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Patterns of Fish Diversity in a Mainstem Missouri River Reservoir and Associated Delta in South Dakota and Nebraska, USA

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Abstract

There is an expansive and expanding delta at the confluence of the Niobrara and Missouri Rivers in the Lewis and Clark Reservoir. The delta provides diverse aquatic habitat that is somewhat similar to the historic Missouri River and to remnant river habitats. As such, the delta may have relatively high fish species diversity compared to lentic reservoir habitats. To compare patterns of fish diversity between the delta and reservoir habitats, we collected fish in several nursery habitats in both areas using four gear types (seine, gill net, electrofisher and fyke net) on three occasions (July, August and September) in 2005. Species richness was higher in the delta ($n = 34$) than the reservoir ($n = 22$). Thirteen species composed more than 1% of delta collections while only four species composed more than 1% of reservoir collections. Species diversity (Fisher's a) was also significantly higher in the delta. Higher species diversity in the delta may be explained by higher habitat diversity. These results suggest that newly forming deltas have the potential to protect and restore fish species diversity, because they retain natural river functions such as sediment transport and habitat formation.

Keywords: Missouri River restoration, fish species diversity, reservoir delta

Introduction

Across the world, dams are filling with sediment and as a result, novel delta habitats are forming in many systems (Palmieri *et al.*, 2001). Sedimentation generally occurs over long temporal scales such that evidence of sedimentation is not readily apparent in some systems, but sedimentation will eventually occur in every reservoir constructed (Palmieri *et al.*, 2001), and in some systems extensive deltas have already formed allowing researchers to begin studying the impacts of delta habitats on fish communities in reservoir systems. Lewis and Clark Reservoir, the most downstream of the mainstem Missouri River reservoirs, is one system where sedimentation has occurred relatively rapidly, resulting in the development of a delta. The delta in Lewis and Clark Reservoir is quite extensive (approximately 34 km) and has formed as a result of sediment deposition from a large tributary to this system, the Niobrara River, which drains northern Nebraska from west to east. Aquatic habitats in the delta are diverse with abundant in-channel bedforms such as sand bars, side channels and backwaters that create a complex riverine landscape. This diverse riverscape has some similarities to the historical Missouri River (e.g. high sediment loads, high width-depth ratios, abundant sand substrate, several wetlands and aquatic vegetation) and habitat conditions are seemingly consistent with recommendations for habitat restoration elsewhere along the Missouri River (Harberg *et al.*, 1993; Hesse and Sheets, 1993; Latka *et al.*, 1993). Further, studies have shown that Missouri River reaches with braided river channels and a diversity of aquatic habitats within the floodplain have diverse fish communities (Schmulbach *et al.*, 1975; Kallemeyn and Novotny, 1977; Jacobson *et al.*, 2001) and are superior for sport fish production as compared to channelized and/or modified reaches (Groen and Schmulbach, 1978). Such reaches also support more diverse invertebrate communities (Morris *et al.*, 1968).

Despite the similarity of the Niobrara River delta to remnant reaches of the Missouri River, fish assemblage studies have focused on tailwater fisheries upstream of or downstream from the Lewis and Clark delta (Walburg *et al.*, 1971; Schmulbach *et al.*, 1975; Kallemeyn and Novotny, 1977; Berry and Young, 2004), or solely on the reservoir (Walburg, 1976; Wickstrom, 2000, 2004). Thus, our objective was to compare fish species diversity between the Lewis and Clark delta

and reservoir habitats. We hypothesized that reservoir deltas represent additional areas where some ecological characteristics of the historic Missouri River persist (i.e. high species diversity), even though deltas occur in modified habitats (i.e. reservoirs), because they retain natural river functions such as sediment transport and habitat formation, which are disrupted in riverine sections of the Missouri River below dams.

Methods

Lewis and Clark Reservoir, located on the Missouri River along the South Dakota-Nebraska border, is the downstream most of seven mainstem reservoirs. The reservoir has a surface area of approximately 105 km², maximum depth of 16.7 m, and mean depth of 5.0 m (Wickstrom, 2004). Approximately 74 km of riverine habitat exist upstream from the reservoir to Fort Randall Dam. This riverine habitat is composed of two distinct segments: a delta that extends approximately 34 km above the reservoir, and the Missouri National Recreational River reach that encompasses the upper 40 km of this system. Our study focused on the delta and reservoir habitats of this system.

