 1.17 shows that the authors contend that a flow of 21,280 cfs is required to maintain the channel morphology. Their estimate of requiring 39,800 cfs at Louisville is absurd. The Coalition should challenge all results or recommendations based on the presumed effective discharge rates shown in Table 1.17 (these are repeated in Table 8 of the Opinion – see more discussion below).

Fundamental Defect 12. Platte River Dams are Unfairly Faulted

1. The authors' claim (p. 183) that "continued development" and "retention of spring flows behind dams is likely to decrease average spring discharge rates in the lower Platte" implies that the Platte River dams are linked in the authors' minds (but not by direct claims or by any supporting data) to the success or failure of species in the study reach. Any implications about Platte River dams is not consistent with the authors' statement on p. 183 that, "the natural spring rise in discharge provided by the waters of the Loup and Elkhorn Rivers allows migration." UNL studies (Bentall 1982, Marlette and Walker 1968) of the source of flow and channel-forming discharges in the lower Platte also show that it is dominated by contributions from the Loup and Elkhorn.

2. The authors do not state whether these "retention sites" are Platte River dams or other dams (Calamus?), but it readily appears that the Platte river storage facilities are being implicated. Hydrologic analysis of the flow sources to the study reach and their relevance to upstream storage and importance to flows in shaping the morphology of the study reach were not described.

3. This speculation about continued development and retention behind "dams" should either be defended with thorough hydrologic evaluations or omitted.

Fundamental Defect 13. The National Research Council Report Disagrees with the Authors on the Importance of the lower Platte to Pallid Sturgeon

1. The National Research Council (NRC) report concludes that current habitat conditions in the lower Platte do not adversely affect likelihood for survival of the subject species, so it is crucial that the alleged linkage of future reductions in average spring flows in the lower Platte to development in the upper Platte Basin be documented. The National Research Council report also describes the pallid sturgeon as inhabiting "large turbid rivers" having areas with many islands and preferring mouths of tributaries, downstream ends of islands and bars, and areas with strong current and firm substrate.

2. Chapter 10 does not address this obvious anomaly, but proof should be provided that establishes that the lower Platte River provides these "large turbid river" ecologic values.

III. REVIEW OF CHAPTER 11 OF 2007 ECOLOGY REPORT

The following sections identify what the peer review considers to be the primary hydrologic, hydraulic and geomorphologic flaws in the management recommendations listed in Chapter 11 of the 2007 Ecology Report. Chapter 11 has a short introduction section containing one unfounded recommendation, followed by separate management recommendations listed chapter by chapter for each of the previous ten chapters.

HDR's review comments and findings below focus only on the recommendations in Chapter 11 that are based on the materials in Chapter 10. All biological aspects were not reviewed. Chapter 10 included mostly hydrologic, hydraulic and geomorphologic information. The 13 categories of flaws found to exist in Chapter 10 were discussed above. The paragraphs below address only the recommendations in Chapter 11 that are based on the studies described in Chapter 10.

The introduction in Chapter 11 notes that even though the original proposal to list the sturgeon chub as a federally endangered species has been withdrawn, the chub is "still a Nebraska state listed endangered fish species." Similarly, the overall conclusions of Chapter 11 (p. 202) state that management of the flows, sediment and habitats is "critical" to the recovery of the pallid sturgeon and "other (although not identified) threatened and endangered species." This language about endangered species and "critical" habitat is probably included as a precursor to the stringent recommendations provided later as well as the surprisingly-firm, although scientifically-flawed, conclusions in the Draft Biological Opinion.

The goals of the Ecology Report were stated as (1) "not to provide a recommendation of an appropriate normative flow, but to characterize different aspects of the flow regime," and (2) to understand "how the flows found in the lower Platte River may, or may not, support the habitats and needs of Least Terns, Piping Plovers, and Pallid Sturgeon." Contrary to the second goal, the Chapter 11 recommendations based on the Chapter 10 studies go considerably beyond just "understanding" how the flows support (or not) the needs of the species, and more importantly, contrary to the first goal, Recommendation No. 15 (p. 202) urges a full "adjustment" of the "Platte River instream flow allocations" to protect habitat and river connectivity." This goes well beyond recommending a "normative flow," and it should be noted that *the language extends the context from the lower Platte to the full Platte River.*

The Chapter 11 recommendations do not appear to have been written by the authors of the GIS Model Report (Chapter 10) or the companion Hydrologic Analysis Report (Parham 2007). This is because the recommendations are not consistent with the stated goals of the hydrologic and ecology studies. The stated goals of "not recommending a normative flow" and only garnering an "understanding" of the relationship of habitat to flow were evidently misplaced by the time the authors (same?) wrote the management recommendations in Chapter 11. Instead of avoiding "normative" flow recommendations in the lower Platte, Chapter 11 recommends a global *adjustment of flows in the entire Platte River* and presumes that the analyses in Chapter 10 are adequate to not only "understand" the relationships, but can be used to adjust the historical hydrograph using disputed statistical relationships along with geomorphic assessments performed at 20,000 ft above the river.

The term, "Platte River instream flow allocations" that are alleged to be in need of adjustment in Recommendation No. 15 is not described, but the only ways to adjust flows are to (1) store and then release water or (2) deny or re-regulate other uses. Whether this applies to Platte River storage or uses above Columbus or not, HDR's concerns expressed as Fundamental Defects in Sections I and II above regarding an "indirect" focus in the Ecology Report on Platte River dams and Platte River water diversions should continue to be a key objection to this recommendation.

As stated earlier, significant flaws exist in Chapter 10, so the most relevant overall conclusion regarding all the management recommendations in Chapter 11, especially No. 15, is that the fundamental physical-processes were not scientifically analyzed or correctly described (as demonstrated in comments listed in Sections I and II above). This means that the recommendations, and especially implementation of any of them or adherence to the instream flow mandates promulgated by the DBO, should be vehemently challenged.

IV. REVIEW OF 10/19/2007 DRAFT BIOLOGICAL OPINION (DBO)

Chapter 1 of the Ecology Report has a general introduction section with some questionable conclusions, and Chapters 2 through 9 are largely biological subjects which are not reviewed here. The primary conclusion of the Opinion is that any additional issuance of surface water appropriations by the NDNR, including the remaining un-allocated portion of the 1999-approved 5,000 acre ft of "no-jeopardy" water, will jeopardize the continued existence of least tern, piping plover and pallid sturgeon in Nebraska.

The material in the 10/19/2007 DBO leading up to this opinion was reviewed, and a number of flaws in hydrologic, hydraulic and geomorphological analyses and interpretations (listed below in the order of appearance) were discovered. To the extent that the Opinion relied on any or all of the flawed analyses, it is concluded that the Opinion should be challenged on the basis of a seriously-flawed foundational basis for the Opinion, at least with regard to laws of physics.

Both versions of the Peters and Parham Ecology Reports and the Parham Hydrological Analysis Report are cited in the DBO as foundational material leading to the above opinion. HDR identified 13 categories of fundamental defects in those studies. Although more than adequate to reach the conclusion that the Opinion has a flawed foundation, additional problems with the analyses and conclusions exist in the early chapters of the DBO leading up to the final Opinion.

Page 5 of the DBO describes the material relied-upon in developing the Opinion as the "best data currently available," alluding later in the paragraph to the referenced studies relating habitat and connectivity to discharge (both of which are also referenced in the first paragraph of the final "Opinion" section on p. 76). The 13 defects identified earlier, plus the additional flaws noted below, suggest that the conclusion about the data being the "best available technology" is not appropriate.

The DBO (p. 26) repeats a statement already confronted earlier that pallid sturgeon "are well adapted to life on the bottom in swift waters of large, turbid, free-flowing rivers" and they "are found in deep areas with swift current and turbidity" and they "depend on deeper, turbid waters with higher velocity (p. 57)." As noted in above, these descriptions do not describe the hydraulics, hydrology or morphology of the lower Platte River. Even p. 36 of the DBO describes the lower Platte as "a mid-size, shallow, braided river with sandbars and islands," which describes a very different morphology than the one allegedly preferred by the species.

A curious claim is made on p. 60 at the beginning of the "Discussion and Conclusions" section. The first sentence, intentionally reversed here, concludes that even though having been "highly altered," and with centuries-old characteristics that have been "tempered" due to "development and utilization of the water resource," the investigators discovered that the lower Platte River "retains most geomorphic characteristics of the [centuries-old] historic Platte River." This seems to make exactly the opposite case for the NGPC's allegation that the species are in jeopardy, or that the system is unable to experience any other "tempering" (is this a scientific term?) without placing the species in jeopardy. If the system has truly been unaffected by settlement and development of the basin, a better case needs to be made that the system is somehow now at a "threshold to disaster." Several other citations in the DBO allude to their finding that the lower Platte morphology has not been impacted by development.

The allegation is made on page 36 that "much of the Platte River is now narrower with densely vegetated islands *due to reduced river flows* [emphasis added]." While not relevant to the lower Platte, it should be noted that no other reputable investigator, including the staff of the Fish and Wildlife Service and Platte River Office, attribute these changes to a *single* cause. A consensus exists that several factors contributed to these changes, and other scientists have provided credible, alternative explanations than reductions in river flows. Although not true, this type of conjecture is evidently inserted to add irrational credence to the later opinion that river flow is the primary management target and that any further reductions will jeopardize the species.

The DBO uses flows at the Duncan gauge in Figure 8 (and again in Figure 27), apparently to make a point that the median daily flows from 1895 to 1909 are different than the 1975 to 1998 values. Other experts have challenged the validity of the 1895 to 1909 data, but the concern here is that only the Duncan flows are provided. Earlier statements in the DBO (p. 3) state that depletions upstream of the Loup confluence at Columbus are "outside the scope of this consultation and not addressed in this Opinion." The relevance of the graph at the Duncan gauge to the issue at hand is not clear. Potentially more-relevant graphs of similar data for the North Bend and Louisville gauges were not provided.

The majority of the paragraphs in the "Discussion and Conclusions" and the first two paragraphs in the next section on p. 62 allege that "habitat forming," higher flows, defined as bankfull flows which are "essentially considered the dominant discharge" are needed to "scour out deep channels" and create habitat. No independent, scientific support for this conclusion is provided in either the Ecology Report or the Hydrologic Analysis report. Instead, this appears to be an allusion to an unsupported, long-standing predisposition to a flawed understanding of this process. This topic has had considerable investigation by other scientists and the findings consistently refute this claim (Smith 1971, Marlette and Walker 1968, USGS 1981).

A serious error was made when the authors of the DBO chose to define bankfull flow by determining the 1.5-yr flood (see Fundamental Defect No. 13 above). Although not explicitly stated in the Ecology Report, pp. 60-61 of the DBO clearly shows that the authors equate bankfull flow (the 1.5-yr flood) with the effective discharge. The fallacy in using either the 1.5-yr flood rates or bankfull flow rates as the effective (dominant) discharge was shown in the above 13 defects to be inappropriate for a braided river and dangerously misleading. This misnomer, clearly stated for the first time in the DBO (p. 61), is that the 1.5-yr flow magnitude is "essentially the dominant discharge [because] it moves the most sediment over time."

The use of the 1.5-yr flow to represent the channel forming flow is a significant basis, and significant error, in the Opinion, yet the same paragraph on p. 61 attempts to backpedal from this position by stating that, "the 1.5-yr – 2 yr flood event is 'typically' close to the bankfull discharge, although the frequency of this discharge is specific to each river type." While the latter phrase is true, the most egregious statement made in this discussion is the next sentence which states, "This level of analysis for the Platte River has never been evaluated." This is patently false, because Marlette and Walker (1968) completed this evaluation at North Bend, and numerous others have done this for upstream Platte River gauge sites. Even if the 1968 assessment is considered to be out of date, the authors could have easily updated the assessment, especially in light of their (or NGPC's) stated reservations about equating the 1.5-yr flood with the effective discharge. This failure to determine effective discharge by standard, peer-approved methods is inexcusable, and developing an Opinion that places a significant percentage of its mandates on an inappropriate approximation is indefensible.

Pinpointing the mean, median, or modal value (your choice) of discharge that transports the greatest amount of sediment (the effective discharge) is a simple task with industry-standard methods, yet was not performed. The authors' decision to select a highly-uncertain and seriously-misapplied parameter to estimate effective discharge in the lower Platte, versus spending a day or two to pinpoint it, speaks again to the concern stated in Fundamental Defect No. 1 above regarding qualifications of the investigators. It also speaks to a bias for high flows mentioned elsewhere. At North Bend, Marlette determined that the effective discharge is 8,000 cfs (in a peer-reviewed publication), yet the DBO lists it as 21,280 cfs, which is almost three times the actual amount. An Opinion that has the potential of improperly impacting all water users must rely on best available technologies.

Even though not acceptable as measures of effective discharge, the "bankfull" flows provided in Table 8 of the DBO also appear to be flawed and possibly supporting a bias for the highest possible estimates of parameters. They were reportedly developed using "IHA software" which appears to be a tool used in biological sciences but not familiar to hydrologic scientists. The standard procedure used by hydrologists is the U.S. Water Resources Council Bulletin 17B Log-Pearson Type III flood frequency method. To evaluate the accuracy of the IHA values, all peak flows at the USGS Louisville gauge were downloaded and applied to the 17B method yielding results that show that the values in Table 8 are significantly over-stated. For example, Bulletin 17B shows that the 1.5-yr flow rate is 34,580 cfs, not 39,800 cfs. Bulletin 17B places 95 percent confidence intervals on the estimates. The upper limit of the interval is 39,600 cfs. Unless different data sets or different methods were used, this suggests that the values in Table 8 may have been selected at the upper limit of the statistical confidence interval, and if so, reasons for this apparent bias for high-end flows should have been provided in the narrative.

As another indication of misapplication of hydrologic tools and interpretations, Table 10 on p. 68 displays high flows that occurred in the previous 1.5 years of the greatest habitat suitability and describes them on p. 69 as "infrequent." The 65,710 cfs flow in Table 10 at Louisville is a 4.1-yr flood (per Bulletin 17B), which most hydrologists would not refer to as "infrequent."

The Opinion on p. 76 contains numerous paragraphs mandating specific instream flow requirements. Yet the stated objectives of the Ecology Report and Hydrologic Analysis report, containing the studies that are the basis for the Opinion, were "not to provide a recommendation of an appropriate normative flow, but to characterize different aspects of the flow regime." The authors of the Opinion somehow applied studies that were "not intended to recommend normative flows" to not only prescribe "normative" flows but also create a full prescription for the annual hydrograph.

The Opinion prescribes mandates for 8,100 cfs for 100 percent connectivity from April 1through June, 7,000/6,000 cfs during successive halves of July, and 4,950 cfs (greater precision than normally found) throughout the rest of the year to "maintain habitat for pallid sturgeon." Serious problems with the analysis of connectivity were identified in the above comments in Sections I and II, and it appears that the 8,000 cfs described in the Ecology Report and Hydrologic Analysis Report has been increased to 8,100 cfs. The 7,000/6,000 cfs or 4,950 cfs mandates appear for the first time in the Opinion, and their foundational analyses are not readily found in the Ecology Study or Hydrologic Analysis reports.

CONCLUSION

This completes our peer review of Chapters 10 and 11 of the Ecology Report, the Hydrologic Analysis Report, and the 10/19/2007 NGPC Draft Biological Opinion. Because significant flaws were found in the foundational material, the most relevant overall conclusion regarding the management recommendations and the flows mandated in the Opinion is that any recommendations or opinions that rely on the two reports should not be approved by the Coalition nor implemented by the NGPC or other agencies until such time that the defects and deficiencies identified in both reports are addressed and corrected.

The Ecology Study states that a primary goal was to understand "how the flows found in the lower Platte River may, or may not, support the habitats and needs of Least Terns, Piping Plovers, and Pallid Sturgeon." The number and content of flaws described above can only lead to the conclusion that this goal was NOT met. As shown above, a number of significant defects were discovered in the hydrologic, hydraulic and geomorphologic (channel dynamics) aspects of the Ecology Report. These include:

- the authors do not appear to be trained in fundamentals of geomorphology,
- the relationships derived cannot be used to predict habitat change due to changes in discharge,
- channel morphology is not a singular function of discharge,
- 20,000 ft imagery cannot possibly be used for management decisions,
- highly relevant literature by other investigators disagrees with the Ecology Report findings,
- with the exception of the mouth, the morphology of the study reach is not consistent with morphology identified as favorable to sturgeon habitat,
- the tools developed are not applicable to terns and plovers and not transferable to other rivers,
- connectivity "data" for low discharge events is incorrectly interpreted and inconsistent with literature,
- standard industry methods of describing hydraulic geometry were available but not applied,
- bias is evident in setting flow rates required for connectivity,
- several allegations in the hydrologic analysis report are inaccurate,
- bias is evident toward storage behind Platte River dams, and
- the National Research Council report disagrees with the authors on the importance of the lower Platte to pallid sturgeon.

Based on all of the above, serious failings in the analysis are evident, and the results and conclusions related to the stated goals need to be challenged. Vehement objections should be raised by the Coalition if the tools developed in the Ecology Report or the prescribed instream flows in the Opinion are proposed as management mandates for river discharges.

Sincerely,
HDR Engineering, Inc.

Gary L. Lewis, Ph.D., P.E.

