Effects of Hurricane Katrina on the Fish Fauna of the Pascagoula River Drainage

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Large tropical storms can have dramatic effects on coastal, estuarine and terrestrial ecosystems. However, it is not as well understood how these types of disturbances might impact freshwater communities further inland. Storm surges can change critical water quality parameters for kilometers upstream, potentially causing subtle shifts in community structure or more drastic fish kills. Hurricane Katrina was one of the largest such storms to strike the coast of Mississippi and provides an opportunity to examine these effects in areas where we had pre-storm fish community data. In the weeks following the storm, fish kills were reported from some of the lower portions of the drainage. As part of a separate ongoing research project, monthly electrofishing surveys were conducted in 2004 and 2005 at ten sites throughout the Pascagoula River drainage. Survey effort was evenly divided among bank, sandbar and open channel habitats at each site from June through November. Sites ranged from 90 to 250 river km from the mouth of the Pascagoula River, creating a gradient of storm impact with which to judge storm effects on big river fish fauna. In addition, we compare pre- and post-storm communities along Black Creek, a medium-sized tributary, as well as in a group of small, headwater tributaries.

Keywords: Ecology, Surface Water

Introduction

Ecological disturbances are characterized by their unpredictability and destructive power (Resh et al. 1988; Poff and Ward 1990, Fausch and Bramblett 1991). While ecologists have long recognized the importance of understanding disturbance impacts, the most severe disturbances are difficult to study due to their rarity and force. Investigators often lack complete datasets of appropriate spatial and temporal scales to assess pre- and post-disturbance community structure. As a result, studies linking changes in community structure to major disturbances are generally lacking (Tillman 1989; Collins 2000).

Hurricanes are one of the most severe forms of disturbances to coastal ecosystems. While hurricanes are natural phenomena, they are disturbances and their impacts may be enhanced in areas where anthropogenic changes to the landscape have reduced ecosystem resilience to such stressors (Naiman and Turner 2000; Mallin et al. 1999; Mallin et al. 2002). While the mechanisms for hurricane impacts on estuarine (e.g., erosion, storm surge) or inland terrestrial systems (e.g. wind damage) are fairly obvious, similar mechanisms are not as well understood for river ecosystems. Floods are a necessary component of riverine ecosystems, and river discharges after hurricanes are often not significantly greater than typical high water levels. One might also expect riverine systems to be well sheltered from direct wind effects. However, the combination of high winds and intense precipitation can defoliate trees and deposit large amounts of litterfall material in streams. Litterfall mass from hurricanes Hugo and Gilbert were up to twice as high as mean annual inputs (Lodge and McDowell 1991). Fallen trees combined with intense precipitation might also increase erosional deposition of sediments. In smaller headwater streams, downed trees and debris can alter flows and habitat structure by creating debris dams (Golladay et al. 1986). Finally, downstream portions of coastal drainages might also be exposed to storm surges that could raise salinities or disturb sediments.

One of the ways hurricanes are thought to impact fish communities is through immediate drops in dissolved oxygen (DO). While the precise cause of the lower DO is not known, there are a number of possible contributing factors in our study system. First, a spike in the biological oxygen demand (BOD) caused by high temperatures and leaf and wood debris input. Second, the storm surge may have disturbed anoxic sediments in the Gulf of Mexico or lower Pascagoula River (Buck 2005). Finally, water treatment plants or other sources of polluted water might have found their way into the river as a result of flooding (MS Department of Wildlife, Fisheries and Parks 2005).

Study System and Hurricane Katrina

The Pascagoula River system is the largest unimpounded drainage remaining in the continental United States (Dynesius and Nilsson 1994). As a relatively pristine system, it is ideal for studying fish community dynamics and disturbance effects. Additionally, the system has been well studied in the past and the authors had two independent, ongoing projects documenting fish community structure before hurricane Katrina struck.

