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Population characteristics of Shovelnose Sturgeon during low- and high-water conditions in the lower Platte River, Nebraska

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<A> Abstract

Cycles of low- and high-water periods (i.e., years) in river systems are natural occurrences, but understanding how cyclical climatological patterns affect fishes, especially long-lived species, is unclear. We assessed Shovelnose Sturgeon population dynamics between a period of low- (2001-2004) and high- (2009-2012) water years in the lower Platte River, Nebraska. Low-flow periods in the lower Platte River can cause disconnection(s) between upstream and downstream reaches resulting in isolated pools and elevated water temperatures leading to stressful situations for aquatic life and possible mortality. Our data show no measurable differences between key population indices between flow condition periods which is consistent with current paradigms for long-lived fish species. Shovelnose Sturgeon relative weights were generally > 80 during both low- and high-water periods and the size structure did not differ between the two periods. Shovelnose Sturgeon abundances, however, were greater during high-water conditions compared to low-water conditions (Kruskal-Wallis: $\chi^2 = 6.15$, d.f. = 1, $P = 0.01$). Shovelnose Sturgeon may have migrated to more suitable habitats during low-water periods to seek refuge allowing these individuals to return during more suitable conditions. Shovelnose Sturgeon and other riverine fish have evolved in a variable environment and have been able to endure relatively minor anthropogenic changes within the lower Platte River. Rivers like the lower Platte River that have retained much of their original physical features and flow regimes are likely key components for the resistance and resilience of riverine species. However, as alterations to landscapes continue and uncertainty exists surrounding future climate predictions, it is unknown how these riverine species will be able to adapt to future changes. The reduction in anthropogenic changes that disrupt flow regimes and increasing connectivity among river systems could provide more fish refuge during stressful conditions helping to protect these riverine species.

<A>Introduction

The cyclical nature of climatic events typically results in spates of extreme flow conditions in rivers that lead to low- and high-water periods. Aquatic organisms can use extreme flow events to their advantage if these flow conditions occur at predictable intervals. For example, periods of high-water during spring can positively influence fish recruitment (Sparks 1995; Winemiller 2005), growth (Gutreuter et al. 1999; Sommer et al. 2001;

Schramm and Eggleton 2006), and survival in large river systems (Sommer et al. 2001; Schramm and Eggleton 2006). Schramm and Eggleton (2006) found the greatest growth for almost every age of Blue Catfish *Ictalurus furcatus* occurred during high-water years. Similarly, high-water periods in the Sacramento River, California, increased available forage habitat for Chinook Salmon *Oncorhynchus tshawytscha,* leading to increased growth and survival (Sommer et al. 2001). Less known is how species persist during periods of low-water conditions. Low-water periods may have negative effects on some fish populations through reduced habitat availability, survival, growth, the ability to seek refuge, and other physiological and biological traits (Magoulick and Kobza 2003; Matthews and Marsh-Matthews 2003; Propst et al. 2008; Stefferud et al. 2011).

Currently, limited information exists whether fish populations have the ability to cope with persistent, stressful conditions over a long period (> 2 year). Variability in discharge and depth influences fish population dynamics (Junk et al. 1989; Magoulick and Kobza 2003; Power et al. 2008; Hamel et al. 2014), yet the lack of data that encompass both low-and high-water periods for the same population make it difficult to understand specifically how water level conditions can affect fish populations. Matthews and Marsh-Matthews (2003) reported much of what we know about the influences of low-water periods on fish species through short-term studies (≤ 1 year), but there is a lack of knowledge on fish populations over longer periods, particularly for long-lived riverine species that may experience both (i.e., wet and dry years) climatic conditions throughout their lifespans.

Long-lived species generally have low natural adult mortality (Garrod and Knights 1979), late maturity, and experience sporadic recruitment (Roff 1984; Beverton 1992; Charnov 1993; Winemiller and Rose 1992). Ultimately, long-lived species are thought to have the ability to adapt to low- and high-water periods and remain viable through time; however, few studies have evaluated this in sturgeon species. Shovelnose Sturgeon *Scaphirhynchus* *platorynchus* are a long-lived species that occupy the Missouri, Mississippi, and Ohio River basins. Habitat fragmentation and river alterations (i.e., flow dynamics, channelization) have contributed to much of the range wide decline in the species. Not much is known about the resilience of Shovelnose Sturgeon during low- and high-water fluctuation, but recent evidence has suggested that the flow dynamics of a river could influence the overall population characteristics of Shovelnose Sturgeon resulting in low recruitment, high mortality, and slow growth (Goto et al. 2014; Hupfield et al. 2015). Alternatively, Shovelnose Sturgeon have the ability to migrate long distances (DeLonay et al. 2007), which may give them the ability to seek out refuge in other river systems during unfavorable conditions (Schlosser and Angermeier 1995).

The lower Platte River, Nebraska, is thought to have retained much of the historic physical characteristics of the original shifting and braided channel (Eschner et al. 1983; Randle and Samad 2003; Peters and Parham 2008). The Shovelnose Sturgeon population within the lower Platte River has thought to be in a stable condition (Keenlyne 1997; Koch and Quist 2010; Phelps et al. 2016). Over the past decade the lower Platte River has experienced a shift from a low-water period (2001-2004) to a high-water period (2009-2012). During this time two separate sampling efforts (Peters and Parham 2008; Hammen 2016) examined the population characteristics of Shovelnose Sturgeon within the lower Platte River. These efforts allowed us to compare metrics commonly used to assess fish populations (e.g., relative abundance, size structure, and condition) of Shovelnose Sturgeon during a low- and a high-water period in the lower Platte River, Nebraska, to better understand how varying climatic conditions may affect long-lived riverine species.

