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The Status of Fishes in the Missouri River, Nebraska: Shoal Chub (*Macrhybopsis hyostoma*), Sturgeon Chub (*M. gelida*), Sicklefin Chub (*M.* *meekei*), Silver Chub (*M. storeriana*), Flathead Chub (*Platygobio gracilis*), Plains Minnow (*Hybognathus* *placitus*), Western Silvery Minnow (*H. argyritis*), and Brassy Minnow (*H. hankinsoni*)

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The Status of Fishes in the Missouri River, Nebraska: Shoal Chub (*Macrhybopsis hyostoma*), Sturgeon Chub (*M. gelida*), Sicklefing Chub (*M. meeki*), Silver Chub (*M. storeriana*), Flathead Chub (*Platygobio gracilis*), Plains Minnow (*Hybognathus placitus*), Western Silvery Minnow (*H. argyritis*), and Brassy Minnow (*H. hankinsoni*)

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Abstract

Throughout the past century, the Missouri River has been highly modified which has negatively affected the native fish community. Previous research quantified the reduction of several native *Cyprinidae* species and made several recommendations to aid in recovery. However, these recommendations were not implemented. Therefore, the objective of this paper is to assess the current population trends of eight native cyprinid species and develop the current management objectives. Over 335,000 fish were collected from the Missouri River along Nebraska's eastern border with mini-fyke nets and otter trawls from 2003 to 2012. Target *Cyprinidae* species consisted of less than five percent ($n = 14,610$) of the total catch with Silver Chubs ($n = 11,804$) comprising the majority (81%) of target species captured. State-wide all eight species were captured, although localized extirpations may have occurred. These native cyprinid species are extremely rare or extirpated upstream of Gavins Point Dam and populations continue to be limited downstream of Gavins Point Dam. Generally, relative abundance of these fish increased in the channelized reach, compared to the unchannelized reaches, but they no longer dominate the fish community. This shift in species composition and low relative abundance estimates continue to indicate imperilment of the Missouri River system.

Keywords: Chub, *Hybognathus*, *Macrhybopsis*, Minnow, Missouri River, Status, Threatened

Introduction

From the late 1800s through the 1950s only a few studies investigated the small bodied fish community within the Nebraska reach of the Missouri River (Meek 1894, Evermann and Cox 1896, Johnson 1942). Early studies reported that Flathead Chubs *Platygobio gracilis*, Sicklefing Chubs *Macrhybopsis meeki*, Western Silvery Minnows *Hybognathus argyritis*, and Plains Minnows *Hybognathus placitus* comprised the majority of the small fish community (Johnson 1942); however, since anthropogenic modification altered the Missouri River, these native minnow species have drastically declined (Hesse *et al.* 1993, Hesse 1994, Everett *et al.* 2004). These modifications, which include fragmentation and channelization, have altered the natural hydrograph and temperatures, reduced turbidity, and changed the sediment transport that historically created the dynamic habitat elements necessary for native fauna and flora survival (Hesse *et al.* 1993). Additionally, these modifications have disconnected the Missouri River from its historic floodplain. This disconnection is intimately tied to the linked ecological processes of the rivers natural hydrograph, sediment balance and habitat formation.

Thus, the objectives for this paper are to: (1) present the current status and population trends of eight native cyprinid species in the Missouri River along Nebraska's border from 2003 to 2012, (2) compare current abundance to previous studies, particularly Hesse (1994) and other reaches of the Missouri River and (3) to present management recommendations for these species.

Shoal Chub *Macrhybopsis hyostoma*

The Shoal Chub is a small, slender benthic fish that inhabits large, turbid rivers and resides over fine gravel or sandy substrates with areas of moderate current (Pflieger 1997). Shoal Chubs are generally silvery in color with scattered black spots along the sides (Figure 1). The Shoal Chub's head and snout are moderately rounded with maxillary barbels positioned behind the overhanging snout and are used as external taste buds to locate food as their eyes are small and of little value in turbid waters (Pflieger 1997). Their diet primarily consists of immature aquatic insects but can also include adult insects and plant material (Pflieger 1997). Maximum size rarely exceeds 76 mm (Lee *et al.* 1980) and their life expectancy is very short-lived (< 2 years,



Figure 1. Shoal Chub. Image copyright Joseph R. Tomelleri.



Figure 2. Sturgeon Chub. Image copyright Joseph R. Tomelleri.

Hesse 1994). Therefore, age-1 fish are responsible for reproduction and spawning occurs from early May to late August (Bortrell *et al.* 1964).

Distribution and historic status

The Shoal Chub is found in south central United States from south Texas to southern Minnesota, east to the Appalachian Mountains and west to the Rio Grande River (Lee *et al.* 1980). However, Shoal Chubs have not been documented north of Nebraska in the Missouri River. In Nebraska, Shoal Chubs were historically collected in the Elkhorn, Loup, Republican, lower Platte, Blue and Missouri Rivers (Meek 1894, Evermann and Cox 1896, Johnson 1942, Jones 1963). Recent assessments by the Nebraska Department of Environmental (NDEQ) Quality's Stream Biological Monitoring Program did not capture any Shoal Chubs in Nebraska's interior river systems from 2004 to 2008 (Bazata 2011); however, Peters and Parham (2008) reported capturing 2,021 from the lower Platte River during 2001-2004 and Gaughan (University of Nebraska - Omaha, Pers. Comm.) captured shoal chubs in the lower reach of the Loup and Elkhorn rivers. Hesse (1994) reported the relative abundance of Shoal Chubs had declined by 77% in the channelized sections of the Missouri River (Ponca, NE to the Kansas state line) since the 1970s and possibly extirpated upstream of Lewis and Clark Lake. Therefore, Hesse (1994) recommended Shoal Chubs be listed as a Nebraska endangered species. However to date, this species has not received any state protection.

Sturgeon Chub *Macrhybopsis gelida*

The Sturgeon Chub is a slender, streamlined benthic minnow that inhabits main-stem, turbid rivers and resides over sandy and gravel shoals (Pflieger 1997). Generally, their back is light brown with silvery colored sides and belly (Figure 2) with the defining characteristic being its long snout that overhangs the mouth, similar to the morphology of sturgeon species, and presence of ridge-like projections on many scales (Pflieger 1997). Similar to other chub species, maxillary barbels and external taste buds cover the head and body and are used to locate food in highly turbid waters (Pflieger 1997).

Sturgeon Chubs are benthic insectivores with small eyes that are of little value for locating food. Maximum size has been reported to be 70 mm (Lee *et al.* 1980); however, adults exceeding 100 mm have been captured in the channelized Missouri River (K. Steffensen, unpublished data). The Sturgeon Chubs' life span is approximately 4 years; however, few live beyond 2 years (Pflieger 1997). Spawning occurs in mid-summer (i.e., June and July) over gravel substrates (Stewart 1980).

Distribution and historic status

Sturgeon Chubs are found in the main-stem Missouri River from Montana to the confluence with the Mississippi River, and in the Mississippi River downstream from the mouth of the Missouri River to the mouth of the Ohio River. In Nebraska, Sturgeon Chubs were historically collected in the Missouri, Platte, Republican and Elkhorn Rivers (Evermann and Cox 1896, Johnson 1942). Interior stream assessments by NDEQ did not capture any Sturgeon Chubs from 2004 to 2008 (Bazata 2011); however, Peters and Parham (2008) reported capturing two from the lower Platte River during 2002. Hesse (1994) reported that Sturgeon Chubs are only found in the channelized Missouri River in very low abundance (Hesse 1994). Currently, Sturgeon Chubs are listed in Nebraska as a state endangered species.

Sicklefin Chub *Macrhybopsis meeki*

The Sicklefin Chub is a slender, streamlined benthic minnow that strictly inhabits main-stem, turbid rivers and resides in areas of strong current over sand or gravel shoals (Pflieger 1997). Coloration is similar to Sturgeon Chubs with a light brown back and silvery colored sides and belly (Figure 3); however, it does not have ridge-like projections on its scales. The Sicklefin Chubs defining characteristic is their long, sickle shaped pectoral fins. Maxillary barbels are positioned behind the blunt and slightly overhanging snout (Pflieger 1997). Sicklefin Chubs use these barbels and external taste buds to locate food as their eyes are small and of little value in turbid waters. Their diet primarily consists of immature aquatic insects (Reigh and Elsen 1979). Maximum size rarely exceeds 95 mm (Pflieger 1997) and they



Figure 3. Sicklefing Chub. Image copyright Joseph R. Tomelleri.

have a relatively short life span (< 4 years). Dieterman *et al.* (2006) suggested Sicklefing Chubs spawn in late-July when water temperatures are around 21°C. Furthermore, Dieterman *et al.* (2006) suggest Sicklefing Chubs display a protracted spawning period and may have a high degree of post-spawn mortality.

Distribution and historic status

Sicklefin Chubs are found in the main-stem Missouri River from Montana to the confluence with the Mississippi River and in the Mississippi River downstream from the mouth of the Missouri River to the mouth of the Ohio River (Lee *et al.* 1980). In Nebraska, Sicklefing Chubs were historically collected in the Missouri and Platte Rivers (Meek 1892, Johnson 1942, Morris 1960); however, state-wide interior stream assessments did not capture any Sicklefing Chubs (Peters and Parham 2008, Bazata 2011). In the Missouri River, Sicklefing Chubs may have been extirpated upstream of Lewis and Clark Lake and in very low abundance below (Hesse 1994). Therefore, Hesse (1994) recommended Sicklefing Chubs be listed as a state endangered species. However to date, this species has not received any state protection.