Hurricane Katrina struck the Gulf Coast on August 29, 2005. The eye of the storm struck the coast roughly 113 km west of the mouth of the Pascagoula River and proceeded to move in a north by northeast direction over much of the drainage. Winds in excess of 209 km/h were recorded throughout most of the drainage. The storm surge in Jackson County (where the Pascagoula River enters the Gulf of Mexico) was estimated at 5 m, meaning salt water was likely driven inward over many river kilometers. In the days and weeks following the storm, extremely low DO levels were recorded in large rivers and streams in the lower portions of the drainage (Howell 2006). In the weeks following the storm there were numerous reports of fish kills, primarily in the lower reaches of the Pascagoula River (Buck 2005; MS Department of Wildlife, Fisheries and Parks 2005; Todd Slack, pers. comm.).

The purpose of this study is to assess impacts of hurricane Katrina on fish communities in the Pascagoula drainage by comparing pre- and post-hurricane fish community structure. Data were included from three portions of the drainage, 1st-4th order smaller streams, Black Creek (a medium-sized tributary) and the three large rivers (Leaf, Chickasawhay and Pascagoula) in the drainage (Fig. 1).

Materials and Methods

Pre- and post-hurricane data were compiled for three portions of the drainage: 1st -4th order streams (hereafter referred to as small streams) in the headwaters, the length of Black Creek and the three large rivers (Leaf, Chickasawhay and Pascagoula). Sampling was done by seining in small streams and Black Creek and by boat electrofishing in large rivers. Seines varied in size based on the demands at particular sites but were always 4.8 mm mesh. Seining effort was typically 30-45 minutes per site during which time all available habitat was sampled. For electrofishing surveys, each site contained sand bar, open channel and bank habitat that were electrofished for 400 seconds each. Fish from electrofishing surveys were identified in the field and then released. Fish from seining were preserved in 10% formalin, identified in the laboratory, transferred to 70% EtOH and then deposited in the USM Museum of Ichthyology. For most analyses, we will consider each dataset independently. Although we employed varied sampling methods, the approaches taken were well suited for each type of stream. Finally, pre- and post-hurricane sampling methods were consistent within stream types and datasets.

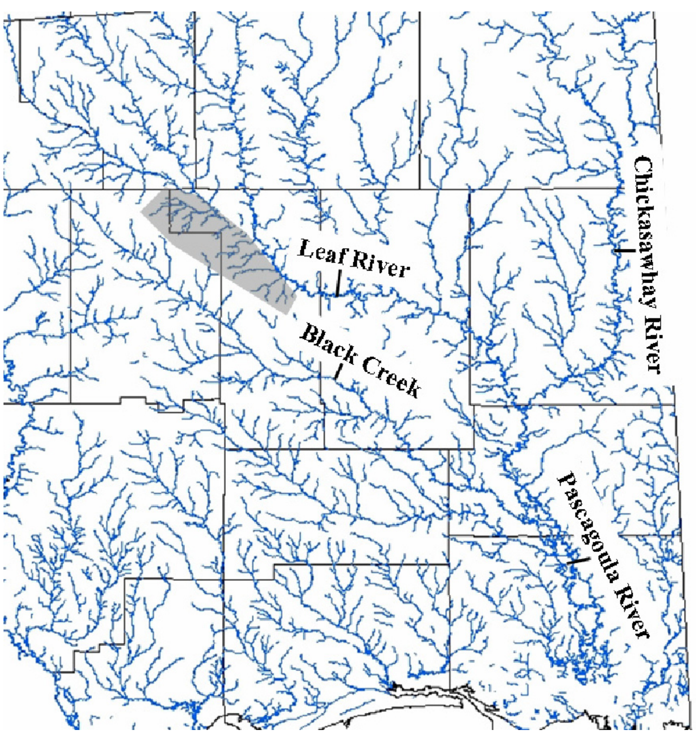

Figure 1. Map of the Pascagoula drainage with the rivers and creeks sampled labeled. The small streams sampled are not labeled but are all within the shaded polygon.

Small Stream Dataset

Five to seven small stream sites were sampled monthly from April 2005 through April 2006. Some site locations changed in certain months depending on water levels or other conditions. Sites were all within six streams: the Bouie River, Hayden Creek, Big Creek, Shelton Creek, Beaver Creek and Okatoma Creek. There was a total of 36 pre- and 44 post-hurricane samples.