<B>Methods

Study Site.- We used spring (March - May) data collected from 1 - 52 river kilometers (rkm) of the lower Platte River, Nebraska (Figure 1). Sample sites in the 2001-2004 had a stratified random sampling approach restricted to accessibility (i.e., boat ramps; Peters and Parham 2008). The 2009-2012 had a more intensive random sampling design throughout the lower Platte River that overlapped sampling sites with the previous 2001-2004 study. Trammel nets were sampled during the low-water period from 2003-2004 and trotlines were sampled from 2001-2004. During the high-water period both trammel nets and trotlines were sampled from 2009-2012. Sampling occurred in the spring to avoid any temperature related stress. Sampling started as soon as the river was accessible and remained continuous until the end of May. This stretch of river holds the majority of the Shovelnose Sturgeon population in the lower Platte River (Hammen 2016). Previous work has shown that the previous year's hydrological conditions can influence the population dynamics of a river's fish community (Freeman et al. 2001; Brown and Ford 2002). Therefore, we used the previous years' annual discharges to determine whether sampling occurred during a low- or high-water condition based on comparisons to the 30 year average.

Fish Collection.– Trammel nets and trotlines were used across both study periods (Peters and Parham 2008; Hamel 2013). These two gears are commonly used to capturing sturgeon species throughout their range in the spring months (Doyle et al. 2008; Koch et al. 2009; DeVries et al. 2015). Trammel nets were drifted for 100 m (min = 75 m, max = 300 m) and made of multifilament nylon netting with an inner wall 2.4 m deep and the outer wall 1.8 m deep and stretched 38.1 m long with 2.5 cm of bar mesh for the inner panel and 20.3 cm of bar mesh for the outer panels. Trotlines were 32 m long and made of 0.6 cm diameter nylon line. Twenty hooks were placed at 1.5 m intervals along the line with a 30 cm hook line.

O'Shaughnessy (size = 3/0) hooks were baited with Earthworms *Lumbricus terrestris*. All sets were overnight with a maximum set time of 24 hours. Shovelnose Sturgeon were measured for fork length (mm) and mass (g).

Data analysis. –Shovelnose Sturgeon Catch Per Unit Effort (CPUE) was calculated for each gear type (trotlines and trammel nets) and then compared between periods using a nonparametric Kruskal-Wallis test (SAS Institute 2004). Trammel nets were calculated per 100m drift set while trotlines were calculated per 20 hook-night. A spearman rank correlation was used to determine any relationships between annual discharge and annual relative abundance for both gears. Differences in length-frequency distributions were compared between water periods using nonparametric Kolmogorov-Smirnov tests. We used relative weight (W_r; Wege and Anderson 1978) to assess the condition of Shovelnose Sturgeon between sample periods calculated using Quist et al. (1998). Comparisons between water periods were made using the mean of each 50-mm length category using an ANOVA with Tukey's HSD for multiple comparisons.

<A>Results

<Discharge>

During the low-water period, mean annual discharge 162 ± 13 m^3/s (mean ± se) was lower than the 30 year average (mean annual discharge ± se = 224 ± 8.79 m^3/s; t-test, t = 1.99, d.f. = 1, P = < 0.01). During the high-water period, mean annual discharge reached 307 ± 30 m^3/s (mean ± se), which was greater than the 30 year average (t-test, t = 2.00, d.f. = 1, P = 0.01).

<B>Relative Abundance

A total of 257 trotlines and 73 trammel nets were deployed during the low-water period and 496 trotlines and 492 trammel nets during the high-water period. There were 484 Shovelnose Sturgeon captured during low-water (2001-2004) and 1,867 Shovelnose Sturgeon were captured during high-water (2009-2012). Trammel net average distance was 117.34-m with a range of 46-300-m. No strong correlations were found between annual discharge and annual relative abundance for neither trotlines (Spearman rank; $r_s = 0.33$, $P = 0.08$) nor trammel nets (Spearman rank; $r_s = 0.43$, $P = 0.13$). Relative abundance for trotlines from 2001-2004 was 1.18 ± 0.12 (mean ± se; Figure 2) with a range from 0 to 14 (Figure 3). Relative abundance for trotlines from 2009-2012 was 0.1.29 ± 0.10 (mean ± se; Figure 2) with a range from 0 to 13 (Figure 3). Relative abundance of Shovelnose Sturgeon caught in trotlines did not differ between periods (Kruskal-Wallis: $X^2= 0.74$, d.f. = 1, $P = 0.39$). Relative abundance for trammel nets from 2001-2004 was 0.72 ± 0.12 (mean ± se; Figure 2) with a range from 0 to 14 (Figure 3). Relative abundance for trammel nets from 2009-2012 was 0.91 ± 0.10 (mean ± se; Figure 2) with a range from 0 to 24 (Figure 3). Relative abundance of Shovelnose Sturgeon was greater in trammel nets collected during the high-water period compared to the low-water period (Kruskal-Wallis: $X^2 = 6.15$, d.f. = 1, $P = 0.01$).

<B>Size Structure

Shovelnose Sturgeon fork length ranged from 362 to797-mm during the low-water period and 258 to 775-mm during the high-water period for both gears combined. The majority of Shovelnose Sturgeon (91%) were 500-700-mm and only 12 (<1%) were > 700mm across periods and gears. There were no differences between length frequencies during the low- and high-water periods from either trotlines (Kolmogorov-Smirnov: KS_a = 1.02, P = 0.25) or trammel nets (Kolmogorov-Smirnov: KS_a = 0.89, P = 0.41; Figure 4).

<B>Condition

There were differences between the mean relative weights (W_r) of Shovelnose Sturgeon captured in the lower Platte River when trotlines were used as a sampling technique. This difference indicated that the low-water (mean ± SE = 85.95 ± 0.53) period had a greater W_r for Shovelnose Sturgeon compared to the high-water (mean ± SE = 84.18 ± 0.35; ANCOVA, F = 8.17, d.f. = 1, P = < 0.01) period (Figure 5). Trammel nets showed a similar trend in the lower Platte River where the W_r of Shovelnose Sturgeon during the low-water (mean ± SE = 88.28 ± 0.73) period was greater compared to the high-water (mean ± SE = 84.59 ± 0.41; ANCOVA, F = 20.67, d.f. = 1, P = < 0.01) period (Figure 5).

