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Comparison of Fish Communities in Recently Constructed Side-Channel Chutes with the Main Stem Missouri River

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ABSTRACT Two United States Army Corp of Engineers (USACE) funded projects were conducted from 2006 to 2008 along the Missouri River to monitor fish communities in recently constructed side-channel chutes and to monitor pallid sturgeon (*Scaphirhynchus albus*) and the associated fish assemblage in the main stem Missouri River. Data from both monitoring projects were compared to evaluate fish assemblages among four mitigated habitats (e.g., constructed side-channel chutes) and the main-stem Missouri River. Chutes had a greater overall number of species (n = 59) and higher species richness (Margalef's index = 5.81), but richness was not different ($F_{1, 4}$ = 0.23, P = 0.22) between chutes and the Missouri River main channel. Non-metric multidimensional scaling (NMDS) showed fish assemblages in side-channel chutes separated out from that of the main river, likely due to chutes having a few unique species that were not sampled in the main river. Relative abundance of native cyprinids that are important food items for pallid sturgeon [e.g., Shoal chub (*Macrhybopsis hyostoma*), sturgeon chub (*M. gelida*), silver chub (*M. storeriana*), sand shiner (*Notropis ludibundus*), and river shiner (*N. blennius*)] all showed a decline in the Missouri River during the period of study but were stable or increased in Upper Hamburg Chute (oldest constructed side-channel chute). Relative abundances of these species in the remaining chutes were variable over time with the exception of silver chub and river shiner, which declined across years in Kansas and Deroin side-channel chutes. Ongoing development of habitat complexity and diversity in these chutes may eventually lead to a more diverse and abundant fish assemblage.

KEY WORDS chutes, Missouri River, side-channel, shiner, chub, restoration ecology

The present-day lower Missouri River hardly resembles the river that Lewis and Clark explored over 200 years ago. In its natural setting, river banks caved readily during floods. Shallow sandbars were numerous during normal flows and often split into many smaller channels with sand in between, and through the intricate process of channel migration and bank sloughing, side-channel chutes and cutoff lakes were numerous (Slizeski et al. 1982). However, dramatic changes have occurred along most of the Missouri River. The Missouri River Bank Stabilization and Navigation Project (BSNP) and Pick Sloan Project included seven different acts of legislation that has brought about the damming and channelization of the Missouri River since the early 1900s (USACE 2001). The BSNP is multi-purpose with primary objectives being flood control, bank stabilization, navigation, hydroelectric generation, and land reclamation along the lower third of the Missouri River (USACE 2001). These various acts have resulted in 67% of the river's length being impounded or channelized at an estimated cost of 6.1 billion dollars (Hesse 1987). In addition, Funk and Robinson (1974) noted that river modification eliminated 98% of the islands from Rulo, Nebraska to the mouth. The chutes or sloughs between the islands and shore, more shallow and with less current than the main channel, provided valuable diversity to the fish habitat, and probably served as nursery and feeding areas for many aquatic species (Funk and Robinson 1974).

The Water Resources Development Act of 1986 allowed for the mitigation, preservation, or development of 19,466 ha of Missouri River habitat for fish and wildlife, and the Water Resources Development Act of 1999 added an additional 48,018 ha for Missouri River habitat mitigation related to the BSNP (USACE 2004). Part of this mitigation project was to reconstruct lost side-channel chute habitat. The BSNP Mitigation Project also provided for evaluation of fish communities in constructed side-channel chutes (Travnichek 2009). Additionally, the U.S. Fish and Wildlife Service (USFWS) completed a Biological Opinion on the operation of the Missouri River in 2000 related to least tern (*Sternula antillarum*), piping plover (*Charadrius melodus*), and pallid sturgeon (*Scaphirhynchus albus*) populations (USFWS 2000). In light of this document, the U.S. Army Corps of Engineers (USACE) responded by funding multiple habitat restoration and monitoring programs. The long-term Pallid Sturgeon Population Assessment Monitoring Program currently evaluates population characteristics of the pallid sturgeon and associated benthic fish community in the main stem Missouri River from Fort Peck Dam, Montana (river km 2850.0) to the confluence of the Missouri and Mississippi rivers in St. Louis, Missouri (river km 0.0; Drobish 2008). These two USACE funded monitoring programs complemented each other with similar study designs, objectives, and sampling gears. These two programs also provided valuable information that increased

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the understanding of fish assemblages and habitat in the Missouri River leading to informed management decisions.