Silver Chub *Macrhybopsis storeriana*

The Silver Chub is an elongated, slender minnow that inhabits medium to large rivers and resides in areas of lethargic currents with pools and backwaters (Pflieger 1997). Sand or gravel is the preferred substrate habitat as Silver Chubs live on or near the bottom (Pflieger 1997). Silvery coloration is relatively uniform with no distinct markings on the body (Figure 4). The Silver Chubs mouth is positioned sub-terminally below a blunt, rounded snout (Pflieger 1997) with large eyes which aids in locating food. Silver Chubs are more generalists in their feeding behavior consuming immature and adult aquatic and terrestrial insects, plant seeds, crustaceans and mollusks (Etnier and Starnes 1993). Maximum reported size is 231 mm (Lee *et al.* 1980) but adults rarely exceed 135 mm in the Missouri River (Pflieger 1997). Their life span is relatively short (< 3 years, Lee *et al.* 1980) and little is known about spawning time or

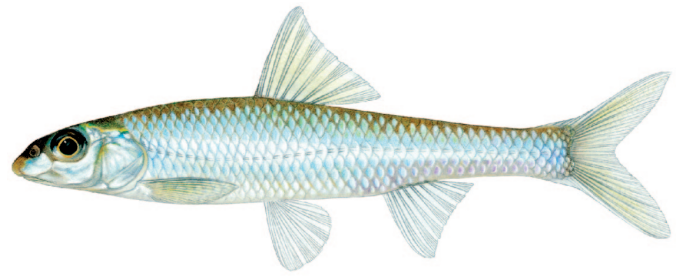


Figure 4. Silver Chub. Image copyright Joseph R. Tomelleri.

substrates preference. However, Scott and Crossman (1973) and Becker (1983) suggest that spawning occurs when water temperatures reach 20°C.

Distribution and historic status

Silver Chubs are found throughout the central United States, ranging longitudinally from the Gulf Coast up through the Mississippi River basin and into the Red River of the North in Southern Manitoba and latitudinal from the Ohio River basin into eastern Nebraska (Lee *et al.* 1980). Silver Chubs have not been documented north of Nebraska in the Missouri River. In Nebraska, Silver Chubs were historically collected in the Missouri, Platte, Loup, Elkhorn, and Republican Rivers (Meek 1894, Evermann and Cox 1896, Johnson 1942, Jones 1963). Recent studies have reported capturing 136 Silver Chubs from the Platte River during 2002-2004 (Peters and Parham 2008) and 29 Silver Chubs from the Niobrara River during 2009 (Wanner *et al.* 2011). However, no Silver Chubs were collected from the interior stream assessments by NDEQ from 2004 to 2008 (Bazata 2011). Hesse (1994) collected minimal numbers of Silver Chubs in the unchannelized Missouri River and reported that the relative abundance of Silver Chubs had declined by 70% from the 1970s in the channelized sections (Ponca, NE to the Kansas state line). Therefore, Hesse (1994) recommended Silver Chubs be listed as a state endangered species. However to date, this species has not received any state protection.

Flathead Chub *Platygobio gracilis*

The Flathead Chub is a streamlined minnow that inhabits the main channel of medium to large, turbid rivers in areas of swift current (Olund and Cross 1961). Sand or gravel is the preferred substrate as Flathead Chubs live on or near the bottom in large rivers (Pflieger 1997). The Flathead Chubs coloration features a light brown back, silvery sides and belly with no other distinct marking on the body (Figure 5). Its mouth is sub-terminal below a flattened, wedge shaped head with maxillary barbels (Pflieger 1997). Flathead Chubs use these barbels and external taste buds to locate food as

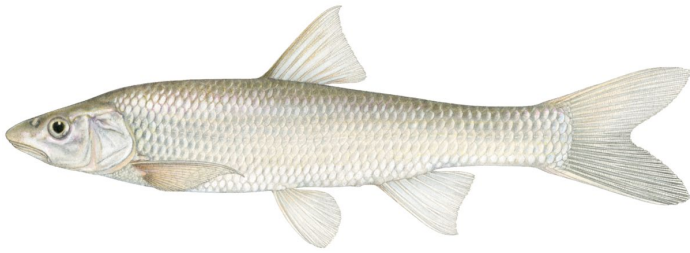


Figure 5. Flathead Chub. Image copyright Joseph R. Tomelleri.

their eyes are small and of little value in turbid waters (Pflieger 1997). Their omnivorous diet primarily consists of terrestrial insects and small invertebrates and to a lesser extent plant material (Olund and Cross 1961). Maximum reported size is 317 mm (Lee *et al.* 1980) but adults are typically less than 190 mm (9.5 in) in the Missouri River (Pflieger 1997). The longitudinal range of Flathead Chubs greatly influences the species life span; however in states proximal to Nebraska, maximum age has been estimated at three to four years (Martyn and Schmulbach 1978, Pflieger 1997). Spawning occurs from mid-July through mid-August when water temperatures vary from 18-25°C (Martyn and Schmulbach 1978).

Distribution and historic status

Flathead Chubs are found throughout the central United States and Canada (Lee *et al.* 1980). It ranges longitudinally from the Gulf Coast through the middle and lower Mississippi River (below the confluence of the Missouri River) and northwest throughout the Missouri River basin and the Northwest Territories and eastern Yukon of Canada (Olund and Cross 1961, Lee *et al.* 1980). A disjunct population is also found in the Rio Grande River in New Mexico. In Nebraska, Flathead Chubs were historically collected throughout all large rivers and their main tributaries except the Blue River system (Johnson 1942, Jones 1963). Wanner *et al.* (2011) reports capturing 702 specimens from the Niobrara River in 2009; however, interior stream assessments by NDEQ did not capture any Flathead Chubs from 2004 to 2008 (Bazata 2011). Hesse (1994) reported that the relative abundance of Flathead Chubs had declined by 98% in the channelized section of the Missouri River (Ponca, NE to the Kansas state line) and that they may be extirpated upstream of Lewis and Clark Lake. Therefore, Hesse (1994) recommended Flathead Chubs be listed as a state endangered species. However to date, this species has not received any state protection.

Plains Minnow *Hybognathus placitus*

The Plains Minnow is a small, silvery minnow that inhabits medium and large, turbid rivers and resides in shallow, slow water or pool habitats (Baxter and Stone

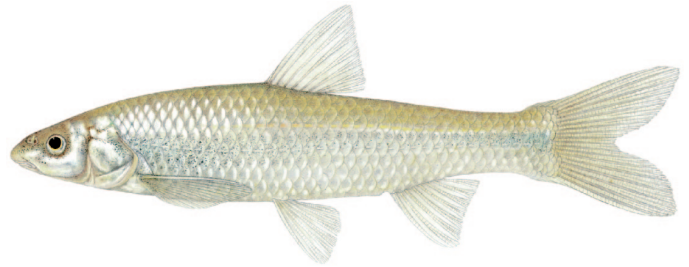


Figure 6. Plains Minnow. Image copyright Joseph R. Tomelleri.

1995) and colonize areas with sandy substrates (Pflieger 1997). Coloration includes a yellowish back that fades into a silver colored belly that is bisected by a greenish mid-dorsal stripe and a black peritoneum (Figure 6). Plains Minnows are commonly associated with the Western Silvery Minnow and although appear similar, Plains Minnows have a smaller eye and a narrow, peg-like basioccipital process with a back margin that is nearly straight (Pflieger 1997). Their herbivore diet primarily consists of algae and other organic materials (Cross 1967). Maximum size is 125 mm (Lee *et al.* 1980) and Plains Minnows are typically short-lived (< 2 years, Hesse 1994). Plains Minnows spawn from late-April into August generally during periods of increased flows and high levels of post-spawning mortality typically follow (Taylor and Miller 1990, Pflieger 1997).

Distribution and historic status

Plains Minnows are found west of the Mississippi River and east of the Rocky Mountains from Texas to Montana in most medium and large rivers (Lee *et al.* 1980). In Nebraska, Plains Minnows were historically the most abundant *Hybognathus* species and were collected throughout all large rivers and their main tributaries except the Blue River system (Johnson 1942, Jones 1963). Peters and Parham (2008) reported capturing 47 specimens from the Platte River in 2002; however, interior stream assessments by NDEQ did not capture any Plains Minnows (Bazata 2011). Hesse (1994) reported that Plains Minnows and Western Silvery Minnows combined and these minnow species comprised less than one percent on the total catch in both unchannelized reaches. In the channelized section of the Missouri River (Ponca, NE to the Nebraska state line), relative abundance had been reduced by 96% from the 1970s. Therefore, Hesse (1994) recommended *Hybognathus* species be listed state endangered. However to date, the Plains Minnows have not received any state protection.

Western Silvery Minnow *Hybognathus argyritis*

The Western Silvery Minnow is a small, silvery minnow that inhabits a range similar to the Plains Minnow but tend to colonize areas with little current and



Figure 7. Western Silvery Minnow. Image copyright Joseph R. Tomelleri.

a silt bottom (Pflieger 1997). The Western Silvery Minnows coloration is similar in appearance (Figure 7) to the Plains Minnow but Western Silvery Minnows have a broad and blade-like basioccipital process with a back margin that is straight or only slightly concave (Pflieger 1997). Their diet consists of a variety of algae, organic materials, diatoms, and fungi (Whitaker 1977). Life history and spawning cues are not completely understood but theorized to be similar to Plains Minnows.