<A>Discussion

Shovelnose Sturgeon population parameters measured in this study largely showed no meaningful influence from low- or high-water periods besides the changes in abundance in trammel nets. These results seem logical given the Platte River still maintains connectivity among habitats throughout the study area and other river systems. This connectivity may lead to pathways of escape or refuge as needed. For example, natural disturbance regimes maintain an interactive pathway across riverine landscapes, and when these pathways remain predictable and constant, it can result in positive influences on aquatic biota (Ward 1988). Riverine species like Shovelnose Sturgeon have evolved to endure such hydrological disturbance experienced in rivers even when many of these river systems have experienced some anthropogenic change. The lower Platte River is no different where some anthropogenic alterations have occurred. The loup power canal occupies the upper portion of the lower Platte River and influences the river system through alterations of daily and weekly flow fluctuations (Spurgeon et al. 2016). Even with these anthropogenic changes, the lower Platte River has maintained most of its historic physical features allowing the flow regime to resemble historic conditions unlike many of rivers in the United States of America (i.e., Missouri River; Eschner et al. 1983; Randle and Samad 2003). It is unknown how highly altered river systems that have changed in historic flow regimes will influence the ability of these long-lived species during similar low- and high-water periods. These larger alterations have disrupted the natural flow regime and physical characteristics resulting in negative influences on aquatic biota (Ward 1988) resulting in altered aquatic habitats and fish communities (Poff et al. 1997; Burcher et al. 2007; Poff and Zimmerman 2010; Perkin et al. 2014). Highly altered river systems that have disrupted historic flow regimes could present greater challenges to riverine fish, limiting their abilities to recover from disturbances similar to these low- and high flow periods (Dudgeon et al. 2005; Poff and Zimmerman 2010). It will become important to understand how long-lived species like Shovelnose Sturgeon are fully impacted by alterations to riverine ecosystems that change historic flow regimes and physical features of the river.

Variability in catch rates did exist between low- and high-water periods. Both these gears have been considered effective at catching Shovelnose Sturgeon at a variety of flow regimes (Doyle et al. 2008; Koch et al. 2009; DeVries et al. 2015); however, like most gears, limitations do exist. Trotlines have defined, finite capture ability (e.g., 20 hooks) whereas trammel nets have the capabilities to capture a higher capacity of Shovelnose Sturgeon when they are available. For example, the maximum number of Shovelnose Sturgeon captured in this study for trotlines was 14 where trammel nets exceeded that number four times and all four of these samples were during the high-water period (not shown). The two gears may yield different relative abundance results due to the finite capture ability associated with trotlines. Therefore, caution should be considered when using trotlines to estimate changes in relative abundance for Shovelnose Sturgeon. Further evaluation of the gears is needed to determine what gear is most appropriate during low-and high-water periods.

Trammel nets did yield a higher relative abundance during the high-water period than low-water period. It is possible that the lower relative abundance is attributed to mortality or lowered recruitment within the lower Platte River during low-water periods. These low-water periods likely reduce prey production and limit forage opportunities (Boulton 2003; Rose et al. 2008) that could lead to declines in the survival of several fish species. Goto et al. (2015) predicted that low-water periods in rivers could lead to a steady population decline and slow gonadal development. Additionally, Shovelnose Sturgeon will experience mortality during low-water conditions when temperatures exceed 28°C (Hupfeld et al. 2015; Mike Archer, Nebraska Department of Environmental Quality, personal communication). However, during the low-water period in this study the temperatures rarely reached these high temperatures, and the connectivity of the river was still intact (Peters and Parham 2008); therefore, high mortality during this time in juvenile Shovelnose Sturgeon likely was likely not plausible due to water temperature and did not lead to the changes in relative abundance in trammel nets.

Movement of Shovelnose Sturgeon in and out of the lower Platte River during changing water levels likely contributed to changes in relative abundances. Habitat availability will change during water level fluctuations. Low-water periods would have a reduction in habitat availability, and high-water periods would have an increase in habitat availability (Junk et al. 1989; Schlosser 1991; Magoulick and Kobza 2003; Boix et al. 2010). Shovelnose Sturgeon are capable of long movements (Bramblett 1996; Delonay et al. 2007; Peters and Parham 2008, Hammen 2016), which would allow them to seek refuge during an environmental disturbance (i.e., drought). Curtis et al. (1997) reported that during low-water periods in the Mississippi River, Shovelnose Sturgeon moved from side channels into the main channel to seek refuge. Additionally, Goto et al. (2014) predicted that Shovelnose Sturgeon in the lower Platte River would move downstream to more suitable spawning locations during low-water periods. Low-water periods likely influence Shovelnose Sturgeon by stimulating a downstream movement possibly leading outside the lower Platte River where more suitable conditions may be available (e.g., Missouri River). These movements would also allow Shovelnose Sturgeon to maintain healthy condition during low-water periods by reducing stresses, which may be associated with low-water (i.e., temperature). When water levels begin to increase, available habitat will increase allowing riverine species like Shovelnose Sturgeon to return and recolonize (Magoulick and Kobza 2003). When connectivity of a river system is maintained, it allows riverine species to adapt to changing environments and persist during unfavorable conditions. The long-term persistence of a riverine species is a crucial management goal for many programs therefore the protection of this connectivity may play a key factor in successfully meeting this management goal.

