The Influence of River Connectivity on the Fish Community and Sport Fish Abundance in Demopolis Reservoir, Alabama

Jeffery W. Slipke, *Department of Fisheries, 203 Swingle Hall, Auburn University, AL 36849–5419*

Michael J. Maceina, *Department of Fisheries, 203 Swingle Hall, Auburn University, AL 36849–5419*

Abstract: Demopolis Reservoir is a short-retention (three-day) mainstream impoundment where sedimentation over the past 50 years has caused separation of some backwater areas and sloughs that were historically connected to the reservoir during normal water level periods. We collected fish with direct-current electrofishing from closed-access backwater (separated from the reservoir unless flood events occur), open-access backwater, and mainstream riverine habitats four times a year over a year and a half to document species richness, diversity, evenness, and relative abundance of all fish and major sport fish. Species richness, represented by more than one individual, was the lowest in closed-access backwater habitats and highest in the open-access habitats. Fish communities were similar, but closed access habitats were more dissimilar from riverine habitats. Species diversity and evenness were highest in riverine habitats, as gizzard shad (*Dorosoma cepadianum*) and centrarchid sport fish that included largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis* spp.), bluegill (*Lepomis macrochirus*), and redear sunfish (*L. microlophus*), were more abundant in closed- and open-access backwater habitats than in riverine habitats. Re-establishing connectivity to closed-access backwaters to riverine portions of the reservoir will not only provide anglers access to fishery resources, but permit exchange of diverse fish faunas.

Key words: connectivity, sedimentation, fish community, similarity, diversity, sport fish

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Floodplains, sloughs, tributaries, and backwater areas of rivers and reservoirs provide valuable habitat for larval, juvenile, and adult fish (Junk et al. 1989, Bayley 1995). Backwaters are used by fish as spawning and nursery sites, not only by life-long residents, but also by species that live primarily in the main river channel and annually migrate to backwaters for spawning (Nicolas and Pont 1997, Hohausova et al. 2003). Sedimentation can cause these areas to be physically separated from mainstem rivers and reservoirs all or part of the year. Typically in the southeastern United States, greatest riverine flows occur in the late winter and spring which coincides with most fish spawning activity (Mettee et al. 1996). Thus, connectivity of backwater areas to mainstream areas is vital to the maintenance of fish populations in these systems. Declines in yellow perch (*Perca flavescens*) and largemouth bass

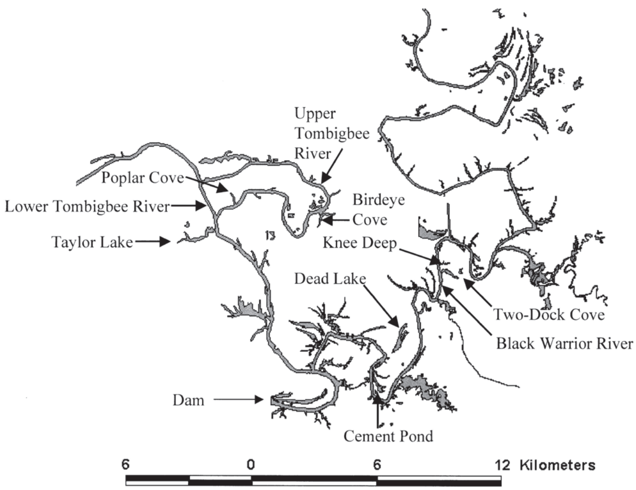

Figure 1. Map of Demopolis Reservoir and the location of sample sites.

(*Micropterus salmoides*) populations in a backwater lake of the Illinois River were associated with sedimentation (Jackson and Starret 1959). In addition, loss of backwaters in the lower Missouri River has been accompanied by a decline in the abundance of many fish species in this system (Funk and Robinson 1974).

Unlike tributary storage impoundments, which are characterized by large expansive embayments and a dam forebay area, Demopolis Reservoir is composed primarily of the mainstem Tombigbee and Black Warrior rivers and numerous backwater areas (Fig. 1). While many of these backwater areas remain connected to one of the main river channels throughout the year, many others have become either permanently or seasonally isolated from the river due to sedimentation over the past 50 years since impoundment. Thus, these areas have and are becoming inaccessible to anglers who fish from boats and may result in the loss of connectivity for fish. Currently, limited information exists regarding fish communities in backwater areas that have become separated or nearly separated from riverine portions of southeastern reservoirs. The objectives of this study were to describe and compare fish assemblages and relative sport fish abundances in three major habitat types (riverine, open-access backwater, and closed or nearly-closed backwater) that have been differentially impacted by sedimentation in Demopolis Reservoir, Alabama.