Decrease in fish diversity was related to a decrease in habitat diversity (Funk and Robinson 1974). The altering of big-river ecological functions and habitats in the Missouri River were believed to be the primary cause of decline in federally endangered pallid sturgeon (USFWS 1993) as well as many small-bodied fishes that pallid sturgeon rely on as prey items (USFWS 2000). Gerrity et al. (2006) found that sturgeon chub (*Macrhybopsis gelida*) and sicklefin chub (*M. meeki*) comprised 79% in number of identifiable fish in juvenile pallid sturgeon stomachs, while sand shiner (*Notropis ludibundus*) and three other species comprised the remaining 21%. Hoover et al. (2007) noted that speckled chub (*M. aestivalis*), silver chub (*M. storeriana*), and unidentified cyprinids were important food items for pallid sturgeon in the Mississippi River. Shoal chub (*M. hyostoma*) were not native to the upper Missouri River basin (Brown 1971, Lee et al. 1980, Galat et al. 2005), but were thought to be an important prey item along with other native cyprinids in the lower Missouri River basin for pallid sturgeon (Hoover et al. 2007).

Our objectives were to compare fish assemblages in recently constructed side-channel chutes to the main channel of Missouri River and evaluate performance of both habitats for sensitive species of interest [(e.g., shoal chub, sturgeon chub, silver chub, sand shiner, and river shiner (*N. blennius*)]. Results of this project could provide information into a feedback loop essential to the adaptive management process for future side-channel restoration design and development projects.

STUDY AREA

Four side-channel chutes located between river km 893.6 and 838.2 and the segment of the main-stem Missouri River outside the chutes from river km 896.2 to 834.1 were used during our study (Fig. 1). This section of the main-stem Missouri River consisted of 20 different bends and is bordered by Nebraska, Iowa, and Missouri. It was characterized by a narrow channel with revetted banks and numerous dike structures.

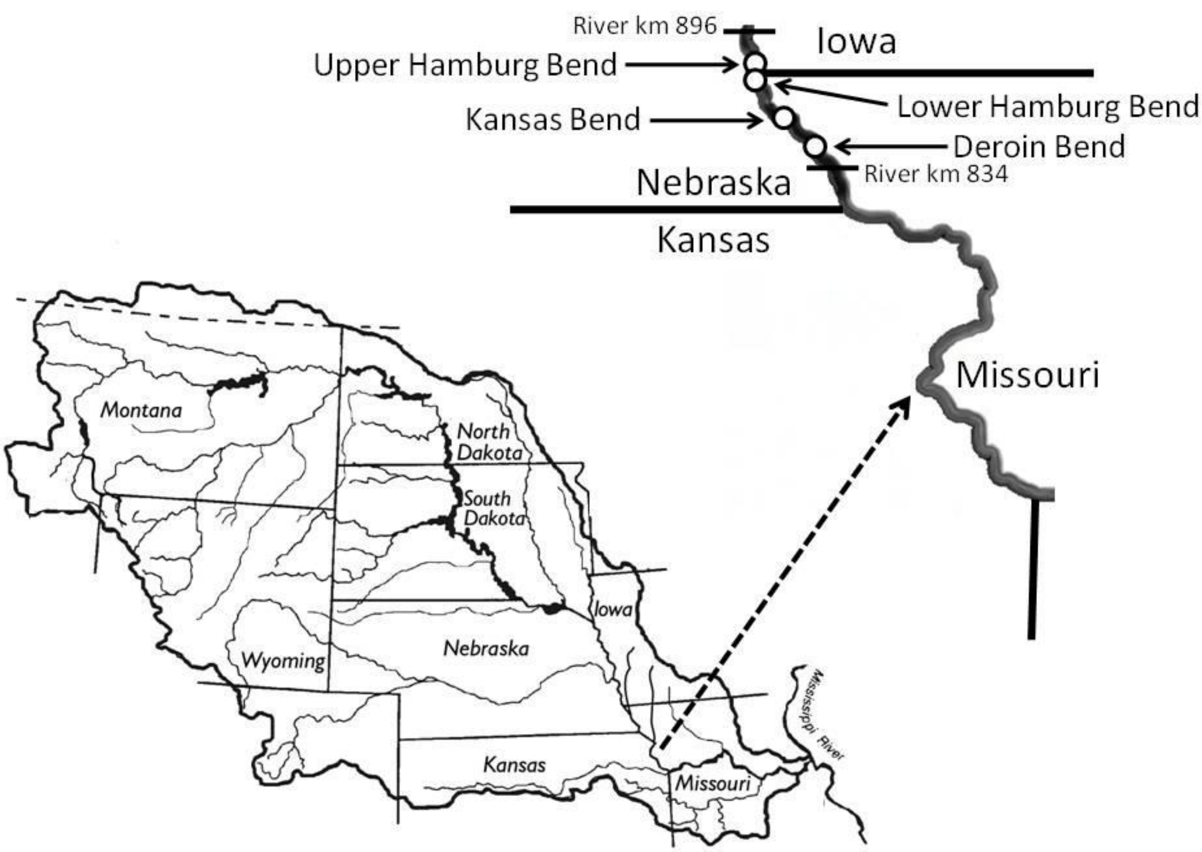

Figure 1. Location of recently constructed side-channel chutes and section of the mainstem Missouri River sampled April to October, 2006–2008.