Distribution and historic status

Western Silvery Minnows are found exclusively in the Missouri River basin and the Mississippi River downstream from the confluence with the Missouri River to the Ohio River (Lee *et al.* 1980). In Nebraska, Western Silvery Minnows were historically very abundant and were collected throughout all river large rivers and their main tributaries except the Blue River system (Johnson 1942, Jones 1963); however, it rarely occurred any distance upstream in any tributary. Peters and Parham (2008) reported capturing one specimen from the Platte River in 2002 while the interior stream assessments by NDEQ from 2004 to 2008 did not capture any Western Silvery Minnows (Bazata 2011). Western Silvery Minnows have seen a dramatic reduction in their range throughout Nebraska and is now extremely rare in Nebraska (Cunningham and Hrabik, Pers. Obs.) To date, the Western Silvery Minnows have not received any protection in Nebraska.

Brassy Minnow *Hybognathus hankinsoni*

The Brassy Minnow is the smallest *Hybognathus* species in Nebraska and generally inhabits smaller, less turbid streams (Scheurer *et al.* 2003) but small populations do occur in the Missouri River and some of its tributaries (Pflieger 1997). Brassy Minnows colonize areas with low water velocities (i.e., slow runs or pools) with silt substrate (Scheurer *et al.* 2003). Coloration is similar in appearance (Figure 8) to Plains Minnow and Western Silvery Minnow but the Brassy Minnow's dorsal fin is distinctly rounded at the tip and with dissection the basioccipital process that is similar in shape to

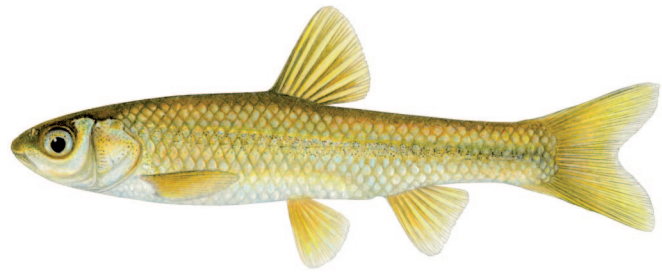


Figure 8. Brassy Minnow. Image copyright Joseph R. Tomelleri.

Western Silvery Minnow but slightly narrower (Pflieger 1997). Their herbivore diet primarily consists of algae and other organic materials (Baxter and Stone 1995). Maximum size is 97 mm (Lee *et al.* 1980) and is typically a longer-lived (up to 4 years) *Hybognathus* species (Pflieger 1997). Brassy Minnows spawn from early May into mid-June over vegetation (Copes 1975).

Distribution and historic status

Brassy Minnows are found mainly north of the 40th parallel into Canada and from Montana east to the St. Lawrence River in New York. Brassy Minnows accounted for 5.6% of all fish collected from 2004-2008 during NDEQ's interior stream assessment (Bazata 2011). Peters and Parham (2008) reported capturing only one specimen from the Platte River in 2002 and Wanner *et al.* (2011) reported capturing 101 specimens during 2009 from the Niobrara River. To date, the Brassy Minnows have not received any protection in Nebraska as this species is more frequent in smaller order stream and generally does not do well in large rivers.

Materials and methods

Study area

For this analysis, the Missouri River along Nebraska's border was divided into 5 reaches, four riverine reaches and one reservoir, based on physical and morphological characteristics (Figure 9). The upper unchannelized reach begins at the Nebraska / South Dakota border (rkm 1,411.0) and continues downstream to the headwaters of Lewis and Clark Lake (rkm 1,331.7). Fort Randall Dam is 5.0 rkm upstream of the state border between South Dakota and Nebraska and highly influences this reach through hypolimnetic and power peaking discharges (Hesse and Mestl 1993). Water management practices have altered the natural hydrograph and temperature regime, reduced turbidity, and degraded the channel upstream of the Niobrara River. The Niobrara and Missouri river confluence is located at rkm 1,358.0. Resembling the unaltered river, the Missouri River downstream of the Niobrara River confluence has

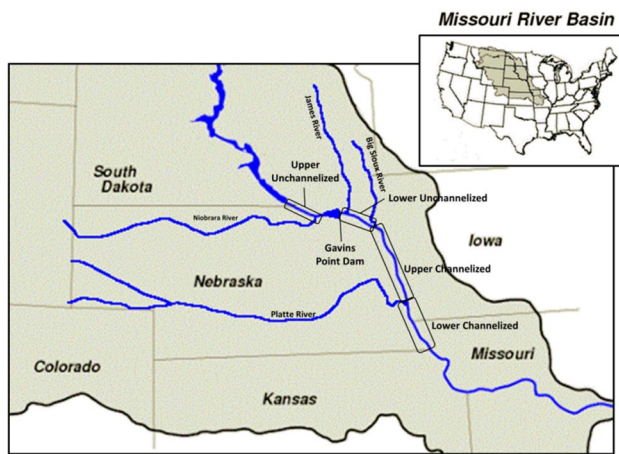


Figure 9. Map of the Missouri River basin. The four study reaches along Nebraska's eastern border are indicated within the rectangles.

formed a large braided delta extending into the former headwaters of Lewis and Clark Lake. The effects of the hypolimnetic releases from Fort Randall are reduced by Niobrara River outflows, with increased water temperature, turbidity and bed load.

Gavins Point Dam (rkm 1,305.2) impounds the Missouri River forming Lewis and Clark Lake which is the smallest and most downstream main-stem Missouri River reservoir. The main purpose of Gavins Point Dam is to stabilize the irregular discharges from Fort Randall Dam to support navigation on the lower Missouri River (Hesse and Mestl 1993). The lower unchannelized reach begins at Gavins Point Dam and continues downstream to approximately Ponca, NE (rkm 1,211.8) where channelization begins. Like the upper unchannelized reach, this reach also experiences channel bed degradation, hydrograph alterations, and reduced turbidity levels; however, water temperatures are less affected.

Downstream of the lower unchannelized reach is a 29.5 rkm reach where channelization begins by "training" the river through a series of bends and dike structures. This reach more closely resembles the channelized reach; therefore, capture data is included with the upper channelized reach. The channelized portion of the Missouri River starts upstream of Sioux City, IA (rkm 1,182.4) and continues to the confluence with the Mississippi River (rkm 0.0) and includes 394.0 rkm along Nebraska's eastern border. Along the Nebraska border, this channelized section was divided into two reaches by the Platte River (rkm 957.6): the upper channelized reach (Ponca, NE to the Platte River confluence) and lower channelized reach (Platte River confluence to the Nebraska / Kansas state line [rkm 788.4]). The upper channelized reach has a highly degraded channel; however, tributary (i.e., Big Sioux River and Little Sioux

River) impacts increase turbidity levels. The lower channelized river has an aggrading channel due to the influence of the Platte River and floods more frequently. Seasonally, the Platte River can highly influence the tributary, temperature and hydrograph on the lower channelized reach. Channel morphology in the channelized reaches consists of a series of dike structures on the inside bends and revetment on the outside bends and is limited to a few habitats types.

Data collection

Data were acquired from three Field Offices associated with the U.S. Army Corps of Engineers (USACE) funded Pallid Sturgeon Population Assessment (PSPA) Project. The USACE formed a long-term monitoring and assessment project in response to the 2000 Missouri River Biological Opinion (Bi-Op, USFWS 2000) and the 2003 Amendment (USFWS 2003). Sampling was initiated in 2003 in the upper unchannelized and lower channelized reaches with full implementation along Nebraska's eastern border in 2005. The U.S. Fish and Wildlife Service (USFWS) Great Plains Fish and Wildlife Conservation Office sampled the upper unchannelized reach while South Dakota Department of Game, Fish and Parks (SDGFP) sampled the lower unchannelized reach. Nebraska Game and Parks Commission (NGPC) sampled the two channelized reaches. The PSPA Project operates under a stratified random design in which the reaches are the strata and the experimental unit (i.e., river bends) are annually randomly selected (Welker and Drobish 2012a). Twenty-five percent of the bends per segment were randomly selected and sampled with a suite of standard gears. Standard gears were deployed annually throughout all reaches in the available habitats. Sampling efforts began in April or May and continue through mid-October. Sampling was limited throughout all reaches in 2011 due to the record inflows in the upper Missouri River basin which subsequently resulted in record discharges from the Missouri River main stem dams.

Fish were collected following the standard operating procedures developed for the PSPA Project using a variety of gears (Welker and Drobish 2012a, Welker and Drobish 2012b). Gears used (annually) to monitor the target cyprinid populations included: otter trawls and mini-fyke nets. Benthic 4.9 m otter trawls were actively towed downstream while mini-fyke nets were fished overnight for a maximum set time of 24 hours. Catch per unit effort for otter trawls is reported as fish per 100 m trawled and fish per net night for mini-fyke nets. All fish sampled were measured to the nearest millimeter. See Welker and Drobish (2012a, 2012b) for sampling gear specifics.

Catch per unit effort was calculated for each gear deployment then averaged by year to get an annual CPUE

and a measure of variance. Annual CPUE's were calculated for the standard gear (i.e., otter trawls and mini-fyke nets) that collected the majority of the fish throughout all reaches. Therefore, otter trawl catch rates were used to assess the abundance and population trends of Shoal Chubs, Sturgeon Chubs, Sicklefin Chubs and Silver Chubs; whereas, mini-fyke net catch rates were used to assess Flathead Chubs, Plains Minnows, Western Silvery Minnows and Brassy Minnows. Finally, PSPA Project published data was acquired from the upper Missouri River (Fort Peck Dam [rkm 2,850.0] to the headwaters of Lake Sakakawea [rkm 2,523.5]) and the lower Missouri River (Nebraska/Kansas state line [rkm 788.4] to the confluence of the Mississippi River [rkm 0.0]) was used for the basin-wide species composition comparisons.