Black Creek Dataset

Steve Ross, along with colleagues, conducted extensive surveys of the Black Creek fish fauna in the 1970's and 1980's and from 2000-2003. These surveys involved a variety of gears and efforts and were sometimes targeted on a single taxa. To control for this, we examined all 176 collections made in the creek during this period. We eliminated records that did not use seines (e.g. some sites were sampled with eel traps) or that did not sample on the appropriate scale (e.g. some sites were divided into very small subsections). Original field notes were available to clarify questions we had about gear or sampling protocol. Because Black Creek represents a gradient from a smaller stream to a larger river, we divided it into five longitudinal sections defined by road or boat access points. We compiled 63 pre- and 11 post-hurricane samples among the five sections. All post-hurricane data were collected in April 2006 by re-sampling localities that were part of the pre-hurricane database.

Large Rivers Dataset

Ten large river sites were sampled by monthly boat electrofishing from June through November in 2004 and 2005. Four sites were in the Leaf River, three in the Chickasawhay River and three in the Pascagoula River (Mickle 2006). There was a total of 67 pre- and 14 post-hurricane samples. Post-hurricane sampling was not conducted in September 2005 but began the next month.

Statistical Analyses

The complete dataset consisted of 235 collections (166 pre- 69 post-hurricane) and 92 species. Descriptive statistics calculated included the proportion of samples that contained individuals of a species and the mean rank abundance of a species. To calculate mean rank abundance, rank abundances for a species (within individual collections) were averaged across all collections for that

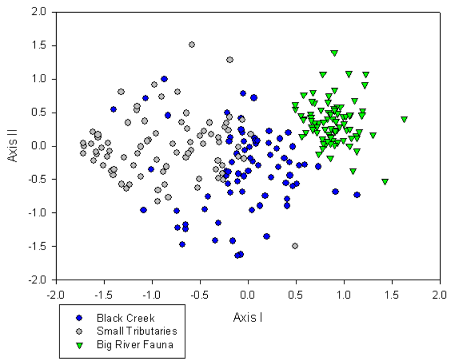

Figure 2. NMS plot of all three datasets from Mississippi rivers.

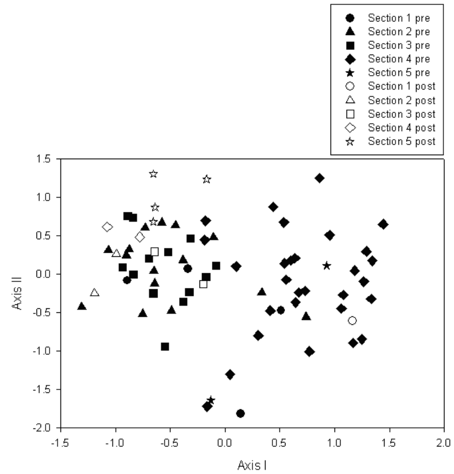

Figure 3. NMS plot of samples from Black Creek. Longitudinal creek sections are represented by different symbols. Open symbols represent post-hurricane samples, closed symbols are pre-hurricane.

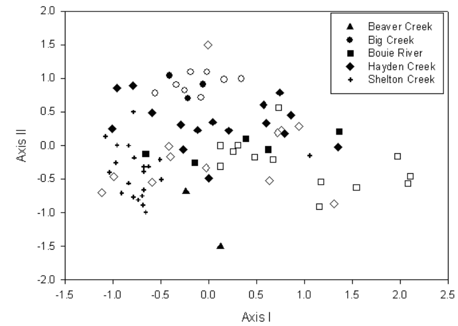

Figure 4. NMS plot of samples from the small streams. Individual streams are represented by different symbols. Open symbols represent post-hurricane samples, closed symbols are pre-hurricane.

locality or stream. For example, if a species was present in 4 out of 5 samples at a site and it was most abundant in two samples and fourth in rank abundance in the other two, we would report its mean rank abundance as 2.5 and present in 80% of samples. Community similarity was assessed visually by clustering patterns in two-dimensional ordinations (nonmetric multidimensional scaling, NMS) based on Bray-Curtis similarity among sites. Ordinations were run for the entire matrix to assess community differences among the three datasets and then on each of the datasets individually to assess hurricane effects. All analyses were performed on raw abundance data using the software package Primer (version 5.0).