Upper Hamburg Bend Chute was located at river km 893.6 in Otoe County, Nebraska. After channelization, the 625-ha area was used traditionally as agricultural land (Barnes 2004*a*). In 1996, the USACE reconstructed the 4,942-m side-channel chute. The side-channel chute was engineered with a 3.05-m wide pilot channel (Barnes 2004*a*). High water events in 1997 and in 2007 changed the constructed morphology of the side-channel chute. Lower Hamburg Bend Chute was located at river km 890.6 and consisted of 1,047 ha located primarily in Atchison County, Missouri with a small portion of the northern boundary located in Fremont County, Iowa. Reconstruction of the 3,912-m side-channel chute and 1,304-m backwater began in 2004 with a 22.9m wide pilot channel and new control structures (Owens 2004). In addition to the pilot channel, native hardwoods and grasses were planted to reclaim the agricultural land (Owens 2004). Kansas Bend Chute was located at river km 879.6 in Nemaha County, Nebraska. The area consisted of 427 ha that was separated into two sections by private farmland (Barnes 2004*b*). Two side-channel chutes were constructed in 2004 with the upper channel being 2,115 m long and the lower channel being 1,645 m. The channels were constructed with a 3.05m wide pilot channel. Deroin Bend Chute was located at river km 838.2 in Holt and Atchison counties, Missouri. It consisted of 438 ha of Missouri Department of Conservation owned land (Skelton 2004). It was constructed in 2001 with control structures, a 5,421-m long, 21.4-m wide pilot channel and a 1,251-m backwater (Skelton 2004). Nebraska Game and Parks Commission managed Upper Hamburg Bend and Kansas Bend chutes and the Missouri Department of Conservation managed Lower Hamburg Bend and Deroin Bend chutes.

METHODS

Our standardized sampling gears included push trawls, mini-fyke nets, trammel nets, 2.4-m otter trawls, and 4.9-m otter trawls (Drobish 2008). We originally used bag seines in 2006 but not during the remaining sampling seasons because of limited bar habitat in most chutes and because similar catch results were obtained using push trawls and mini-fyke nets in the main river. We initiated sampling with push trawls in 2007 because this gear could effectively sample shallow water areas with swift current that bag seines could not.

We sampled in side-channel chutes during April through October 2006–2008. We separated each side-channel chute into 16 equal sampling segments and subsequently sampled 8 randomly selected segments monthly using each gear type. In cases where a selected segment could not be accessed or the specific gear could not be fished, we randomly selected another segment. We divided the main stem Missouri River below Gavins Point Dam (lowermost dam on mainstem Missouri River) into 14 segments. We randomly selected and subsequently sampled 25% of the main channel Missouri River bends in each segment each year (Drobish 2008). We sampled year-round in the main channel and took ≥8 samples per gear within each randomly selected main channel river bend (Drobish 2008). For comparisons in this study, we examined and used data collected during April through October from 2006 to 2008 from the main channel of the Missouri River near the side-channel chutes.

We used only samples collected with similar gears from April through October during 2006 to 2008 in the analysis. We analyzed raw abundance data for Margalef's index of species richness (d; Ludwig and Reynolds 1988):

$$d = (S - 1)/\log_e N$$

where S equals number of species and N equals the total number of individuals; Shannon's diversity (H'; Kwak and Peterson 2007):

$$H' = -\sum i\ p_i \log_e(p_i)$$

where p_i is the proportion of the total count arising from the *i*th species; Pielou's evenness index (J'; Kwak and Peterson 2007):

$$J' = H'/H'max = H'/\log_e S$$

where S equals number of species and H'max is the maximum possible value of Shannon diversity that would be achieved if all species were equally abundant ($\log_e S$). We used analysis of variance (PROC ANOVA; SAS Institute Inc., Cary, NC, USA) to compare fish richness, evenness, and diversity among Missouri River side-channel chutes and the main channel. We conducted all analyses among side-channel chutes and the main channel Missouri River across all three years of sampling. We pooled and subsequently compared data among side-channel chutes for all three years of sampling to our pooled data from the main channel Missouri River.

We used non-metric multidimensional scaling (NMDS; Primer-E Ltd software, Plymouth, United Kingdom) to map the relative association among side-channel chutes and the main channel using relative abundance data. The NMDS plots graphically illustrated differences in the fish community structure spatially. Prior to computing the NMDS, we square-root transformed data to down-weight the effect of highly abundant species (Brown and Guy 2007). We analyzed transformed data using a Bray-Curtis similarity index, and these similarity values were used for NMDS (Clarke and Warwick 2001). We conducted preliminary data analyses with all species of fish and re-analyzed data using a reduced dataset where species that were represented at only one site or only by a few individuals were eliminated. Our results were similar between analyses; therefore, we used our reduced dataset for NMDS analyses. We analyzed fish data with NMDS annually among side-channel chutes and the main channel Missouri River.