Results

Between 2003 and 2012, over 45,000 fish were collected from 7,000 otter trawl deployments from the four reaches of the Missouri River along Nebraska's eastern border (Table 1). Additionally, 290,000 fish were collected from almost 3,000 mini-fyke net deployments (Table 2). Overall, Silver Chubs were the most abundant target species (N = 11,804) followed by Shoal Chubs (N = 1,074), Plains Minnows (N = 1,049),

Sicklefin Chub (N = 276), Brassy Minnow (N = 215) and Sturgeon Chub (N = 179). Western Silvery Minnows (N = 5) and Flathead Chubs (N = 8) were the most infrequently captured target species. Silver Chubs made up 3.5% of the total catch while the other seven target species represented only 0.8% of the total catch with otter trawls and mini-fyke nets from 2003 to 2012.

Total catch per unit effort (CPUE) for otter trawls increased in a downstream trend with the lower channelized reach resulting in the highest overall CPUE (9.28 fish per 100 m trawled, Table 1). Total CPUE of the otter trawl for the targeted species (i.e., Shoal Chubs, Sturgeon Chubs, Sicklefin Chubs and Silver Chubs) was 9 to 15 times greater in the upper (CPUE = 2.05) and lower (CPUE = 1.70) channelized reaches than in the upper (CPUE = 0.19) and lower (CPUE = 0.14) unchannelized reaches. Otter trawl target species contributed only eight percent of the overall otter trawl CPUE in the lower unchannelized river compared to 18% in the upper unchannelized reach and lower channelized reach. Target species were most abundant (26%) in the upper channelized reach with otter trawls with Silver Chubs representing the majority of target species captured.

Total CPUE from mini-fyke nets also tended to increase in a downstream trend with the exception that the upper channelized CPUE (138.2 fish per net night)

Table 1. Number of otter trawl deployments (effort), total distance trawled, total number of fish collected, mean CPUE (fish per 100m trawled) of all species collected and CPUE for the target species (i.e., Shoal Chub, Sturgeon Chub, Sicklefin Chub and Silver Chubs) from 2003-2012.

Year	Effort	Distance (km)	Total Fish	Overall CPUE	Target Spp CPUE	Effort	Distance (km)	Total Fish	Overall CPUE	Target Spp CPUE
Upper Unchannelized						Lower Unchannelized				
2003										
2004										
2005	166	46.3	588	1.22	0.47	91	20.8	225	1.21	0.10
2006	181	54.0	310	0.57	0.13	201	35.8	518	1.39	0.10
2007	190	54.5	453	0.80	0.11	354	51.2	1,050	2.01	0.27
2008	295	75.1	1,362	1.79	0.17	356	45.7	1,308	3.00	0.25
2009	195	50.1	478	0.96	0.11	388	51.5	808	1.54	0.12
2010	190	52.1	480	0.93	0.26	459	59.3	788	1.33	0.08
2011										
2012	179	50.4	667	1.30	0.19	196	27.1	409	1.57	0.07
Total	1,396	382.7	4,338	1.08	0.19	2,045	291.5	5,106	1.73	0.14
Upper Channelized						Lower Channelized				
2003						96	16.8	1,037	7.86	1.29
2004						90	10.4	770	7.95	1.66
2005	331	41.7	1,916	5.21	1.22	202	28.5	1,383	6.18	2.36
2006	443	49.9	5,832	12.78	6.69	292	41.1	5,619	13.73	3.67
2007	296	32.7	3,871	13.51	3.31	174	20.9	3,296	18.45	2.45
2008	258	33.6	1,632	5.19	0.69	153	20.0	1,290	7.14	0.74
2009	258	31.0	1,247	4.38	1.11	196	24.2	2,250	11.83	1.92
2010	242	36.7	2,203	7.80	0.80	133	15.2	731	6.22	0.77
2011										
2012	252	28.9	1,740	6.42	0.63	170	18.9	782	4.12	0.43
Total	2,080	254.6	18,441	7.90	2.05	1,506	196.0	17,158	9.28	1.70

Table 2. Number of mini-fyke net deployments (effort), total number of fish collected, mean CPUE (fish per net night) of all species collected and CPUE for the target species (i.e., Flathead Chub, Plains Minnow, Western Silvery Minnow and Brassy Minnow) from 2003-2012.

Year	Effort	Total Fish	Overall CPUE	Target Spp CPUE	Effort	Total Fish	Overall CPUE	Target Spp CPUE
Upper Unchannelized				Lower Unchannelized				
2003								
2004	87	2,045	23.5	0.0				
2005	80	12,151	151.9	0.0	104	8,147	79.8	< 0.1
2006	80	2,005	25.1	0.0	107	7,288	69.4	< 0.1
2007	80	3,046	38.1	0.1	102	11,366	112.5	0.0
2008	80	1,819	22.7	0.5	96	8,846	92.1	0.1
2009	81	1,989	24.6	0.1	96	7,555	78.7	0.1
2010	80	2,217	27.7	1.6	96	3,058	32.2	< 0.1
2011								
2012	80	4,016	50.2	< 0.1	96	12,403	134.8	0.0
Total	648	29,288	45.2	0.3	697	58,663	85.4	< 0.1
Upper Channelized				Lower Channelized				
2003					50	717	14.3	< 0.1
2004					40	774	19.4	0.7
2005	136	2,604	20.0	< 0.1	88	1,809	22.9	0.0
2006	144	31,979	223.6	0.2	111	14,869	133.9	0.4
2007	121	12,400	103.3	< 0.1	72	7,386	102.6	1.9
2008	120	15,666	138.6	0.9	72	35,836	504.7	7.9
2009	120	3,928	33.3	0.1	96	3,975	41.8	1.0
2010	120	46,318	406.3	0.4	96	3,543	38.5	< 0.1
2011								
2012	120	4,418	39.8	0.0	80	16,112	214.8	< 0.1
Total	881	117,313	138.2	0.1	705	85,021	124.1	0.8

was slightly higher than the lower channelized (CPUE = 124.1, Table 2). Total CPUE for the mini-fyke net target species (i.e., Flathead Chubs, Plains Minnow, Western Silvery Minnow and Brassy Minnow) did not follow this same pattern whereas the CPUE of these target species was 3 to 8 times greater in the upper and lowermost reaches compared to the middle reaches. The mini-fyke target species made up less than 0.6 % of the total catch from all reaches.

Total CPUE from otter trawls was highly variable with no overall apparent trend. Catch rates peaked in the unchannelized reaches in 2008; whereas, CPUE peaked in 2007 in the channelized reaches (Table 1). The CPUE for the otter trawl target species was also highly variable and also did not follow any apparent trends. The otter trawl target species CPUE was highest in the upper unchannelized reach in 2005 when 38% of all fish collected were target species; comparatively, peaked in 2007 in the lower unchannelized reach and in 2006 for both channelized reaches. Annual CPUE from mini-fyke nets has also been highly variable with no discernible temporal trends (Table 2).

Shoal Chub

Shoal Chubs were not collected in the upper unchannelized reach from 2005 to 2012 and were collected infrequently (N = 13) in the lower unchannelized

reach (Figure 10). The lack of collections in the upper unchannelized suggests this species may be extirpated above Gavins Point Dam and very rare in the unchannelized reach below. Shoal Chubs were more frequently collected in the channelized reaches of the Missouri River in Nebraska and most frequently captured in the lower channelized (N = 702). Relative abundance increased in a downstream trend and peaked in the lower channelized reach where Shoal Chubs represent 4.1% of all fish sampled with otter trawls. Annual catch rates were highly variable but annual catch rates have steadily declined in both channelized reaches since 2006 (Figure 10).

Sturgeon Chub

Sturgeon Chubs are the rarest *Macrhybopsis* species in Nebraska's reach of the Missouri River. Sturgeon Chubs appeared to be extirpated in the upper unchannelized reach as they were not collected from 2005-2011; however, two Sturgeon Chubs were collected in 2012 (Figure 11). Similarly, the infrequent occurrences of Sturgeon Chubs indicate the rarity of these species throughout the lower unchannelized (N = 4) and upper channelized (N = 27) reaches. Sturgeon Chubs are most frequently collected in the lower channelized reach (N = 142) of the Missouri River in Nebraska but represent less than 1.0 % of the total otter trawl catch (Table 3). Similar to Shoal