The long-term stability of any population relies on the resilience of the species to endure changes in its environment (Connell and Sousa 1983). For most fish species the resilience of that species is directly influenced by the complex physical habitats associated with that particular system (Schlosser 1985, 1991) and by the ability of these species to resist changes (Poff et al. 1997). River systems that have maintained historical physical habitats (i.e., lower Platte River) likely have the ability to accommodate a range of natural changes (e.g., changes in climate) to maintain the long-term stability of many riverine species. The preservation of these types of river systems and the restoration of highly altered river systems will become even more critical with many uncertainties surrounding the potential changes (i.e., development, climatic change) that exist for these systems. For example, drought conditions are increasing globally (Dai et al. 2004) while short-term extreme rain events are becoming more common (Easterling et al. 2000; Groisman and Knight 2008; Trenberth 2011). Climate models predict more extensive high-water and low-water periods in the Great Plains region (Easterling et al. 2000; Dai et al. 2004; Groisman and Knight 2008; Trenberth 2011). These extremes may exceed the limits of many riverine species to withstand unpredictable or mistimed events. Understanding conditions that exceed a species' capacity to cope with a new stress warrants concern for its long-term sustainability.

Our analysis suggests that Shovelnose Sturgeon and possibly other riverine fish have the ability to be resilient with historic cyclic flow patterns in a river system that has maintained its original physical characteristics during the past two decades with little or no manifestation of stress in the population characteristics in the lower Platte River. The perseverance of these riverine fishes will rely on the ability of these riverine fishes to withstand large scale anthropogenic and climatic changes in the future. Therefore it is crucial to protect our rivers that have maintained relatively natural physical features and flow regimes for the perseverance of many riverine fish species. It is important to take a proactive approach to the management of these riverine species to preserve them during these uncertain times. Managers need to reduce the influence of anthropogenic alterations to a river to maintain habitats that current fish populations have likely evolved to survive. Additionally, increasing the connectivity among these river systems would increase potential refuge habitats during stressful low-water periods that would allow fish species to escape stressful situations and return during more favorable conditions.

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<A>References

Beverton, R. J. H. 1992. Patterns of reproductive strategy parameters in some marine teleost fishes. Journal of Fish Biology 41:137-160.

Boix, D., E. García-Berthou, S., Gascó, L. Benejam, E. Tornés, J. Sala, J. Benito, A. Munné, C. Solà, S. Sabater. 2010. Response of community structure to sustained drought in Mediterranean rivers. Journal of hydrology 383:135-146.

Boulton, A. J. 2003. Parallels and contrasts in the effects of drought on stream macroinvertebrate assemblages. Freshwater Biology 48:1173-1185.

Bramblett, R. G. 1996. Habitats and movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri rivers, Montana and North Dakota. Doctoral dissertation. Montana State University, Bozeman, Montana.

Brown, L. R., and T. Ford. 2002. Effects of flow on the fish communities of a regulated California River: Implications for managing native fishes. River Research and Applications 18:331-342.

Burcher, C. L., H. M. Valett, and E. F. Benfield. 2007. The landcover cascade: relationships coupling land and water. Ecolgy 88:228-242.

Charnov, E. L. 1993. Life History Invariants: Some Explorations of Symmetry in Evolutionary Ecology. Oxford University Press, Oxford (UK).

Connell, J. H., and W. P. Sousa. 1983. On the evidence needed to judge ecological stability or persistence. American Naturalist 121:789-824.

Curtis, G. L., J. S. Ramsey, and D. L. Scarnecchia. 1997. Habitat use and movements of shovelnose sturgeon in Pool 13 of the upper Mississippi River during extreme low flow conditions. Environmental Biology of Fishes 50:175-182.

Dai, A., K. E. Trenberth, and T. Qian. 2004. A global dataset of Palmer Drought Severity Index for 1870-2002: Relationship with soil moisture and effects of surface warming. American Meteorological Society 5:1117-1130.

DeLonay, A. J., D. M. Papoulias, M. L. Wildhaber, M. L. Annis, J. L. Bryan, S. A. Griffith, S. H. Holan, and D. E. Tillitt. 2007. Use of behavioral and physiological indicators to evaluate *Scaphirhynchus* sturgeon spawning success. Journal of Applied Ichthyology 23:428-435.

Devries, R. J., D. A. Hann, and H. L. Schramm Jr. 2015. Increasing capture efficiency of pallid sturgeon *Scaphirhynchus albus* (Forbes and Richardson, 1905) and the reliability of catch rate estimates. Journal of Applied Icthyology 31:603-608.

Doyle, W., C. Paukert, A. Starostka, and T. Hill. 2008. A comparison of four types of sampling gears used to collect shovelnose sturgeon in the Lower Missouri River. Journal of Applied Icthyology 24:637-642.

Dudgeon, D., A. H. Arthington, M. O. Gessner, Z. I. Kawabata, D. J. Knowler, C. Lévêque, R. J. Naiman, A. H. Prieur-Richard, D. Soto, M. L. J. Stiassny, and C. A. Sullivan. 2005. Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews 81:163-182.

Easterling, D. R., G. A. Meehl, C. Parmesan, S. A. Changnon, T. R. Karl, and L. O. Mearns. 2000. Climate extremes: Observations, modeling, and impacts. Science 289:2068-2074.

Eschner, T. R., R. F. Hadley, and K. D. Crowley. 1983. Hydrologic and morphologic changes in the channels of the Platte River basin in Colorado, Wyoming and Nebraska: A historical perspective. U. S. Geological Survey Professional Paper 1277-A, Washington D. C.

Freeman, M. C., Z. H. Bowen, K. D. Bovee, and E. R. Irwin. 2001. Flow and habitat effects on juvenile fish abundance in natural and altered flow regimes. Ecological Applications 11:179-190.

Garrod, D. J., and B. J. Knights. 1979. Fish stocks: Their life history characteristics and responses to exploitation. Pages 361-382 *in* P. J. Miller, editor. Fish Phenology: Anabolic Adaptiveness in Teleosts. Symposia of the Zoological Society of London 44. Zoological Society of London (UK).

Goto, D., M. J. Hamel, J. J. Hammen, M. L. Rugg, M. A. Pegg, and V. E. Forbes. 2014. Spatiotemporal variation in flow-dependent recruitment of long-lived riverine fish: Model development and evaluation. Ecological Modelling 296:79-92.

