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Fish communities associated with a complex Mississippi stream system

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Abstract
Complex habitats such as sloughs, oxbows, and wetlands provide important ecosystem services for fish communities. While human manipulation of rivers and streams for flood control often reduce this complexity, some construction practices may provide an unexpected benefit. Structures such as borrow pits excavated for levee construction may mimic the functions of other back water features like oxbows or sloughs. Fish were collected in both Abiaca Creek channel and borrow pits created during the construction of a 360 ha floodway to examine the value of borrow pits as a backwater resource. Taxa richness, true diversity and other diversity indices were calculated to compare the communities of fish at the various sample locations. Lentic habitats created by borrow pit excavation contributed to the overall diversity. Greatest fish diversity was in the unaltered upper channel site while lowest was in the lower channelized sample reach. One of the borrow pits with relatively low diversity was found to support a strong sports fishery and exhibited characteristics of a managed resource. Catch per unit effort was higher in the pits which contained a higher proportion of species that reached larger adult sizes while number per unit of effort was higher in the upper channel site.

1. Introduction

Flooding of rivers and streams into off-channel aquatic habitats such as sloughs, oxbows, and wetlands provide important resources for fish survival, feeding, and reproduction. (Knight, 1981; Robinette and Knight, 1981; Ross and Baker, 1983; Junk *et al.* 1989; and Lyon *et al.* 2010). Conceptually, complex habitats such as those associated with ecotones provide more niches and therefore greater species richness (Holland *et al.* 1991; Gosz, 1993 and Risser, 1995). Stream systems, like Abiaca Creek in Mississippi, which cut across the transition from central hill into the Mississippi River alluvial plain or Mississippi Delta also cross relatively steep ecological or environmental gradients that should support greater biological diversity than watersheds of similar size but more uniform landscape (Gosz, 1992 and Fagan *et al.* 2003).

Human manipulation of rivers and streams for flood control typically reduce habitat heterogeneity (Shields and Abt, 1989; Gore and Shields, 1995 and Schramm *et al.* 2008). Channel straightening and channel constraining with levees often results in uniform channel depths, bottom substrates, reduced shoreline vegetation and scarce large woody debris. Draining of backwater areas for agricultural production or agricultural irrigation further reduces watershed habitat. However, some anthropogenic disturbance may have unexpected benefits. The excavation of borrow pits for levee construction for example may contribute to overall watershed habitat heterogeneity particularly if these pits are within the levees and experience periodic hydrologic connection with the adjacent river or stream (Bartosova *et al.* 2001 and Dembkowski and Miranda, 2011).

Because of its unique landscape location and anthropogenic activities that produced periodically flooded borrow pits, Abiaca Creek provide a unique venue for examining fish diversity in complex habitats. The purpose of this study was to compare and contrast fisheries characteristics, particularly measures of diversity in fish communities in lower Abiaca Creek watershed.

Abiaca Creek watershed is located in Carroll, Holmes and Leflore counties in central Mississippi (Fig. 1). The watershed comprises 202 km^2 with the main channel and its tributaries generally flowing east to west out of the central hills west toward the Yazoo River Basin in the Mississippi River alluvial plain known locally as the Mississippi Delta. The channel crosses a bluff that demarcates the central hills from the Delta and in doing so changes gradient from moderate slope to generally flat (4.82 $cm \cdot m^{-1}$).