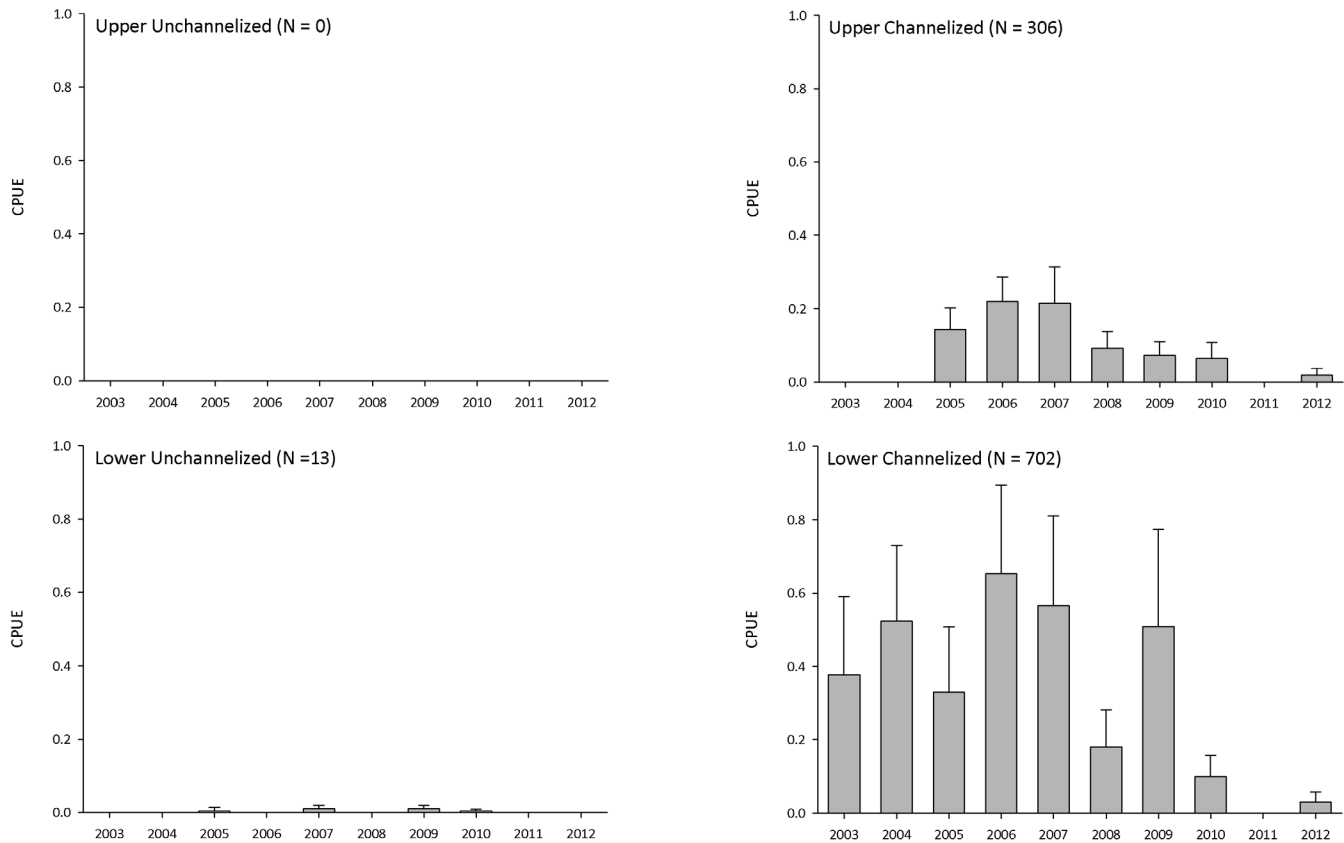


Figure 10. Mean otter trawl catch per unit effort ($\pm 2SE$) for Shoal Chub by reach in the Missouri River along Nebraska's eastern border from 2003-2012.

Chubs, annual catch rates have been declining in the lower channelized reach since 2006 (Figure 11).

Sicklefin Chub

Sicklefin Chubs, although not common, are captured more frequently in Nebraska's reach of the Missouri River compared to Sturgeon Chubs. Sicklefin Chubs were not collected in the upper unchannelized reach over the past ten years and appear to be extirpated (Figure 12). Sicklefin Chubs were occasionally

collected in the lower unchannelized reach (N = 16) but remain rare. Sicklefin Chubs, like other *Macrhybopsis* species, are most frequently collected in the channelized reaches of the Missouri River in Nebraska and are most frequently captured below the Platte River in the lower channelized reach. Sicklefin Chubs represent only 1.1 % of the total otter trawl catch in that reach (Table 3). Similar to other *Macrhybopsis* species, catch rates of Sicklefin Chubs continue to decline in the channelized reaches since 2006 (Figure 12).

Table 3. Percent composition of eight cyprinid species otter trawled or mini-fyke netted from 2005 to 2012 by reach.

Species	Upper Unchannelized	Lower Unchannelized	Upper Channelized	Lower Channelized
Otter Trawl				
Shoal Chub	0.0	0.3	1.7	4.1
Sturgeon Chub	> 0.0	0.1	0.1	0.8
Sicklefin Chub	0.0	0.3	0.3	1.1
Silver Chub	17.0	8.0	27.4	14.3
Mini-Fyke Net				
Flathead Chub	> 0.0	0.0	0.0	0.0
Plains Minnow	> 0.0	0.0	0.2	1.0
Western Silvery Minnow	> 0.0	0.0	0.0	0.0
Brassy Minnow	0.6	> 0.0	> 0.0	> 0.0

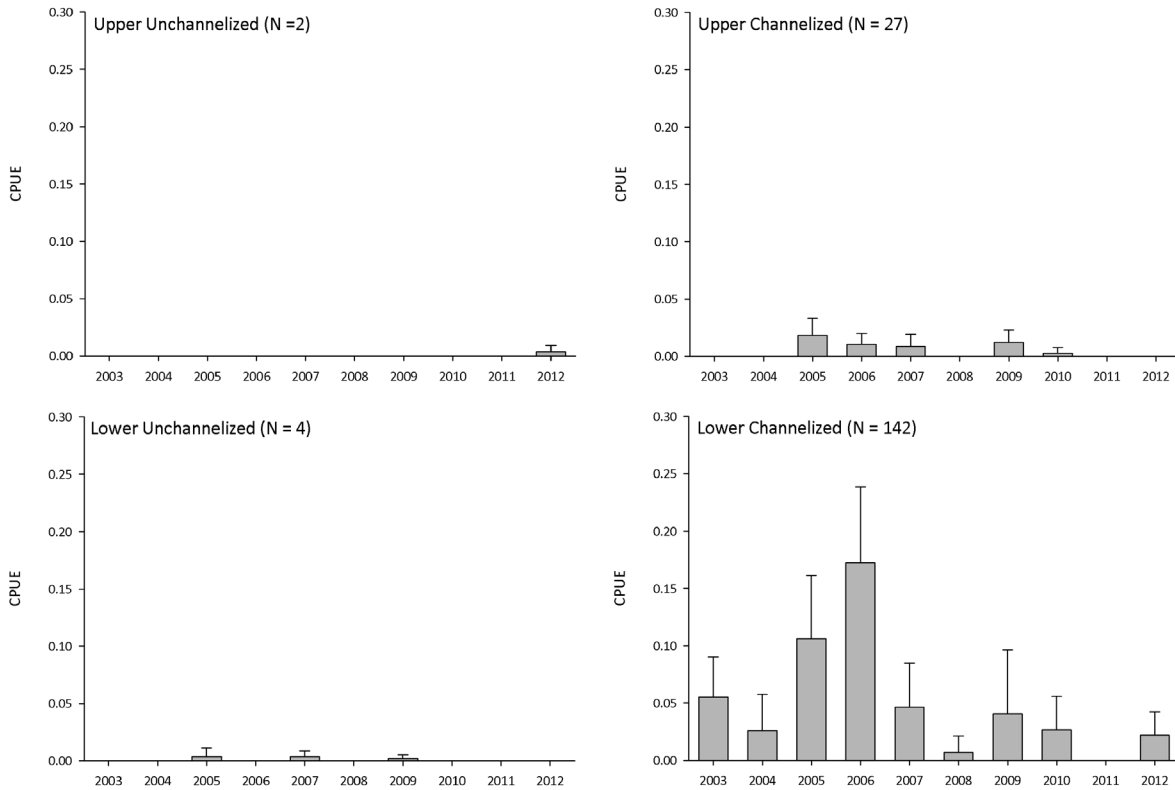


Figure 11. Mean otter trawl catch per unit effort (± 2 SE) for Sturgeon Chub by reach in the Missouri River along Nebraska's eastern border from 2003-2012.

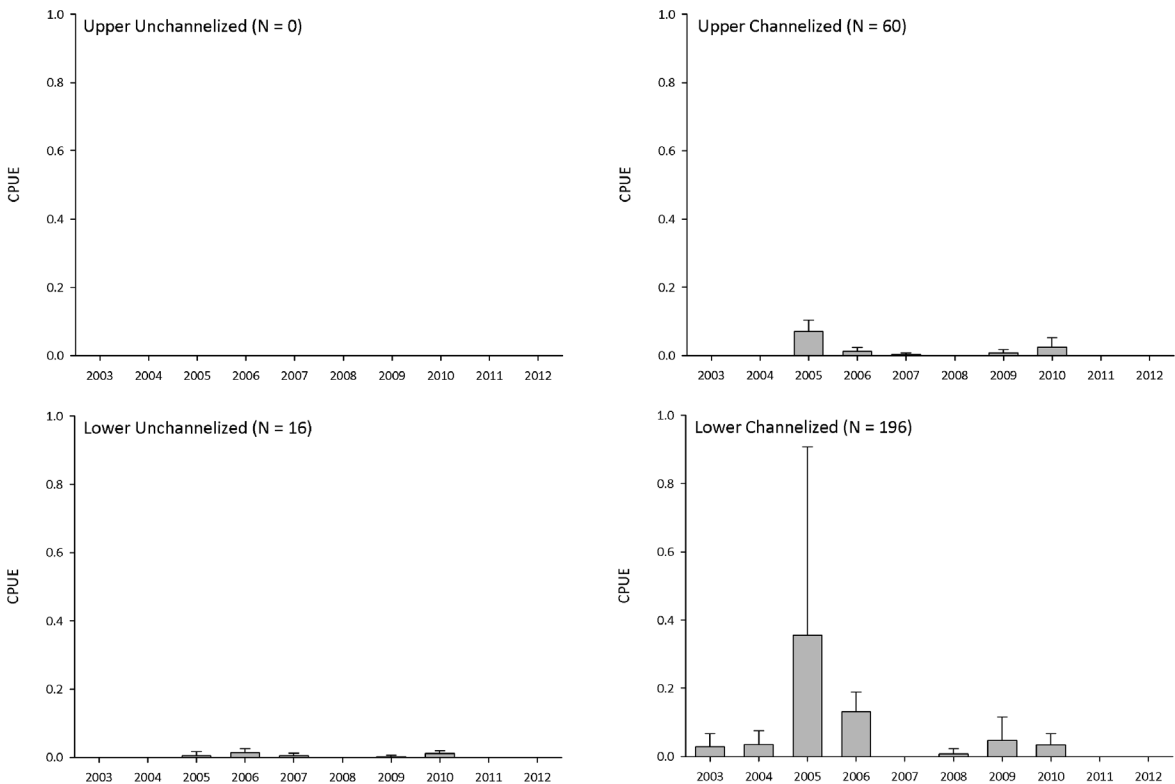


Figure 12. Mean otter trawl catch per unit effort (± 2 SE) for Sicklefin Chub by reach in the Missouri River along Nebraska's eastern border from 2003-2012.