Groisman P. Y., and R. W. Knight. 2008. Prolonged dry episodes over the conterminous United States: New tendencies emerging during the last 40 years. Journal of Climate 21:1850-1862.

Gutreuter, S., A. D. Bartels, K. Irons, and M. B. Sandheinrich. 1999. Evaluation of the flood pulse concept based on statistical models of growth of selected fishes of the Upper Mississippi River system. Canadian Journal of Fisheries and Aquatic Sciences 56:2282-2291.

Hamel, M. J. 2013. Determining Scaphirhynchus sturgeon population demographics and dynamics: Implication for range-wide management, recovery, and conservation. Doctoral Dissertation. University of Nebraska-Lincoln, Nebraska.

Hamel, M. J., J. J. Spurgeon, M. A. Pegg, J. J. Hammen, and M. L. Rugg. 2014. Hydrologic variability influences local probability of Pallid Sturgeon occurrence in a Missouri River Tributary. River Research and Applications DOI: 10.1002/rra.2850.

Hammen, J. J. (2016). Population characteristics, habitat associations, and population estimate of shovelnose sturgeon in the lower Platte River, Nebraska. Doctoral dissertation. University of Nebraska-Lincoln, Lincoln, Nebraska.

Hupfeld, R. N., Q. E. Phelps, M. K. Flammang, and G. W. Whitledge. 2015. Assessment of the effects of high summer water temperatures on shovelnose sturgeon and potential implications of climate change. River Research and Applications 31:1195-1201.

Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river floodplain systems. Canadian Special Publications in Fisheries and Aquatic Science 106:110-127.

Keenlyne, K. D. 1997. Life history and status of the shovelnose sturgeon, Scaphirhynchus platorynchus. Environmental Biology of Fishes 48:291-298.

Koch, J. D., M. C. Quist, C. L. Pierce, K. A. Hansen, and M. J. Steuck. 2009. Effects of commercial harvest on shovelnose sturgeon populations in the Upper Mississippi River. North American Journal of Fisheries Management, 29:84-100.

Koch, J. D., and M. C. Quist. 2010. Current status and trends in shovelnose sturgeon (Scaphirhynchus platorynchus) management and conservation. Journal of Applied Ichthyology 26:491-498.

Magoulick, D. D., and R. M. Kobza. 2003. The role of refugia for fishes during drought: a review and synthesis. Freshwater Biology 48:1186-1198.

Matthews, W. J., and E. Marsh-Matthews. 2003. Effects of drought on fish across axes of space, time and ecological complexity. Freshwater Biology 48:1232-1253.

Peters, E. J., and J. E. Parham. 2008. Ecology and management of sturgeon in the Lower Platte River, Nebraska. Nebraska Technical Series Number 18.Nebraska Game and Parks Commission.

Phelps, Q. E., S. J. Tripp, M. J. Hamel, J. Koch, and E. J. Heist. Status of knowledge of the Shovelnose Sturgeon (*Scaphirhynchus platorynchus*, Rafinesque, 1820). Journal of Applied Ichthyology 32:249-260.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The natural flow regime. Bioscience 47:769-784.

Poff, N. L., and J. K. H. Zimmerman. 2010. Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows. Freshwater Biology 55:194-205.

Pope, K. L., and C. G. Kruse. 2007. Condition. Pages 423-471 *in* C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Behesda, Maryland.

Power, M. E., M. S. Parker, and W. E. Dietrich. 2008. Seasonal reassembly of a river food web: floods, droughts, and impacts of fish. Ecological Monographs 78:263-282.

Propst, D. L., K. B. Gido, and J. A. Stefferud. 2008. Natural flow regimes, nonnative fishes, and native fish persistence in arid-land river systems. Ecological Applications 18:1236- 1252.

Quist, M. C., C. S. Guy, and P. J. Braaten. 1998. Standard weight (W_r) equation and length categories for shovelnose sturgeon. North American Journal of Fisheries Management 18:992-997.

Randle, T. J., and M. A. Samad. 2003. Platte River flow and sediment transport between North Platte and Grand Island, Nebraska (1895-1999), Draft. Bureau of Reclamation, U. S. Department of the Interior, Denver, Colorado.

Roff, D. A. 1984. The evolution of life history parameters in teleosts. Canadian Journal of Fisheries and Aquatic Sciences 41:989-1000.

Rose, P. L. Metzeling, and A. Arthington. 2008. Can macroinvertebrate rapid bioassessment methods be used to assess river health during drought in south-eastern Australian streams? Freshwater Biology 53:2626-2638.

SAS institute. 2004. SAS/STAT 9.2 User's Guide. SAS Institute, Cary, North Carolina.

Schlosser, I. J. 1985. Flow regime, juvenile abundance, and the assemblage structure of stream fishes. Ecology 66:1484-1490.

Schlosser, I. J. 1991. Stream fish ecology: A landscape perspective. BioScience 41:704-712.

Schlosser, I. J., and P. I. Angermeier. 1995. Spatial variation in demographic processes in lotic fishes: conceptual models, empirical evidence, and implications to conservation. American Fisheries Society Symposium 17:360-370.

Schramm, H. L, and M. A. Eggleton. 2006. Applicability of the flood-pulse concept in a temperate floodplain river ecosystem: thermal and temporal components. River Research and Applications 22:543-553.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325-333.

Sparks, R. E. 1995. Need for ecosystem management of large rivers and floodplains. BioScience 45:168-182.

Spurgeon, J. J., M. J. Hamel, and M. A. Pegg. 2016. Multi-scale approach to hydrological classification provides insight to flow structure in altered river system. River Research and Applications DOI: 10.1002/rra.3041.

Stefferud, J. A., K. B. Gido, and D. L. Propst. 2011. Spatially variable response of native fish assemblages to discharge, predators and habitat characteristics in an arid-land river. Freshwater Biology 56:1403-1416.