2. Materials and Methods

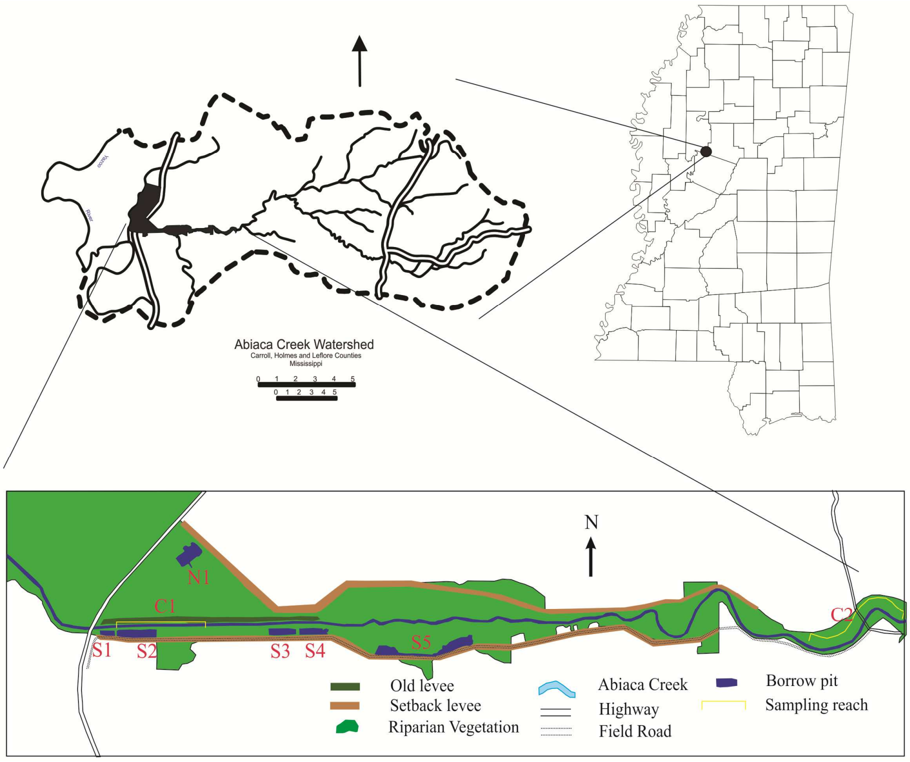

Fig. 1. *Map of Abiaca Creek, Mississippi with collection site numbers*

This transition and the reduced velocities associated with the gentler slope resulted in the deposition of bed materials between the bluffline and a forested wetland area at the confluence of Abiaca and the Yazoo River (33◦20.76'N, 90◦14.53'W) designated the Mathews Brake National Wildlife Refuge. This deposition of bed materials created a channel perched above the surrounding land which became subject to flooding. To prevent destruction of crops by floods a levee system was constructed immediately adjacent to the channel. As additional materials were deposited the levee system became inadequate to control floods and was replaced by 17 km of setback levees in 1998 (Fig. 2). These levees created a 360-ha floodway designed to trap and store sediments from upstream sources to prevent deposition in Matthews Brake National Wildlife Refuge. Materials for levee construction were excavated from pits within the floodway creating permanent pools.

(a)

(b)

Fig. 2. *Aerial photos of Abiaca Creek, before (a) and after (b) floodway construction.*

The watershed land-use in Abiaca Creek watershed is primarily pasture (49 %) and forest (43%). Croplands, wetlands and open water make up the remaining 8% (MSDEQ 2002). Channel erosion, agricultural activity, and gravel mining / washing operations contributed to several segments of Abiaca Creek and a section of Coila Creek, a tributary of Abiaca Creek, being placed on the Mississippi 1998 Section 303(d) list of impaired waterbodies (MSDEQ 2002). Only the portion of the watershed in the bluffline and extending to the confluence of the Yazoo were included in this study.