Results

Stress values on all NMS analyses were less than 0.24 indicating that the analysis was able to accurately place samples in two dimensions so that Euclidian distance among samples in NMS space and Bray-Curtis similarity were highly correlated. Stress values in this range are considered acceptable for community analyses.

Overall Community Patterns

The large river fish communities were distinct from those in Black Creek and the small streams (Fig. 2). Large river collections contained a number of species not found in the other two datasets (Tables 1-3). Some of the more abundant distinct large river species were: *Alosa alabamae, Alosa chrysochloris, Aplodinotus gruniens, Anchoa mitchilli, Carpiodes velifer, Hiodon tergisus, Lepisosteus oculatus* and *Mugil cephalus*. Black Creek and the small streams partially overlapped (Fig. 2) and contained a number of species not found in the large river samples: *Etheostoma lynceum, E. stigmaeum, E. swaini, Luxilus chrysocephalus, Lythrurus roseipinnis, Notropis baileyi*. (Tables 1-3). Within Black Creek, the pre-hurricane upstream and downstream sections (1-3 and 4-5, respectively) generally clustered separately (Fig. 3). In the small streams dataset, Shelton Creek and Big Creek clustered separately from the other three small streams, which broadly overlapped (Fig. 4).

Hurricane Impacts

There were no clear hurricane impacts in the small streams (Fig. 4), upstream sections of Black Creek (Fig. 3) or the Leaf and Chickasawhay rivers (Fig. 5). In each of these cases, the post hurricane community samples were clearly clustered with pre-hurricane samples. In contrast, the hurricane clearly affected fish communities in the Pascagoula River (Fig. 5) and downstream portions of Black Creek (Fig. 3). In downstream portions of Black Creek, post hurricane samples (open diamonds and stars of Fig. 3) did not cluster with pre-hurricane samples. In the Pascagoula River, post-hurricane samples (open circles in Fig. 5) did not cluster with pre-hurricane samples or with any of the other large river samples. In the Pascagoula River, the post-hurricane communities were numerically dominated by two species (*Anchoa mitchilli* and *Mugil cephalus*) not particularly abundant in previous samples in the large rivers (Table 3).

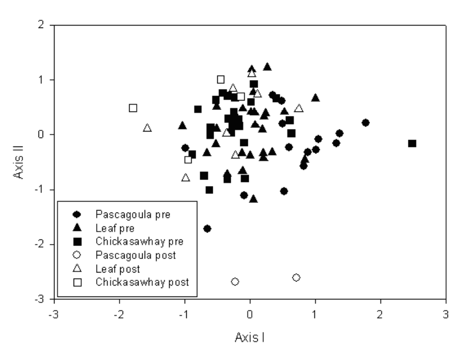

Figure 5. NMS plot of samples from the Leaf, Chickasawhay and Pascagoula rivers. Each river is represented by a different symbol. Open symbols represent post-hurricane samples, closed symbols are pre-hurricane.

Table 1. Pre- and post-Katrina mean rank abundance and proportion of samples containing species in the smaller tributaries sampled.