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Prepared By:Kenneth Gerow

Chapter One: General Introduction

This chapter is a general introduction to the entire report, and does not contain any statistical analyses, nor descriptions of intended analyses.

Chapter Two: Overview of Field Methods, catch and a comparison of gear effort

Physical characteristics of river habitat (depth and mean column velocity) were taken from a previous study, meant, as I read it, to characterize the distribution of these in the river system. These measurements were also taken where and when fish captures were attempted with each of their five capture gears, and at locations where telemetered fish were caught. This allowed some comparisons of habitat features associated with use of different gears. For example, Figure 2.13 shows that trotlines were used in much deeper water than were seines, and that trotline depths were almost exclusively used in deeper reaches of the river (the distribution of trotline depths sits almost exclusively among the deepest 25% of depths recorded in the IFIM study). Other habitat measurements not recorded in the IFIM study (bottom velocity, temperature, etcetera) were similarly compared among the five gear types (and with locations of telemetered fish).

The statistical summaries in the chapter are just that (visual and numerical summaries with no formal statistical inferences), which require no assumptions.

Chapter Three: Ambient River Conditions in the Lower Platte River

Variables that could be considered “water quality” variables were measured at several stations, with a fairly intensive temporal recording schedule. The distribution of these variables is summarized graphically (measured value versus time, with distinct symbols to separate different years).

The only aspect of statistical matters in this chapter that might need attention is the substrate component.

1. I could not locate Table 32 (referenced on page 72). Did they mean Table 3.2 (which I also failed to find)?
2. On page 72 (*et seq*), they mention a pairwise multiple comparison procedure, from which they calculated p-values to compare substrate composition at different locations in the river. They don’t say what that procedure was (several could fit that description). Composition data have peculiarities of distributional form and variation that could make that choice critical. In particular, in a habitat where, for instance the proportion of sand is very low, it will also be not particularly variable from sample to sample. Where a proportion is closer to 50%, on average, it is also likely to be more variable. Then at the upper end (near 100%) variability will decline. This

patterned lack of homoscedasticity needs to be considered and possibly accommodated, depending on how bad it is.

Chapter Four: Habitat Use, Movement, and Population Characteristics of Pallid Sturgeon in the Lower Platte River

P. 90. I don't know of a "Mann-Whitney t-test" (at least, not by that name). I guess they mean the test called the Mann-Whitney U test (also called the Mann-Whitney-Wilcoxon (MWW), Wilcoxon rank-sum test, or Wilcoxon-Mann-Whitney test).

Are the p-values from a M-W or a t-test on the untransformed variables?

What does "pairwise comparisons" mean when (as I understand it) there are two "treatments" (with some variation on how the "control" is defined). If so, then the phrase is unnecessary.

Why no boxplots (maybe dot-lots for the very small n data…)? Visual summaries are often very informative, beyond simply comparing means.

Chapter Five: Habitat Use, Movement, and Population Characteristics of Shovelnose Sturgeon in the Lower Platte River

p.102: M-W Rank Sum test (sounds more like it; see my comments from p. 90) According to Table 5.1, they have tons of data, so Normality is not an issue for validity of test procedures, and equal variances can be stepped around (if they wish) by using appropriate t-tests.

P 103: sand substrate was also the dominant where there were *no* fish (no difference between the two, I guess).

The summary in Table 5.3 would be elegantly captured with a logistic regression (I'll help with that if they wish). If they want to stick with the categories, some explanation of how to interpret the numbers in Table 5.5 is necessary. In all their presentations of triplets of tables like Tables 5.3 – 5.5, it seems to me that the essential flavor of the story is told in the first two tables. What additional information is conveyed in the third table of these triplets? That should be addressed since the third table is not as direct to interpret as the first two.

Chapter Six: Food Habits of Shovelnose Sturgeon in the Lower Platte River

P 122: They may have used logistic regression in a setting where comparing proportions directly may have been more appropriate (for my tastes, a simpler analysis is preferred over a more complicated one unless there are benefits to using the more complicated one that are not available from the simpler one).

Chapter Seven: Habitat Use and Population Characteristics by Chub Species (Sturgeon, Shoal, Silver, and Flathead Chub in the Lower Platte River

Check on the "Normalized" habitat stuff: how was it calculated, and what does it mean?

Statistical issues are mirrored in Chapter five: for some species, there are lots of data so nonparametric tools are not necessary; interpretation of habitat table (as per Chapter Five).

Chapter Eight: Phenology and Relative Abundance of Larval Fishes in the Lower Platte River

This chapter essentially identified presence of larvae (and other early life-stages) of different species, which in turn demonstrated existence of spawning activity by those species in the river. The statistical content of the chapter is summative (numerical and graphical), validity of which does not require any particularly troubling assumptions.

Chapter Nine: Creel Survey of the Lower Platte River

Nothing remarkable statistically…

Chapter Ten GIS Model of Habitat type Availability, River Connectivity, and Discharge in the Lower Platte River

Very complicated (and of arbitrary form) models were used to predict relative abundance of various habitat types as a function of discharge. The bottom line (Figure 10.11) elegantly captures the results. I guess one could, argue for different models, in this way and that (indeed, could likely go bonkers doing so), but I also guess that any reasonable (meaning they fit the data reasonably well) models would yield only small variations to Figure 10.11. This might be worth pursuing, just to be sure that the big picture conclusions shown in Figure 10.11 aren't particularly sensitive to particular model choices. For each of the curves in Figure 10.11, one could pick two (say) other contender models), and follow the combinations (there would be 8) through to equivalents of Figure 10.11. The hope would be that the figures portrayed by those variations would not be dramatically different from the original.

Chapter Eleven: Management Recommendations for Sturgeon and Chub Populations in the Lower Platte River.

No statistical content…

Comments on the Least Tern and Piping Plover Sections of J.E. Parham's Hydrologic Analysis of the Lower Platte River and NGPC Draft Biological Opinion for the Lower Platte River

October 2008

The following comments are submitted to the Lower Platte Basin Coalition (LPBC) and the Proponents of Sound Science for the Lower Platte River Policy Coalition (Sound Science Coalition) by Jim Jenniges (Environmental Specialist, Nebraska Public Power District, Kearney, NE), Mark Peyton (Senior Biologist, The Central Nebraska Public Power and Irrigation District, Gothenburg, NE) and Mark Czaplewski (Biologist, Central Platte Natural Resources District, Grand Island, NE) on two documents related to the lower Platte River:

- James E. Parham's 2007 "Hydrologic analysis of the lower Platte River from 1954-2004 with special emphasis on habitats of the endangered least tern, piping plover, and pallid sturgeon" prepared for the Nebraska Game and Parks Commission (NGPC) (Parham Report).

- Nebraska Game and Parks Commission's (NGPC) October 19, 2007, Draft Biological Opinion related to surface water use in the lower Platte River (prepared in anticipation of jurisdictional actions by the Nebraska Department of Natural Resources)(DBO).

This review specifically relates to sections of these two documents that deal with the biology of the interior least tern (*Sternula antillarum athalassos*) and piping plover (*Charadrius melodus*).

<u>Parham Report</u>-

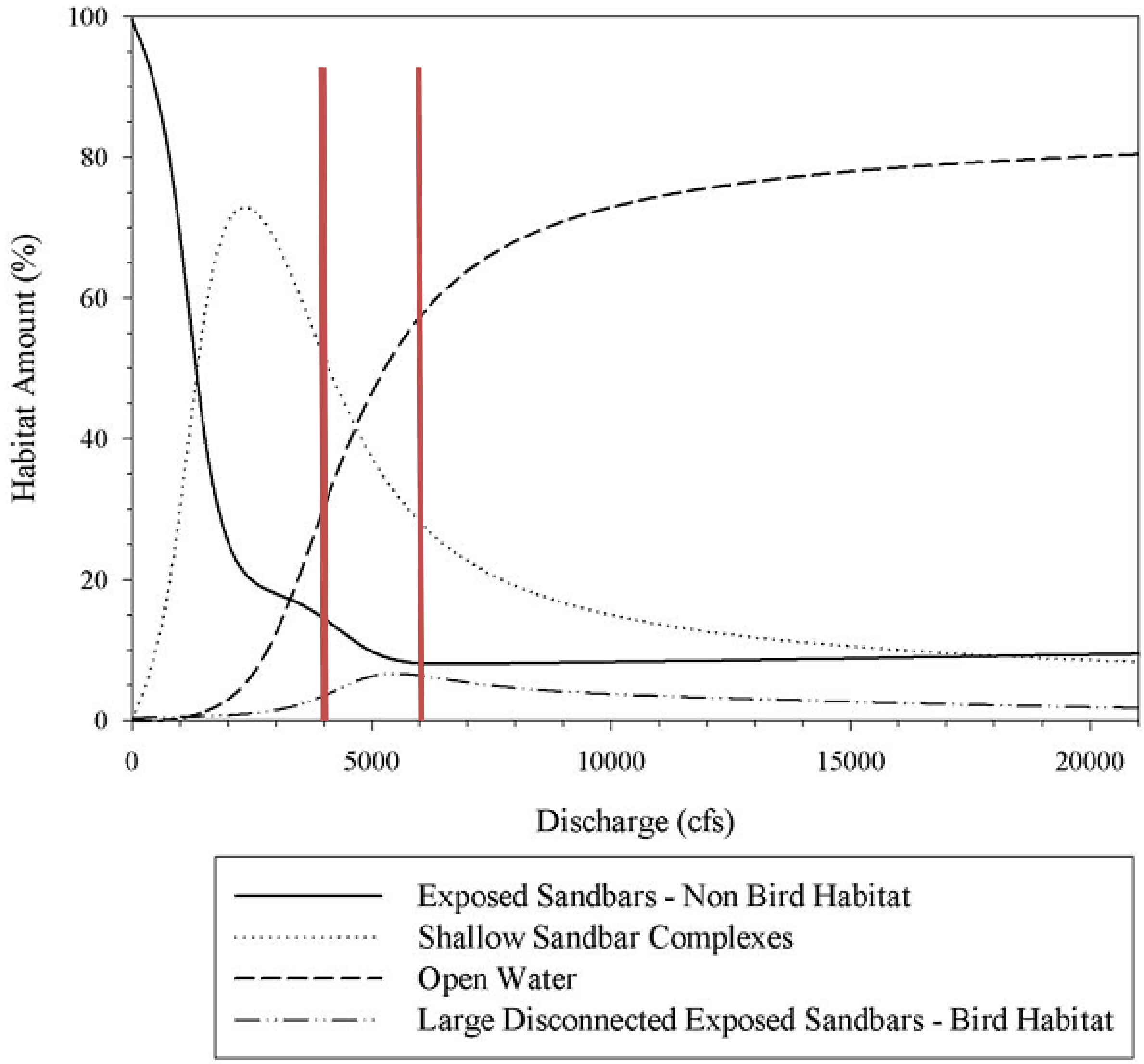
Chapter 2 of the Parham Report is entitled "Estimation of least tern and piping plover nesting habitat in relation to river discharge. The text focuses exclusively on least tern and piping plover nesting use of riverine habitat in the lower Platte (defined in the document as the Platte River downstream of the mouth of the Loup River near Columbus, Nebraska).

The document's foundational statement on river geomorphological processes lacks technical support or citation. The author (page 2-39) talks about the "natural process of sandbar formation" at work on the lower Platte, but rather than offering technical support for the statement, the reader is offered photographs and asked to draw observational conclusions.

A very basic biological premise is that species utilize a given set of resources to fulfill there life needs and that this set of resources is habitat for that species. Parham has utilized hydrological modeling and aerial photography to predict the quantity of nesting habitat available to least terns and piping plovers in any given year and further modified that estimate by evaluating if that habitat was available for a long enough period of time to provide for successful recruitment of young from the nests that did exist. While such modeling of habitat is commonplace, it often is an exercise in modeling physical conditions of the environment that has limited applicability in predicting or replicating actual use by the species. The approaches utilized by Parham may be reasonable, and he readily admits that his analysis of habitat suitability cannot predict if birds will successfully fledge young due to other factors such as predation. If, however, the methods used do indeed model the availability of habitat, it should be possible to look at the results of the model in relation to actual number of nests.

The number of least tern nests on the river from 1986 to 2005 was estimated from the graphs in the report and ranged from 5 nests in 1998 and 2005 to 115 nests in 1994. Presumably this variability was due to the quantity of nesting habitat available to the birds and could be predicted by the models developed by Parham. A simple correlation of the quantity of habitat predicted from the model and the actual number of nests resulted in a negative correlation of -0.1537. A simple linear regression that tried to predict number of nests based on the estimated quantity of habitat had the same negative relationship but was insignificant ($P = 0.53$) and had an R-square of only 0.02. Parham's models are based on very limited data that are better addressed by statisticians and hydrologists, but it appears their value in actually quantifying habitat (and thus predicting the number of least terns that will be nesting in the lower Platte River) is quite low.

All model work is done using a sandbar height of 1.5 feet, which was derived from Ziewitz et al., 1992. Parham then looks at large disconnected sandbars and came up with a flow of 5,480 cfs during the summer as needed to maintain large unconnected sandbars. This is a key component of the model and any evidence to show it is not accurate would result in significant changes in the model outcomes. The average height above water from the previous 1.5 year high flood was actually 1.83' indicating that 5,480 cfs is higher than necessary.



The caption for Figure 2.3 oversimplifies the cause of vegetation developing on potential nesting sandbars resulting "(i)f higher water discharge does not occur". Johnson (1994) and others have documented that ice scour and drought are also major factors affecting the vegetative condition of such sandbars.

Parham's model uses the depth of channel at its deepest point and converts that to height of sandbar. In other words, if the river channel is five feet deep, the corresponding sandbar created will be five feet high. Thus, if flows recede and river stage was to drop by three feet, the sandbar is modeled to be two feet above the water surface. This modeling approach needs to be reviewed by a hydrologist to ensure this approach is valid. Personal experience on the Platte River leads us to believe this is an erroneous approach to modeling sandbar height and assumes bars will build to the top of the water column.

A flaw in Parham's methods (see page 2-42) relates to his definition of "nesting periods". He defines a period of 60 consecutive days for incubation and fledging and his rolling time slots starting on May 1 and going through August 31 in each year, noting a total of 63 possible 60 day "nesting periods." That number may be theoretically possible for plovers, but the reality for terns (which he notes "arrive in late May"), means their "nesting periods" cannot start on May 1 and so instead of 63 possible "nesting periods" there can only be about one-half that many. Parham does cite references that document average incubation and fledging time periods of 42 to 56 days (see page 2-43).

Parham's first assumption documented on page 2-43 acknowledges the fact that his model's use of a 1.5-year time frame overestimates the period that newly formed sandbars likely remain unvegetated. We also believe 1.5 years is an over estimation. The significance of this is that once a bar is formed under Parham's model it is available for two nesting seasons, when in reality it likely only available for one.

Parham's third assumption (see page 2-44) regarding the necessity for a 1.5-foot bar elevation is from Ziewitz et.al. (1992). It is assumed that the 1.5 feet comes from the mean elevation of nests above a flow of 113 cms (3990 cfs) as reported in Ziewitz et al. 1992. However, the elevation above water that nests were initiated at in that study was 0.03 m (0.10 feet) to 1.18 m (5.94 feet). Many times in resource selection the mean of a sample has very little bearing on actual preference by the species or necessity to fulfill life needs, but instead is the mean of the available resources. It would appear this is the case in Ziewitz et al. (1992) where the mean maximum elevation of nests was not different then the mean maximum height of the island. It would seem there is likely a much wider range of flows that would provide suitable habitat than implied by Parham's modeling efforts.

The paucity of habitat quantity data (see page 2-46) is a concern. Parham notes that habitat data was only developed from photographs taken in three years, and that none of that data is more recent than nearly ten years old (i.e., 1993, 1994 and 1999) with limited data from one additional flight in August of 2003. He notes that photographs were taken at several different dates in those years, but the reader cannot be certain of the timing of those photo dates and how the timing relates to tern and plover nesting or geomorphic forces potentially affecting channel morphology. The 2003 data was apparently collected to provide insights into drought conditions, but the data is not described or developed. The dates the photos were taken could obviously have a major impact on vegetative conditions and therefore, quantification of habitat data in the analysis. Was quantification conducted during the nesting season? Other related issues may also give rise to concerns about the comparability of habitat data derived from different photo scales, different discharge rates, and different times of the year. The criteria measured can obviously be biased by the flow at the times photographed and the season. The reader needs to understand how the photographs used in the analysis match up temporally and spatially. As presented, the study results are not replicable.

The “Determining Favorable Flow Characteristics” section (page 2-48) is confusing and would benefit from clarification. This portion of the analysis fails to adequately link with actual bird use.

The different numbers noted on page 2-55 regarding what appears to be the same values for available and maximum habitat are confusing (e.g., “a maximum of only 6% to 7%”, “maximum of 6.7% available”, and “available habitat ranged from 0 to 5%”). The author should note whether the “$r^2 = 0.45$” is significant.

The photographs used in Figure 2.9 are inconsistent in so many ways, they do not provide for meaningful comparison. The multitude of scales, dates and locations provided here do not allow for analysis. These photographs would not provide any quantitative means of knowing sandbar height on the dates the photographs were taken. What is the point of the figure?