Detailed physical attributes of the borrow pit collection sites may be found in Shields and Knight (2013). Sites within Abiaca Creek channel were designated C1 and C2, while N1 was the designation for the only borrow pit on the north side of the creek and S1-5 for the borrow pits on the south side. Site C1, (33^o 20' 29.40", 90^o 14' 12.81") located at the confluence of Abiaca Creek and Mathews Brake National Wildlife Refuge (Fig. 1) was a channelized stream reach approximately 21 m wide with shifting sand bed materials. This straight stream segment contained little woody debris and virtually no pool habitat. Water depth was uniform and averaged 1.40 m. Banks were vegetated in grasses and willow (*Salix* sp.). This portion of Abiaca Creek was aggrading with sand and finer sediments being transported and deposited from the hillier watershed upstream. Site C2 (33^o 20' 25.83" N, 90^o 9' 3.07" W), located approximately 8 km to the east of C1, was a meandering, unaltered stream reach with gravel bed material and abundant woody debris. Water depth varied from 0.5 to 1 m deep in pools to shallow riffles. Banks were covered in herbaceous riparian vegetation and mature mixed species of trees. N1, located approximately 570 m north of C1, had a surface area of 4.79 ha and mean depth of 0.93 m. Shore vegetation was grass. Sites S1 through S5 were located between 50 to 250 m south of Abiaca Creek channel (Fig. 1). Surface area ranged from 0.35 at S1 to 11.74 ha at S5 (Table 1). Mean depth ranged from 0.47 to 1.72 m. Bank vegetation was comprised of grasses, small willows, shrubs and herbaceous species. Bottom sediments in all the borrow pits were comprised of hard clay overlain in certain locations with sand splay deposited by overbank flows from the creek. Site S5 featured the most complex habitat. It was formed by two connecting separate pits. Beaver activity had resulted in the presence of piles of woody debris and conical beaver lodges. Additionally, this pit complex was surrounded by more mature trees. S5 had the greatest surface area and depth.

Table 1. *Physical characteristics of Abiaca Creek borrow pits*

	N1	S1	S2	S3	S4	S5
Surface area, ha	4.79	0.35	1.47	1.84	2.02	11.74
Shoreline length, km	0.96	0.36	1.03	0.71	0.91	3.6
Mean depth, m	0.93	1.82	0.47	1.24	1.44	1.72

Fish were collected in borrow pits by electroshocker during two to four 20-minute sampling periods using direct current. Sampling effort was recorded as seconds of applied electrical current. Fish from Abiaca Creek channel were also collected by electroshocker along two 50 m sampling reaches. Because water quality conditions varied during the sampling period and across the different habitat types, voltages were adjusted to provide maximum catch. All major habitat types were sampled. These included shoreline, debris piles, and open water. Fish were identified to species and measured for length in the field then released. Specimens that were too small or difficult to identify in the field were preserved in 10% formalin solution and transported to the laboratory of identification. Primarily these specimens were identified using taxonomic keys to the inland fishes of Mississippi by Ross (2001) however several other sources were occasionally consulted when necessary (Robison and Buchanan, 1988, Etnier and Starnes, 1993 and Boschung and Mayden, 2004). Once identified specimens were either deposited with the Mississippi Museum of Natural Science or disposed of as hazardous waste. Following identification and measuring for total length fish weights were estimated using length-weight regression formulas based on regional fish collections. Fishing effort, weights and counts of fish were used to calculate total catch, catch per unit of effort (CPUE) and number per unit of effort (NPUE). Relative abundances were calculated based on counts and biomass. Several diversity measures were calculated based on number of species and individuals collected including Shannon's H', Simpson's index, Gini-Simpson index and the Probability of Interspecific Encounter, Effective Number of Species and Evenness (Banos, 2006; Guiasu and Guiasu, 2010 and Pielou 1977).

3. Results

A total of 3,142 specimens weighing 496.9 kg and representing 45 species were collected from Abiaca Creek (Table 2 and 3). Highest catch per unit of effort was measured at sites S1, S2 and S5. The dominant species by weight in sites S1 and S2 were catostomids of the genus *Ictiobus*, while a greater proportion of the catch in S5 were centrarchids (Fig. 3). Site C2, which produced much smaller individuals, had the lowest catch per effort but by far the largest numbers per unit of effort. As might be expected in a gravel stream, cyprinids dominated the catch by number at site C2. NPUE, CPUE, and number of species were lower at C1 than any other site. Since the catch was primarily comprised of smaller bodied cyprinids, this too was expected.