We collected fishes from nursery habitats at two delta stations and two reservoir stations (Figure 1). Sampling was conducted monthly from July through September 2005. Targeted nursery habitats included main channel margins, side channels, backwaters, river channel shoreline embayments, shallow pools among sandbars, and reservoir shorelines. We targeted shallow waters (<1.5 m) in these habitats using 3-mm bar mesh beach seines (3.7m long, 1.2m deep), a boat mounted electrofisher (Coffelt VVP-15 control unit; C-phase, pulsed-DC current), modified fyke nets (1.5m by 0.8m frames, 19-mm bar mesh), and experimental gill nets (100m total length; 50m of 0.32-cm and 50m of 0.65-cm bar mesh). We standardized sampling effort during our study; we electrofished 10, 5-min runs per station, made 10 seine hauls (10–15 m) either upstream in areas with current, or perpendicular to shorelines in slack water habitat, and deployed four fyke nets and four gill nets for approximately 4 h per station. Our gear was effective for small-bodied fishes of all ages (e.g. shiners [Cyprinidae]) but for only juveniles of large-bodied fishes (e.g. largemouth bass *Micropterus salmoides*). Thus, incidental catches of adult large-bodied

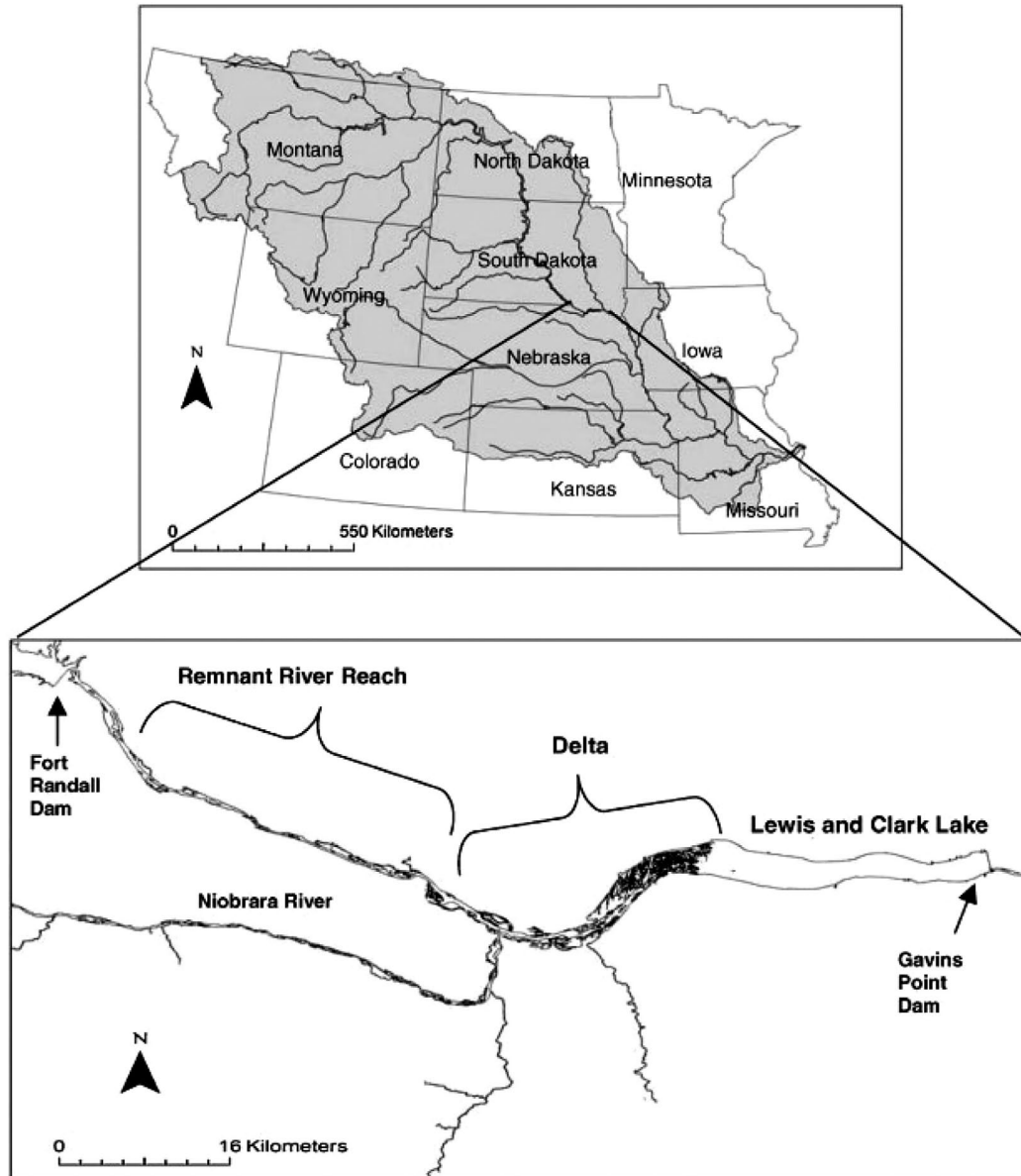


Figure 1. Lewis and Clark reservoir and Missouri River study area

fishes were not included in our analyses. Fishes were immediately preserved in 90% ethanol and later identified to species and enumerated in the lab.

We analyzed fish species diversity as species richness (total number of species, number of common species) and species diversity (Fisher's α). Species richness is a common diversity measure, but it ignores differences in species dominance (MacArthur and MacArthur, 1961)

and is affected by sample size (Preston, 1962). A simple summary of species richness may include incidental (nonresident) species. Thus, we also enumerated species that composed more than 1% (herein referred to as common species) of the total delta or reservoir sample (all months combined). Fisher's α provided a more rigorous estimate of species diversity as it represents species of average abundance (neither highly abundant species nor