Study Site

Demopolis Reservoir is a 4,049-ha mainstream impoundment of the Tombigbee and Black Warrior rivers in west central-Alabama (Fig. 1). Impounded in 1954, the dam is located on the Tombigbee River approximately 6 km downstream of its confluence with the Black Warrior River. The reservoir has a long-term historic retention time of approximately three days, a mean depth of 3.7 m, and an annual regulated water level fluctuation of about 0.3 m.

Table 1. Morphometric characteristics of the seven backwater areas sampled at Demopolis Reservoir, Alabama, during 2002–2003.

Site	Habitat type	Surface area (ha)	Mean depth (m)	Depth at entrance (m)
Two Dock	Open	10.30	2.14	1.0
Taylor Lake	Open	32.15	2.18	1.5
Poplar Cove	Open	3.34	2.22	1.6
Birdeye Cove	Open	8.58	1.38	1.7
Knee Deep Cove	Closed[a]	2.19	0.93	0.3
Cement Pond	Closed	11.70	0.73	—
Dead Lake	Closed	28.81	1.11	—

a. Cove was nearly closed off at normal water levels.

Ten sites were selected for this project based on three major habitat types: 1) backwaters with closed or nearly-closed access to main river channel which occurred at normal summer pool elevations of 22.6 m above mean sea level, 2) open-access backwaters connected to the main river channel, and 3) river channel habitat (Fig. 1). Mean depth, surface area, and the depth at the entrance to backwaters from the river was determined for each site when the reservoir was at normal summer pool elevation (Table 1). Average growing season (April–September) chlorophyll *a* concentrations were highest (48 mg chlorophyll a/m^3) in the closed-access backwaters, intermediate (26 mg chlorophyll a/m^3) in the open-access backwaters, and lowest (11 mg chlorophyll a/m^3) in the riverine sites (Maceina and Slipke 2004).

Methods

Between February 2002 and August 2003, fish were sampled quarterly using pulsed (120 pulses-per-sec) direct-current electrofishing (4–5 amps; conductivity = 130 *u*ohms/cm) to describe the fish community in three major habitat types. This electrofishing configuration was not designed to collect ictalurids as lower pulse rates are normally used to collect these fish (Rachels and Ashely 2003). Three replicate 15-min electrofishing samples were taken during each sampling period at each of the 10 sampling sites during daylight hours. Upon collection, larger fish were identified to species, measured (mm TL), weighed (g) then released. Fish less than 200 mm were placed in a solution of 300 *u*g/L MS-222 until expired, placed on ice, and returned to the laboratory for processing.

Catch-per-unit-effort for both number (CPUE) and weight (WPUE) were computed separately for each habitat using species abundance data that comprised at least 5% of the total catch as both the number and weight (in kg) caught per electrofishing h. For largemouth bass, crappie (*Pomoxis* spp), bluegill (*Lepomis macrochirus*), and redear sunfish (*L. microlophus)*, CPUE and WPUE were computed only for fish ≥ stock length (defined by Anderson and Neumann 1996). Since fixed stations ($N = 30$)

were repeatedly sampled over time, repeated-measures analysis of variance (Maceina et al. 1994) was used to compare catch rates among habitat types. Catch for both number and weight among major habitat types were compared using the Student-Neumann-Keuls multiple comparison test at $P \leqq 0.10$ (SAS 2001). We compared estimates of fish species richness (total number of species) and species richness where more than one individual of a species were collected from each of the three habitats. For data pooled among collections, we computed Spearman rank correlations (Daniel 1990) for numeric catch data pooled among all collections to compare community similarity among habitats. To assess fish community structure, we computed Margalef and Shannon-Wiener (natural log base) diversity indices and Pielou's evenness index (Brower and Zar 1984) for fish assemblage data and compared these among the three habitats using the software program provided by Eckblad (1989).

Results

A total of 12,292 fish representing 49 species were collected during this study (Table 2). Species richness was similar among habitats and varied from 37 to 38 species (Table 3). However, some species were represented by only one individual observed during the entire study. Species richness counts represented by more than one individual were the least in closed-access backwater habitats and highest in the open-access habitats (Table 3). Bluegill was the most abundant species and represented 33% of all fish collected. Largemouth bass represented 14% of the total catch, followed by threadfin shad (*Dorosoma petenense*, 11%), gizzard shad (*D. cepedianum*, 8%), white crappie (*P. annularis*, 6%), redear sunfish (5%), and spotted gar (*Lepisosteus oculatus*, 5%).