Diversity calculations may be found in Table 4. The creek site C1, located near the entrance to Mathews Brake National Wildlife Refuge, had the lowest richness value of all sites. The creek site C2 that exits the hills into the alluvial plain had the highest richness and effective number of species or true diversity calculated using Shannon Diversity. Of the borrow pit sites, S2 had the highest richness at 23 species, which was 28% lower than that of C2. All pit sites ranged from 17 to 23 species. Little difference was observed in the true diversity based on the reciprocal of the Gini-Simpson index; however, S5 and S2 at 5 species were about half that of C2 with 9. Sites C2 and N1 had higher values than other sites, indicating the presence of a few numerically dominant taxa.

Table 2. *Number of specimens collected by species for each site.*

	Site							
Species	**C1**	**C2**	**N1**	**S1**	**S2**	**S3**	**S4**	**S5**
Ameiurus natalis		3						
Amia calva	1				1	1		
Aphredoderus sayanus		2						
Aplodinotus grunniens	1		3		5	7	1	1
Campostoma anomalum		13						
Carpiodes carpio	1	1	6	2	3	7	2	
Cyprinella camura	3	40						
Cyprinella lutrensis		2						
Cyprinella venusta		6						
Cyprinus carpio		6	5	1	5	4	2	18
Dorosoma cepedianum		24	44	3	97	26	79	190
Dorosoma petenense			1	21	43	245	31	38
Erimyzon oblongus		2						
Etheostoma chlorosoma		4						
Etheostoma whipplei		9						
Fundulus olivaceus	1	26		1		1	2	
Gambusia affinis		3	1					
Ictalurus punctatus	7	32	5			1	1	3
Ictiobus bubalus			43	14	5	45	10	5
Ictiobus cyprinellus			9	2		10	1	1
Ictiobus niger						1		
Labidesthes sicculus					2	3	4	20
Lepisosteus oculatus	10	4	14	7	7	8	12	13
Lepomis cyanellus	2	12	5		2	11	1	
Lepomis gulosus	1	3	1	2	6		6	
Lepomis humilis			28	57	11	94	33	17
Lepomis macrochirus	9	50	18	26	78	84	100	232
Lepomis megalotis	1	10		1	1	29		
Lepomis microlophus				2				2
Lepomis miniatus					3			
Lythrurus umbratilis		34						
Micropterus punctulatus	1	11						
Micropterus salmoides		2	3	11	13	23	31	100
Minytrema melanops		1	1	1	3	4	11	
Moxostoma poecilurum		6					1	
Notemigonus crysoleucas								2
Notropis rafinesquei		169						
Noturus phaeus		18						
Opsopoeodus emiliae			1	3	3		5	48
Percina sciera		14						
Pimephales notatus		48				10		
Pimephales vigilax	2	2						
Pomoxis annularis		1	47	17	47	25	28	22
Pomoxis nigromaculatus			3			3		4
Semotilus atromaculatus		81						
Totals	40	639	238	171	335	645	361	716

Table 3. *Catch statistics by site for Abiaca Creek, Mississippi*

Site	C1	C2	N1	S1	S2	S3	S4	S5	Total
Number	40	639	238	171	335	332	361	716	3142
Effort (hr)	0.42	1.13	2.07	0.92	2.46	1.67	2.02	2.60	13.29
Catch kg	11.39	8.43	56.59	39.76	128.62	56.88	65.17	131.51	496.9
CPUE kg/hr	27.09	7.48	27.34	43.25	52.30	34.03	32.25	50.60	37.40
NPUE num/hr	3.51	75.78	4.21	4.30	2.60	5.84	5.54	5.44	5.70
No. of species	13	32	19	17	23	18	20	17	45

Table 4. *Values for diversity measurements by site for Abiaca Creek, Mississippi*