rare species) and is unaffected by sample size (Kempton and Taylor, 1974; Magurran, 1988). It is derived using the formula: $\alpha = N(1 - x)/x$, where x is from iterative solution of: $S/N = (1 - x)/x[-\ln(1 - x)]$, where S = number of species and N = number of individuals. Fisher's α values have the added benefit of potential for statistical comparison using confidence limits calculated as variance: $\text{Var}(\alpha) = \alpha/[-\ln(1 - x)]$ (Magurran, 1988).

Results

A total of 9788 individuals representing 37 fish species were collected (Table I). Overall, species richness was greater at the delta sites ($n = 34$) compared to the reservoir sites ($n = 22$; Table I). Species diversity (Fisher's α) was higher within the delta (mean \pm variance, 5.6 ± 0.9) than within the reservoir (mean \pm variance, 2.8 ± 0.4). Thirteen fish species were common (>1% total catch) in the delta (Table I). Four of these (gizzard shad *Dorosoma cepedianum*, emerald shiner *Notropis atherinoides*, white bass *Morone chrysops*, freshwater drum *Aplodinotus grunniens*) were also common in the reservoir. No species was common only in the reservoir.

Discussion

We found higher fish diversity in upstream delta habitats than reservoir habitats in Lewis and Clark Reservoir. Our findings corroborate other studies along the Missouri River in which fish species diversity was high in river reaches with high habitat diversity. Fish and wildlife productivity along the Missouri River declined due to effects of reservoir construction and operation (Funk and Robinson, 1974; Whitley and Campbell, 1974), but areas that maintained some characteristics of the historical Missouri River remain as strongholds of species

Table I. Numbers of fish species collected at four stations (two delta, two reservoir) over three sampling periods (July, August, September) in 2005 at Lewis and Clark Reservoir, South Dakota. 'Common' fish species (defined as those that composed >1% of the total sample at each habitat type (i.e. delta or reservoir) are denoted by asterisks. Relative abundance (%) is noted in parentheses for each common species; all other species represented less than 1% of the relative abundance.