The author indicates that use of the entire river was once common and uses as reference the nesting records reported by Tout (1947) and Wycoff (1960). It should be noted that the locations noted by Wycoff and Tout (Lexington, Nebraska and the confluence of the North and South Platte Rivers) continue to support nesting birds to this day, despite the author’s statement on page 2-68. In fact, if the known locations for least tern and piping plover nesting through history were compared to present day nesting you would essentially see the same spacial pattern. The only real difference in distribution of nesting birds is the author’s method of depicting the range. The author has drawn a line connecting historic points of known nesting while only showing dots for current nesting.

We do not believe that Ziewitz et al. 1992 provides any data that would support terns and plovers select islands that are 2.99 feet above a flow of 5,480 as suggested by Parham. He seems to have taken components of measured habitat use and modeled habitat availability and formed in to some measure of desired conditions. On page 2-73 Parham inappropriately compares the frequency of peak flows over 38,170 cfs at Duncan (above the confluence of the Loup River and the Loup PPD return with the occurrence of this same peak at Louisville (downstream of the Loup River, Loup PPD return, the Elkhorn River and salt Creek). Parham then inappropriately uses these discharges to compare habitat patterns.

Parham’s analysis and conclusions (page 2-78) deal with available conditions noted in selected time periods and not with suitable habitat. He notes that “measures of suitable habitat produced here does not directly measure whether birds successfully fledged young in those years examined”, he should have gone on to note that his measure of available conditions do not translate into suitable habitat, bird use or reproductive success. Mischaracterization of his direct meaning and measure of his modeling is problematic throughout the report.

Draft Biological Opinion-

References (General)

Several concerns with references used in the DBO were identified. These concerns include the lack of citations for statements made and opinions offered, the use of references that were not peer reviewed, and the omission of pertinent references, which would support differing positions.

The DBO does not include a Literature Cited section and although many of the references cited are relatively common, there are references which are unidentifiable. Examples of citations used in the text that are obscure or not known from the published literature include: Galat et al. 2005a, Tibbs and Galat 1997, Dinsmore and Dinsmore 2007.

Examples of statements made with a total lack of documentation include statements made on page 38 regarding very broad effects of hydrocycling on fish and potential impacts related to sandbar formation. The DBO makes generic mention of a study on the lower Platte but offers no citations or references.

The DBO similarly offers no reference for very definitive statements such as "Nesting habitat will continue to change and become unattractive to terns without intervening periods of disturbance. For instance, suitable river sandbars are maintained by the hydrology of the river and the movement of its alluvial bedload."

Other papers cited are "grey literature" and have not been peer reviewed. An example of this is "Kirsch (2001)" (see page 10). The Kirsch (2001) reference used in the DBO is not a study itself, rather a criticism of data and study methods utilized by Nebraska Public Power District and The Central Nebraska Public Power and Irrigation District (Districts) in their studies of least terns and piping plovers nesting. However the Districts methods Kirsch criticizes were based on recommendations of U.S. Fish and Wildlife Service (FWS) and are the same methods as used by the Tern and Plover Conservation Partnership and have been adopted as part of the monitoring protocols currently used by the Platte River Recovery Implementation Program (Program). The NGPC is represented on the Technical Advisory Committee (TAC) of the Program. The TAC's least tern and piping plover monitoring protocol has undergone independent review.

Kirsch stated the fledge ratios being reported by the Districts were "startlingly high". In reality, since 2001 fledge ratios at nesting sites that have some form of management protection have consistently met and exceeded the fledge ratios documented and reported by the Districts. Kirsch was comparing unprotected nests on riverine islands and sandpits with those at sites that are protected and intensely monitored. Data since 2001 has shown that fledge ratios are consistently higher than those measured by Kirsch.

A variety of references considered important to a complete understanding of tern and plover use of Nebraska habitats are misused or conspicuously absent from the DBO. These omitted citations would counter statements made in the DBO. Examples include Wycoff 1960, District monitoring and permit reports 2000-2007, Kirsch 1996 and Lingle

1993. This point gets directly at the DBO's claim of using the "best data currently available" (page 5), however the document does not support that.

The DBO uses a reference to Wycoff 1960 to describe the historic distribution of least terns on the Platte. What they fail to mention is the fact that the tern habitat he was monitoring near Lexington, Nebraska was not a naturally occurring riverine sandbar, but rather was created by sand and gravel mining (Wycoff 1950)

The DBO on page 12 indicates that terns nesting on sandpits have lower fledge ratios than birds nesting on rivers and cite Kirsch (1992) and Lackey (1994) and oddly do not cite the only study that did a direct comparison (Kirsch 1996) which found no difference in "productivity (nest success and fledglings per pair)" between the two habitat types.

The 2007 DBO contains little data more current than 2000. The DBO does not indicate that tern fledge ratios from the Districts comes from intensively managed sites and are similar to the tern fledge rates observed on lower Platte pits when they are managed. The document makes no mention of plovers use of sandpits or on the shores of Lake McConaughy (page 17).

The following comments relate to various identified sections of the DBO:

Interior Least Tern

Distribution

The DBO references Wycoff (1960) reporting 35 nesting least terns in 1949, 20 in 1950, 24 in 1953, and 25 in 1954. These birds were nesting on a "low, sandy island not over 75 feet wide, about 200 feet long, and lying nearly a quarter-mile west of the Platte River bridge which is straight south of Lexington, Nebraska." As noted above, it is important to point out that this "island" was a spoil pile from a gravel mine that was adjacent to the river. Thus, a problem of perception is perpetuated with the distribution maps in the DBO. The map (page 8) skews the historic tern distribution by depicting a solid line (inferring continuous distribution) from a use site at North Platte to the Wycoff "riverine" site at Lexington and then Lexington with the Lower Platte. This insinuates there are distribution records for the entire stretch of river between these locations and the fact is there are not. The fact is, there are as continuous records of nesting on the upper and central Platte today as there were historically and there is no evidence of a loss of nesting by least terns in these areas.

The two distribution maps (page 8) were obviously drawn up utilizing very different methods for showing distribution. A list of the locations and references used to depict distribution would eliminate any such skew and use of the same methods of mapping would show virtually identical areas of historic and current distribution and remove this apparent bias from the DBO.

The DBO states that "(t)he lower Platte River from Columbus to the mouth, lower portions of the Loup River, the lower Niobrara River and a few stretches of the Missouri

River below Ft. Randall Dam and Gavins Point Dam are the only river segments in Nebraska that still provide naturally occurring sandbar nesting habitat used by least terns. Because riverine nesting habitat has been severely reduced or eliminated in the central and upper Platte River, nesting rarely occurs there; sand and gravel pits adjacent to the river now provide the majority of the nesting habitat. The Loup River has been highly altered in the reach below Genoa with a canal diversion system to a hydropower facility."

Again, there is no evidence to show that riverine nesting habitat existed in the upper and central Platte Rivers other than the two documented cases mentioned. A far more compelling argument could be made that this portion of the river was never conducive to tern colonization prior to 1941 because the river regularly went dry in July, right in the middle of the least tern reproductive season. A dry river would have catastrophic consequences on young terns trying to feed on small fish.

Reproduction
The DBO (page 9) states that terns "typically arrive in Nebraska in May and begin establishing feeding and nesting territories….Ziewitz et al (1992) found that least terns initiated nesting on the Platte River from May 19 to June 23, but nest initiation can occur later into the first two weeks of July (Jorgensen 2007). Sidle (1992) found that most fledging is completed by July 31." It should be noted that historic Platte River peak flows occurred in late May through June (see DBO Figure 8) and that the river upstream of the confluence with the Loup was often dry by mid to late July. This does not leave a very large window of opportunity for birds nesting in the upper and central Platte.

On page 9, the DBO notes "Incubation lasts approximately 21 days. The newly hatched young are weak and helpless, and must be attended to by both adults. Chicks are able to fly about 20-21 days after hatching…They are dependent on their parents for food even after they become strong fliers." Thus, at a minimum there must be 42 days between any significant peak flow and a dry river in order for terns to successfully reproduce on upper and central Platte River sandbars.

Demographic Parameter Estimates
The DBO (page 10) states that "In Nebraska, fledge ratio estimates range form 0.12 to 1.26. However, fledge ratios should be interpreted cautiously. Logistical constraints likely bias fledge ratio estimate include: 1) adults are not individually marked, 2) the colony is visited infrequently, 3) the inability to monitor all young until they fledge (Erwin and Custer 1982), and 4) emigration/immigration of juvenile birds to non-natal colonies." The fact is that there is significant data available since 1982 that give accurate fledge ratios.

The DBO goes on to state "Lingle's (1993b) and Kirsch's (1992) work are the only studies where birds were individually marked, thus overcoming a major source of potential bias. Fledge ratios from these studies range from 0.12 to 0.49. Kirsch's (1992) estimated fledge ratios for birds breeding at sandpits ranged from 0.19 to 0.32." Again, the fact of the matter is there is considerable evidence of marked birds on the Missouri River by the U.S. Army Corps of Engineers and Virginia Tech University, which are readily available in the literature. The NGPC does not utilize the data or explain why it fails to exclude it. The NGPC's Table 1 (page 10) displays published estimates of least tern fledge ratios. The table is woefully incomplete. The DBO was created in 2007 and the NGPC has access to the entire pertinent set of data and yet, only use data up to 2000 for their analysis of central Platte and no data more current than 2005 for the lower Platte. It should also be noted that no data at all is presented from riverine areas of the lower Platte after 1990. This is despite at least limited monitoring by the NGPC and others working on the lower Platte during that timeframe.

Foraging
The DBO makes a brief note of tern foraging distances being documented on the Missouri River that indicate that may invalidate much previous thought regarding the previous thoughts on the importance of shorter foraging distances noted by the majority of other references in this section.

Artificial and Alternative Habitats
As noted earlier, the DBO contends that terns nesting on sandpits have lower fledge ratios than birds nesting on rivers and cite Kirsch (1992) and Lackey (1994) and fail to cite a study which did a direct comparison of the two habitat types (Kirsch 1996). Kirsch found no difference in "productivity (nest success and fledglings per pair)" between the two habitat types.

The DBO states that "Range wide, least terns will nest in locations other than riverine sandbars, but in Nebraska, quality alternative habitat is limited." How is "quality" defined here? If terns use an area then it seems by definition, it constitutes habitat. What data does the NGPC use to discern differences if the quality of tern habitat and alternative habitat?

The DBO notes that historic data indicates "terns were utilizing sandbars in the river channel", and given the context of the document, one would assume the reference is to lower Platte data. However, little or none of the text that follows in this section of the DBO relates to lower Platte data.

The DBO (page 12) states that "Least terns use sandpits that result from gravel/sand mining operations as nesting habitat. These sandpits are often found in close proximity to the river, but evidence suggests that these artificial habitats are ecological "sinks."" This conclusion is made without reference or analysis to back it up. It is similar to a statement made in 1992 by Kirsch with no data to back it up.

The DBO states "Lower fledge ratio estimates from sandpits illustrate that although a direct cause of lower fledge ratios cannot be determined, the sandpit habitat is not adequate for population maintenance or recovery. Kirsch (1992) estimated that fledge ratios ranged from 0.19 to 0.32, similar to Lackey's (1994) estimated 0.30. These estimates are well below estimates of 1.0 or greater that are suggested for population maintenance (Thompson1982, Dugger 1997, Aron 2005)." Here, once again the NGPC quotes 1992 study from Kirsch when there is a more recent and far more extensive data. Kirsch's 1996 monograph gives fledge ratios on sandpits as ranging from 0.28 to 0.64

and on sandbars in the river from 0.21 to 0.73. In both cases it is below the estimates of 1.0 or greater to suggest population maintenance. If sandpits are "sinks", then so are sandbars in the lower Platte River.

The DBO states "Lingle (1988) reported that least tern nest losses varied between natural and artificial habitats. The major cause of nest failure on natural riverine sandbars was flooding, while nest failure at sandpits was the result of predation and abandonment." It is important to know that, in Lingle's study the percentage of nests lost in the river were much, much higher than the percentage of nests lost on sandpits. Thus, while the cause of loss is different, the overall results were greater success on the sandpits than in the river.

The DBO states "Sandpits may provide temporary habitat, but these habitats will become overgrown as the sand mining is completed, unless extensive maintenance is implemented. Other sites are converted to housing developments, which no longer provide nesting habitat. Sandpits offer only a temporary habitat that without considerable management, do not offer a viable, long-term solution for least tern nesting habitat." Sand bar habitats are also temporary habitats and also become overgrown in time. Kirsch's 1996 Monograph stated the following: "Because least terns on the lower Platte River did not use much of either habitat that was apparently available and did not prefer one habitat over the other, the amount of usable habitat does not seem to limit this population." Kirsch further stated: "Mortality of young and productivity did not differ between sandbars and sandpits, but varied tremendously among colonies within both habitats".

Continuing Threats

Habitat Loss and Degradation –

The DBO states "Changes in natural river hydrology due to channelization, diversion of river flows for irrigation and hydropower production, construction of reservoirs, bank stabilization (rock armoring, revetment, hard points), levees and unnatural, managed river flows have contributed to the elimination of much of the least tern's sandbar nesting habitat (Funk and Robinson 1974, Hallberg et al. 1979, Sandheinrich and Atchison 1986)." Once again, the document offers no data specific to the Platte and specific to least terns. Also, it would seem there should be more up to date information referenced than the 21 year old 1986 citation.

The DBO states: "In much of the least tern's range, sediment had been reduced from flowing water as it settles out in reservoirs. Historical high flows, which are now tempered, are important to introduce and transport organic material from the floodplain to the river system supports the system's productivity." The NGPC need to better define what is meant by productivity in this context. It would be helpful if the studies showing this lack of high flows have impacted productivity and hence the availability of small fish for terns to feed upon would be referenced and better justified.

Human Disturbance –
The DBO states: "Human disturbance affects tern productivity in many locations, (Massey and Atwood 1979, Goodrich 1982, Burger 1984, Dryer and Dryer 1985, Dirks and Higgins 1988, Schwalbach 1988, Mayer and Dryer 1990)." Again, the document cites to 17 year old data. Is there no better, more up to date, and lower Platte specific information on human disturbance?

The DBO states: "Predation may occur at varying intensity if the river channel is not dynamic such that sandbars are only located in limited areas where predators learn of nesting activities and prey upon colonies annually. With the loss of much least tern nesting habitat, predation has become a significant factor affecting least tern productivity in many locations (Massey and Atwood 1979, Jenks-Jay 1982)." Most predators of this species can either fly or swim. Multiple years of surveys on the Niobrara, a "natural" river with a number of sandbars where terns nest, show the sandbars are basically in the same places year after year and are related to certain characteristics of the channel. Thus, the idea of the sandbars moving around and being dynamic is misleading because the sandbars may not move appreciably

The DBO is quick to point out that "Additionally, sandpits present unique challenges as colonies are not isolated by flowing water and more easily subjected to different predators using adjacent terrestrial habitats." And predation may be greater on sandpits, however, flooding occurs far more often in the river than on pits. The DBO seems to ignore that fact. Bottom line plain and simple needs to be where the best recruitment of young into the population is.

Current Status
The DBO states that "Long term trends are difficult to quantify for the least tern on a region wide scale. Focused survey efforts for the entire distribution of the least tern have only recently been implemented….The first range wide least tern survey was completed in 2005, although least terns were previously counted in the International Piping Plover Census. From the 2005 survey, there were a total of 17,591 least terns counted from 489 colonies. Most terns were counted on rivers (89.0%). The Platte River system had 7.4% of the total number of colonies. The Platte River system contributed a total of 588 adults including 53 adults from 2 colonies on the lower Platte River and 328 adults from 13 colonies on sandpits associated with the lower Platte River (Lott 2005)." This data clearly show there are far more terns in Nebraska and in the Platte basin than previously thought. Throughout this section of the DBO, tern populations at Lake McConaughy, and on the upper and central Platte are discussed, but it is not clear if the 588 adults noted above include those birds. This needs to be clarified. If they are not included in the 588 "total" and are added to the "Platte" birds, the total becomes 663, which (while 88% of the recovery goal for the Platte) the 17,591 birds is 235% of the recovery number for the interior subspecies.

The DBO states: "Since 1987, the Commission has coordinated a standardized survey of all least tern and piping plover nesting along the lower Platte River from Columbus to Plattsmouth, including both riverine and sandpit nests. Although numbers of adults least terns remains relatively consistent, available riverine habitat has declined dramatically across Nebraska, to the point that the lower Platte River is one of the few remaining locations where terns are nesting in natural habitats (See Environmental Baseline Section for further details)." If riverine habitat is declining as the NGPC suggest, and yet the numbers of adults remain consistent, then maybe it isn't riverine habitat that is, or has been for 20 years, sustaining the population.

Piping Plover

Distribution

Figure 4 of the DBO depicts the historic and current breeding distribution of the piping plover in Nebraska. As is the case with the least tern (see comments above), the DBO's historic map shows a continuous line connecting known historic breeding areas and the current distribution map shows only distinct spots for the current breeding areas. If the same criteria and methods were used for the historic map as the current map, it would show an apparent increase in breeding distribution by piping plovers over time. There is no evidence to show there was continuous breeding in the Platte River historically.

The DBO states: "On the Platte River, piping plovers were apparently very abundant in the 1860s (Ducey 2000). Additional breeding records from the Platte River systems prior to 1960 are from Hall, Platte, Douglas, and Cass Counties (Ducey 1988)." Given there is no references cited section in the DBO, what is this reference?