Site Name	C1	C2	N1	S1	S2	S3	S4	S5	All Sites
Richness	13	32	19	17	23	18	20	17	45
True Diversity (exp(H'))	8	14	10	8	9	8	9	7	17
True Diversity (1/1-)	6	9	8	6	5	6	6	5	11
N	40	639	238	171	645	332	361	716	3142
Shannon's H'	2.127	2.665	2.296	2.122	2.143	2.049	2.191	1.928	2.821
Evenness	0.829	0.769	0.779	0.749	0.683	0.709	0.731	0.680	0.741
Simpson's Index	0.159	0.113	0.133	0.173	0.195	0.182	0.157	0.206	0.093
Gini–Simpson	0.841	0.887	0.867	0.827	0.805	0.818	0.843	0.794	0.907
Probability of Interspecific Encounter	7.290	8.932	7.744	5.947	5.159	5.577	6.455	4.890	10.786

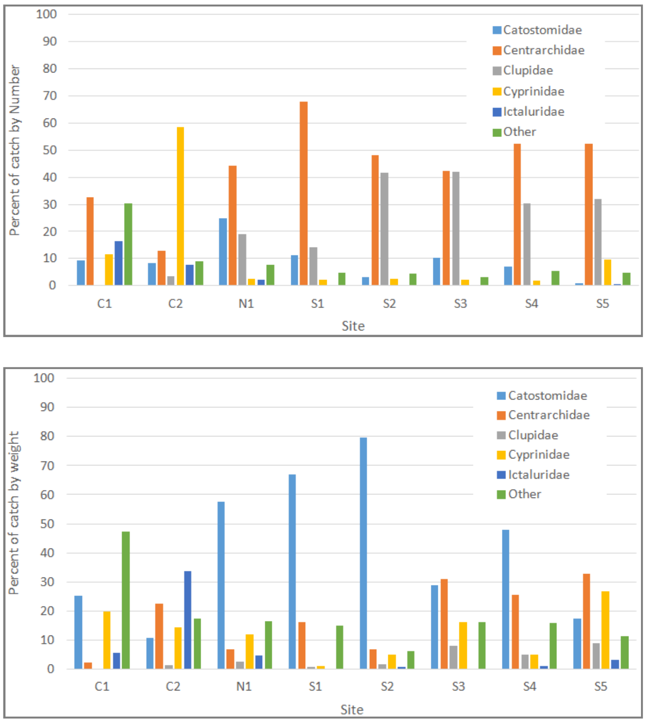

Fig. 3. *Proportion of catch by number and weight for major families of fishes.*

Shannon's Index, which is sensitive to both richness and abundance, was lowest in the borrow pit site S5. S5 also exhibited the lowest evenness and the highest Simpson index which reflects both evenness and richness. Conversely, creek site C1 had the highest evenness value. Probability of Interspecific Encounter (PIE), which is the probability that two fish collected from the site are different species was highest in C1, C2 and N1.

4. Discussion

Mississippi is home to 288 species of fish, of which 204 are native freshwater or diadromous fishes (Ross 2001). The 45 species found in Abiaca Creek study area is comparable to the species richness reported from similarly sized watersheds in the central hill lands of Mississippi such as Otoucalofa Creek with 52 species (Knight and Cooper 1987) and from those in the Mississippi Delta like Bear Creek with 45 (Cooper et al. 1982).

Comparing the community of fishes from heavily altered C1 to the unaltered site at C2 shows some interesting differences. C1 produced fewer species (13 versus 32) and greater biomass (27.09 kg/hr compared to 7.48 kg/hr) but lower catch by number (3.5 fish/hr versus 75.8 fish/hr) and fewer species of relatively intolerant fishes such as cyprinids, percids and catostomids. The more tolerant *Lepisosteus oculatus* and *Amia calva* collected from C1 were able to attain a much larger adult body size, thus accounting for the higher catch per effort than those at C2. C2 was the only site that included darters (Percidae) as a part of the community. C2 also included a number of rare species, i.e. species represented by few individuals thus scoring high when comparing richness values, Gini-Simpson and PIE. The high diversity and evenness at Site C2 produced the highest Shannon score of all sites. The management implication is that homogeneous habitat such as that found at C1 was not as favorable to supporting a varied fish community as the habitat complex C2 site. However, C1 did support larger bodied fishes such as *L. oculatus*, *Ictalurus punctatus* and *A. calva*, as well as contributing two species not found at C2.