	Small Tributaries			
	Pre		Post	
	Abund.	Prop.	Abund.	Prop.
Ambloplites ariommus	8.5	5.6		
Ameiurus natalis	8.0	2.8		
Ammocrypta beani	5.3	27.8	5.4	31.8
Ammocrypta vivax	10.2	13.9	10.4	18.2
Cyprinella venusta	5.0	55.6	4.9	36.4
Ericymba buccata	6.0	38.9	5.8	27.3
Etheostoma chloroso-mum	16.0	2.8	6.0	2.3
Etheostoma lynceum	5.5	47.2	2.5	47.7
Etheostoma parvipinne	6.7	16.7	6.0	2.3
Etheostoma stigmaeum	6.4	55.6	3.5	54.5
Etheostoma swaini	6.2	50.0	6.6	34.1
Fundulus olivaceus	8.6	38.9	6.8	11.4
Gambusia affinis	6.9	30.6	8.4	25.0
Hypentelium nigricans	6.8	58.3	7.8	25.0
Ichthyomyzon gagei	6.7	8.3	4.0	2.3
Labidesthes sicculus			10.8	9.1
Lepomis cyanellus	7.0	8.3		
Lepomis gulosus			4.0	2.3
Lepomis macrochirus	6.6	38.9	7.0	13.6
Lepomis megalotis	7.0	16.7	9.2	11.4
Luxilus chrysocephalus	2.9	91.7	3.2	79.5
Lythrurus roseipinnis	4.0	58.3	5.3	27.3
Micropterus punctulatus	8.1	41.7	8.0	18.2
Micropterus salmoides	8.5	11.1	11.0	2.3
Micropterus sp	10.0	2.8		
Moxostoma poecilurum	10.5	22.2	12.3	9.1
Nocomis leptocephalus	6.4	52.8	7.5	31.8
Notemigonus crysoleu-cas	10.0	2.8		
Notropis baileyi	5.1	66.7	3.3	54.5
Notropis longirostris	4.7	58.3	4.2	52.3
Notropis texanus	8.7	27.8	6.9	31.8
Notropis volucellus	8.0	5.6	5.5	18.2
Notropis winchelli	9.3	36.1	6.7	27.3
Noturus leptacanthus	9.1	33.3	6.9	15.9
Opsopoeodus emiliae			8.8	13.6
Percina nigrofasciata	4.0	91.7	3.8	86.4
Percina sciera	8.1	27.8	6.0	38.6
Pimephales vigilax	8.0	2.8		
Pomoxis annularis			12.0	2.3

Discussion

The observed differences in community structure among the large rivers and the other two river types are not unexpected. While one would expect to see differences among such disparate habitats, it should be noted that different sampling techniques likely exacerbated these effects. Many of the species only sampled in the large river habitat are large bodied species that are extremely difficult to sample by seine. Seining and electrofishing are both known to selectively sample some taxa more effectively than others. With this sampling bias in mind, all of our tests for hurricane impacts were conducted within the three separate datasets where sampling gear and effort was standardized.

Community structure differed significantly between upstream and downstream sections of Black Creek. The upstream portions of Black Creek and many of the small stream samples had higher abundances of species that are considered riffle and gravel substrate specialists (Tables 1 and 2).

Hurricane Impacts

Hurricane impacts were most pronounced in the areas closest to the Gulf of Mexico. There were large changes in community structure in the Pascagoula River and lower portions of Black Creek. The remaining sites are all further (in river km) from the Gulf of Mexico and did not show any change in fish community structure. Pre- and post-hurricane samples in the smaller streams and upstream portions of Black Creek showed no shifts in community structure.

After the hurricane, fish kills were reported in the Pascagoula River and generally attributed to low DO. It is difficult to directly link species absence in post hurricane samples to tolerance of these

Table 2. Pre- and post-Katrina mean rank abundance and proportrion of samples containing species in the five sections of Black Creek. Section one is in the headwaters, section five near the confluence with the Pascagoula River.