Trenberth, K. E. 2011. Changes in precipitation with climate change. Climate Research 47:123-138.

Ward, J. V. 1988. Riverine landscapes: Biodiversity patterns, disturbance regimes, and aquatic conservation. Biological Conservation 83:269-278.

Wege, G. J., and R. O. Anderson. 1978. Relative weight (W_r): a new index of condition or largemouth bass. Pages 79-91 *in* G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. Special Publication 5, North Central division, American Fisheries Society, Bethesda, Maryland, USA.

Winemiller, K. O., and K. A. Rose. 1992. Patterns of life-history diversification in North American fishes: implications for population regulation. Canadian Journalof Fisheries and Aquatic Sciences 49:2196-2218.

Winemiller, K. O. 2005. Floodplain river food webs: generalizations and implications for fisheries management. Pages 285-312 *in* R. L. Welcomme and T. Petr, editors. Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries. Mekong River Commission: Phnom Penh, Cambodia.

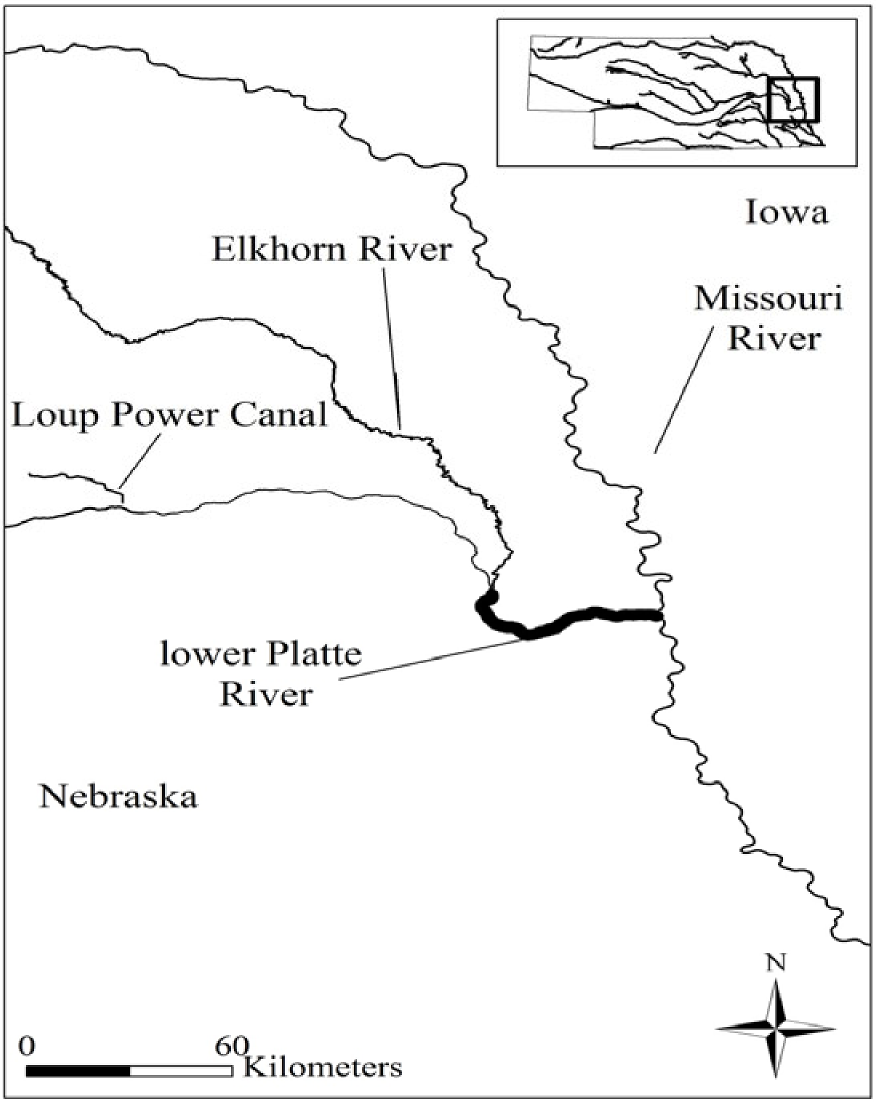

Figure 1. Map of lower Platte River, Nebraska. Bold line represents the entire sampling area.