Table 1. Diversity indices (Margalef's species richness, Pielou's evenness, and Shannon's diversity) for Missouri River side-channel chutes and main channel river fish assemblages, 2006–2008.

Sample	Total number of species	Total number of fish	Margalef's species richness[a]	Pielou's evenness[b]	Shannon's diversity[b]
Upper Hamburg 2008	41	4,419	4.77	0.70	2.61
Upper Hamburg 2007	35	2,346	4.38	0.75	2.66
Upper Hamburg 2006	34	1,825	4.40	0.69	2.43
Lower Hamburg 2008	34	968	4.80	0.80	2.82
Lower Hamburg 2007	35	1,376	4.71	0.72	2.53
Lower Hamburg 2006	31	725	4.56	0.66	2.26
Kansas 2008	29	773	4.21	0.75	2.53
Kansas 2007	29	606	4.37	0.85	2.86
Kansas 2006	30	4,577	3.44	0.37	1.27
Deroin 2008	39	1,869	5.04	0.70	2.55
Deroin 2007	33	976	4.65	0.80	2.79
Deroin 2006	28	1,341	3.75	0.75	2.50
Missouri River 2008	43	17,026	4.31	0.58	2.17
Missouri River 2007	42	4,300	4.90	0.74	2.77
Missouri River 2006	49	9,512	5.24	0.58	2.26
Side-channel Chute Total	59	21,801	5.81	0.65	2.66
Missouri River Total	53	30,838	5.03	0.68	2.69

[a] Ludwig and Reynolds (1988); [b] Kwak and Peterson (2007).

RESULTS

Total number of fishes sampled in side-channel chutes was 21,801, representing 59 species. Side-channel chutes were comprised mostly of emerald shiner (*N. atherinoides*; 25.8%), river shiner (11.4%), channel catfish (*Ictalurus punctatus*; 9.7%), sand shiner (9%), and freshwater drum (*Aplodinotus grunniens*; 6.9%). The five most abundant species within each chute accounted for >50% of all fishes collected within each site. Channel catfish and emerald shiner accounted for >25% of all fishes collected at each site. River shiner were among the five most common species collected within Upper Hamburg, Lower Hamburg and Kansas chutes. Sand shiner were among the five most common species collected within all chutes with the exception of Lower Hamburg. Silver chub were among the five most common species collected within Upper and Lower Hamburg chutes while freshwater drum were common species in Lower Hamburg and Deroin chutes. Red shiner (*Cyprinella lutrensis*) and shovelnose sturgeon (*S. platorynchus*) were among the five most common species collected in only one of the four chutes (Kansas and Deroin, respectively). Relative abundance of emerald shiner was 52.4% at Kansas Bend, and this value was influenced by a single mini-fyke sample in 2006 that collected 2,159 individuals. This single sample accounted for >47% of all fishes collected at this site during 2006. Thus, Margalef's species richness, Pielou's evenness, and Shannon's diversity were reduced at this site in 2006 (Table 1). Species unique to chutes included channel shiner (*N. wickliffi*; *n* = 97), bullhead minnow (*Pimephales vigilax*; *n* = 35), spotted bass (*Micropterus punctulatus*; *n* = 19), western mosquitofish (*Gambusia affinis*; *n* = 17), yellow bullhead (*Ameiurus natalis; n* = 5), mooneye (*Hiodon tergisus*; *n* = 2), striped bass (*Morone saxatilis; n* = 2), walleye (*Sander vitreus*; *n* = 2), ghost shiner (*N. buchanani*; *n* = 1), rainbow smelt (*Osmerus mordax*; *n* = 1), and white perch (*Morone americana*; *n* = 1).

Total number of fishes sampled in the main channel of the Missouri River was 30,838 consisting of 53 species. The fish assemblage was dominated by bluegill (*Lepomis macrochirus*; 23%), emerald shiner (12.2%), freshwater drum (11.9%), red shiner (8.4%), and river shiner (4.4%). Species only found in the main river included: grass carp (*Ctenopharyngodon idella; n* = 10), shorthead redhorse (*Moxostoma macrolepidotum; n* = 3), suckermouth minnow (*Phenacobius mirabilis; n* = 1), presumed saugeye (*Sander canadense x Sander vitreus; n* = 1), and river redhorse (*M. carinatum; n* = 1).

The Missouri River had a higher total number of species and species richness in any given year compared to chutes (Table 1). However, side-channel chutes had a higher number of species as well as higher species richness (d = 5.81) when compared to the main channel (d = 5.03) over the three years combined. No significant differences in richness ($F_{1,4}$ = 2.08, and P = 0.22), evenness ($F_{1,4}$ = 0.23, and P = 0.66), or diversity ($F_{1,4}$ = 0.40, P = 0.56) were identified between chutes and the main river for pooled data.