	Section 1				Section 2				Section 3				Section 4				Section 5			
	Pre		Post		Pre		Post		Pre		Post		Pre		Post		Pre		Post	
	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.
Ambloplites ariommus													11.2	20.7						
Ammocrypta beani	3.8	83.3			3.7	76.9			7.0	92.3	9.0	100.0	7.1	31.0	4.0	100.0				
Aphredoderus sayanus													9.6	24.1			1.0	50.0	8.0	25.0
Carpiodes cyprinus									11.0	7.7					13.0	50.0				
Cyprinella venusta	2.4	83.3			1.8	92.3	4.0	100.0	1.7	100.0	2.5	100.0	4.4	65.5	1.5	100.0	3.0	50.0	1.3	100.0
Elassoma zonatum													10.9	24.1						
Ericymba buccata	4.0	16.7			3.9	61.5			4.5	84.6	1.0	50.0	5.8	20.7	7.0	100.0				
Erimyzon tenuis									14.0	7.7	9.0	50.0	13.5	6.9						
Esox niger			9.0	100.0	10.0	7.7	8.0	50.0					12.0	13.8			6.0	50.0		
Etheostoma lynceum	6.5	33.3			9.3	30.8			6.5	84.6	8.0	100.0	7.8	27.6						
Etheostoma stigmaeum	7.0	16.7			7.0	38.5	7.0	50.0	10.3	84.6	7.0	100.0	7.1	65.5	9.0	50.0				
Etheostoma swaini	1.0	16.7					7.0	50.0	10.5	15.4			6.0	55.2			6.0	50.0		
Fundulus notti													7.5	6.9	8.5	100.0				
Fundulus olivaceus	7.3	66.7	6.0	100.0	5.9	61.5	4.0	100.0	8.6	84.6	10.0	50.0	4.7	79.3	6.0	100.0	4.0	50.0	4.0	25.0
Gambusia affinis	5.0	16.7	3.0	100.0	8.5	15.4	6.0	50.0					8.3	31.0			6.0	50.0	1.0	25.0
Hypentelium nigricans	7.0	33.3			8.2	38.5			8.8	69.2	13.0	50.0	12.8	13.8						
Hybognathus nuchalis																			5.0	50.0
Ichthyomyzon gagei					7.0	7.7							20.0	3.4			6.0	50.0		
Ictalurus punctatus					7.0	15.4			12.0	15.4									4.0	25.0
Labidesthes sicculus	4.5	33.3	2.0	100.0	5.3	30.8	3.0	100.0	11.3	30.8	8.0	50.0	5.4	44.8	5.5	100.0	4.0	50.0	3.0	25.0
Lepomis cyanellus					15.0	7.7			11.0	7.7			20.0	3.4						
Lepomis gulosus													14.0	10.3						
Lepomis macrochirus	4.0	16.7	9.0	100.0	7.3	30.8	2.5	100.0	8.3	30.8			5.9	44.8	9.5	100.0	6.0	50.0	10.0	25.0
Lepomis marginatus	7.0	16.7											7.0	6.9						
Lepomis megalotis	7.5	33.3	5.0	100.0	6.3	53.8	5.0	50.0	6.5	46.2	9.5	100.0	5.2	51.7	3.0	50.0	3.0	50.0	5.5	50.0
Lepomis microlophus	2.0	16.7			9.0	7.7	5.0	50.0	5.0	7.7			25.0	3.4	13.0	50.0				
Lepomis miniatus													9.5	6.9						
Luxilus chrysocephalus					8.8	30.8			10.2	46.2	9.0	50.0	7.0	3.4	10.0	50.0				
Lythrurus roseipinnis	1.0	16.7	1.0	100.0	5.0	46.2	1.5	100.0	7.3	92.3	5.5	100.0	1.9	82.8	10.0	50.0	1.0	50.0		
Macrhybopsis aestivalis					14.0	7.7			10.3	23.1										
Macrhybopsis storeriana					15.0	7.7													4.5	50.0
Micropterus punctulatus	6.0	50.0			5.8	92.3	7.0	50.0	7.8	100.0	10.0	50.0	11.7	20.7	8.0	100.0				
Micropterus salmoides	8.0	16.7			10.5	15.4	7.0	50.0	19.0	7.7			8.6	17.2						
Minytrema melanops					10.0	7.7							10.7	10.3			6.0	50.0		
Moxostoma poecilurum					6.0	7.7			12.0	23.1			5.0	3.4						
Notemigonus crysoleucas									21.0	7.7			12.0	3.4						
Notropis atherinoides					11.0	15.4														
Notropis baileyi			7.0	100.0	10.0	7.7			16.0	7.7										
Notropis longirostris	2.0	100.0			2.9	100.0			3.3	100.0	1.5	100.0	7.4	17.2	1.5	100.0			2.0	50.0
Notropis texanus	4.0	50.0	9.0	100.0	6.0	7.7	7.0	50.0	11.0	15.4			2.8	72.4	7.0	50.0	2.0	50.0	3.7	75.0
Notropis maculatis			7.0	100.0			8.0	50.0												
Notropis volucellus					7.4	38.5			9.5	46.2	3.0	50.0	6.0	17.2	5.0	50.0	4.0	50.0	5.0	25.0
Notropis winchelli					7.4	38.5			11.8	30.8			9.7	10.3						
Noturus funebris	7.0	16.7											4.0	3.4						
Noturus leptacanthus	7.5	66.7							7.3	30.8			4.4	34.5	13.0	50.0	2.0	50.0		
Noturus nocturnus													12.0	6.9						
Opsopoeodus emiliae			4.0	100.0									12.0	17.2			4.0	50.0		
Percina nigrofasciata	5.8	66.7			7.1	53.8			6.3	100.0	3.5	100.0	4.6	86.2	13.0	50.0	6.0	50.0		
Percina sciera	8.3	50.0			7.7	53.8			9.0	69.2	8.0	100.0	9.0	20.7						
Percina sp					10.0	7.7			6.0	7.7										
Percina vigil	8.0	16.7			8.0	30.8			11.0	7.7					9.0	50.0			6.0	25.0
Pteronotropis welaka													7.0	6.9						
Trinectes maculatus	5.5	33.3							12.0	7.7									3.0	50.0