Demographic Parameter Estimates

The DBO states: "Information on survival is limited. Root et al. (1992) estimated mean adult survival in the northern Great Plains at 0.664 ± 0.057 (SE). With additional data, Larson et al.(2000) reanalyzed and revised the earlier estimate to 0.737 ± 0.092. Larson et al. (200) also estimated juvenile survival to be 0.318, however this estimate is likely biased downward for multiple reasons. Juvenile survival from the Atlantic Coast is somewhat higher (0.48; Melvin and Gibbs 1996). Estimates of reproductive success, specifically fledge ratios, are variable and range from 0.3 to 1.5 fledglings per pair. In Nebraska, fledge ratio estimates range form 0.37 to 1.93. Fledge ratios should be interpreted cautiously. Kirsch (2001) was highly critical of estimates from Nebraska Public Power District and Central Public Power and Irrigation District (e.g. Peyton and Wilson 2000)." Once again, fledge ratios from the Missouri River and other efforts including those on the lower Platte are very much in line with those reported by the power districts, and while Kirsch considered them "too high", that consideration was based upon her work on unmanaged habitats during the 1990's

The DBO Table 2 notes published estimates of Piping Plover fledge-ratios in Nebraska. Why does the document not include readily available data from the Districts since the year 2000? There is no mention of the river surveys done thought the Platte River Cooperative Agreement and Recovery Implementation Program. Some of this data has even been publish in the Nebraska Bird Review.

Artificial and Alternative Habitat

The DBO states: "As with least terns, piping plovers will use artificial habitats such as sandpits. Again, sandpits provide transitory habitat, and should not be considered a long-term alternative to riverine habitat. Others have concluded that "sandpits do not provide the full complement of essential elements for tern and plover reproduction, and is not a suitable substitute for riverine nesting habitat" (NRC 2005). Similarly the U.S. Fish and Wildlife Service (2002) stated that "sandpits are artificial and temporary in nature, not all of the necessary biological and physical features that are essential to the conservation of the species are present at sandpits" and "sandpits do not provide for piping plover recovery in the long term." Sandpits are effectively biological sinks, even when intensive management efforts are employed." No original research is referenced here. The NRC summary was based upon comments by NGPC staff, John Dinan. It was his personal opinion and not the conclusions of a research study. The FWS based their conclusion on the same opinion with no references what so ever to show that sandpits in fact do not provide all the necessary biological and physical features essential to conservation.

The DBO states: "Fledge ratio estimates for piping plovers breeding at unmanaged sites have been well below levels required for population maintenance (Lackey 1994). Fledge ratio estimated to maintain numbers range from 1.13 to 2.0 fledgling per pair (Prindiville Gaines and Ryan 1988, Ryan et al. 1993, Plissner and Haig 2000, Larson et al. 2002, Melvin and Gibbs 1994). Even when intensive protection efforts that include nest predator exclosures, electric fences, and other techniques are utilized, fledge ratios are generally below the aforementioned levels required for population maintenance. Reasons for low fledge rates at sandpits are complex, but may be associated with available food resources. Catch rates and density of invertebrates, the prey base for piping plovers, is higher for river channel habitat sites than gravel mines (Corn and Armbruster 1993)." No data from the Corn and Armbruster study shows that plovers at pits are not finding enough food and that fledged chicks are less robust than those on the river.

The DBO states: "They also found that invertebrates are distributed more or less uniformly across riverine foraging habitat, but decline with increasing distance from the water's edge at sand pit locations. Research has found that invertebrate abundance also increased more dramatically over the course of the summer on riverine sites when compared to sand pit sites (Corn and Armbruster 1993). These patterns of invertebrate occurrence translated into greater foraging activity on river channel habitat sites even when birds nested off the river (Corn and Armbruster 1993b). Their research emphasizes the importance of river channel habitat for foraging. Lingle (1988) observed banded piping plovers known to be nesting at sandpits foraging 0.5-mile away in riverine habitat. The issue of forage availability is critical to the survival and reproduction of piping plovers. Chick mortality is correlated with reduced growth rates (Cairns 1982), potentially a result of reduced prey availability. Piping plover chicks studied along the Atlantic coast typically tripled their weight during the first two weeks after hatching; and chicks that failed to achieve at least 60 percent of this weight gain by day 12 were unlikely to survive (USFWS 1996a). D. Catlin (Virginia Tech University, personal communication, August 2007) found that chicks with slower growth rates spend more time in the pre-fledge state, thus increasing the time they are vulnerable to predators. Piping plovers will also use shorelines of reservoirs when water levels are sufficiently low and will use sandhill lakes." This seems to indicate that plovers are primarily riverine birds that will, if necessary, use other habitat. It would seem that given the vast majority of all plovers are presently found along the shore of reservoirs, that these birds are shore birds, not riverine birds, and that while they obviously use river sandbars, a shore line is their preferred habitat. The shore and availability of food along the shore of a large reservoir like Lake McConaughy is probably more like that of a sandpit than a river, and yet, Lake McConaughy has proven to be the most important single location for piping plovers in Nebraska.

The DBO states: "In Nebraska, uses of these locations is minimal compared to historical use of riverine sandbars." What reference is this statement base on? There is none know we are aware of.

Continuing Threats

Habitat Loss and Degradation

The DBO states: "Since the early 1900s, habitat alteration and destruction from channelization, irrigation, and the construction of reservoirs on our nation's large river systems constitute the primary reason for the species' decline and current status according to the Recovery Plan." Does this hold true for the North Dakota and Canadian birds? What about those of the Great Lakes and Atlantic Coast?

The DBO states: "Historical high flows, which are now tempered, are important to introduce and transport organic material from the floodplain to the river system." What function would that organic material within the floodplain have on the biology of the plover?

Predation –

The DBO states: "Predation may occur at varying intensity if the river channel is not dynamic such that sandbars are only located in limited areas where predators learn of nesting activities and prey upon colonies annually. Additionally, sandpits present unique challenges as colonies are not isolated by flowing water and more easily subjected to different predators using adjacent terrestrial habitats." This is little more than an often repeated theory which is supported by very little actual data. A review of the list of predators noted in the DBO, will show that all can be found on sandpits and on riverine sandbars.

Current Status

The DBO states: "Since 1987, the Commission has coordinated a standardized survey of all least tern and piping plover nesting along the lower Platte River, from Columbus to Plattsmouth, including both riverine and sandpit nests (See Environmental Baseline Section of this document). These counts indicate that Piping Plover numbers have declined markedly on the Lower Platte River, but numbers have remained relatively stable at sandpits." This statement seems to negate the DBO's earlier argument that sandpits are not suitable habitat?

The DBO states: "Kirsch (2001), using the same data, concluded a negative "population" trend for the lower Platte River." This data is now seven years old. Is the trend still negative?

Recovery Plan
The DBO states: "The Service finalized a recovery plan for the Great Lakes and Northern Great Plains Piping Plover in 1988 that established a recovery goal for the northern Great Plains piping plover population of 1,300 pairs (USFWS 1988a). The recovery plan states that the population must remain stable for a period of at least 15 years." Surveys have been conducted starting in 1991, which is now 17 years ago. In each and every one of these surveys, the number of birds counted exceeded the 2,600 birds. The most recent survey resulted in a count exceeding 4,000 birds. The present trend may be that the birds are well on their way to reaching that recovery goal.

<u>Environmental Baseline</u>

The Platte River

Hydrocycling
The DBO states: "Results in the lower Platte River (Peters et al. 1989) report that macroinvertebrate colonization and production along hard materials and woody and plant debris was impacted by repeating water level fluctuations as occurs with diel discharges from LPPD hydropeaking activities." What reference is this based on? Given that peaking is a constant activity, how did Peters et al. determine that repeated water level fluctuations impacted invertebrates?

The DBO states: "Evidence suggests that hydropeaking decreases the number of taxa and density of invertebrates in shallow water and that some taxa such as ephemoptera and trichoptera are extremely intolerant to the diel fluctuations (Troelstrup and Hergenrader 1990)." In Corn and Armbruster's study there were few if any ephemoptera or trichoptera. These are more common in cold water and clear streams, not on sandy, plains rivers.

Least Terns and Piping Plovers in the lower Platte River
The DBO states: "Least terns and piping plovers have a reproductive strategy that in Nebraska is dependent upon highly dynamic riverine systems, which results in ephemeral habitat." Twenty years of data on Nebraska least terns and piping plovers indicate the species are not "dependent" upon the river as most nests are located either on the shore of reservoirs or on sandpit spoil piles.

The DBO states: "In years with high flows, nests might be inundated depending on the timing of high flows, but new sandbars would be created. Floods, such as those on the Platte River in 1983 and 1995, scoured existing sandbars, replenished sand, removed vegetation and created new sandbars. In other years, low and average flows provided ideal nesting conditions on exposed sandbars, surrounded by water (Sidle et al.1992, Kirsch and Sidle 1999). During a drought period, existing sandbars may sustain for a time, but will slowly become vegetated, and will no longer provide adequate quality nesting habitat for terns and plovers. Historically, several river systems in eastern

Nebraska provided substantial habitat that supported large numbers of least terns and piping plovers." This is a very broad generalization and is not supported by data. In fact, in this DBO the lower Platte, lower Loup, lower Elkhorn and Missouri rivers are the only ones indicated as having either species, and they all contain both species today.

The DBO states: "Natural variability across a large geographic scale in these systems increased the likelihood that quality habitat was available at some locations. Today, most of Nebraska's major rivers have been altered, and nesting habitat is becoming scarce. The Platte River from Keith County to the confluence of the Missouri River has a long history of use by nesting terns and plovers." Specific locations do, and in most cases there are still birds at or near those same locations. However, there was never any data to show consistent use of the river, or even intermittent use between those areas. This is speculative and the maps discussed earlier show this same unfounded assumption.

The DBO states: "The historical seasonal and interannual flow variation within the framework of a shallow, braided river with sandy and gravel substrate and were an ideal combination for creating least tern and piping plover nesting habitat. In the late 1980's, Sidle et al. (1988) documented that the Platte River supported approximately 13% of the interior least tern population." We would not argue that following periods of high flow, nesting habitat becomes available. The years of 1983 and 1984 were the highest flows ever recorded in the central Platte. It so happened that following those years of high flows are when the initial surveys for both terns and plovers were made, resulting in an artificially high baseline in terms of bird numbers and numbers of nests. Following the high flows years of 1995-1999 on the central Platte, another peak in numbers and nests can be seen. It seems rather odd and inconsistent, that in some places within the DBO the tern and plover data ends at 1998 or 2000, but in this section it includes all data to 2007.

The DBO states: "Numbers have fluctuated over the years with changing river conditions. The Platte River in Nebraska has accounted for a high portion of least terns (6.2-13.6 percent) (Kirsch and Sidle 1999, Jones 2001). Recent, more rigorous surveys dedicated to the interior least tern in 2005 suggest that the Platte River system numbers have declined and now supports 4.4 percent of the population (Lott, 2005), which accounts for 7% of the Platte River recovery goal." This is a very misleading statement. The Platte River system accounts for only 4.4% of the population, a population of over 17,000 individuals which is 237% larger than the 7,500 adult recovery goal. There were 782 least terns counted on the Platte System in 2005, 381 on the lower Platte. The recovery goal is 750 for the Platte System, thus in 2005 the number of least terns on the lower Platte exceeded the recovery goal. How does that constitute a "decline"? How is that only 7% of the Platte River Recovery goal? Is the answer that NGPC accounts for all Platte birds at all sites in the 4.4% number, but only the 53 that nested on sandbars within the river to arrive at the 7% number?

The DBO states: "In the late 1980's, the Platte River provided nesting habitat for 9% of the piping plover population of the northern Great Plains (USFWS 1988) with 2,137 to 2,684 adult plovers in the Northern Great Plains/Prairie region, 28 adults in the Great Lakes region, and 1,370 to 1,435 adults along the Atlantic Coast (Haig and Oring 1985)

(USFWS 2000). The International Piping Plover Censuses provide the most reliable information on rangewide population trends and was conducted in 1991, 1996, 2001 and 2006. These surveys indicate a range wide decline for most years in the northern Great Plains/Prairie Canada population (Ferland and Haig 2002, Plissner and Haig 1992, Plissner and Haig 1997). Preliminary results from the 2006 International Piping Plover Census suggest that the U.S. Great Plains/Canadian Prairie region had 4700 birds, which could indicate an increase in this population. However, these numbers are not finalized, as data verification is not complete (Elliott-Smith 2007, personal communication). Given that the NGPC was the agency who tabulated all the data in Nebraska and submitted it, and given that Nebraska does annual surveys, the number of over 700 in Nebraska may be considered "finalized" and "verified". Again, while there may have been a decline from 1991-2001, all counts resulted in numbers that exceeded the overall recovery goal. A count of 700 plovers in Nebraska in 2006 is 1.6 times the recovery goal of 430 for Nebraska.

The DBO states: "The Platte River has been altered and the natural dynamics that recreate the ephemeral habitat that least terns and piping plovers depend on has been diminished or eliminated." The first surveys in the late 1980's are apparently the baseline for this statement. Specifically, what alterations have occurred to the river since this time? Any alterations that occurred before the 1980's would be accounted for and it can only be those that have occurred since that would cause the loss of habitat described.

The DBO states: "Accordingly, tern and plover numbers have declined as riverine nesting habitat decreases and nesting birds then are restricted to artificial, non-riverine habitats such as sandpits." Again, what alternations occurred that caused the decline from 1988 to 2007?

The DBO states: "Least terns are now extirpated as a breeding species within the central Platte River upstream of the Loup River, due to modifications made to the Platte River's form and function (NGPC database) (Figure 16)." Least terns were documented nesting in the central Platte in 2007. However, even following the flood of record in the early 1980's, there were never large numbers of terns nesting on the central Platte. The DBO fails to mention that 1983 and 1984 were historic flood events or that all nesting after 1987 was on man-made bars. The numbers for years 1985, 1987 and 1988 are inconsistent with Lingle (1993) who conducted all this monitoring.

The DBO states: "As with the least tern, the piping plover is now extirpated as a breeding species from river sites from the central Platte River from Columbus to Lexington and over much of the central Platte River (Figure 17)." Same comment as above.

The DBO states: "Since 1999, there has been no successful reproduction in this stretch of the river channel, with the exception of two restored river sites near Gibbon. The terns and plovers are still present and routinely use the river for foraging, but are primarily utilizing sandpits near the river for nesting and have also taken advantage of low water levels at Lake McConaughy. Sandpits are currently providing temporary habitat, but as mentioned in the species section of this document, without intensive management, sandpits are essentially biological sinks, and may accelerate population decline either locally or regionally if birds immigrate to these poor quality sites." Unmanaged sandpits are not as productive as managed ones, but in all studies to date, the productivity of unmanaged sandpits was equivalent to that of unmanaged sandbars in the Platte. Thus, if unmanaged sandpits are considered to be population "sinks", then unmanaged sandbars are as well.

The DBO states: "Locations such as Lake McConaughy also provide only temporary habitat. Additionally, sandpits are ephemeral, and eventually are converted to housing developments or become overgrown after mining stops." The ephemeral nature of all tern and plover habitat means that both species must be able to relocate in years when that habitat is not available and to exploit the habitat when it is available. The large number of piping plovers at Lake McConaughy are indicative of that. Production at Lake McConaughy cannot account for the dramatic increase in the number of plovers there from 2000-2005. Immigration is believed to have accounted for 22% and 24% of the population increase of piping plovers in 2000 and 2001, and 32% and 24% of the increase seen in 2003 and 2004 (Peyton and Wilson in prep). River habitat is as ephemeral and temporary as are the sandpits and reservoir. High water, like that in 1995-1999 inundated all but the highest sandbars and extended periods of low flows, like that in the drought years of 2002-2006 allowed for vegetation encroachment. It should be expected the populations of both terns and plovers will reflect these conditions and the overall impact to the species will be similar to the loss of sandpits to housing and the reservoir shoreline to higher storage.

The DBO states: "The lower Platte River still has least terns and piping plovers nesting on sandbars in the lower Platte River, due to the remaining semblance of the natural hydrograph in portions of the lower Platte River. The stretch of the Platte River benefits from flow and sediment contributions of the Loup River, Elkhorn River and Salt Creek, and the remaining inputs from the central Platte River which when combined with flows from the much reduced central Platte River's reach, are now the foundation of the hydrograph as we see it today. As such, while substantial water resource development has significantly altered the hydrograph of the lower Platte River, it continues to retain a semblance of the seasonal and interannual flow patterns with higher spring flows. Since 1987, the Commission has coordinated a standardized least tern and piping plover survey along the lower Platte River from Columbus to Plattsmouth that includes both the river and sandpits. Data from these surveys suggests least tern numbers, overall, have remained relatively stable when including both river and sandpit use during this 20 year period on the lower Platte River, but that Piping Plovers have declined (Figure 18-19)." Given that 86% of the terns are nesting on sandpits seems to indicate the pits are not as temporary as suggested. Is the reduction in piping plover numbers tied somehow to the dramatic increase at Lake McConaughy and reservoir shorelines on the Missouri?