Taxa richness ranged from 19 to 23 species across all the borrow pit sites compared to a range of 13 to 32 for the stream sites. Lentic pit sites had 11 species not found in C1or C2 compared to 16 that were found exclusively in the lotic creek sites. Abundant *Ictiobus sp.*, *L. oculatus* and *Micropterus salmoides*, all of which attain large adult sizes, accounted for CPUEs that were in some cases almost twice that of C1 and about seven times that of C2. Centrarchids and clupeids commonly associated with lentic habitats (Ross 2001) were abundant in all pit sites.

The northern borrow pit N1 had one of the higher richness values and the highest true diversity among the borrow pits. This is surprising given the fact that Shields and Knight (2013) reported higher mean suspended solids (135 mg/L) and mean turbidity (123 NTU) in N1 compared to the southern borrow pits whose means suspended solids ranged from 27 to 84 mg/L and whose mean turbidity ranged from 22 to 87 NTU (Table 5). The 19 species found in N1 were fairly uniformly represented within the catch as evident by high evenness, Shannon index and true diversity based on Simpson.

In contrast to N1, S5 concentrated abundance in centrarchids, particularly *Lepomis macrochirus* and *M. salmoides*, resulting in a high Simpson, low evenness, low Shannon and low effective number of species based on Simpson. In ponds and reservoirs managed for a sports fishery, it is desirable to maximize the relative abundance of L. *macrochirus* and *M. salmoides*, while reducing richness or other forms of diversity in order to produce a sustainable yield. Limiting species richness reduces stability but allows for surplus production in *L. macrochirus* and *M. salmoides.* While discussions with landowners adjacent to S5 did not indicate the pit was managed for a sports fishery, the diversity measures and catch statistics indicate that this was the case.

Table 5. *Mean ±standard deviations of water quality conditions at levee borrow pits, Abiaca Creek, Mississippi. Means followed by different subscripts are significantly different p < 0.05, Kruskal–Wallis one-way ANOVA on ranks with Tukey test or Dunn's method for pairwise comparisons (adapted from Shields and Knight 2013)*

Parameter	N1			S1			S4			S5		
Conductivity, mS/cm	53	±	17^{a}	91	±	34^{b}	50	±	15^{a}	49	±	15^{a}
pH	6.9	±	0.6^{a}	6.6	±	0.8^{b}	6.7	±	$0.7^{a,b}$	21	±	$0.9^{a,b}$
Temperature, ◦C	21.4	±	8.7	20.9	±	8.1	21.6	±	8.1	21.7	±	8.6
Suspended Solids, mg/L	135	±	104^{a}	86	±	89^{b}	62	±	40^{b}	27	±	29^{c}
Turbidity, NTU	123	±	103^{a}	87	±	75^{a}	60	±	45^{b}	22	±	22^{c}
Dissolved O_2, mg/L	8.2	±	2.7^{a}	6.4	±	2.9^{b}	7.9	±	2.1^{a}	8.3	±	2.0^{a}

5. Conclusions

Abiaca Creek provided sufficiently diverse habitats to support a wide variety of fish species. The lentic habitat provided by the borrow pits and lotic habitats of the main channel in the lower portion of Abiaca Creek watershed produced 3,142 specimens weighing 496.9 kg and representing 45 species. This species richness was similar to those reported for similar Mississippi watersheds (Cooper *et al.* 1982 and Knight and Cooper, 1987). Distinct differences in richness, evenness and diversity measures between the unaltered upper channel site and channelized lower site provided evidence of habitat loss resulting from channel modification for flood control. Borrow pits provided quiescent backwater pools that improved overall taxa richness supporting 11 species not found in either channel site.

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