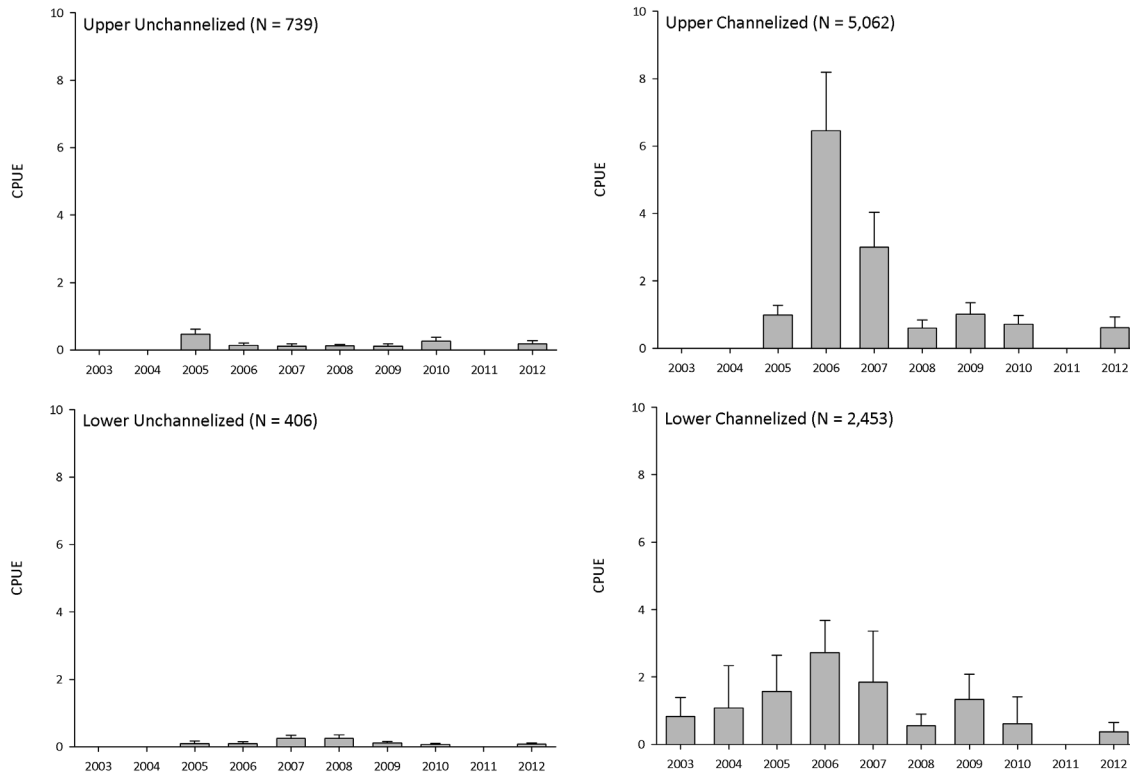


Figure 13. Mean otter trawl catch per unit effort ($\pm 2SE$) for Silver Chub by reach in the Missouri River along Nebraska’s eastern border from 2003-2012.

Silver Chub

Silver Chubs are the most common *Macrhybopsis* species in Nebraska’s reach of the Missouri River and are regularly sampled in all reaches, although they are more frequently captured in the channelized reaches (Figure 13). Silver Chubs were collected annually in the upper and lower unchannelized reaches and represent 17% and 8% of the species composition from otter trawls, respectively (Table 3). Silver Chubs are also the most frequently captured targeted *Macrhybopsis* species in the channelized reaches and account for 27% of the species composition in the upper channelized reach and 14% in the lower channelized reach. Annual catch rates are variable, similar to the other *Macrhybopsis* species, but overall catch rates have declined since 2006.

Flathead Chub

Flathead Chubs are rarely collected in Nebraska’s reach of the Missouri River and appeared to be extirpated from the upper unchannelized reach, as none were collected from 2005-2011. However, two Flathead Chubs were collected in 2012 (Figure 14) and may indicate that a few individuals were relocated from upriver or from tributaries during the 2011 flood. No Flathead

Chubs were collected in the lower unchannelized or upper channelized reach and only six fish were collected in the lower channelized reach.

Plains Minnow

Plains Minnows were captured infrequently in the upper unchannelized reach (N = 6) during this study and were not sampled in the lower unchannelized reach (Figure 15). Plains Minnows were more frequently captured in the channelized reaches; however, annual catch rates declined since 2008 to near zero catch rates the past several years. Like many of the target species, Plains Minnows increase in abundance in a downstream trend on the Missouri River in Nebraska (Table 3).

Western Silvery Minnow

Western Silvery Minnows were rarely collected in Nebraska’s reach of the Missouri River from 2003 to 2012 (Figure 16). These fish were collected from both the uppermost (N = 2) and lowermost (N = 3) reaches.

Brassy Minnow

Brassy Minnows have been captured every year since 2008 and comprise 0.6% of the total mini-fyke net catch

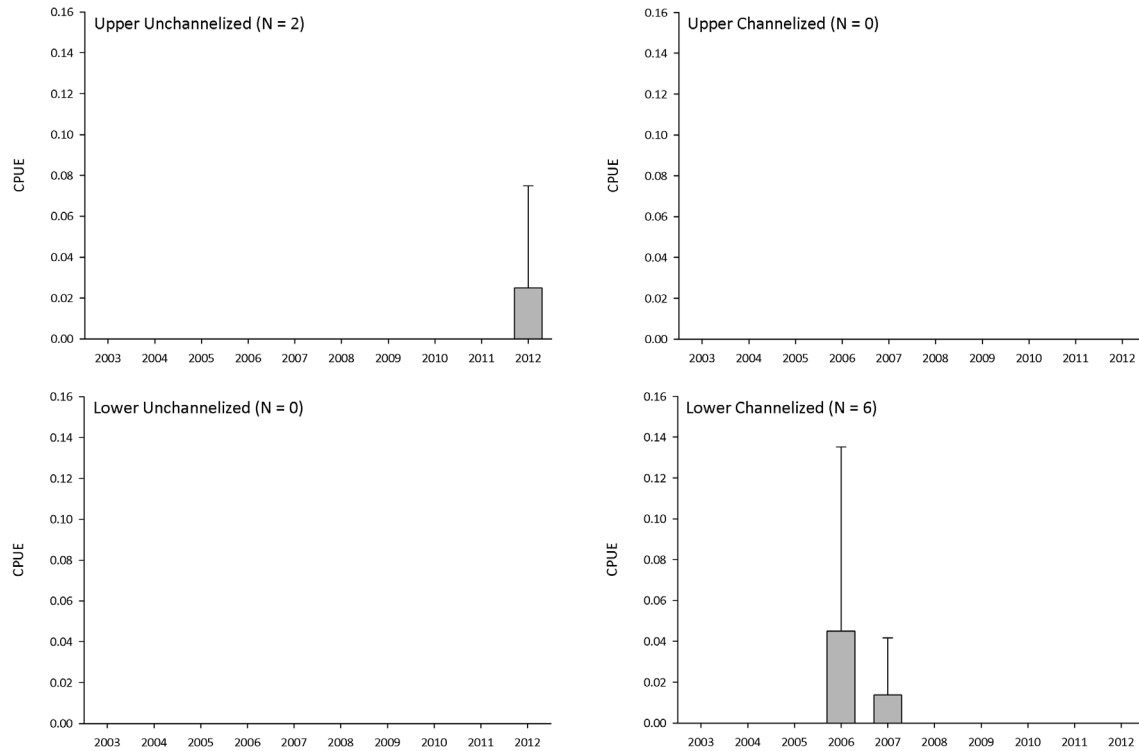


Figure 14. Mean mini-fyke net catch per unit effort ($\pm 2SE$) for Flathead Chub by reach in the Missouri River along Nebraska's eastern border from 2003-2012.