The DBO states: "While there is some semblance of a natural hydrograph, the lower Platte River has been altered and the evidence can be seen in least tern and piping plover trends." The trend is from the late 1980's, thus any trends seen in population numbers would have to be in response to something that has happened over that period of time. What alterations to the natural hydrograph have occurred on the lower Platte since 1980?

The DBO states: “It is well established that when riverine sites disappear, least terns and piping plovers nest in alternate locations, but in Nebraska the alternate options are limited and suboptimal.” The “suboptimal” characterization is based upon personal opinion and not on any documented data. If sandpits were “suboptimal” is would seem strange the number of terns nesting at the pits has remained stable over a 20 year period of time.

The DBO states: “The change in nesting locations from riverine to sandpit exemplifies the altered hydrologic regime and declining habitat. As seen in the central Platte River, the gradual relocation of birds from the river sandbars to sandpits is beginning in the lower Platte River (Figures 20 - 23).” Is that due to the alteration of the river, or is that a response to drought?

The DBO states: “A good nesting season for least terns and piping plovers with an approximate 60 day period when suitable sandbars are available, and are not inundated by higher flows increases the likelihood that birds will successfully reproduce. Although flooding is possible and does occur throughout the year, least terns and piping plovers have a reproductive strategy that temporally corresponds with the historic hydrograph which maximizes the likelihood that birds will successfully reproduce. These birds typically arrive in May and begin nest initiation in late May to early June as the water level historically peaks and then begins to recede (Figure 27).” As can be seen in Figure 27, the peak flow is mid June, not early June. For piping plovers that arrive in late April and early May, this would be devastating. A simple 60-day window is not sufficient to say nesting is possible. Renesting would be possible, however other studies have shown that renests are less successful on average and they produce fewer fledged birds. Given the chronology we see in nesting piping plovers and the Figure referenced above, one could conclude that the lower Platte historically was never optimum piping plover nesting habitat and in fact it may have been a reproductive sink.

Figure 31 of the DBO shows the following (*red line added*):

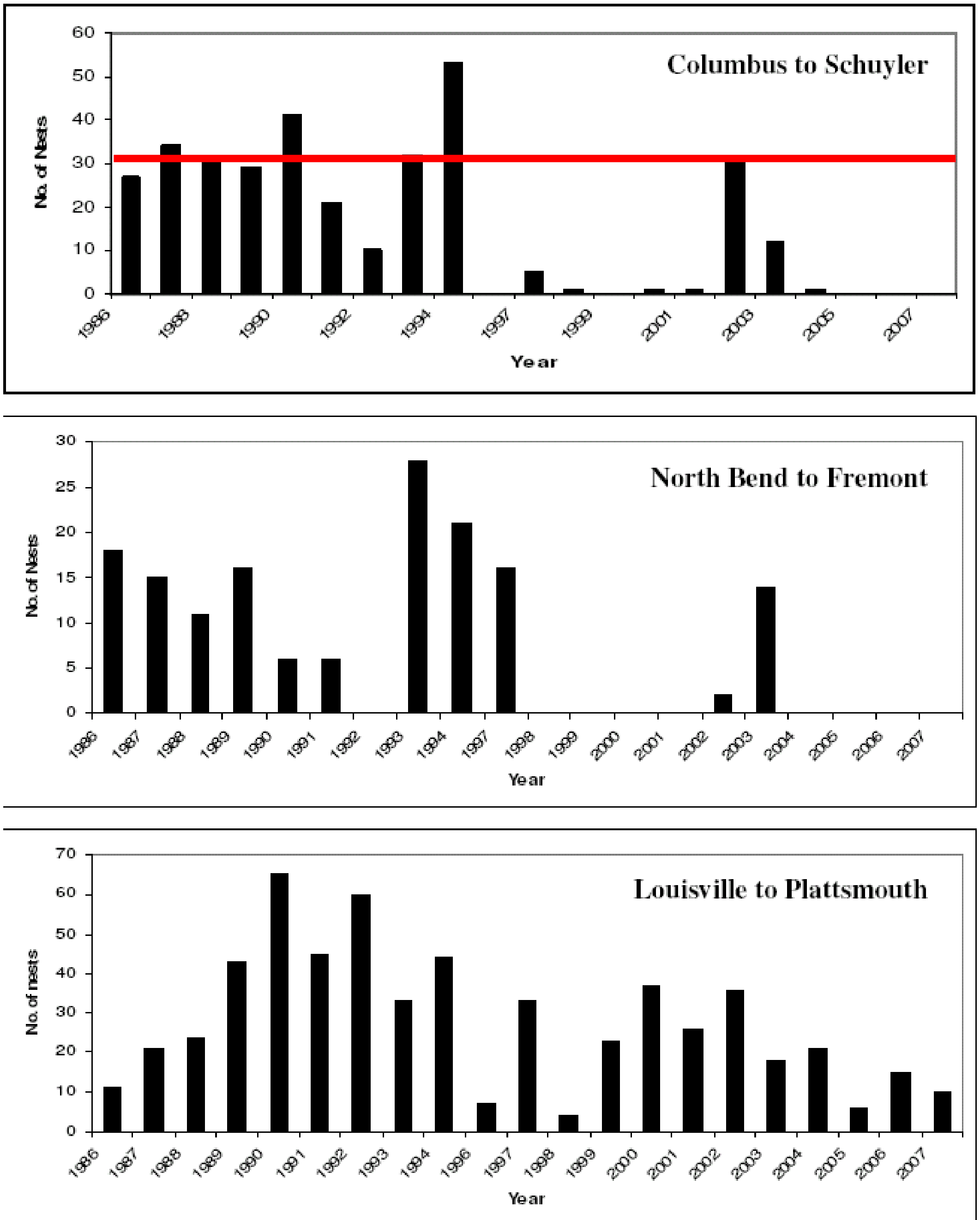


Figure 31. Number of least tern nests from selected river segments recorded during Nebraska Game and Parks Commission annual surveys. Data indicates decline and effectual extirpation of breeding birds on the Platte River in upper segments (Columbus to Schuyler and North Bend to Fremont) resembling declines and extirpation from the Central Platte River. In contrast, breeding birds have been observed on the river in the lower segment (Louisville to Plattsmouth) through 2007 where river function is not as greatly degraded and affected by diversion.

If you look at the top two graphs the scale to the right is not the same. There are actually more birds upriver. That doesn't seem to match up with the discussion on sandbar height and flows.

The DBO states: "Least terns and piping plovers have very limited available habitat available along Nebraska's rivers when compared with historical distributions. In Nebraska, much of the habitat utilized is inadequate to sustain the populations of least terns and piping plovers." Compared to historically documented least tern and piping plover numbers, there are actually more in Nebraska now than historically. The DBO's opinion there were more historically is not supported by documented sightings. If the habitat is inadequate to sustain populations, then why are there greater numbers of both least terns and piping plovers in the state now than the recovery objective that was established during the "hey day" of birds nesting in the river?

<u>Literature Cited</u>

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ENVIRONMENTAL CONSULTANTS

Memorandum

To: Jaron Bromm, Fennemore Craig, P.C.
From: Jon Kehmeier and Ann Widmer, SWCA Environmental Consultants
Date: November 18, 2008
Re: Review of Peters and Parham (2007), Parham (2007), and 2007 Biological Opinion

At the request of Fennemore Craig, P.C. and Lower Platte Basin Coalition of Proponents for Sound Science, SWCA has completed a preliminary review of the following technical and regulatory documents:

- Parham, J.E., 2007. Hydrologic Analysis of the Lower Platte River from 1954-2004, with Special Emphasis on Habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

- Peters, E.J. and J.E. Parham. 2007. Ecology and Management of Sturgeon in the Lower Platte River, Nebraska. Nebraska Technical Series No. 18, Nebraska Game and Parks Commission, Lincoln, Nebraska.

- Nebraska Department of Game and Parks Draft Biological Opinion dated October 19, 2007 related to Nebraska Department of Natural Resources continued issuance of surface water appropriations.

There are numerous major flaws in the analyses and interpretation presented in the reports. Many of the issues identified by SWCA are possible fatal flaws that limit or preclude the use of the information contained in the reports for water and wildlife/fisheries management purposes. Additionally, the power of the datasets is too limited to be used to develop water and habitat management recommendations. These issues call into question most of the major conclusions contained in the three documents and do not justify the recommendations made in the biological opinion to eliminate future additional degradation of the magnitude or structure of hydrograph and to not allow additional depletions that would reduce the magnitude, timing, and frequency of 8,100 cfs flows in the Lower Platte.

SWCA's initial preliminary review was completed prior to our review of the other concurrent independent reviews to eliminate any bias or influence from those reviews. Our review constitutes a preliminary assessment of major flaws in the three documents and does not focus on numerous smaller errors or flaws that were identified. The comments contained in this document will be used with the other concurrent reviews to develop a comprehensive synthesis of all comments and a final review of the usefulness of any water or species management recommendations.

Major/Fatal Flaws

The base flow recommendations are biased towards higher magnitude flows. This is meant to provide year-round habitat for adult pallid sturgeon. However, Peters and Parham 2007:

- Did not document year-round use by adult pallid sturgeon in the lower Platte River. Mature adults were only observed in the spring and all returned to the Missouri River shortly after being tagged.
- Did not provide evidence that the lower Platte River is or ever was good habitat for pallid sturgeon. Rather, the evidence suggests that the lower Platte River was marginal habitat on the outer fringe of the pallid sturgeon range. In 5 years of sampling, they only collected 15 pallid sturgeon.
- Indicated in their literature review that pallid sturgeon preferred the areas just downstream of sandbars or along sandbar ledges, yet weighted "open water" habitat higher than "sandbar complexes" in their analysis of habitat quality. The preference for open water was based on the radio telemetry data from the 6 fish that were tagged with radio transmitters. A total of 32 data points were collected from the 6 tagged fish. It appears that the authors used each of the 32 data points as unique, independent observations of habitat use even though individual fish accounted for multiple observations. Additionally, of the 32 observations, 26 (81% of observations) came from just 2 fish (Fish 621 and Fish 542). Therefore, the authors are largely describing the habitat use of just 2 fish and it would be difficult and inappropriate to extrapolate these habitat use patterns to the larger pallid sturgeon population in the Lower Platte.

The spring flow recommendations are biased towards higher magnitude flows. This is meant to provide an uninterrupted corridor so that adult pallid sturgeon may seasonally migrate upstream to spawn. However, Peters and Parham 2007:

- Did not provide evidence that pallid sturgeon spawn in the lower Platte River. In 7 years of larval drift sampling, only 14 sturgeon larvae (species unknown) were collected. (Note: given the number of resident shovelnose sturgeon that they documented in the river, we would have expected them to have collected more sturgeon larvae. They may have been collecting in the wrong places, at the wrong times, or using the wrong method.)

- Did not document an organized migration of pallid sturgeon into or out of the lower Platte River during the spring or any other season. Pallid sturgeon movement into the lower Platte River could have been random, made more likely by slightly higher spring flows or warmer temperatures.
- Did not study or consider the swimming abilities or patterns of pallid sturgeon. Peters and Parham assume that adult pallid sturgeon would be averse to swimming through narrow channels (anything less than 25 m wide) or water less than 1.5 meters deep in move into or search for suitable habitat upstream (even though they documented adult sturgeon in water only 0.6 m deep). This assumption is very conservative and likely overestimates the discharge necessary to provide functional connectivity. Additionally, placement of a 25 meter buffer around all sand bars and sand bar complexes is arbitrary and likely underestimates the amount of habitat available. There is no scientific basis for placing a buffer of any size around shallow habitats.

The habitat needs of larval and juvenile pallid sturgeon (and shovelnose sturgeon) are not studied or considered in the flow recommendations. Peters and Parham primarily sampled deep habitats, looking for adult pallid sturgeon. They used seine nets and minnow traps to occasionally sample shallower habitats, but did not specifically report the captures of young-of-the-year sturgeon, if there were any. If the lower Platte River is used by pallid sturgeon for reproduction, it is likely necessary to maintain habitat for their offspring. Although the reproductive habits and nursery habitat requirements of pallid sturgeon are largely unknown, the young of most freshwater fish species require warm, productive, sheltered habitats, such as inundated floodplains or emergent vegetation along shorelines. While Peters and Parham suggest that the lower Platte River should be managed to sustain a mosaic of different habitat types (which would include nursery habitats) and ran models in the IHA software to define flow patterns necessary to maintain ecological integrity, their specific flow recommendations focus on setting minimum flows. More information on channel forming flows, lateral migration of the channel, floodplain connectivity, the influence of antecedent flow conditions, and sediment transport would be desirable.

The use of the fish capture data in determining habitat utilization is problematic. The authors did an admirable job of maximizing the probability of capturing sturgeon in the Lower Platte by using a variety of gear types that had been proven in the Missouri River and elsewhere. These data are likely useful for generally describing the demographics and condition of the fish that were subject to capture with these gear types. Additionally, these data are likely useful in supporting that sturgeon generally use areas that are deeper and swifter than average. However, none of the gear types were adequate for identifying specific habitat use by sturgeon for the following reasons:

- Drifting trammel and gill nets were effective in capturing sturgeon and other species. However, when sturgeon were captured, the authors inappropriately used average depths and velocities over the entire 200-400 m sampled reach to characterize sturgeon habitat. Generalizing habitat conditions at this scale ignores the site-specific micro- or meso-habitat conditions that sturgeon select. Additionally, averaging reach-wide habitat conditions assumes that the fish are using the most abundant habitat and fails to recognize that many species select habitat in a manner that is disproportionate to its availability.
- Use of trotlines for establishing habitat use is inappropriate. Trotlines are baited with food items meant to attract fish from the habitats they are currently in to the habitat where the trotline is set. Use of habitat data taken from fish captured using trotlines is simply describing the conditions where the trotline was set, not the conditions that the fish typically use.
- Use of radio telemetry is better than the other methods to identify specific locations of fish habitat use. However, in a relatively shallow river like the Platte, the areas fish are documented as using with telemetry methods could reflect their escape habitat rather than the habitat they most often would select. Radio tracking fish requires that air boats or wading be used to identify the exact location of a tagged fish. Both of these methods are likely to cause the tagged fish to move to areas where they feel safest. This could be a larger issue with a short term tracking study such this. Tagged fish likely would attempt to escape any humans or equipment that they might associate with their capture and tagging event. Additionally, the authors did not consider that the tagging event could cause changes in behavior as the individuals recover from the incisions and stress sustained during the tagging process.

Depth to discharge relationships were established from only 9 transects that were located around the mouth of the Elkhorn River. It was not established that the morphology of the channel in this reach is representative of the larger lower Platte River. Being located around a major tributary, we might reasonably expect sediment deposition in this section to be higher than average. Based on personal observation in other river systems, the channel may also be wider and shallower than average (a natural consequence of sediment deposition). If this were the case for the transect study area, baseflow and peak flow recommendations for the whole lower Platte River which depend on this depth to discharge relationship could be biased high—it would take a greater quantity of water to produce and maintain deeper channels and higher sandbars in this reach than the majority of the lower Platte River.

The analysis of piping plover and least tern nest success assumes that the birds would abandon the nest if sandbar height (height above the water surface) dropped below 1.5 feet due to dampness. However:

- The 1.5 ft cutoff is somewhat arbitrary. It was based on one literature reference, which indicated that this was the lowest elevation that nets were observed. Parham (2007) doesn't provide any information about their survey methods, the number of observations made, or the antecedent conditions. The elevation cutoff would be more objective if based on the soil's water conductance capabilities—is it physically possible for Platte River sand to draw water up a vertical 1.5 feet? More or less?
- The birds may not abandon the nest if brief dampness occurred near the end of the 60-day nesting period. While it is true that the birds could not keep a young chick or egg warm in a damp nest, a larger chick is more capable of thermoregulation and has greater mobility (personal communication with Larry Semo, avian specialist).

Thus, the analysis may be overestimating the necessary height of the sandbars or exaggerating the need for stable flows during the nesting period. Historically, the lower Platte River probably experienced greater flow variability that present, which is illustrated in Figure 3.5 of Parham 2007.

The flow recommendations for the pallid sturgeon and the two bird species are contradictory. The habitats of all three species require occasional large flushing flows—those flows that move the channel, form new sandbars, and scour deep channels. In the spring and summer, however, the Parham 2007 indicates that the birds need lower flow conditions than the sturgeon.

Habitat quantification for pallid sturgeon was conducted by one technician from relatively low resolution photos and no groundtruthing was conducted to check accuracy. To cover the uncertainty associated with this method, the authors were very conservative in their habitat classifications. For example, a channel less than 50 m wide between two sandbars would be classified as "sandbar complex", regardless of its depth. This same classification would be used to describe a large sand flat covered in 10 cm of water, even though one might actually provide high quality habitat to sturgeon while the other is uninhabitable by large fish. This conservative approach quantification approach may have grossly underestimated the amount of high quality habitat available, particularly for pallid sturgeon at moderate flows. Likewise, the only islands greater than 3.58 acres in size were considered nesting habitat for piping plover and least tern, when much of the population might be willing to use smaller islands. Thus, the analysis likely underestimates the actual habitat available for the two bird species.