Four species were collected from the closed-access backwaters that were not collected in the other habitat types: bullhead minnow (*Pimephales vigilax*), blackspotted topminnow (*Fundulus olivaceus*), pirate perch (*Aphredoderus sayanus*), and southern starhead topminnow (*F. blairae*). Four species were collected only from the open-access backwaters: blacktail redhorse (*Moxostoma poecilurum*), chain pickerel (*Esox niger*), flier (*Centrarchus macropterus*), and Mississippi silvery minnow (*Hybognathus nuchalis*). Three species were collected only from the river proper: flathead catfish (*Pylodictis olivaris)*, green sunfish (*Lepomis cyanellus*), and striped shiner (*Luxilus chrysocephalus)*.

Positive Spearman rank correlations indicated that the three major habitats were similar in species composition (Table 4). However, based on rank correlations, species compositions between the closed-access and open-access habitats were the most highly correlated, whereas the closed-access backwater and river habitats were the least correlated. Rank correlations showed more dissimilarity between open and closed-access backwater areas compared to river habitats due to the dominance of centrarchids and gizzard shad in the open and closed-access backwater habitats (Table 2). Similarly, Margalef and Shannon-Wiener diversity indices and Pielou's evenness index were slightly higher in river habitats than in the closed-access and open-access habitats (Table 3).

Table 2. Numbers of fish species collected by electrofishing from three major habitat types in Demopolis Reservoir, Alabama, from February 2002 through August 2003.

Family	Common name	Scientific name	*N* collected		
			Closed	Open	River
Amiidae	Bowfin	*Amia calva*	59	38	5
Aphredoderidae	Pirate perch	*Aphredoderus sayanus*	1	0	0
Atherinidae	Brook silverside	*Labidesthes sicculus*	27	32	1
	Inland silverside	*Menidia beryllina*	21	5	30
Belonidae	Atlantic needlefish	*Strongylura marina*	1	3	8
Catostomidae	Blacktail redhorse	*Moxostoma poecilurum*	0	23	0
	Quillback	*Carpiodes cyprinus*	12	44	2
	Smallmouth buffalo	*Ictiobus bubalus*	14	88	12
	Spotted sucker	*Minytrema melanops*	1	22	0
Centrarchidae	Black crappie	*Pomoxis nigromaculatus*	174	149	52
	Bluegill	*Lepomis macrochirus*	1,600	1,667	826
	Flier	*Centrarchus macropterus*	0	1	0
	Green sunfish	*Lepomis cyanellus*	0	0	1
	Longear sunfish	*Lepomis megalotis*	6	22	45
	Largemouth bass	*Micropterus salmoides*	379	1,125	226
	Orangespotted sunfish	*Lepomis humilus*	6	9	3
	Redear sunfish	*Lepomis microlophus*	401	213	57
	Red spotted sunfish	*Lepomis miniatus*	1	3	0
	Spotted bass	*Micropterus punctulatus*	1	8	44
	Warmouth	*Lepomis gulosus*	16	19	1
	White crappie	*Pomoxis annularis*	162	526	35
Clupeidae	Gizzard shad	*Dorosoma cepedianum*	418	498	136
	Skipjack herring	*Alosa chrysochloris*	1	8	3
	Threadfin shad	*Dorosoma petenense*	518	479	315
Cyprinidae	Bullhead minnow	*Pimephales vigilax*	1	0	33
	Blacktail shiner	*Cyprinella venusta*	0	3	77
	Common carp	*Cyprinus carpio*	58	5	3
	Emerald shiner	*Notropis atherinoides*	4	0	250
	Golden shiner	*Notemigonus crysoleucas*	8	0	1
	Mississippi silvery minnow	*Hybognathus nuchalis*	0	1	0
	Pugnose minnow	*Opsopoeodus emiliae*	5	13	5
	Silverside shiner	*Nortopis candidus*	39	131	111
	Striped shiner	*Luxilus chrysocephalus*	0	0	9
	Weed shiner	*Notropis texanus*	16	1	
Esocidae	Chain pickerel	*Esox niger*	0	3	0
Fundulidae	Blackspotted topminnow	*Fundulus olivaceus*	1	0	0
	Northern starhead topminnow	*Fundulus dispar*	1	0	2
	Southern starhead topminnow	*Fundulus blairae*	1	0	0
Ictaluridae	Brown bullhead	*Ameiurus nebulosus*	2	0	0
	Channel catfish	*Ictalurus punctatus*	26	30	30
	Flathead catfish	*Pylodictis olivaris*	0	0	2
Lepisosteidae	Spotted gar	*Lepisosteus oculatus*	284	239	67
Moronidae	White bass	*Morone chrysops*	0	4	12
	Yellow bass	*Morone mississippiensis*	0	2	3
Mugilidae	Striped mullet	*Mugil cephalus*	1	6	17
Percidae	Mobile logperch	*Percina* spp.	1	6	1
Poeciliidae	Western mosquitofish	*Gambusia affinis*	2	0	1
Polyodontidae	Paddlefish	*Polyodon spathula*	0	1	1
Sciaenidae	Freshwater drum	*Aplodinotus grunniens*	46	65	58