Table 3. Pre- and post-Katrina mean rank abundance and proportrion of samples containing species in the three large rivers of the Pascagoula drainage.

	Chickasawhay River				Leaf River				Pascagoula River			
	Pre		Post		Pre		Post		Pre		Post	
Species	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.	Abund.	Prop.
Alosa alabamae	11.5	8.3			6.0	39.3	3.7	37.5	6.0	37.5		
Alosa chrysochloris	8.0	20.8	9.0	25.0	8.9	25.0			11.5	12.5		
Ambloplites ariommus	7.6	29.2	7.0	50.0	11.2	17.9			11.0	6.3		
Ammocrypta beani					9.0	3.6						
Anguilla rostrata	10.5	12.5	9.0	25.0								
Aplodinotus grunniens					7.5	21.4	7.7	37.5				
Anchoa mitchilli					4.0	3.6					3.0	50.0
Carpiodes velifer	3.4	87.5	3.3	75.0	2.9	92.9	2.8	75.0	3.3	100.0		
Cycleptus meridionalis	7.0	16.7			10.7	10.7	6.0	12.5	7.5	25.0		
Cyprinella venusta	1.3	95.8	2.0	75.0	1.9	92.9	1.3	75.0	2.9	100.0	4.0	50.0
Dorosoma cepedianum	5.4	62.5	3.5	50.0	7.4	57.1	5.4	87.5	3.8	50.0	2.0	50.0
Dorosoma petenense	2.0	4.2	9.0	50.0			5.0	12.5	5.0	6.3	2.0	50.0
Hypentelium nigricans	7.4	25.0	15.0	25.0	8.7	35.7	7.8	62.5	11.0	6.3		
Hybognathus nuchalis	3.5	37.5	6.0	25.0	5.9	42.9	5.0	37.5	2.4	87.5	4.0	50.0
Hiodon tergisus	8.4	33.3	4.0	50.0	8.9	39.3			9.0	6.3		
Ictiobus bubalus	7.3	12.5			7.0	17.9	12.0	12.5	8.0	25.0		
Ictalurus furcatus	8.5	8.3	11.0	25.0	11.7	10.7			7.0	6.3		
Ictaluriu punctatus	7.8	33.3	8.0	75.0	8.6	46.4	5.5	50.0	7.8	31.3		
Labidesthes sicculus					8.0	7.1	6.0	25.0	7.0	12.5		
Lepomis macrochirus	5.8	50.0	6.5	50.0	8.3	25.0	4.0	12.5	6.0	25.0		
Lepomis megalotis	4.5	62.5	3.7	75.0	6.1	78.6	6.4	62.5	6.3	68.8		
Lepomis microlophus	6.3	12.5	9.0	25.0	8.0	7.1	8.3	37.5	9.0	12.5		
Lepisosteus oculatus	6.6	58.3	8.0	75.0	7.4	32.1	8.0	12.5	6.5	87.5	2.0	50.0
Lepisosteus osseus	14.0	8.3	6.0	25.0	8.8	14.3	7.0	25.0	8.0	18.8		
Macrhybopsis storeriana	4.7	37.5	15.0	25.0	7.4	39.3	8.3	37.5	8.3	18.8		
Micropterus punctulatus	5.6	83.3	6.0	50.0	5.8	82.1	5.8	75.0	6.4	75.0		
Micropterus salmoides	8.5	33.3	5.7	75.0	7.4	25.0	5.0	25.0	8.9	43.8		
Moxostoma poecilurum	5.7	75.0	2.3	75.0	5.5	82.1	4.7	87.5	8.0	31.3		
Mugil cephalus	4.5	33.3	7.5	50.0	3.9	85.7	5.7	75.0	4.5	81.3	1.0	100.0
Notropis atherinoides	4.3	79.2	2.0	50.0	5.6	71.4	2.6	62.5	6.2	93.8	4.0	50.0
Notropis longirostris	6.3	41.7			8.0	46.4	8.7	37.5	6.9	50.0		
Notropis texanus	7.7	12.5			8.3	10.7	9.0	12.5	2.0	6.3		
Notropis volucellus	9.0	4.2	9.0	25.0	10.0	3.6	9.0	12.5	9.0	6.3		
Notropis winchelli					9.0	3.6	9.0	12.5				
Noturus leptacanthus	14.0	4.2										
Percina nigrofasciata	9.0	4.2			9.0	3.6						
Percina lenticula	10.5	8.3			11.0	3.6			7.0	6.3		
Pimephales vigilax	8.3	25.0	11.0	25.0	8.0	10.7	7.0	37.5	14.0	6.3		
Pomoxis nigromaculatus			9.0	25.0	8.3	10.7	9.0	12.5				
Strongylura marina									7.0	6.3		