There are fundamental flaws with the GIS digitization of open water habitats which could invalidate any of the habitat/flow relationship analyses. These flaws include:

- There are steps missing in the habitat classification process. Generally, ground verification that shows the accuracy of classification is used to verify results of the photo interpretation method.
- There was not mention of what the Minimum Mapping Unit (MMU) was for the classification. The 1:5000 scale that is reported is just the scale of the imagery on the screen, not the MMU of the classification. MMU provides some reference on how big a polygon of a class must be to call it a class. It was impossible to determine whether the authors created polygons for everything they could find or just "eye-balled" it. This calls into question the accuracy of the classification and is likely the reason that the authors placed an arbitrary 25 meter buffer around shallow sandbar complexes.
- It is not clear what resolution and distortion they had when rectifying the 2003 camera data. It is a non-standard camera and may have introduced errors in their processing. Also they rectified it to 1994 data rather than the more recent 1999 data.

Because of naturally high turbidity in the Lower Platte River, delineation of open water habitats from aerial photographs is inappropriate. Davies-Colley and Smith (2001) reviewed relationships between visible depth and turbidity. Data presented in that paper demonstrate that visible depth is approximately 6 cm at 100 NTU in New York and 10 cm at approximately 70 NTU for 97 rivers in New Zealand. Additionally, Figure 2.1 in the hydrological analysis report by Parham that accompanied the Peters and Parham documents that shallow bars can be immediately under the water surface yet not visible because of high turbidity. Photos used to classify habitat conditions were taken during river discharge conditions ranging 0 to 21,000 cfs. Chapter 3 of the Peters and Parham report clearly demonstrates that high turbidity is expected for nearly all flows in the Platte River. Because of the high turbidity it is possible that the open water habitats delineated from photos taken during turbid river conditions are not open water as defined in the Peters in Parham report. Rather, much of the habitat is likely inundated, shallow sand bar complexes. This error likely biases all flow and management recommendations made and overstates the amount of water needed to provide adequate habitat.

It is very unclear how the authors linked the IFIM, photo interpretation, fish capture, and geomorphology transect data to determine what habitat was available at a given flow. It appears that the authors used the IFIM data from the 1980s to provide an approximate proportion of aquatic habitat types for each of the flows for which habitat was delineated. Using IFIM data that are 10-20 years old is not appropriate for this purpose. Additionally, use of IFIM data for a dynamic sand bed river is questionable. Kehmeier et al. (2007) discussed that cross-sectional, 2-dimensional analyses such as IFIM and PHABSIM assume a stable bedform and cross-sectional profiles for prediction of changes in habitat conditions in response to changes river discharge. This assumption is violated in dynamic sand bed river such as the Platte where bed scouring and sand bar migration result in variable cross-sectional profiles even at the same discharge. Additionally, IFIM data were only collected at flows up to 6,767 cfs. Even if use of IFIM were valid in the Platte River, any discharge greater than this could not be linked to any sturgeon habitat data collected at flows greater than 6,767 cfs and calls into question any resulting habitat models presented in the Peters and Parham report.

The authors took the data points generated from the aerial photo interpretation and created curves that predicted habitat availability at discharge. Due to the relative scarcity of data points, the authors had to group the data for the entire length of the river. For each taxon (birds and fish), the authors created one habitat quantity to discharge curve per habitat type (for birds there was only one habitat type). The implicit assumption of this method is that the discharge to habitat type availability relationship is the same throughout the lower Platte River, which contradicts their physical description of the river. The curve fit seems decent for fish (r^2 ranging from 0.86 to 0.89, Figures 10.8 to 10.10 in Peters and Parham 2007), but was poor for the birds ($r^2 = 0.45$, Figure 2.10 in Parham 2007), although the authors interpreted it "moderately good". This weak relationship introduces uncertainty into their model that predicts the % of habitat available from daily mean flow and the determination of favorable conditions. Additionally, most of the models describing relationships between habitat and discharge were complex nonlinear equations. Given the limited amount of data available to define these relationships the results are questionable. Any set of data can be fit with a curve if enough parameters are used. The high number of parameters and the illogical equations that were fit to the data could indicate that the relationship is not real and instead the authors could simply be fitting a curve to their dataset.

<u>Other Flaws:</u>
No pre-development flow data were available for the majority of the river reaches. Peters and Parham advocate recreating historical flow patterns, but it is unknown whether their flow recommendations achieve this purpose.

It is unclear why the authors summarized flow conditions with mean monthly discharge. Summarizing the data in this manner does not recognize the importance of single large flow events that are very important for creating both shallow and deeper water habitats in a dynamic sand bed channel. Additionally, it does not allow for comparison of individual fish capture events to the antecedent or current discharge and habitat conditions. Periodic high flow events are important to sandbar formation, channel scouring, sediment transport, lateral channel migration, floodplain connectivity that produce the diverse mosaic of habitat that these protected species need. The authors advocate "protecting or enhancing the spring rise in the lower Platte River" for this purpose, but they don't make specific recommendations for the frequency or magnitude of these channel forming flows.

On page 97 of the report the authors state that the growth of pallid sturgeon in the lower Platte can be inferred from the growth histories of the stocked fish that were captured. It is unlikely that one could infer anything from these growth rates as these fish generally moved hundreds of miles before being captured in the Platte River.

Table 5.5 is very confusing. It cannot be determined from this report what "normalized selected habitat" is. It is believed that this selected habitat measure would be very important for determining habitat use and availability in the Platte River. Greater detail on how it is calculated and what it is would be useful.

Tables 5.1, 5.6, 5.11, and 5.16 indicate that generally, none of the measured habitat characteristics (depth, velocity, substrate, water quality) can be reliably used to define presence of shovelnose sturgeon. As datasets were not adequate for this type of analysis for pallid sturgeon, it cannot be determined whether this would hold true for that species. Insignificant relationships between fish presence/use and these measured habitat variables could be caused by the biases of the sampling gears described above. However, it is interesting to note that for the smaller bodied species analyzed in Chapter 7, the same type of analysis reveled more significant relationships using trawl and seine data.

The following pages contain a detailed review of the biological opinion. Because of the considerable overlap between the Peters and Parham (2007) and Parham (2007) reports and the biological opinion, many of these comments also apply to the two technical reports.

1. In the introduction, the author(s) of the Biological Opinion (BO) established that inadequate scientific data initially existed on the ecological requirements of the pallid sturgeon to determine the impacts of surface water appropriations on pallid sturgeon, so Dr. Ed Peters and Dr. Jim Parham were contracted to complete a large ecological study of the species in the Lower Platte River (LPR) (Peters and Parham 2007). The BO reiterates the objectives of this ecological study, but fails to critically evaluate whether the objectives were met. In our opinion, the study by Peters and Parham did not meet all of its objectives, so there may still not be enough information to determine the impacts of surface water appropriations on pallid sturgeon.
    a. Objective 1 was to document habitat use, relative habitat preference, and species assemblages associated with adult and juvenile pallid sturgeon and sturgeon chub in the LPR.
        i. Peters and Parham 2007 provides no data on juvenile sturgeon habitat use. It is not clear whether the habitat analyses were not separated by age group or whether no juvenile sturgeons were captured during the study. Sampling was heavily biased towards the capture of adult sturgeon.
        ii. Peters and Parham 2007 documents the occasional presence of adult pallid sturgeon at very low densities near the mouth of the Missouri River. In 5 years of study, only 15 pallid sturgeons were captured. The study did not conclusively determine what type of habitat the LPR is for adult sturgeon (e.g., spawning, foraging, year-round, etc.).
        iii. Habitat "preferences" of pallid sturgeon determined by Peters and Parham (2007) are based on the locations of 32 telemetry recaptures of 6 tagged fish, 26 of which were the repeated captures of just 2 individual fish. This is not a robust enough dataset for habitat utilization analysis.
    b. Objective 2 was to document the phenology and relative abundance of larvae for pallid sturgeon, sturgeon chub, and associated species in the lower Platte River.

i. In 7 years of larval drift sampling, only 14 sturgeon larvae (species unknown) were collected (Peters and Parham 2007). Either the LPR is not an important spawning location for sturgeon, or the larvae collection method was ineffective.

ii. Due to low capture numbers, this study did not adequately characterize the phenology or the relative abundance of sturgeon larvae (pallid or shovelnose).

c. Objective 3 was to determine if changes in ambient river habitat conditions influence habitat use by pallid sturgeon and surgeon chub life stages in the lower Platte River.

   i. None of the habitat analyses in Peters and Parham 2007 were life stage specific.

   ii. Peters and Parham 2007 used aerial photographs to roughly assess habitat availability and river connectivity at different flows (ambient river habitat conditions?). They didn't assess how sturgeon habitat use may have changed as flows or other river conditions changed.

2. Figure 2 needs additional features labeled, including highways (6 and 50 are mentioned in text), counties, and relevant USGS gages.
3. Figure 3 needs a figure caption.
4. The introduction quotes Wycoff's (1960) account that 20-35 pairs of least terns were nesting on a "low, sandy island not over 75 feet wide, about 200 feet long, and lying nearly a quarter mile west of the Platte River bridge which is straight south of Lexington Nebraska" in the years 1949-1954. While this citation was meant to illustrate the historic range nesting habitat, it also documents least terns repeatedly using an island that is only 0.3 acres in area. This area is far smaller than the minimum island size (3.5 acres) assumed to be least tern habitat by Parham 2007. Therefore, Parham (2007) may have greatly underestimated the river sandbar habitat available to least terns.
5. Page 12 states, "Lower fledge ratio estimates from sandpits illustrate that although a direct cause of lower fledge ratios cannot be determined, the sandpit habitat is not adequate for population maintenance or recovery." While it is true that the fledge rates are not high enough for population maintenance or recovery, the data provided in Table 1 (particularly Kirsh 1992) actually show higher fledge rates on spoil piles and gravel mines than river sandbars.

6. The BO specifically mentions that water quality in the LPR (particularly Se contamination) is harmful to all three species. Water quality is an important aspect of habitat, especially for young animals or year-round residents. However, water quality was not considered in habitat quality and quantity determinations by Parham 2007 and Peters and Parham 2007 that are used to set flow targets in the BO. River discharge may not be the only factor limiting habitat availability for these species.
7. The nest incubation and fledging times for piping plovers (25 to 31 days) and least terns (up to 41 days) provided in the BO appear to be substantially less than the nesting period assumed by Parham 2007 (60 days), although Parham's (2007) estimate also includes time (20-30 days?) for initiation of the nest (which consists of a scrape in the sand). If Parham overestimated the duration of the nesting period, then he likely also overestimated the rate of nest failure due to river inundation.
8. In the introduction to pallid sturgeon (p. 25), the BO describes habitat of this species as being the bottom of swift waters of large, turbid, free flowing rivers with braided channels, dynamic flow patterns, flooding of terrestrial habitats and extensive microhabitat diversity. If these are the habitat elements that are important to sturgeon, then why didn't the habitat quantification in the LPR look specifically for these elements? Instead, Peters and Parham (2007) relied heavily on habitat data collected at the locations of a few recaptures of tagged pallid sturgeon. The recapture locations of these few fish, which were probably influenced by the sampling method, led the authors to rate open water habitat as being much higher quality habitat for pallid sturgeon than sandbar complexes. Yet, sandbar complexes are the habitat type that would provide the braided channels and diverse microhabitats that allegedly characterize pallid sturgeon habitat. According to this BO, Snook (2001) found pallid sturgeon in water as shallow as 0.15 m in the LPR. Peters and Parham's (2007) emphasis on open water habitats biases the recommendations in the BO towards high flows without necessarily protecting the microhabitat diversity that supports pallid sturgeon, least tern, and piping plover. Ultimately, the timing and variation in flow, as well as the channel morphology, may be much more important to the conservation of these species than minimum flow.
9. The "likely" spawning cues of pallid sturgeon described on page 28 of the BO (i.e., increased temperature, turbidity, and nutrient cycling) depend on floodplain connection during high spring flows. Page 37 of the BO mentions land use within the floodplain, residential floodplain levees, bank stabilization,

and timber encroachment, implying loss of floodplain connectivity in some areas of the LPR. Hence, spawning cues may be a limiting factor for pallid sturgeon in the LPR.

10. The BO does not provide evidence of wild or stocked pallid sturgeon spawning in the LPR, migrating seasonally into the LPR, or residing year round in the LPR. This document describes one gravid female pallid sturgeon that was tagged by Peters and Parham (2007) that stayed around the Louisville area for several days and then moved rapidly downstream to the Missouri River. The BO presumes that this fish spawned, but this fish was not recaptured and it is unknown whether this fish spawned in the LPR or not. Similar behavior was exhibited by tagged pallid sturgeon after a back flushing operation by the MUD water treatment plant (described on page 32). The BO describes how Peters and Parham (2007) captured larval sturgeon on May 23, 2001, just prior to the female sturgeon moving downstream. In actuality, only one sturgeon larva was captured in the year 2001 and the species is unknown (Table 8.1 in Peters and Parham 2007)— not convincing evidence that pallid sturgeon are spawning in the LPR.
11. The BO describes gravid female pallid sturgeon implanted with radio tags moving up the Yellowstone River to spawn (page 33). No data are presented on the distances these fish move up the Yellowstone River or the type of habitat used for spawning. It would be useful to know if the LPR contained habitat similar to that in the Yellowstone River.
12. The BO describes the Coefficient of Dispersion (CD) calculated by Parham 2007 as, "an index that illustrates whether the river is rising and falling with a "natural pattern" with values closer to 1 being "natural". Parham (2007) describes this index differently, indicating that it is a measure of the spread of the data similar to a coefficient of variation. As presented in Tables 3 through 7 of the BO, CD can be used to compare variability in flow (i.e., the spread of the data) among months or seasons. As one would expect, the least variation occurs during the winter base flows (CD near 1). The CD increases during the summer months, which would also be expected; summer flows naturally vary inter- and intra-annually, given storm events, snowpack, and weather. A high CD in the summer months is not an indication of unnatural conditions. Furthermore, the data used are from 1954 to 2005, during which time no "natural" flow regimes occurred anyway. Trends in monthly CD over years may be a more useful analysis to evaluate flow regime change.

13. It isn't clear whether the exceedance flows were calculated from daily mean cfs or monthly mean cfs during the period of record 1954-2005. This should be indicated in the figure captions in Figures 9 through 14. Maximum and minimum flow information would also be useful.
14. Figure 17 has no caption.
15. Figures 16 through 23 illustrate the decline in the number of piping plovers and least tern nesting on sandbars in the LPR since 1987 and increased use of managed sand pits. Can this decline be attributed to changes in median flow conditions or bankfull flow patterns over the last 30 years? Could the availability of attractive alternative nesting habitats (like intensively managed sandpits) have increased over this time period? These data doesn't necessarily support the need for minimum flow standards.
16. On page 57, the BO says the National Research Council (2005) found that the LPR contains the habitat with a flow regime most similar to the original, unaltered habitat of pallid sturgeon. How and where was the "original, unaltered" habitat of pallid sturgeon characterized? Peters and Parham (2007) indicate that the LPR channel is substantially shallower than in the pallid sturgeon population centers.
17. The BO states on page 57, "Low catch rates of pallid sturgeon make [population estimates] difficult, but the use by the closely related shovelnose sturgeon illustrate the importance of the lower Plate River to sturgeon species." Peters and Parham (2007) documented that shovelnose sturgeon use shallower water and forage on macroinvertebrates rather than small fish as pallid sturgeon do. Use of the LPR by shovelnose sturgeon does not illustrate the importance of the LPR to pallid sturgeon, the species of concern in this BO.
18. There was 1 recapture of stocked pallid sturgeon for every 2.1 miles of river in the Platte River compared to 1 recapture for every 8.8 miles of Missouri River (p. 57-58). This was used as evidence of the importance of the LPR to pallid sturgeon. However, these numbers haven't been corrected for sampling effort and may be biased by differences in fish catchability between the two rivers (i.e., the deeper and wider Missouri River may be more difficult to sample). These data don't conclusively demonstrate a higher density of stocked pallid sturgeon in the LPR than RPMA 4 of the Missouri River. The overall numbers of pallid sturgeon captured in the LPR (stocked or wild) by Peters and Parham (2007) were low.
19. Page 58 states, "These areas of the river that provide suitable habitat will occur within the matrix of various depths and velocities throughout the lower Platte

River when there is adequate flow." Adequate flow will only provide these habitats provided "adequate" antecedent conditions. Flow variability (including high channel forming flows), lateral bank movement, and sediment scour and deposition are key river processes required to produce a matrix of habitats.

20. Page 58 states that several factors make a strong argument that pallid sturgeon are using the lower Platte River for spawning, with the most compelling evidence being the fact that larval sturgeon less than one day old have been sampled in the LPR and have been captured in multiple years in May and June. This is not convincing evidence of pallid sturgeon spawning. The larvae were most likely shovelnose sturgeon, a known long-time resident of the LPR. Furthermore, it is unknown how similar pallid and shovelnose sturgeon spawning habitats are. Earlier in this document, it was suggested that shovelnose and pallid sturgeon were hybridizing primarily due to habitat degradation.
21. Parham 2007 assumed that 1.5 years was appropriate frequency for bankfull discharge in the hydrology models; this value is supposedly an average bankfull frequency value (Rosgen 1996). Most of Rosgen's work is based on hard-bottomed stream beds, so a 1.5 year frequency may or may not be appropriate for maintenance of a sand bed channel. When making recommendations, it is important to remember that this frequency was picked somewhat arbitrarily.
22. Page 62 of the BO states that, "Peters and Parham (2007) found that once a woody island was established, there was no correlation between moderate flows and the amount of woody island vegetation, meaning that flows as high as 21,000 cfs are not sufficient to remove this vegetation." This isn't an accurate interpretation of the analysis. Peters and Parham (2007) found no relationship between the total area of wooded islands (i.e., the abundance of that habitat type) and discharge based on the analysis of aerial photographs. The fact that the area of the islands didn't change at high flow suggests that the islands were not inundated at high flow. Peters and Parham (2007) did not document the elevation of the islands, which may have been built up during the last 10- or 100-year flood. There is no evidence to suggest that bankfull flows wouldn't remove newly-established woody vegetation from a low-elevation sand island.
23. Some of the numbers in Tables 8 and 9 are inconsistent with those in Parham 2007 (did they come from a different version?). Furthermore, Parham 2007

assumes a minimum necessary sandbar height of 1.5 feet for nesting habitat of least tern and piping plover, whereas the BO incorrectly reports it as a minimum height of 1.0 feet.