The NMDS plot for fish communities (2 dimensions, stress = 0.1) showed a separation of the main channel Missouri River from side-channel chutes across years (Figs. 2, 3, 4, 5, and 6). Fish assemblage at Upper Hamburg Chute clustered among the three years sampled (Figs. 2, 3, 4, 5, and 6). However, fish assemblages in the remaining three side-channel chutes were not clustered in a discernable pattern across years (Figs. 2, 3, 4, 5, and 6). Further analyses showed that shoal chub, sturgeon chub, silver chub, sand shiner, and river shiner declined in relative abundances across years in the main channel Missouri River according to the NMDS plot for each species (Figs. 2, 3, 4, 5, and 6, respectively). Conversely, there were increases in shoal chub, silver chub, sand shiner, and river shiner relative abundances (Figs. 2, 4, 5, and 6, respectively) and stable relative abundances of sturgeon chub in Upper Hamburg Chute (Fig. 3). Silver chub and river shiner relative abundances decreased across years in Kansas and Deroin chutes (Figs. 4 and 6, respectively). However, no discernable trends were observed among years for the remaining three species (i.e., shoal chub, sturgeon chub, and sand shiner) at Lower Hamburg, Kansas, and Deroin chutes (Figs. 2, 3, and 5, respectively).

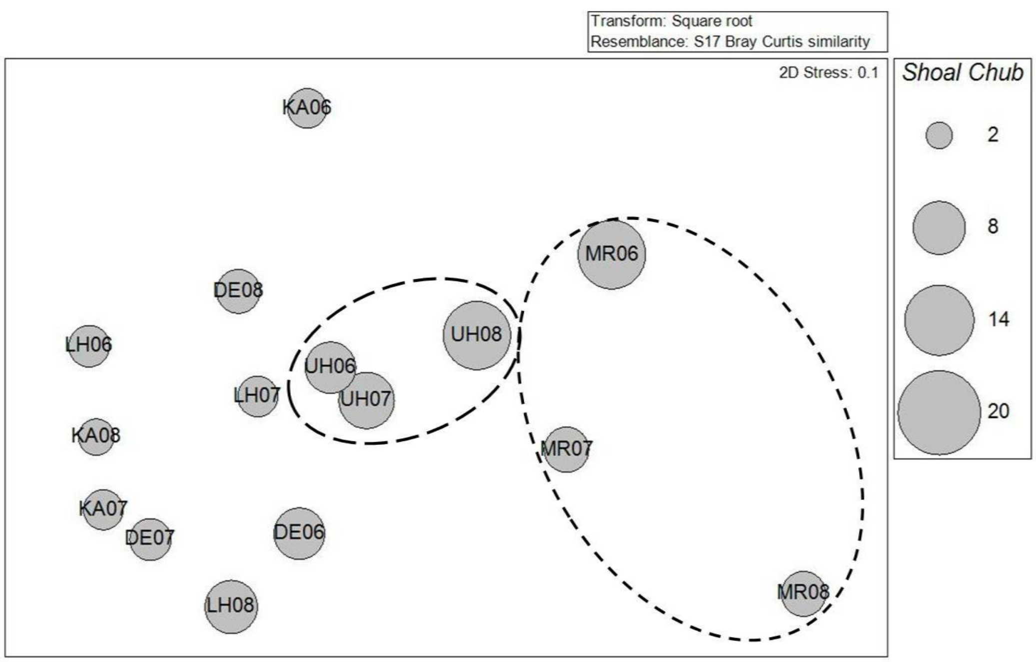

Figure 2. Non-metric Multidimensional Scaling (NMDS) bubble plot of yearly fish assemblage data during 2006–2008 for Missouri River side-channel chutes and the main channel[a] overlaid with square root transformed abundances for shoal chub (*Macrhybopsis hyostoma*). [a]UH = Upper Hamburg Chute, LH = Lower Hamburg Chute, KA = Kansas Chute, DE = Deroin Chute, MR = Main Channel Missouri River.