Table 3. Total number of species, total number of species where more than one individual of a species was collected, Margalef's diversity index, Shannon-Wiener diversity, and Pielou's evenness index among major habitat types in Demopolis Reservoir, Alabama.

	Habitat types		
Parameter	Closed-access	Open-access	River
Total species	38	37	38
Total species > 1 individual	26	33	31
Margalef's index	4.42	4.22	4.73
Shannon-Wiener index	2.16	2.15	2.42
Pielou's index	0.59	0.60	0.67

Table 4. Spearman rank correlations were computed and used to compare community similarities among major habitat types in Demopolis Reservoir, Alabama. Rank correlations were significant ($P < 0.05$).

Habitat type	Closed-access	Open-access
River	0.56	0.58
Open-access	0.71	

Catch rates for both number and weight were highest ($P < 0.10$) in the open-access backwaters, lowest in the river, and intermediate in the closed-access backwaters for largemouth bass, crappie (black crappie [*P. nigromaculatus*] and white crappie combined), and gizzard shad (Fig. 2). Catch for number and weight of threadfin shad were higher in the open-access backwaters compared to the closed-access backwater and river habitats. Conversely, CPUE of bluegill and redear were highest ($P < 0.10$) in the closed-access backwaters, lowest in the river, and intermediate in the open-access backwaters, with spotted gar catches highest in the closed-access backwaters (Fig. 3). Bluegill, redear, and spotted gar WPUE were highest in the closed-access backwaters, while lower, but similar WPUEs were observed for these species in the open-access backwater and river habitats (Fig. 3).

Discussion

Demopolis Reservoir supported a diverse fish community as 49 species were collected that represented 20% of the 236 species which inhabit the Mobile basin and nearly 40% of the species which inhabit the upper Tombigbee River system (Mettee et al. 1996). The similar species richness among the three habitats and positive rank

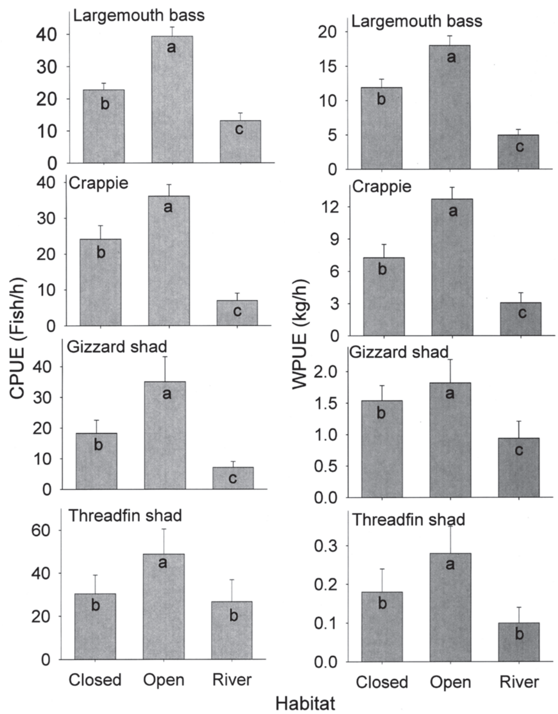

Figure 2. Mean catch-per-unit for number (CPUE; left panels) and weight (WPUE; right panels) of largemouth bass, crappie, gizzard shad, and threadfin shad collected from three habitats in Demopolis Reservoir. Within species, CPUE and WPUE with the same letters were not significantly ($P > 0.10$) different. Error bars represent one SE.