24. I was unable to find the analysis in Figure 26 of the BO in Parham 2007. It appears that this analysis was done on a subset of the data used in Parham's (2007) analysis of habitat availability by discharge (Figure 2.10). Please provide more detail on the method of this analysis and criteria for omitting data, if that occurred. The curve in Figure 26 of the BO based on spline interpolation appears to have better fit than that in Figure 2.10 of Parham 2007 ($r^2 = 0.45$).
25. Page 72 states, "Parham (2007) found that a flow of 2,350 cfs for the lower Platte River resulted in the maximum level of shallow water habitat." However, the habitat to flow relationship is largely dependent on antecedent conditions in a dynamic sand-bottomed channel.
26. The results of the analysis of sturgeon habitat preferences in Figure 32 don't make sense. Why was the second highest frequency of pallid sturgeon found in a habitat type (0.6 m deep) that the species allegedly avoids? Similarly, why do the authors assume that pallid sturgeon select deep habitat types when the frequency of capture becomes increasingly rare as the water depth increases? This analysis is based on very sparse data for pallid sturgeon and appears to be biased toward deep water habitats. Same for Figure 33, but the bias is towards higher velocity water.
27. Eight of the 20 data points in Figure 35 fall outside the 95% confidence intervals. The confidence in this analysis is clearly overstated.
28. The author's interpretation of Figure 35 is that 8,100 cfs are required for 100% connectivity. However, the data points in the figure show that 100% connectivity is achieved at 5,500 cfs at all but one of the sites analyzed. While the exceedance rate for 8,100 cfs is 45%, the exceedance rate for 5,500 cfs is somewhat better at 65%. Recommendations for maintenance of flows of 8,100 cfs from April through June, 7,000 cfs from July 1 to July 15, and 6,000 cfs from July 16-31 seem overly conservative for the purpose of river connectivity. Seasonal flows higher than these would still be necessary for channel and sandbar maintenance.
29. At 4,950 cfs, 59% of pallid sturgeon habitat is apparently available in April through July, but the figure cited on page 78 for this statement (Figure 26) describes habitat availability for birds. Where did this value of 4,950 cfs come from? Figure 34?

30. The opinion states that bankfull flows occur approximately every 1.5 years and that these flows may occur at any time of the year. The 1.5 years is an artifact of the assumed return rate that Parham 2007 used in his hydrology model (see comment 21). It would likely benefit all three species if the bankfull flows occurred in the spring or early summer, coinciding with spring runoff.
31. The BO emphasizes the need for microhabitat diversity and repeatedly describes key elements of river function, including sediment movement, high flows, and floodplain contribution of nutrients. The Opinion establishes minimum flow targets, but makes no specific recommendations for the maintenance of microhabitat diversity or river function.

Review by Bernard Kuhajda of the document Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon, J.E. Parham (2007).

Chapter 1

This chapter details a hydrological analysis of the lower Platte River form 1954- 2002. I did not review this chapter.

Chapter 2

This chapter estimates nesting habitat of the least tern and piping plover in relation to river discharge. I did not review this chapter.

Chapter 3

This chapter estimates suitable habitat and connectivity for pallid sturgeon in relation to river discharge. Methodology employed in determining discharge rates that provide adequate habitat and connectivity for pallid sturgeon in the lower Platte River is beyond the scope of my expertise, but I can comment on references to pallid sturgeon life history characteristics.

In the Introduction and Results sections, the few references to Peters and Parham (*in press*) do accurately reflect finding in the Peters and Parham (2007) report on ecology and management of sturgeon in the lower Platte River, Nebraska. In the Conclusions, the few references to pallid sturgeon life history characteristics are accurate. There was little information in this report for me to review.

Review by Bernard Kuhajda of the document Nebraska Technical Series No. 18: Ecology and Management of Sturgeon in the Lower Platte River, Nebraska, E. Peters and J. Parham (2007).

Chapter 1:

A description of the study area in the lower Platte River, NB, is provided in both historic and present-day conditions. An overview is given on past anthropogenic modifications and the recent state of the physical characteristics of channel morphology and water quality and quantity for the lower Platte River proper and its three major tributaries (The Loup and Elkhorn rivers and Salt Creek). It is noted that during the period of this study (2000-2004) precipitation was very low in the Platte River drainage and that the Loup and Elkhorn rivers were a major source of flow for the lower Platte River. Even with these anthropogenic changes in the lower Platte River, this system represents one of the last remnants of semi-natural riverine habitat left in the Great Plains. Of the 100 species of fishes that have been recorded from this drainage this study concentrated on three, the pallid sturgeon (*Scaphirhynchus albus*), the shovelnose sturgeon (*S. platorynchus*), and the sturgeon chub (*Macrhybopsis gelida*).

Chapter 2:

Habitat use by pallid and shovelnose sturgeon and sturgeon chubs in the lower Platte River was assessed in this study by sampling for these species with a wide variety of gear including drifted gill and trammel nets, stationary gill nets, trotlines, trawls, seines, and minnow traps. The authors cite previous studies on the Platte River that did not find these three species in shallow water or shoreline habitats, therefore their sampling concentrated on the deeper and swifter sections of the river. This methodology is sound for the following reasons. Trotlines are one of the most effective ways to capture sub-adult and adult pallid and shovelnose sturgeon, especially during times of higher flow and in deeper and swifter waters. Drifting gill and trammel nets are also very effective at collecting sub-adult and adult sturgeons, while trawls are relatively effective at sampling for juveniles (Kilgore et al. 2007, Wanner et al. 2007). In other river systems, adult *Scaphirhynchus* typically inhabit areas of high to moderate flows at depth from 0.9-10 m, usually 4-6 m (Keenlyne, 1997; Wilson and McKinley, 2004), therefore sampling the deeper and swifter portions of the lower Platte River is targeting the most appropriate habitat for these sturgeons in this system.

Measurements were taken on all *Scaphirhynchus* collected in this study to calculate a morphological character index (Sheehan et al. 1999) to help assess the proper identification between pallid and shovelnose sturgeon, with additional measurements taken starting in 2003. Across the range where these two sturgeon species co-occur, identification can be difficult, especially for smaller specimens (Kuhajda et al. 2007). In the current study photo vouchers were also taken of each sturgeon with a ruler reference. The procedures used in this study are standard for differentiating between these two sturgeon species, although taking tissues samples from pallid and shovelnose sturgeon with subsequent microsatellite analyses would have provided additional support for species identifications.

Measurements and methods used in this study to describe habitat sampled for all gear types were appropriate, as were the combination of measurements employed to describe the area used by telemetry tagged sturgeon.

This study managed to catch only 13 pallid sturgeon; 3 in drifted nets and 10 with trotlines. Two additional pallid sturgeon were collected by The University of Nebraska Statewide stream inventory crew within the study area during the study period. Although this total number of only 15 pallid sturgeon appears low, especially when compared to the 1,138 shovelnose sturgeon collected with the pallid sturgeon, one must consider that the pallid sturgeon is quite rare, especially in the part of the Missouri River basin where this study occurred (Recovery Priority Management Area 4). Given the large number shovelnose sturgeon collected, it is apparent that this study did target the appropriate habitat and utilize the correct gear to adequately sample the lower Platte River for *Scaphirhynchus*. This is further supported by data that demonstrates sampling methods did cover the range of depths and mean column velocities occupied by radio-tagged shovelnose sturgeon.

No mention of results from measurements taken for the morphological character index (Sheehan et al. 1999) to help assess the proper identification between pallid and shovelnose sturgeon appeared in Chapter 2 but are discussed in Chapter 4.

Chapter 3

In this study water quality and substrate composition were measured at four locations (including Elkhorn River and Salt Creek) in the lower Platte River to further describe habitat quality. Results indicated that dissolved oxygen issues can arise in tributaries, high conductivity and salinity in Salt Creek affects the Platte River proper downstream of its confluence, and suspended solids at the most downstream site in the Platte River (Louisville) is affected by all other upstream sites. Methods and results are appropriate.

Chapter 4

Habitat use, movement, and population characteristics of the pallid sturgeon were examined using methods and data presented in detail in Chapter 2 and additional data presented in this chapter. Pallid sturgeon captures by anglers in the lower Platte River prior to and during this study were presented in the introduction of this chapter in the form of two maps with capture sites marked. Capture dates (if available) would have been useful information to compare with the current study, where all but two captures occurred in April and May. Methodology used in this study for sampling pallid sturgeon, gathering habitat data from sampling efforts and radio-tagged sturgeon, and collecting weight and measurement data for examining population characteristics and species identification were appropriate.

15 pallid sturgeon were captured in the lower Platte River during the study period, 13 in this study and 2 by The University of Nebraska Statewide stream inventory. Six of these were hatchery-produced individuals, seven were assumed to be wild, and two were of unknown status. Eight pallid sturgeon were large enough (494 to 1,030 mm SL) to be implanted with radio tags (one female and seven unknowns), where telemetry was used to gather data on habitat preferences and movement. Other pallid sturgeon captured during this study by the investigators were small (284 to 334 mm SL).

Capture data from this study shows that pallid sturgeon occupy the deepest and swiftest areas within the lower Platte River over a sand substrate, averaging 1.6 m deep and 0.8 m/s mean column current velocities. Radio-tagged pallid sturgeon occupied similar habitat, averaging almost 1.3 m in depth and with a mean column current velocity of 0.74 m/s, and were typically associated with underwater dunes. Based on the methodology and results of this study, I agree with the authors that pallid sturgeon occupy the deepest and swiftest habitats within the lower Platte River.

In this study all 13 adult, sub-adult, and juvenile pallid sturgeon were collected by the investigators in April and May, and all radio-tagged individuals left the lower Platte River by early June. These data demonstrate conclusively that pallid sturgeon utilize the lower Platte River in spring. These data also fit into what we know about migration of sturgeons. One step spawning migrations entail a direct upstream migration to the spawning site in the winter or spring followed immediately by the spawn, then a return downstream. This is the most common migration pattern in adult sturgeons (Bemis and Kynard, 1997) and the type used by adult *Scaphirhynchus* in other systems within the Missouti and Mississippi River basins. It has recently been shown that juvenile pallid sturgeon in the Missouri River have similar season movements to adults but are more variable (Jordan et al. 2006). The one female pallid sturgeon captured during this study was carrying late-stage eggs and did exhibit movement patterns that suggest it had entered the lower Platte River to spawn. Although not conclusive, the data presented in this study do indicate that pallid sturgeon may use the lower Platte River for spawning. The University of Nebraska Statewide stream inventory crew captured two small pallid sturgeon, one in July and one in September, indicating that pallid sturgeon also use the lower Platte River, though to a lesser degree, in summer and early fall.

Identification between pallid and shovelnose sturgeon can be problematic, especially for juveniles and sub-adults, where allometric growth can delay the development of diagnosable morphological characters (Kuhajda et al., 2007). This study took measurements on all sturgeon collected in the lower Platte River to calculate a morphological character index (Sheehan et al. 1999) to help assess the proper identification between pallid and shovelnose sturgeon. On this index pallid sturgeon have a mean of -0.69, shovelnose sturgeon 0.71, and hybrids of these two species have an intermediate mean of 0.03 (Sheehan et al. 1999). Results from this analysis show that four pallid sturgeon had scores above the average for this species, with two specimens having extremely high scores near 0.0. The results are not presented in a format within this study that gives scores and associated data (size, stocked or wild) for each individuals, but the text in the report indicates that specimens with higher “less pallid” scores were all small individuals under 334 mm SL and that most (all?) of these were hatchery sturgeon (known pallid sturgeon). As stated above, smaller individuals typically do not possess diagnosable morphological characters, so these results are not surprising. Four of the pallid sturgeon collected in this study had lengths surpassing the maximum size of shovelnose sturgeon in the lower Platte River (880 to 1,030 mm SL). Several shovelnose sturgeon had negative scores, some as low as -0.73. Based on these scores some of these individuals may have been pallid sturgeon or hybrids. It is mentioned that tissues samples had been taken from specimens for molecular analyses, but it is unclear if these included pallid sturgeon, shovelnose sturgeon with “pallid-like” scores, or what the results may have been from these analyses. There is always some doubt regarding species identification for some individuals in any study where these two sturgeon species co-occur, and examining a second dataset (molecular) would provide additional support for species identification, but this study has adequately demonstrated that the vast majority of pallid sturgeon collected in this study have been correctly identified.

Chapter 5

Habitat use, movement, and population characteristics of the shovelnose sturgeon were examined using methods and data presented in detail in Chapter 2 and additional data presented in this chapter. Methodology used in this study for sampling shovelnose sturgeon, gathering habitat data from sampling efforts and radio-tagged sturgeon, and collection of weight and measurement data for examining population characteristics were appropriate.

Shovelnose sturgeon were common in the lower Platte River, with 1,338 specimens collected during this study. Results from this study showed that shovelnose sturgeon used a wider range of habitats relative to pallid sturgeon, but were predominately in moderately deep and moderately swift water (greater than 0.3 m deep and mean column velocities over 0.3 m/s). Most radio-tagged shovelnose sturgeon (71%) were located near structure (sandbar ledges, underwater dunes, and cover). Results also showed shovelnose sturgeon had seasonal movements within the lower Platte River, including upstream movements in April and May and downstream movements in June and July. These observations of seasonal movements are typical for *Scaphirhynchus*. Population estimates in this study for the lower Platte River range from 23,000 to 69,000 shovelnose sturgeon. Based on the above methods and results, I agree with the authors' characterization of habitat and movement of shovelnose sturgeon in the lower Platte River.

Chapter 6

Pulsed gastric lavage was used to examine the diet of shovelnose sturgeon in the lower Platte River. This is a common non-lethal method to determine the stomach contents of *Scaphirhynchus*. As with other studies on this species, this study found that shovelnose sturgeon are opportunistic benthivores, with a predominance of aquatic insects in their diet.

Chapter 7

This chapter is on the habitat use and population characteristics of chubs in the genera *Macrhybopsis* and *Platygobio*. I did not review this chapter.

Chapter 8

In this study fish larvae were collected with rectangular stationary nets in the lower Platte River predominately from May through June or July from 1998 to 2004. Specimens were formalin-fixed upon capture, therefore no molecular work could be done on the specimens to differentiate between pallid and shovelnose sturgeon. Of the 42,785 larvae collected, only 14 were *Scaphirhynchus* larvae. All sturgeon larvae were collected between 15 May and 24 June. Given that all were 1day post-hatch, larvae identification to species based on morphology was not possible due to the lack of distinguishing features at this early stage of development. The authors note that all sturgeon larvae except one were collected following a decline in discharge, with nine specimens collected following peak discharges greater than 21,000 cfs.

The authors conclude that given the large number of shovelnose sturgeon relative to pallid sturgeon, it is probable that these sturgeon larvae were not pallid sturgeon, but the documentation of spawning by *Scaphirhynchus* in the lower Platte River suggests that there is potential for spawning by pallid sturgeon. They also state that the loss of flow volume and fluctuation in the Platte River is confining quality habitat for sturgeons to more downstream reaches of the Platte River.

I agree that spawning habitats for pallid and shovelnose sturgeon are likely similar, and the presence of *Scaphirhynchus* larvae in the lower Platte River does allow for the possibility of suitable habitat and conditions existing for pallid sturgeon to spawn, especially given the presence of adult pallid sturgeon in the lower Platte River during this same period. Pallid sturgeon have evolved for tens of thousands of years in Great Plains rivers that consisted of highly braided channels and turbid waters that experienced elevated discharges in spring. Because the lower Platte River is one of the few remaining semi-natural systems left in the Missouri River basin it is not surprising that pallid sturgeon would be drawn to or use this habitat. I also agree that reduction in natural flow volume and fluctuation is detrimental to habitat for pallid and shovelnose sturgeon, especially during spawning and larval drift periods (April to June). Reduction of natural flows can alter migratory cues for potential spawning *Scaphirhynchus* (Mayden & Kuhajda, 1997a) and can also lead to warmer water temperatures which can negatively affect embryo development and hatching success (Van Eenennaam et al., 2005).

Chapter 9

This chapter is on a creel survey for sturgeon on the lower Platte River. I did not review this chapter.

Chapter 10

This chapter presents two models to aid in understanding the relationship between river discharge and sturgeon habitat requirements in the lower Platte River. One model describes changes in sturgeon habitat with respect to river discharge, while the other model develops a relationship between connectedness of sturgeon habitats and discharge. In combination, these models provide a way to examine quantity and accessibility of sturgeon habitats with respect to river discharge.