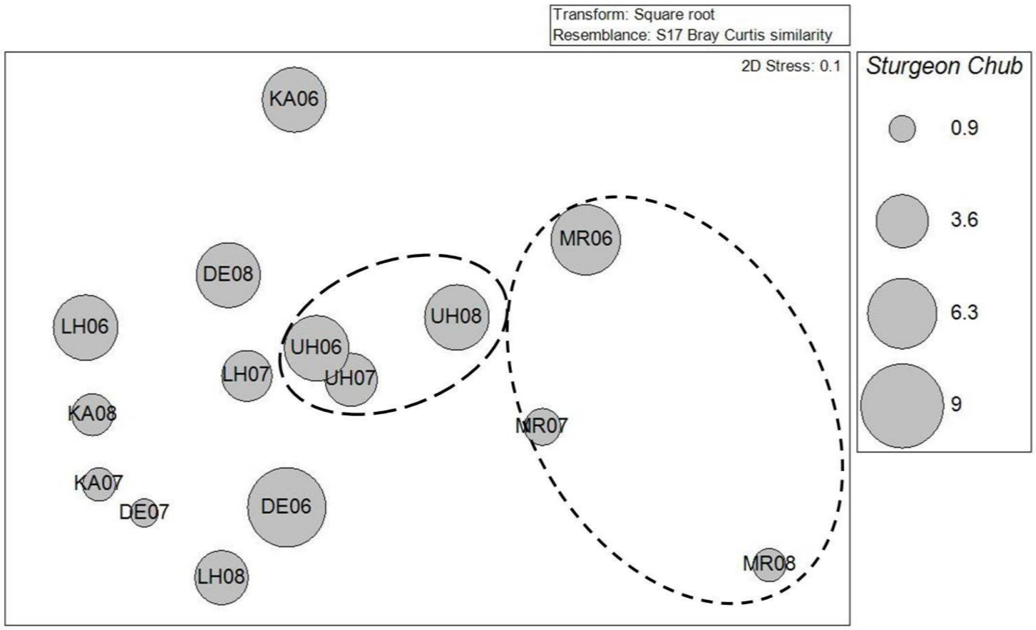

Figure 3. Non-metric Multidimensional Scaling (NMDS) bubble plot of yearly fish assemblage data during 2006–2008 for Missouri River side-channel chutes and the main channel[a] overlaid with square root transformed abundances for sturgeon chub (*Macrhybopsis gelida*). [a]UH = Upper Hamburg Chute, LH = Lower Hamburg Chute, KA = Kansas Chute, DE = Deroin Chute, MR = Main Channel Missouri River.

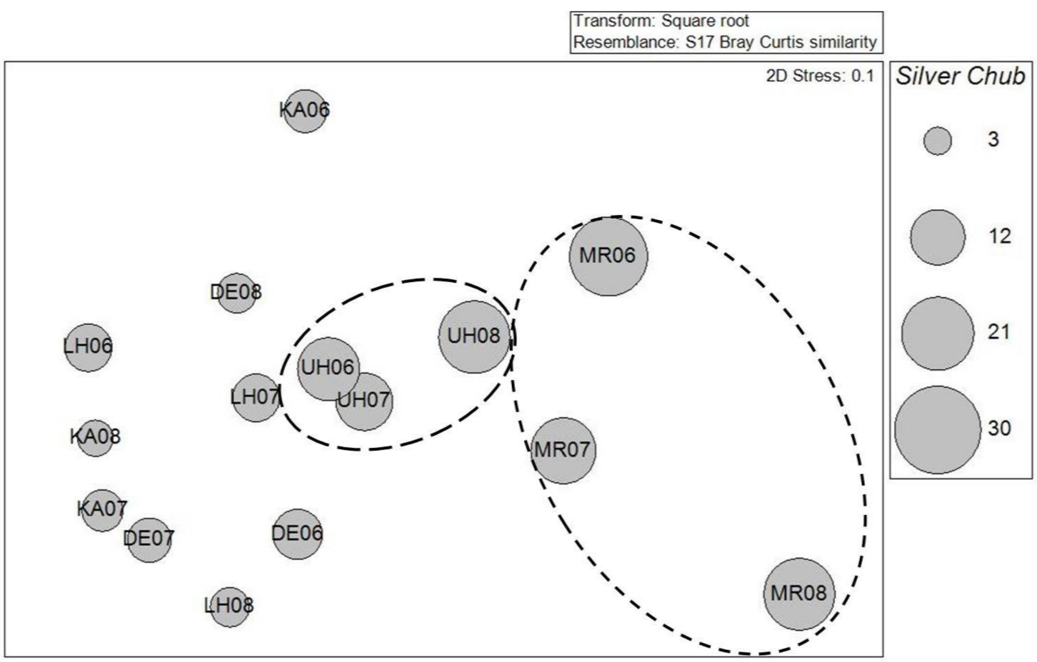

Figure 4. Non-metric Multidimensional Scaling (NMDS) bubble plot of yearly fish assemblage data during 2006–2008 for Missouri River side-channel chutes and the main channel[a] overlaid with square root transformed abundances for silver chub (*Macrhybopsis storeriana*). [a]UH = Upper Hamburg Chute, LH = Lower Hamburg Chute, KA = Kansas Chute, DE = Deroin Chute, MR = Main Channel Missouri River.

DISCUSSION

Channelization has drastically altered the river's flow, sediment transportation and deposition, and fish assemblages within the Missouri River. Thirteen hundred km of the lower Missouri River has now permanently accreted to terrestrial habitat (Hesse 1987). The channelized Missouri River (e.g., below the lowermost reservoir near Yankton, SD, USA) has lost nearly all of the sandbars, sloughs, chutes, backwaters, and cutoff lakes (Morris et al. 1968, Hesse 1987). A large loss of available fish habitat has resulted from these changes. The Missouri River has had 1.6 million ha of its ecosystem switched to agriculture or inundated with reservoir waters (Hesse and Shmulbach 1991, Hesse and Sheets 1993). This has changed the fish diversity in portions of the Missouri River.