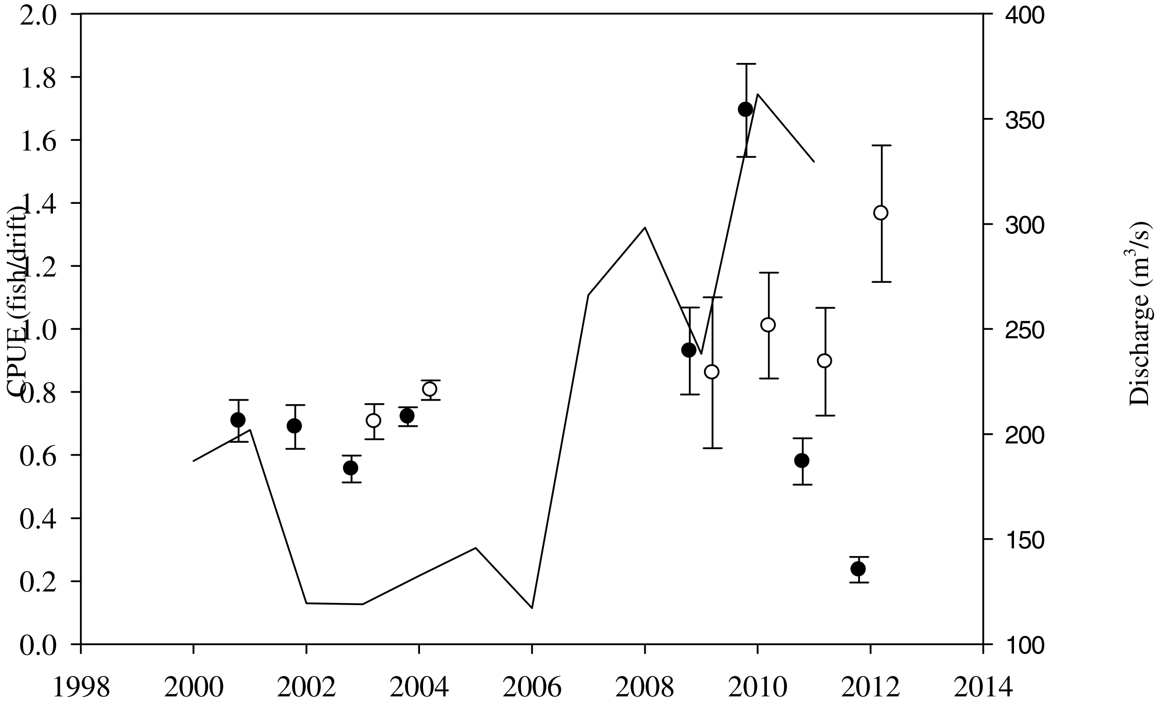

Figure 2. Mean relative abundance (CPUE ± 2 SE) of Shovelnose Sturgeon in the lower Platte River, Nebraska, in both trotlines (filled dots) and trammel nets (open dots) from 2001-2012. Solid horizontal line represents the mean annual discharge.

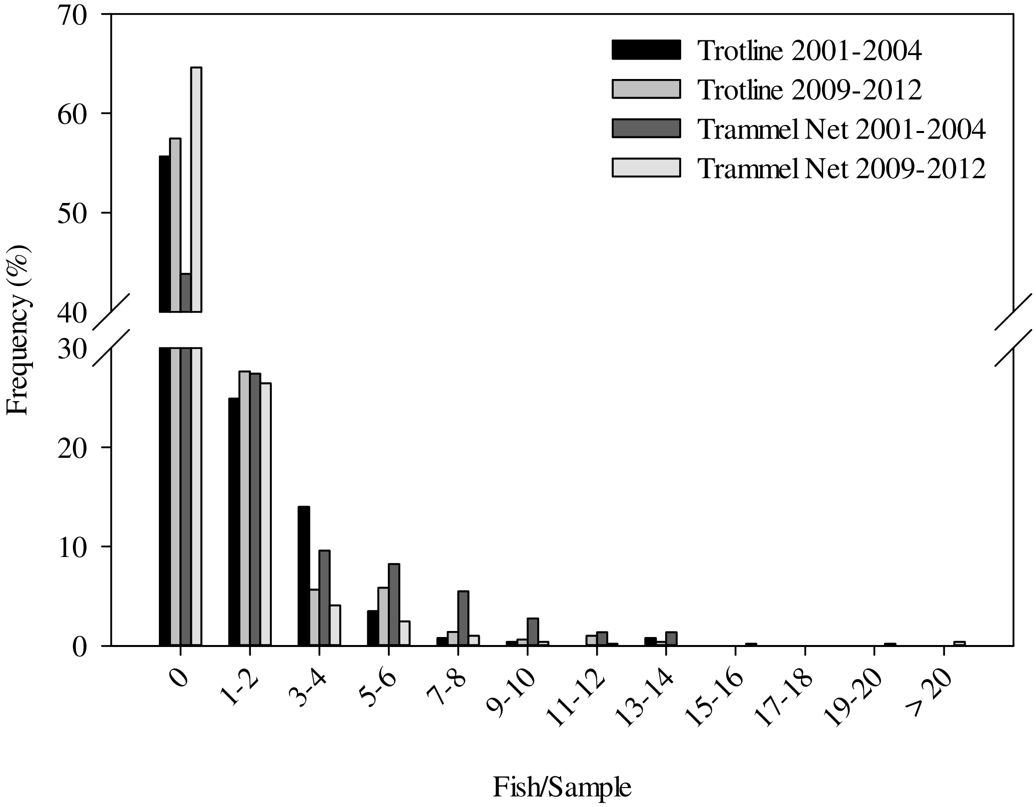

Figure 3. Frequency distribution of the total number of Shovelnose Sturgeon captured in each sample run for both gears during low-water (2001-2004) and high-water periods (2009-2012) in the lower Platte River, Nebraska.