Methodology employed in the development of these models is beyond the scope of my expertise, but I can comment on some of the habitat definitions associated with these models. In the development of the Habitat Type Availability Model, riverine habitat from aerial photos was classified as exposed sandbars (above the surface of the water), woody islands, sandbar complexes (bottom of river visible or exposed sand bars less than 50 m apart), and open water (water too deep to see bottom but outside of sandbar complexes). Habitat quality of the abovementioned instream habitat types was determined using transect data from a previous study, where exposed sandbars were defined as points above the water line, open water was defined as points deeper than 0.5 m for section greater than 50 m wide, and sandbar complexes were points not in either of the other categories. In developing the Connectivity Model, an additional 25 m buffer was placed around sandbar complexes that extended into open water to account for the gradual transition from one habitat type to the other. This buffer (25 m) is less than 5% of the average river width, with the assumption by the authors that a sturgeon was not likely to move through shallow sandbar complexes if less than 5% of the width of the river was open water (less than a 25 m width of 0.5 m or deeper water).

So how do these definitions and assumptions correlate with habitats occupied by pallid sturgeon in the lower Platte River? This study found that, based on capture data, pallid sturgeon occupy areas in the lower Platte River that average 1.6 m deep, 0.8 m/s mean column current velocity, are not in close proximity to sandbar ledges, and typically had shallow and exposed sandbars within 50 to 100 m of the capture location. Habitat use for pallid sturgeon based on telemetry data is described as 1.27 m deep, 0.74 m/s mean column current velocity, located within 10 m of sandbar ledges only 15% of the time but among water dunes 76% of the time. Based on these data, the definitions and assumptions on pallid sturgeon habitat used in developing the two models seem within the ball park, but I would have liked to have seen more discussion on the justification for the numbers used by the authors with respect to data from other chapters of their study (as in the examples above) or from details of this study not presented in this report. For example, did any of the radio-tagged sturgeon move through sandbar complexes with less than a 25 m width of 0.5 m or deeper water? If so, was this a rare or common event? It would also be useful to see how the relationships of discharge to pallid sturgeon habitat availability and connectivity change with small changes to numbers associated with definitions and assumption in these models.

Even with some shortcomings on discussions of model definitions and assumption, I do agree with the overall results from these two models with respect to the life history of the pallid sturgeon. Pallid sturgeon have evolved for tens of thousands of years in Great Plains rivers that consisted of highly braided channels, turbid waters, and elevated discharges in spring from snow melt and rain. These elevated spring discharges are cues for synchronized gonadal development and upstream spawning migration, and the natural slow decline in discharge in late spring and summer allow for spawned adults and drifting larvae to find their way back downstream. Even though the lower Platte River represents one of the last remnants of semi-natural riverine habitat left in the Great Plains, flows have been considerably altered by retention and removal of water through human activities, and these reduced flows threaten the necessary movements of pallid sturgeon in the lower Platte River to complete an important part of their life history.

Chapter 11

Management recommendations for sturgeon and chub populations within the lower Platter River are presented by chapter (1-10). Most of the recommendations are based on data presented in this report, but there are two exceptions. In the overview of Chapter 3 there is a discussion of the presence of endocrine disruptors in the system and power peaking fluctuations in discharge within the Platte River and their potential negative effects on aquatic organisms. Neither issue was presented in Chapter 3 or elsewhere in the report. I question why these issues were presented in this final summary chapter.

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ATTACHMENT E

COLUMBUS POWERHOUSE TURBINE EFFICIENCY DATA

RESULTS AND CONCLUSIONS

The testing of the unit efficiency on Unit 1 was performed on May 21, 2005. During the efficiency testing, the raw field data was corrected to a rated head of 116ft to obtain field results. A total of 19 runs (10 minutes each run) were completed and the data was used to evaluate the unit efficiency against the contractual guarantee points. The table below shows the results of the efficiency testing. These results are also plotted with the contractual guarantees in Figure 20 on page 20.

Unit Discharge	Rated Head	Guarantee Unit Efficiency	Measured Unit Efficiency
1000	117.4	85.5	85.8
1400	116.2	93.0	93.1
1600	115.6	93.3	94.0
1700	115.4	92.2	93.9
	Weighted Totals	**91.0**	**91.7**

Table 15 Efficiency Test Results

The results in the table above were calculated after all the raw field data was corrected to include the excitation losses. To obtain the efficiency at each guarantee point, the raw data was corrected four times to each of the rated heads called out in the guarantees (117.4, 116.2, 115.6, 115.4). The four sets of corrected data was plotted to obtain a polynomial to be used to evaluate the unit efficiency at the guarantee flowrates called out in the specification. The polynomial evaluation was performed by using the program TableCurve to plot the efficiencies against the rated flowrates at the four guarantee heads. The program uses over 3000 equations to best fit the efficiency curve. In order to determine the best-fit equation, the equations were evaluated to ensure the residuals were less then 0.1ft/s. These equations were also plotted and visually checked for anomalies. To remain consistent, the same equation was chosen for all four evaluations.

The result of the field-testing shows that American Hydro passed their contractual guarantees. In fact, the upgraded unit is performing better over a wider operating range than what was shown from the guarantee points. Figure 17 on page 17 shows the field test results and the contractual guarantees plotted against rated discharge. The field-testing plot shows that the unit operates very well past peak efficiency where the contractual graph shows a much greater drop off past peak efficiency.

The field data was evaluated to determine the peak efficiency. Again, TableCurve was used to evaluate the first derivative of the polynomial equation to determine the peak efficiency. The variables used to evaluate the peak efficiency were unit discharge (measured directly from the 7500 acoustic flowmeter) and generator power (measured directly from the Yokogawa power meter). The estimated peak efficiency of Unit 1 occurred at 1640cfs and 15.1MW.

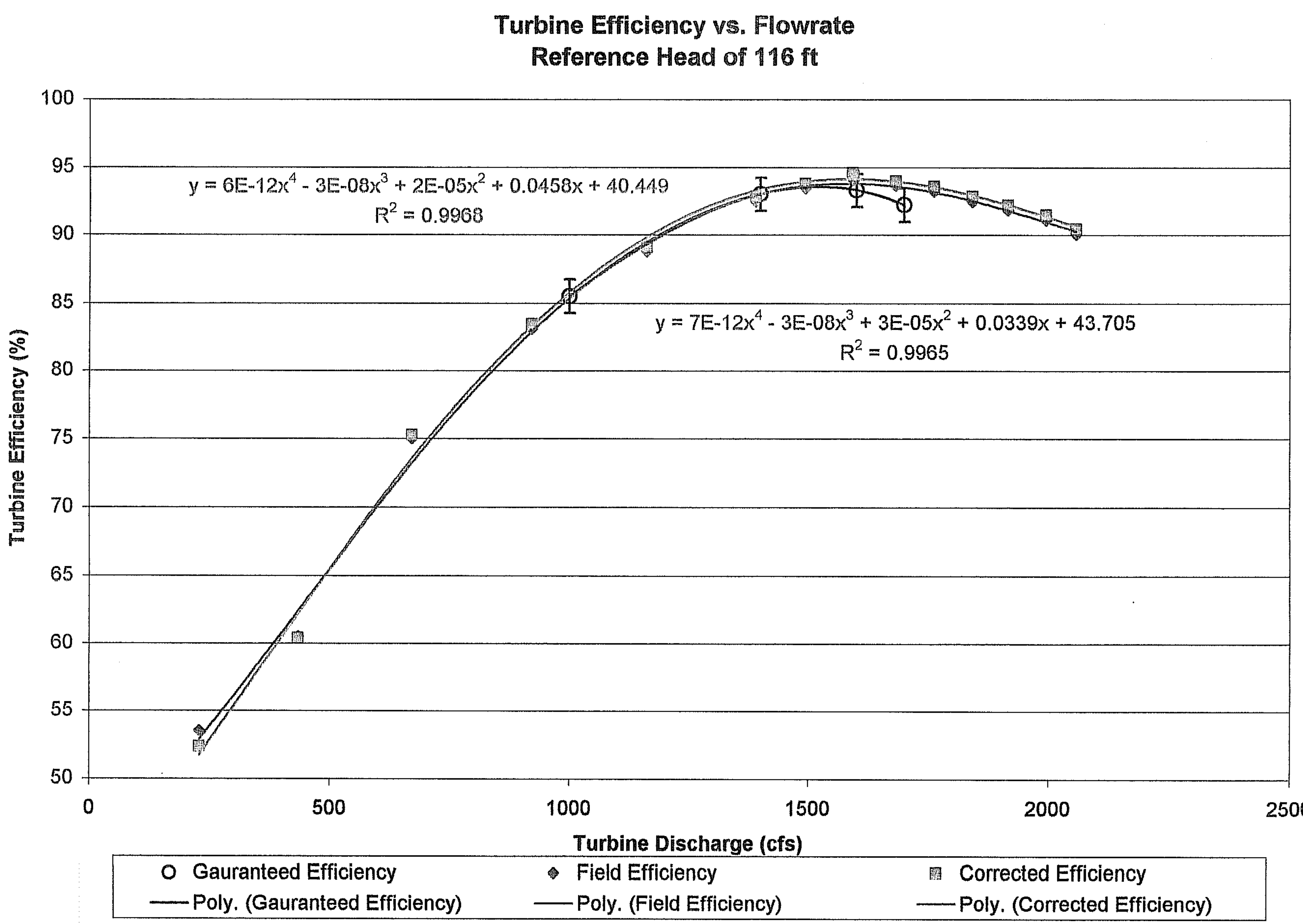

Figure 17 Field Test Data

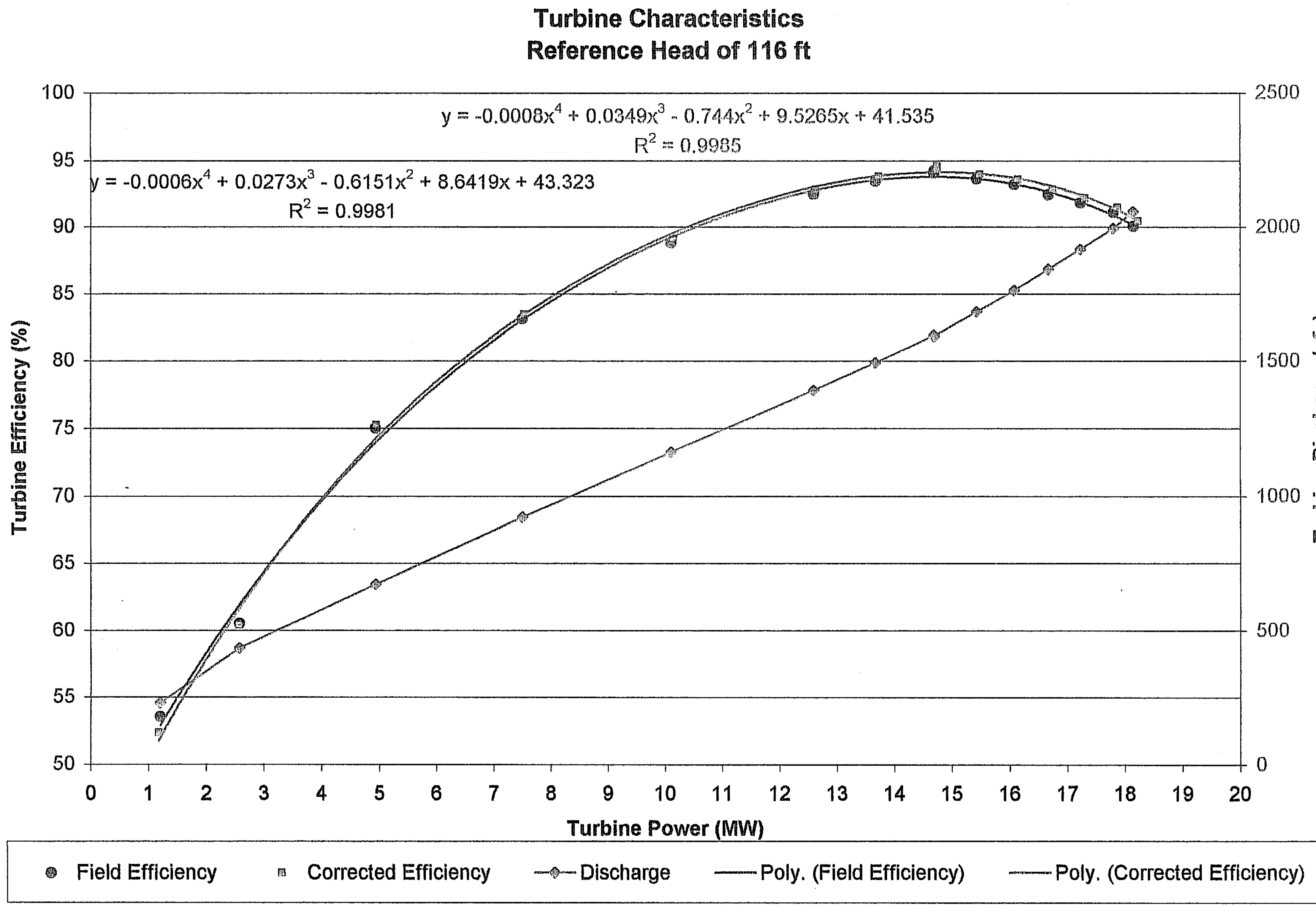

Figure 18 Turbine Data

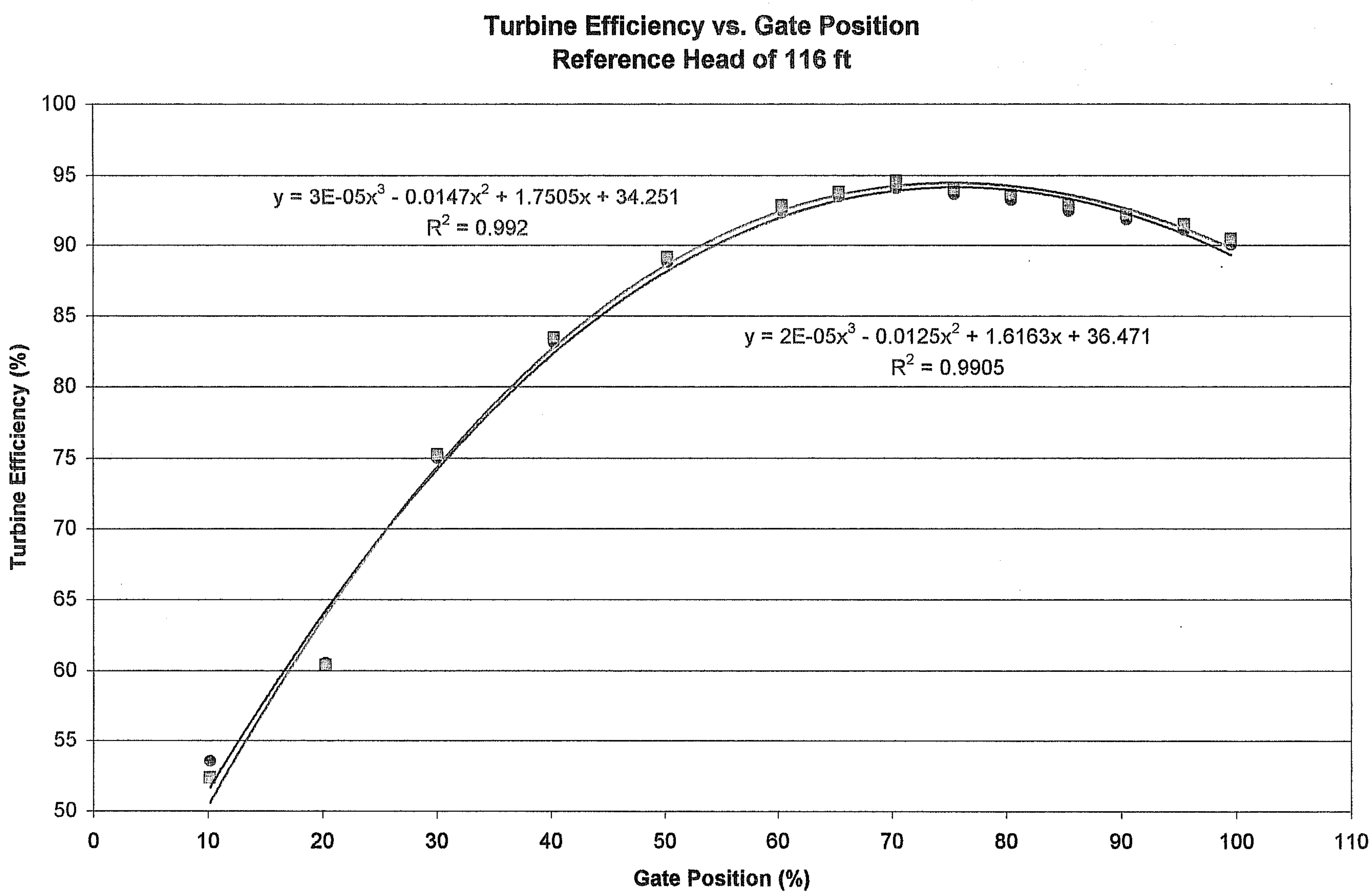

Figure 19 Efficiency vs Gate