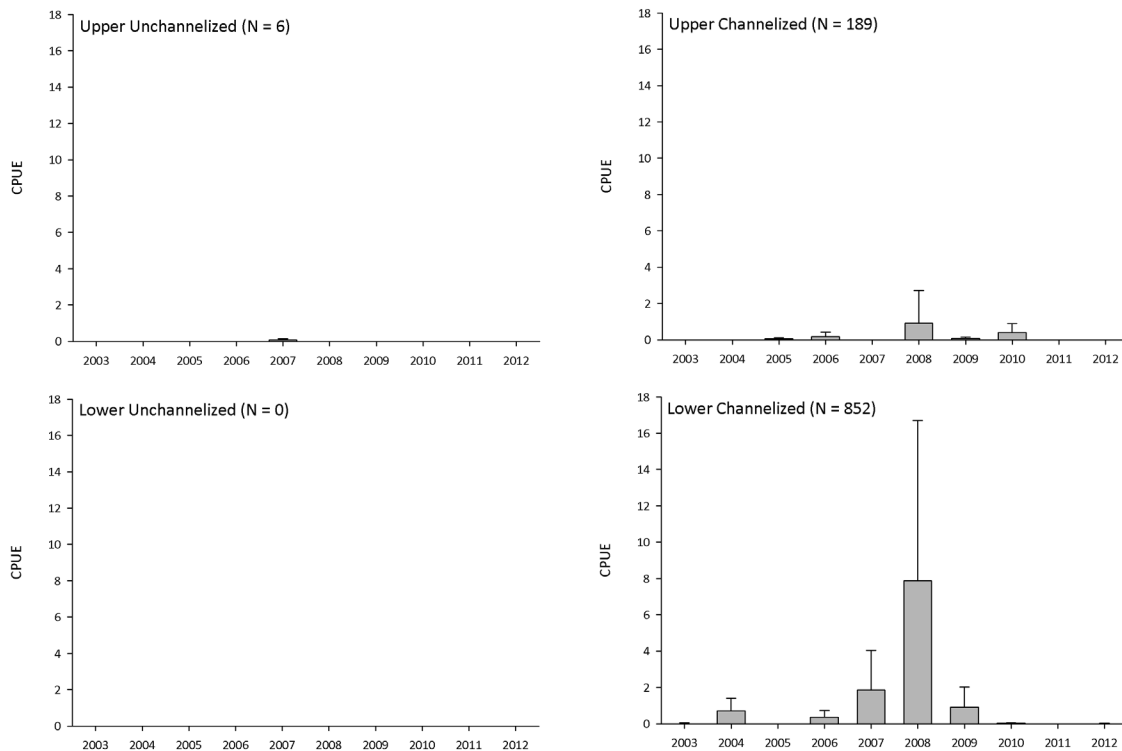


Figure 15. Mean mini-fyke net catch per unit effort ($\pm 2SE$) for Plains Minnow by reach in the Missouri River along Nebraska's eastern border from 2003-2012.

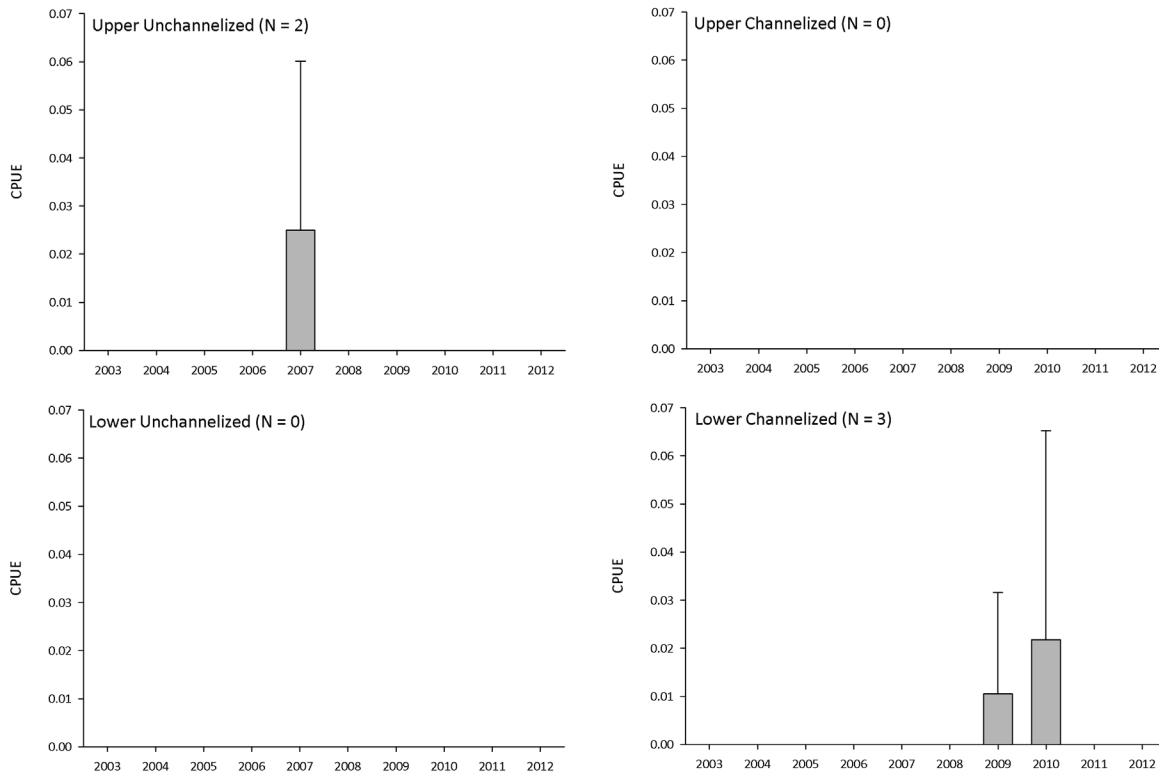


Figure 16. Mean mini-fyke net catch per unit effort ($\pm 2SE$) for Western Silvery Minnow by reach in the Missouri River along Nebraska's eastern border from 2003-2012.

in the upper unchannelized reach (Table 3). Brassy Minnows are rare but collected regularly in the lower unchannelized reach and only occasionally sampled in either of the channelized reaches (Figure 17).

Missouri River Basin Percent Composition Comparison

Within the Missouri River Basin Shoal Chub abundance decreased in an upstream trend throughout Nebraska's reach of the Missouri River and were not found in the upper Missouri River (Table 4). The highest percent composition for Sturgeon Chubs and Sicklefin Chubs were in the upper Missouri River from Fort Peck Dam (rkm 2,850.0) to the headwaters of Lake Sakakawea (rkm 2,523.5). Sturgeon Chub abundance increased slightly downriver from Nebraska in the lower Missouri River; whereas, Sicklefin Chubs percent composition was much higher in the lower Missouri River compared to Nebraska. Silver Chubs were most frequently captured in the Nebraska reaches but were not present in the upper Missouri River. Overall, the mini-fyke net target species (i.e. Flathead Chubs, Plains Minnows, Western Silvery Minnows, and Brassy Minnows) were collected in low abundance throughout the entire Missouri River system.

Discussion with management recommendation

Habitat loss, altered annual flow and temperature regimes, increased average depths and velocities in the channelized reaches, reduced sediment loads and altered turbidity levels from channelization and construction and operation of the mainstem dams have all been cited as contributing causes for Pallid Sturgeon being listed as endangered on the Missouri River (Dryer and Sandvol 1993, USFWS 2013). These changes, with varying degrees of impacts in the different reaches of the Missouri River in Nebraska, have also negatively impacted the populations of native cyprinids. The effects of impoundment are evident as otter trawl catch rates are four to eight times higher in the channelized reaches compared to the unchannelized reaches. Mini-fyke net catch rates displayed a similar trend but not to the degree of otter trawls. Although the unchannelized reaches appear to be in a more natural state, reflective of the historic Missouri River with increased habitat heterogeneity, anthropogenic modifications and management continue to negatively affect the native species composition and abundance. These modifications have altered the natural temperature regime, reduced turbidity, and changed the hydrograph (Petts *et al.* 1989; Pegg

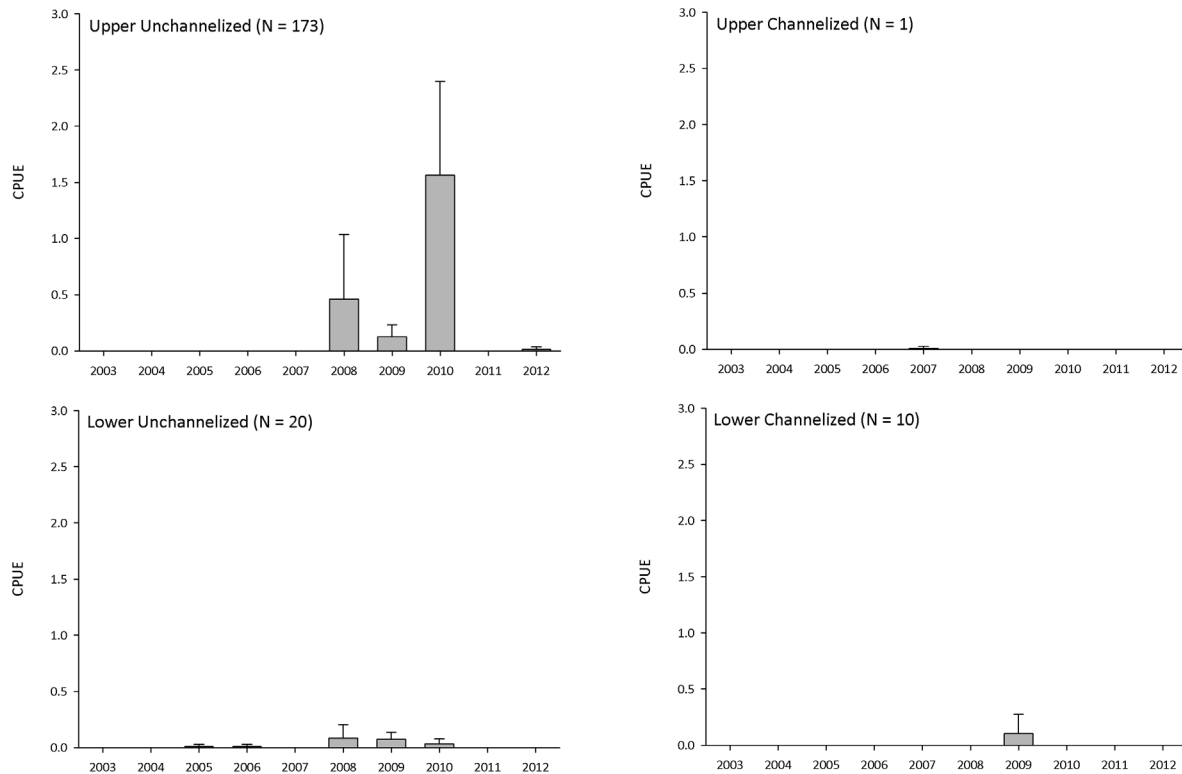


Figure 17. Mean mini-fyke net catch per unit effort ($\pm 2SE$) for Brassy Minnow by reach in the Missouri River along Nebraska's eastern border from 2003-2012.

et al. 2003). Additionally, the lentic conditions upstream of dams has flooded traditional riverine habitat that potentially reduced suitable spawning, feeding, nursery and other required habitats available to native fishes.