conditions. However, post-hurricane samples from the Pascagoula River contained no individuals from two typically abundant families, Centrarchidae and Catostomidae, that made up roughly 18% of all individuals captured in pre-hurricane samples. Some of the most abundant species (e.g. *Mugil cephalus* and *Anchoa mitchilli*, Table 3) in post-hurricane Pascagoula River samples were diadromous or peripheral marine-estuarine species that would likely be tolerant of salinity spikes associated with storm surge.

The community changes in lower sections of Black Creek included decreases in the abundance of some previously abundant darter species (*Percina* sp. and *Etheostoma* sp.) and *Lythrurus roseipinnis* which had been the most abundant species. Conversely, some species (e.g., *Hybognathus nuchalis* and *Trinectes maculatus*) that were relatively abundant post-hurricane had not been seen in pre-hurricane samples of Black Creek. In the Pascagoula drainage, these two species are typically found in sandy or silt bottom portions of larger rivers. One might hypothesize that these species used portions of Black Creek as refugia (Sedell et al. 1990; Chapman et al. 1995) from low DO conditions in the Pascagoula River. Finally, it should be pointed out that our post-hurricane samples from the small streams and large rivers were taken in fall 2005, whereas the post-hurricane samples from Black Creek were not taken until spring 2006.

While there were no immediate impacts on community structure in upstream portions of Black Creek or the smaller streams, these are areas that might have sustained the greatest change in habitat structure. In fall 2005, debris dams altered streamflows at many small-stream sites, and shallow, riffle-type habitat was scarce. Progressing downstream, once channel widths increased beyond what a fallen tree could block, riffle type habitats returned. Community change induced by habitat changes may not be readily visible on the temporal scale at which we collected our data. Longer term sampling (multiple years) of these same sites is necessary to assess recovery of communities closer to the Gulf of Mexico as well as potential shifts in upstream communities due to habitat alteration.

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