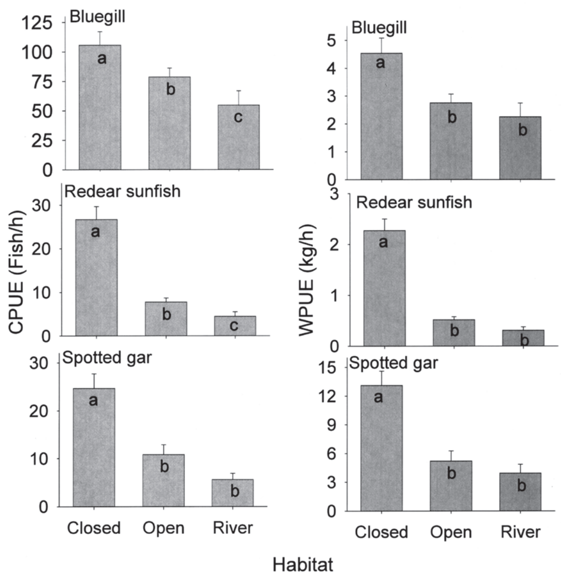

Figure 3. Mean catch-per-unit for number (CPUE; left panels) and weight (WPUE; right panels) of bluegill, redear sunfish, and spotted gar collected from three habitats in Demopolis Reservoir. Within species, CPUE and WPUE with the same letters were not significantly ($P > 0.10$) different. Error bars represent one SE.

correlations among the fish communities of the backwaters and the river proper indicated that lateral movement between these habitats has taken place. When species richness was considered only for those species represented by more than one individual, the open-access backwaters were more diverse and were inhabited by seven more species than the closed-access backwaters. Nicolas and Pont (1997) observed a similar result in the Lower Rhone River in France, where semi-lotic backwaters (i.e., those with adequate connectivity to the river channel to allow for the flow of water) contained a greater number of species than lentic sites. Jackson et al. (2001) stated that the degree of spatial connectivity contributed to higher diversity of fish communities in larger stream ecosystems. Diversity and evenness indices were higher in the riverine habitats compared to both backwaters and was due to higher predominance of centrarchid sport fish and gizzard shad inhabiting both closed and open-access backwater habitats.

The abundance of many fish species in the closed-access backwaters of Demopolis Reservoir indicates that these areas are important to the diversity of the overall fish community. The importance of large river floodplain backwaters have also been documented by other researchers. Kwak (1988) used directional traps to show that fish moved from the Kankakee River, Illinois, to the inundated floodplain during flood events, and that as flood waters receded, fish that were forced off the floodplain tended to seek favorable backwater habitats. Nicolas and Pont (1997) found that backwaters act as refuge sites during floods and that some species seasonally colonize backwaters as feeding areas because of their high productivity. Matthews and Robison (1998) found that the similarity of species assemblages in Arkansas streams was strongly linked to the level of basin connectivity.

Spearman rank correlations for fish assemblages in Demopolis Reservoir were similar among the river and both open-access and closed-access backwaters. Although the closed-access backwaters were disconnected from the river throughout most of the year, the similarity indices strongly suggested that flood events temporarily re-established connectivity between the closed-access backwaters and allowed for lateral movement of fish between the river and these otherwise disconnected backwaters.

The greater abundance of largemouth bass and crappie in the open-access backwaters compared to the closed-access backwaters indicated the importance of connectivity with the main river channel for these species. Conversely, the closed-access backwaters sampled during this study appeared to be particularly favorable for the production of bluegill, redear sunfish, and spotted gar. The closed-access backwaters were generally shallower and more productive than the open-access areas. Slipke et al. (2005) found age-0 abundance of bluegill and largemouth bass was higher in closed and open-access backwater habitats than in riverine portions of Demopolis Reservoir consonant with our findings for stock length and larger fish. Slipke et al. (2005) concluded that backwater areas in Demopolis Reservoir provided valuable habitat for spawning and the production of early life stages of fish.

Clearly, backwaters that were and currently are connected to the riverine sections of Demopolis Reservoir are important components to the overall ecosystem.

Our results indicated that not only are these backwaters utilized to some extent by a diversity of fish species, but they also appear to be the most important component of the largemouth bass, crappie, bluegill, and redear sunfish sport fisheries. Future sedimentation that might eventually cause these areas to become disconnected from the river, will prohibit access to these areas by anglers. Considering that the open-access backwaters contained the highest abundance of largemouth bass and crappie, the most popular sportfish sought by Alabama anglers (USFWS 2001), sedimentation that restricts access by anglers will likely become more problematic in the future. In Demopolis Reservoir, re-establishing connectivity to closed-access backwaters to riverine portions of the reservoir will not only provide anglers access to fishery resources, but permit exchange of diverse fish faunas.

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