Relative abundances of shoal chub, sturgeon chub, silver chub, sand shiner, and river shiner declined in the main river while all five species increased or were stable in Upper Hamburg Chute during this study. Relative abundances in the other three chutes showed no discernable trends for three species but declined for silver chub and river shiner in Kansas and Deroin chutes. Presence of shoal chub has been found to be more likely in chutes with shallow, cool, and turbid water with small substrate (Schloesser et al. 2009). Sturgeon chubs were more likely to prefer fast flowing, turbid chutes while sand shiner preferred cool, less turbid water, and shallow depths with small substrate (Schloesser et al. 2009). Upper Hamburg Chute demonstrated the greatest amounts of depth diversity when compared to the other side-channel chutes (Eder and Mestl 2009). The other side-channel chutes showed less sinuosity, lacked in sandbar habitat, and generally consisted of faster water velocities (Eder and Mestl 2009). These differences at Upper Hamburg Chute may account for the shift in abundances of these species. Creating habitats that benefit these prey items has the potential to aid in the overall recovery of pallid sturgeon.

Non-metric multidimensional scaling tended to show a separation of fish communities between chutes and the main channel Missouri River, but further analysis of diversity indices showed no significant differences. Colonization of a habitat was influenced by the nearest source of colonists, their reproductive capabilities, and the availability of food (Gore 1985, Gore and Milner 1990, Moerke and Lamberti 2003). This would suggest that the fish communities in side-channel chutes would be similar to those in the main river due to it being the only available source. There are several additional species only found in chutes, compared to just a few unique to the main river, suggesting that chutes provided additional habitat for a few species. However, fish communities for both the chutes and the main river were dominated by the same species.

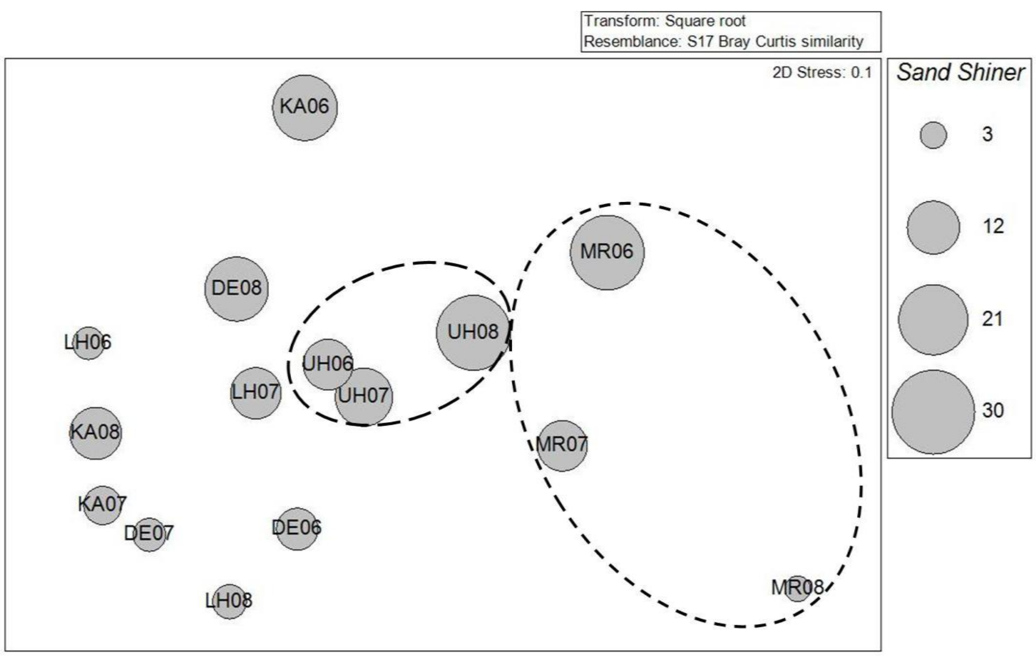

Figure 5. Non-metric Multidimensional Scaling (NMDS) bubble plot of yearly fish assemblage data during 2006–2008 for Missouri River side-channel chutes and the main channel[a] overlaid with square root transformed abundances for sand shiner (*Notropis ludibundus*). [a]UH = Upper Hamburg Chute, LH = Lower Hamburg Chute, KA = Kansas Chute, DE = Deroin Chute, MR = Main Channel Missouri River.