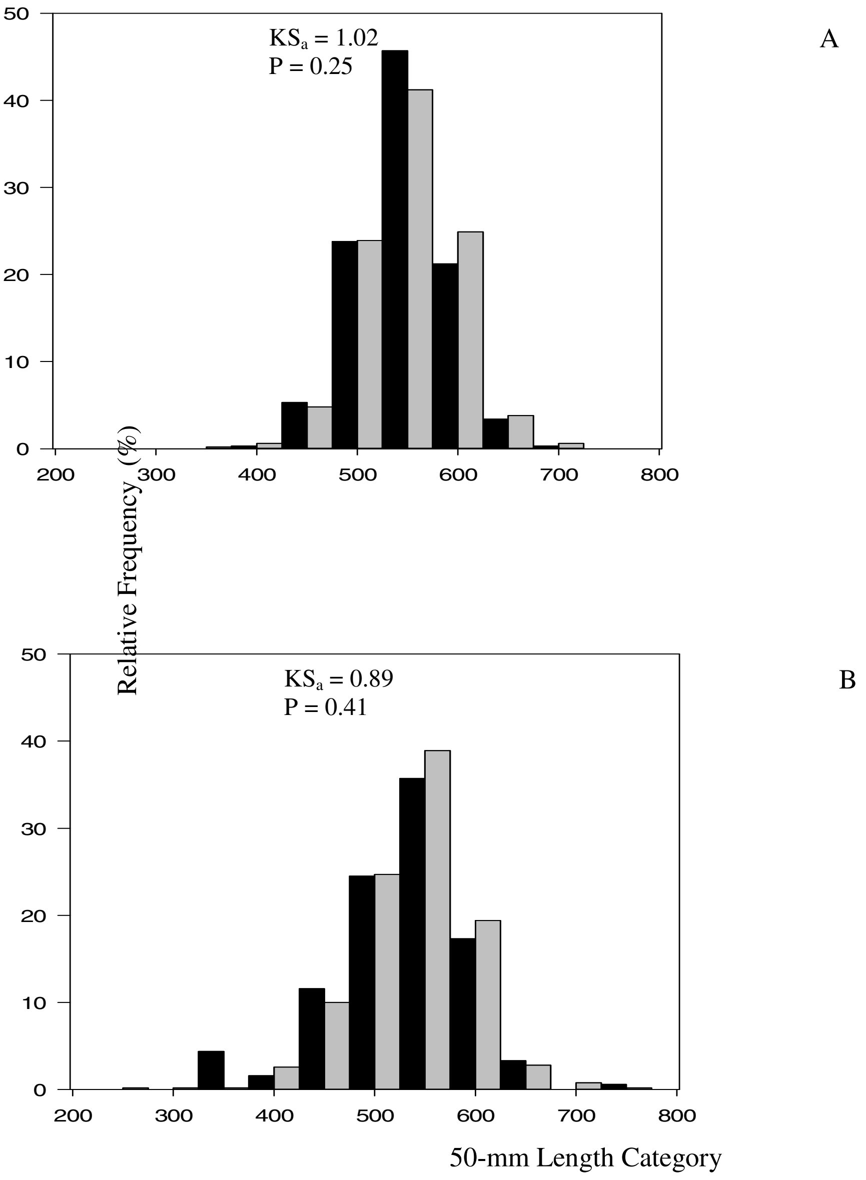

Figure 4. Relative length-frequency distribution for Shovelnose Sturgeon sampled in the lower Platte River, Nebraska, during low-water (black bars) and high-water periods (grey bars) below the Elkhorn River confluence for trotlines (A) and trammel nets (B). Kolmogorov-Smirnov significance test statistic is indicated in the graph.

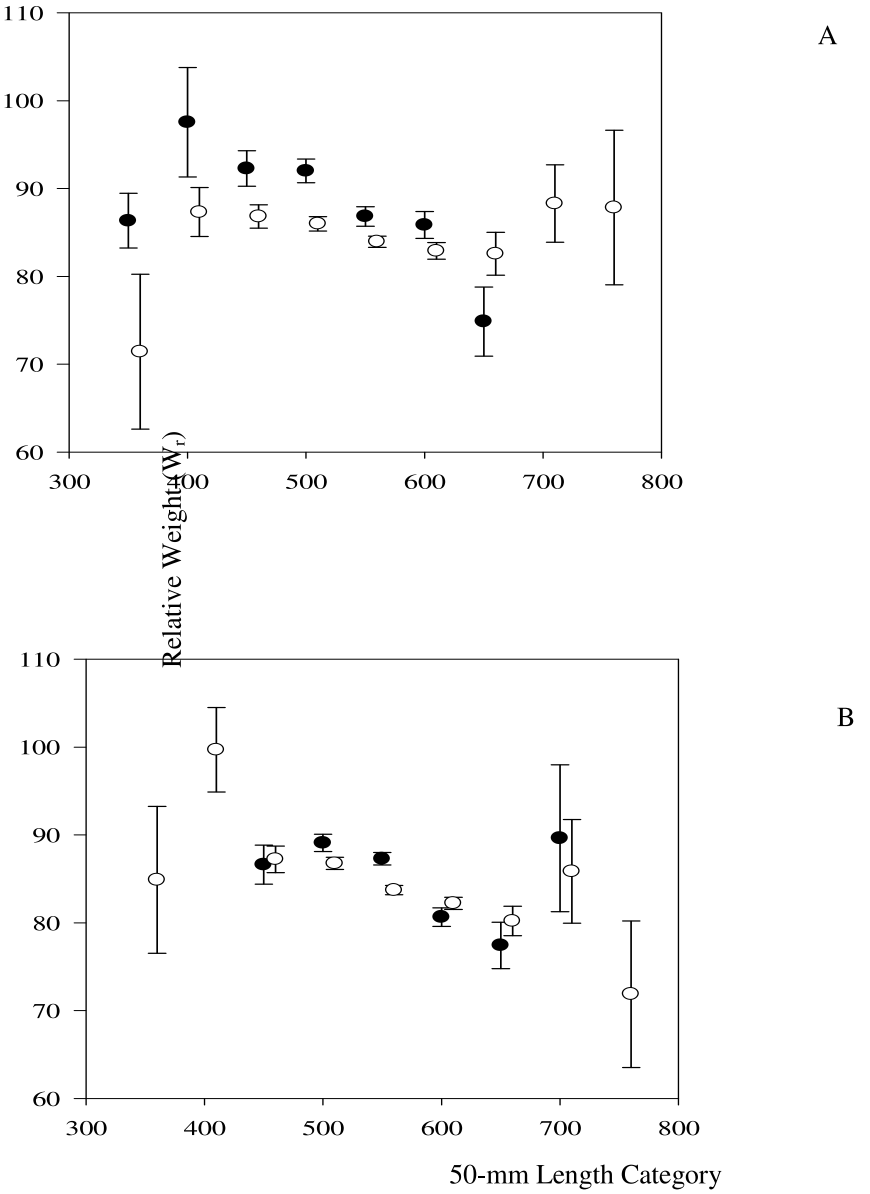

Figure 5. Mean relative weight (W_r) in the spring for both sampling periods for Shovelnose Sturgeon 50-mm length groups in lower Platte River, Nebraska, trotline (A) and trammel net (B). Filled circles represent sampling during the low-water period while open circles represent sampling during the high-water period. Error bars represent ± 2 SE.