| Common name | Scientific name | Delta | Reservoir |
|---------------------------|---------------------------------|-----------|------------|
| Shortnose gar | <i>Lepisosteus platostomus</i> | 2 | 3 |
| Gizzard shad | <i>Dorosoma cepedianum</i> | 270 (11)* | 645 (9)* |
| Central stoneroller | <i>Campostoma anomalum</i> | 2 | 0 |
| Red shiner | <i>Cyprinella lutrensis</i> | 142 (6)* | 3 |
| Spotfin shiner | <i>Cyprinella spilopterus</i> | 391 (16)* | 13 |
| Common carp | <i>Cyprinus carpio</i> | 8 | 1 |
| Brassy minnow | <i>Hybognathus hankinsoni</i> | 22 | 0 |
| Silver chub | <i>Macrhybopsis storeriana</i> | 0 | 2 |
| Golden shiner | <i>Notemigonus crysoleucas</i> | 4 | 0 |
| Emerald shiner | <i>Notropis atherinoides</i> | 552 (22)* | 5890 (81)* |
| River shiner | <i>Notropis blennioides</i> | 163 (6)* | 0 |
| Spottail shiner | <i>Notropis hudsonius</i> | 59 (2)* | 19 |
| Sand shiner | <i>Notropis stramineus</i> | 50 (2)* | 0 |
| Bluntnose minnow | <i>Pimephales notatus</i> | 39 (1)* | 0 |
| Fathead minnow | <i>Pimephales promelas</i> | 16 | 0 |
| Flathead chub | <i>Hybopsis gracilis</i> | 76 (3)* | 0 |
| Bigmouth shiner | <i>Notropis dorsalis</i> | 35 (1)* | 0 |
| Creek chub | <i>Semotilus atromaculatus</i> | 0 | 1 |
| Carp suckers ¹ | <i>Carpionodes</i> spp. | 168 (7)* | 0 |
| Smallmouth buffalo | <i>Ictiobus bubalus</i> | 12 | 7 |
| Bigmouth buffalo | <i>Ictiobus cyprinellus</i> | 15 | 1 |
| Shorthead redhorse | <i>Moxostoma macrolepidotum</i> | 10 | 1 |
| Channel catfish | <i>Ictalurus punctatus</i> | 5 | 1 |
| Flathead catfish | <i>Pylodictus olivaris</i> | 0 | 1 |
| Northern pike | <i>Esox lucius</i> | 2 | 0 |
| White bass | <i>Morone chrysops</i> | 68 (3)* | 542 (8)* |
| Rock bass | <i>Ambloplites rupestris</i> | 4 | 0 |
| Orangespotted sunfish | <i>Lepomis humilis</i> | 4 | 0 |
| Bluegill | <i>Lepomis macrochirus</i> | 49 ((2)* | 11 |
| Smallmouth bass | <i>Micropterus dolomieu</i> | 25 | 3 |
| Largemouth bass | <i>Micropterus salmoides</i> | 86 (3)* | 5 |
| White crappie | <i>Pomoxis annularis</i> | 6 | 0 |
| Black crappie | <i>Pomoxis nigromaculatus</i> | 75 (3)* | 14 |
| Johnny darter | <i>Etheostoma nigrum</i> | 100 (4)* | 18 |
| Yellow perch | <i>Perca flavescens</i> | 5 | 0 |
| Sander ² | <i>Sander</i> spp. | 13 | 13 |
| Freshwater drum | <i>Aplodinotus grunniens</i> | 34 (1)* | 82 (1)* |
| Total | | 2,512 | 7,276 |

¹ Carpsuckers include river carpsucker *Carpionodes carpio*, quillback *Carpionodes cyprinus*, and highfin carpsucker *Carpionodes velifer*. Previous studies indicated that a majority of carpsuckers found in this region were river carpsuckers, but we were unable to differentiate between these species at small sizes (Schmulbach *et al.*, 1975; Wickstrom, 2000, 2004).