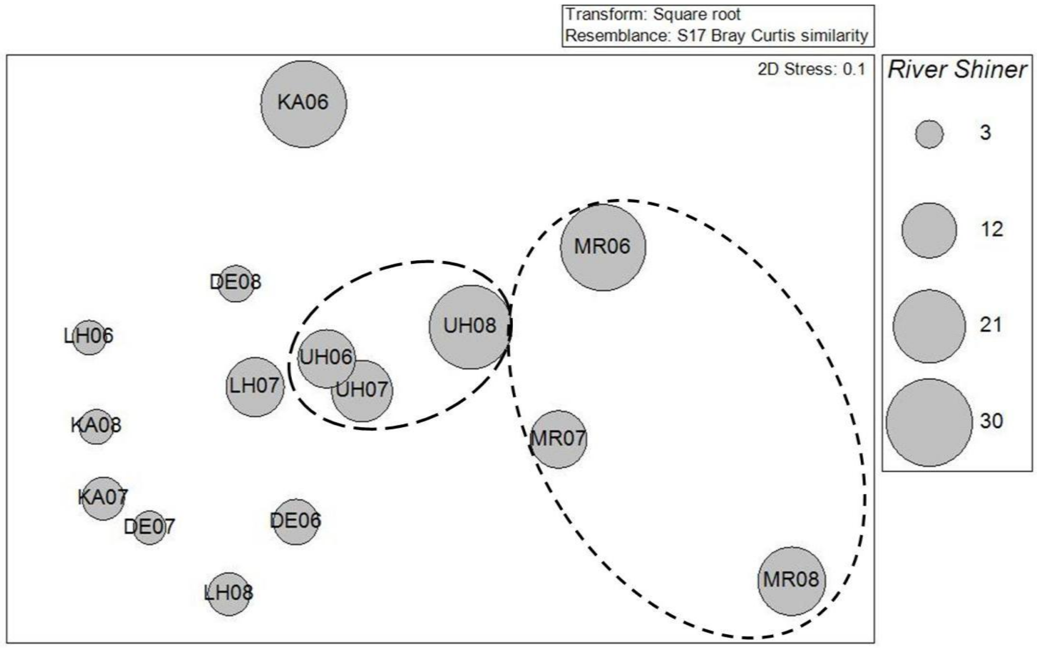

Figure 6. Non-metric Multidimensional Scaling (NMDS) bubble plot of yearly fish assemblage data during 2006–2008 for Missouri River side-channel chutes and the main channel[a] overlaid with square root transformed abundances for river shiner (*Notropis blennius*). [a]UH = Upper Hamburg Chute, LH = Lower Hamburg Chute, KA = Kansas Chute, DE = Deroin Chute, MR = Main Channel Missouri River.

The current designs of side-channel chutes along the Missouri River have been similarly constructed with a narrow pilot channel and low sinuosity. This design in itself was similar to the channelized river in which they were trying to mitigate lost habitat. Other simple side channels have been constructed in the Northwest United States, but were modified or replaced with more complex habitat designs with woody structures that resulted in better growth and survival of Coho salmon (*Oncorhynchus kisutch;* Giannico and Hinch 2003). Additionally, secondary habitat requirements such as quality woody debris in pools and vegetative banks must be taken into account when constructing off-channel projects (Wilson et al. 2001). Other studies have found that fish community structure was tied to habitat structure with current velocity and depth being main factors structuring fish assemblages (Meffe and Sheldon 1988, Moerke and Lamberti 2003). Currently, Missouri River side-channel chutes exhibit some habitat diversity, but most are still fairly simple in design and construction resulting in little secondary habitat structure (Eder and Mestl 2009). However, these side-channel chutes started to develop different habitat types, possibly accounting for the increase in unique species documented during our study.

Channelization of the Missouri River has affected the river's connection to the flood plain and the immediate terrestrial area along the bank. This type of alteration has been reported to lead to a reduction in fish diversity (Schlosser 1991). Current chute construction has limited revetment on its banks and the terrestrial corridors have generally been left alone. However, chutes have been fairly simply constructed with a narrow pilot channel and minimal meander. Several studies have noted that restoration projects that try to create a static or fixed form commonly fail (Kondolf et al. 2003, Wohl et al. 2005). Restoring natural processes has been hypothesized as more likely to have a positive effect compared to fixed form habitat restoration (Wohl et al. 2005). Current side-channel chute construction along the Missouri River incorporated a limited channel meandering design. While this allowed for some natural riverine processes to occur, these limitations may have hampered recovery efforts. Chutes were slowly progressing towards a different habitat than what was currently found in the main channel Missouri River. While fish assemblages in the side-channel chutes were similar to those in the main channel Missouri River, we speculate that over time a greater separation in fish assemblages may be achieved through continued evolution of side-channel chutes.

MANAGEMENT IMPLICATIONS

Currently, side-channel chutes were working on a small scale for providing lost habitat for a few unique species that are potentially important for pallid sturgeon recovery. Creating habitats that benefit these prey items may aid in the overall recovery of this species. Static chute designs or designs that limit the natural processes of erosion and deposition should not be considered in future mitigation plans. While it is unrealistic to believe that a total return to the historic Missouri River is possible, or even desirable, a return of limited natural riverine processes at selected locations along the lower Missouri River is likely the best alternative to mitigating for lost habitats along the Missouri River.

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