Furthermore, main stem impoundment has reduced suitable habitat conditions downstream. Conversely, the highly altered channelized reaches have little to no natural remaining habitats but the hydrograph, temperature,

Table 4. Percent composition of eight cyprinid species otter trawled or mini-fyke netted from 2003 to 2012 by reach.

Species	Upper Missouri River ¹	NE Unchannelized Reaches	NE Channelized Reaches	Lower Missouri River ²
Otter Trawl				
Shoal Chub	*	0.1	2.8	6.0
Sturgeon Chub	19.1	> 0.0	0.4	0.6
Sicklefin Chub	10.5	0.1	0.7	5.1
Silver Chub	*	12.1	21.0	1.8
Mini-Fyke Net				
Flathead Chub	1.3	> 0.0	> 0.0	> 0.0
Plains Minnow	> 0.0	> 0.0	0.5	0.4
Western Silvery Minnow	1.2	> 0.0	> 0.0	> 0.0
Brassy Minnow	> 0.0	0.2	> 0.0	> 0.0

1. Fort Peck Dam (rkm 2,851.0) to headwater of Lake Sakakawea (rkm 2,523.5). Data acquired from: Wilson *et al.* 2006, Haddix *et al.* 2007ab, Wilson 2007, Haddix *et al.* 2008ab, Wilson 2008, Haddix *et al.* 2009ab, Wilson 2009, Haddix *et al.* 2010ab, Wilson 2010, Haddix *et al.* 2011ab, Wilson 2011, Haddix *et al.* 2012ab, Wilson 2012, Haddix *et al.* 2013, Hunziker *et al.* 2013 and Wilson 2013.

2. Nebraska / Kansas state line (rkm 788.4) to the confluence of the Mississippi River (rkm 0.0). Data acquired from: Kennedy *et al.* 2006, Utrup *et al.* 2006ab, Caton *et al.* 2007, Plauck *et al.* 2007, Utrup *et al.* 2007, Niswonger *et al.* 2008, Plauck *et al.* 2008, Utrup *et al.* 2008, Herman *et al.* 2009, Niswonger *et al.* 2009, Plauck *et al.* 2009, Herman *et al.* 2010, Horner *et al.* 2010, Plauck *et al.* 2010, Niswonger *et al.* 2011, Ridenour *et al.* 2011ab, Meyer *et al.* 2012, Niswonger *et al.* 2012, Ridenour *et al.* 2012, Meyer *et al.* 2013, Niswonger *et al.* 2013 and Wrasse *et al.* 2013.

*Species does not occur.

and turbidity regime are more similar to pre-modification regimes. The simplified river channel within the channelized reaches constraints sampling efforts to the inside bend within the dike structures; whereas, the unchannelized reaches have multiple habitats available to distribute sampling efforts. Overall, the entire Missouri River along Nebraska's border has been negatively affected by river alternation and management decisions which resulted in a negative response by the native fish community.

In 1994, Hesse (1994) reported that the abundance of Shoal Chubs had been reduced by 77%, Silver Chubs by 70%, Flathead Chubs by 98% and Plains Minnows by 96% in the channelized reaches of the Missouri River in Nebraska since the 1970s. The rarity of these target species in the unchannelized reaches was evident by the late 1990s, when no Shoal Chubs, Sturgeon Chubs or Plains Minnows were collected and only minimal numbers of the remaining target species when Berry and Young (2004) did a multi-gear assessment, including a bag seine and benthic trawls. Although this studies otter trawl and mini-fyke net data is not directly comparable to the seine data used in the previous studies, it does not appear native species are showing any signs of recovery. Chub populations appeared to be improving in the mid-2000s, during the height of the drought, but most have shown fairly dramatic declines since, despite the large habitat restoration efforts.

Shoal Chubs are on the periphery of their range in the Missouri River in Nebraska but were previously more abundant, especially in the channelized reaches (Hesse 1994). Shoal Chubs catch rates in the channelized reaches peaked during the drought conditions of the mid-2000s but has declined dramatically since. It is unknown whether their low numbers in the unchannelized reaches is due to the presence of main stem dams or simply because they are on the edge of their range. Similar population declines have been observed in Kansas and Iowa (Haslouer *et al.* 2005). Due to the large declines in their population levels in the channelized reaches over the past 40 years and their absence and near absence in the unchannelized reaches, we recommend listing Shoal Chubs as a threatened species in Nebraska.

The benthic sturgeon and Sicklefin Chubs both are found in very low numbers in the channelized sections of the Missouri River in Nebraska and are rare in the unchannelized sections. Nebraska is located within the species central distribution; however, population levels are much higher in the upper Missouri River and slightly higher in the Missouri River downstream of Nebraska. These chub species appear to be highly impacted by the changes and ongoing management of the river. Due to their low population levels in Nebraska and the known role they play in the life history of Pallid

Sturgeon, we recommend the continued listing of Sturgeon Chubs as an endangered species and listing Sicklefin Chubs as endangered species in Nebraska.

Silver Chubs are a macrohabitat generalists benthic species that can tolerant a variety of river conditions and substrates (Cross and Moss 1987, Schloesser *et al.* 2011) and are the most common chub on the Missouri River in Nebraska. Silver Chubs do not inhabit the Missouri River upstream from Nebraska and are currently most abundant in the Nebraska reaches compared to the lower river. Although more abundant than the other targeted chub and minnow species, the populations in Nebraska is a stronghold for the species on the Missouri River; however, Silver Chub catch rates continue to decline since the mid-2000's. At this time, Silver Chubs do not warrant listing as a Nebraska threatened species but continued monitoring is needed.

The Missouri River in Nebraska is the central distribution for Flathead Chubs, Plains Minnows and Western Silvery Minnows. Hesse (1994) indicated that Flathead Chubs and Plains Minnow populations had been reduced by over 98%. As populations declines continued, these species are probably the most impacted over the largest area on the Missouri River. Flathead Chubs and Plains Minnows were historically common in many of the interior rivers of Nebraska but few of have been collected in recent surveys. Therefore, we recommend that Flathead Chubs and Western Silvery Minnows be listed as endangered and Plains Minnows be listed as a threatened species in Nebraska.

Nebraska is on the southern periphery of the range of Brassy Minnows. Brassy Minnows are primarily a prairie headwater stream species that are associated with the clearer tributaries, not the historically turbid mainstem river system. Brassy Minnows collected in the upper unchannelized reach probably reflect the changed conditions associated with the clear water being released from Fort Randall Dam. Under species distribution and habitat niche, we do not recommend protection for Brassy Minnows.

The decreased abundance of these native cyprinids may have an upward trophic level affect. Sturgeon Chubs and Sicklefin Chubs were identified as the primary prey fish of Pallid Sturgeon in the upper Missouri River (Gerrity *et al.* 2006) and Shoal Chubs, Silver Chubs, and other unidentified cyprinids were recovered from Pallid Sturgeon stomach samples in the Mississippi River (Hoover *et al.* 2007). The declines of these chub populations may be correlated to the diminishing wild Pallid Sturgeon population and subsequent listing as an endangered species. Conversely, Wanner *et al.* (2007) found Channel Catfish *Ictalurus punctatus*, Johnny Darter *Etheostoma nigrum* and Emerald Shiner *Notropis atherinoides* in the diet of Pallid Sturgeon in the upper

unchannelized reach demonstrating Pallid Sturgeon maybe more opportunistic than selective when chub populations are diminished. As efforts continue to recover the Pallid Sturgeon through protection, hatchery supplementation, and habitat improvement, the pressure on the small fish community (including the native chub population) will continue to increase as the population of Pallid Sturgeon increase.

State-wide extirpation of these native fish presented in this paper has not occurred, although localized extirpations may have occurred. Except for Silver Chubs and Brassy Minnows, the native cyprinid species presented in this paper are extremely rare or extirpated in the upper unchannelized reach which is isolated between Fort Randall and Gavins Point Dams. Although the unchannelized reach below Gavins Point Dam is open to the lower Missouri River, the native cyprinids populations in question maybe as imperiled as the reach above Gavins Point Dam. The negative effects associated with the main stem dams impacts the river for several hundred kilometers downstream and the input of several major tributaries are needed before these native cyprinids become more abundant. The target native fishes in the channelized reaches are more frequently collected but only represent a small part of the overall fish community. Channelization, dam construction and system wide operations have highly altered the species composition and abundance since Johnson's (1942) assessment. The dominant species are still native species (i.e., Emerald Shiner *Notropis atherinoides*, Red Shiner *Cyprinella lutrensis*, River Shiner *N. blennioides* and Spottfin Shiner *C. spiloptera*, K. Steffensen, unpublished data) but represent a sight feeding generalists guild which are able to take advantage of these altered conditions. The long term impact of this shift in species composition on the Missouri River ecosystem is currently unknown.

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