² Sander include walleye *Sander vitreus*, sauger *Sander canadensis*, and hybrids. Natural hybridization is known to occur in this system (Billington *et al.*, 2004), so it is difficult to distinguish walleye, sauger and hybrids.

diversity and rare native species (Schmulbach *et al.*, 1975; Berry and Young, 2004; Everett *et al.*, 2004; Welker and Scarnecchia, 2004). Although we are unaware of any previous investigations of fish diversity within delta habitats, our results are similar to a study conducted on plants wherein plant diversity was higher within delta habitats than reservoirs (Johnson, 2002). Moreover, Falke and Gido (2006) found higher fish species richness at the confluence of tributary streams with reservoirs than in the tributary streams themselves. These confluence habitats may be similar to the Niobrara River delta.

Our results (34 species in nursery habitats of the delta) compare favorably with results of a much larger study of the fish assemblage in the Missouri River upstream of the delta (43 species; Berry and Young, 2004) and with collections from Lewis and Clark Reservoir (37 species; Wickstrom, 2000, 2004). Most species found in other studies that we did not collect (pallid sturgeon *Scaphirhynchus albus*, shovelnose sturgeon *Scaphirhynchus platyrhynchus*, paddlefish *Polyodon spathula*, goldeye *Hiodon alosoides*, burbot *Lota lota*, stonecat *Noturus flavus*) are big river species, unlikely to occupy nursery habitats (Trautman, 1981; Pflieger, 1997). Others (mimic shiner *Notropis volucellus*, white sucker *Catostomus commersonii*, black bullhead *Ameiurus melas*, grass pickerel *Esox americanus* and green sunfish *Lepomis cyanellus*) were rare in earlier studies. We found one species (bigmouth shiner *Notropis dorsalis*) that was absent from other collections. Thus, the fish assemblage of the delta is similar to that of both the river upstream and reservoir downstream, but nursery habitats of the delta support more species than either of these habitats. We hypothesize that nursery habitats in the delta are important for fish populations of the entire Lewis and Clark Reservoir system.

We attribute high species diversity in nursery habitats of the delta compared to those of the reservoir to habitat diversity. For example the prevalent delta inhabitants red shiner *Cyprinella lutrensis*, spotfin shiner *Cyprinella spiloptera*, river shiner *Notropis blennioides*, and river carpsucker *Carpionodes carpio* primarily inhabit flowing waters (Trautman, 1981; Pflieger, 1997). In contrast, the prevalent spottail shiner *Notropis hudsonius*, largemouth bass *Micropterus salmoides*, black crappie *Pomoxis nigromaculatus*, and johnny darter *Etheostoma nigrum* are characteristic of habitats with little or no current (Trautman, 1981; Pflieger, 1997). The presence of interspersed fluvial habitat and slackwater habitat in the delta evidently contributes to higher

overall species diversity by supporting both flowing water and slack-water fishes. Further, the prevalence of dominant reservoir fishes (gizzard shad, emerald shiner, white bass, freshwater drum) in the delta suggests a link between delta and reservoir fish communities.

Our fish collection occurred only during summer and early fall because we were very interested in including age-0 fishes in our assessment. However, temporal variability in fish species composition may occur throughout the early growing season (spring) and overwinter periods that may affect patterns of fish diversity. Future studies that incorporate expanded temporal coverage of delta and reservoir habitats will increase our understanding of the relative importance of these habitats.

Fish conservation and management along the Missouri River is complex due to the changes and diversity in regulatory agencies involved (McClendon, 1976; Hesse *et al.*, 1989; Galat *et al.*, 2005). However, many researchers agree that habitat diversity and a complex riverine landscape correspond with higher ecological productivity and fish species diversity in the Missouri River (Morris *et al.*, 1968; Funk and Robinson, 1974; Schmulbach *et al.*, 1975; Kallemeyn and Novotny, 1977; Groen and Schmulbach, 1978; Hesse *et al.*, 1988; Brown and Coon, 1994; Galat *et al.*, 1998; Fisher and Willis, 2000; Welker and Scarnecchia, 2003; Dieterman and Galat, 2004). We contend that reservoir deltas may play a role in Missouri River fish conservation and management by increasing aquatic habitat diversity via passive rehabilitation (*sensu* Jacobson *et al.*, 2001) because the natural processes of sediment transport and habitat formation are present and dynamic in the delta. As a result, reservoir deltas may increase management options and provide unique opportunities for studies of ecological processes.

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