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Fish Assemblages on Sand/gravel Bar Habitat in the Alabama River, Alabama

T. Heath Haley[1,2] and Carol E. Johnston[1,*]

Abstract - The Alabama River drainage is a biologically diverse system containing over 180 native fishes and at least 33 endemics. Many studies have surveyed single species of conservation concern, such as the federally endangered *Scaphirhynchus suttkusi* (Alabama Sturgeon), *Alosa alabamae* (Alabama Shad), and *Crystallaria asprella* (Crystal Darter), but few have documented entire fish assemblages. Maintaining fish-assemblage data is an important process in monitoring species and assemblage composition through time so that large-scale ecological change can be detected. In this study, we surveyed fish assemblages of sand/gravel bar habitat in the lower Alabama River and compared these data to those collected from historical surveys. Diel and seasonal surveys were conducted along 19 sandbars from Dixie Landing (river mile 22) to Claiborne Lock and Dam (river mile 72). We recorded a total of 48 species in 41 collections during summer, fall, and spring 2010–2011. Based on the Jaccard index, these samples had low similarity to historical samples collected by R.D. Suttkus and the Geological Survey of Alabama, suggesting temporal fish assemblage shifts. In 2010, we detected extremely high numbers of *Brevoortia patronus* (Gulf Menhaden) during summer and fall, which is a new distributional record. Diel comparisons using the Morisita index indicate low similarity reflecting large numbers of catfish species detected mostly in night collections. These data also indicate seasonal faunal changes among sandbar fish assemblages. Ongoing habitat alteration on the Alabama River is a potential factor leading to assemblage homogenization and potential loss of biodiversity. Future monitoring in the Alabama River should consider diel and seasonal sampling to accurately document fish species and assemblages, including potential shifts that may be occurring over space and time.

Introduction

Anthropogenic changes to aquatic environments often result in alteration of species assemblages and a decline in biodiversity (Ganasan and Hughes 1998, Poff et al. 2007, Strayer and Dudgeon 2010). Because of our heavy reliance on freshwater for water supply, transportation, agriculture, and recreation, riverine systems are often dammed and dredged, and these habitat modifications threaten biotic integrity (Dudgeon et al. 2005, Poff et al. 2007, Taylor et al. 2008). For example, damming of rivers isolates fish assemblages to fragmented habitats both upstream and downstream of dams, which leaves the assemblages vulnerable to habitat degradation and changes in hydrology and water quality (Greathouse et al. 2006, Poff et al. 2007, Rypel and Bayne 2009, Taylor et al. 2008). These isolation events may also have tremendous effects on migratory fluvial fauna that use both upstream and

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downstream areas as spawning sites (Bunn and Arthington 2002, Kondolf and Wolman 1993). Damming also results in the congestion of sediment flow throughout the lotic system, and homogenization of aquatic habitat downstream of the structure may occur due to the deposition of sediment (Kondolf 1997).

Many studies have found that flow regimes impact both the structure and persistence of fish assemblages (Freeman et al. 2001, Shea and Peterson 2007). Poff and Allan (1995) hypothesized that organization of fish communities was related to hydrological variability and conducted a study in which they sampled 34 sites in Wisconsin and Minnesota. They found a strong relationship between hydrological variability and fish assemblage structure, suggesting that changes in flow could potentially modify the fish assemblage structure of an aquatic system. Fish studies are often focused on single species, but monitoring diversity within entire assemblages can provide information on the status of ecosystems more generally (Johnston and Maceina 2009, Scott and Helfman 2001). For example, information on entire assemblages can provide insight into homogenization and shifts in assemblage structure that may be occurring over space and time (Scott and Helfman 2001).

To maintain passage, riverine systems used for navigation are also dredged, causing significant disturbance to the entire system and the destruction of shallow-water habitats (Licursi and Gomez 2009). Removal of the substrate not only destroys the natural habitat, but can create new, low-velocity, sediment-rich habitats. Consequently, these types of habitats are unsuitable for many riverine fishes that require flow (Padmalal et al. 2008, Paukert et al. 2008). The disruption of sediment causes an increase of nutrients (soluble phosphorus) and toxic substances in the water column that can cause changes in aquatic assemblages (Lewis et al. 2001, Licursi and Gomez 2009).

Monitoring efforts are needed to adequately quantify potential effects of these factors on fish assemblages. For a monitoring program to adequately address detection, variability in diel and seasonal patterns must be understood. Studies have been conducted noting significant diel variation of riverine fish assemblages among their associated habitats (Arrington and Winemiller 2003, Hoeinghaus et al. 2003, Roach and Winemiller 2011). Many factors affect diurnal and nocturnal turnover in fish assemblages and community structure including water temperature, water transparency or light levels, and resource availability (Helfman 1981, Reid and Mandrak 2009, Roach and Winemiller 2011). Seasonal effects, primarily driven by temperature, can also effect the detection of fishes and corresponding assemblage structure. For example, higher water temperatures enhance fish activity levels and therefore frequently also yield higher catch rates (Gelos et al. 2010, Gries et al. 1997).

Of the 20 species of conservation concern found in the Mobile system (Mirarchi et al. 2004), monitoring programs for target species such as *Alosa alabamae* (Alabama Shad) and *Scaphirhynchus suttkusi* (Alabama Sturgeon) are well established. However, few recent survey efforts have been aimed at documenting trends in non-game fish assemblages. The objectives of this study were to: 1) provide current data on fish assemblages found in sand/gravel bar habitat in the Alabama

River downstream of river mile 72 (Claiborne Lock and Dam), 2) compare current collections along sand/gravel bar habitat to historic collections to evaluate assemblage persistence, and 3) assess temporal variability among fish assemblages via diel and seasonal collections.

Field-Site Description

The Alabama River system (including the Tallapoosa, Coosa, and Cahaba subsystems) flows through a rich physiographic region with high levels of ichthofaunal diversity and endemism including 184 native fishes and 33 endemics (Boschung and Mayden 2004, Freeman et al. 2005). The system includes species that are federally listed as threatened or endangered such as the Alabama Sturgeon and *Cyprinella caerulea* (Blue Shiner) (Freeman et al. 2005). The Alabama River is formed by the confluence of the Coosa and Tallapoosa rivers just north of Montgomery, AL. The river flows west to Selma and then southwest until it converges with the Tombigbee River. The river measures 312 miles in length and is entirely navigable throughout. The Alabama River has three dams: Claiborne (RM 72.5), Miller's Ferry (RM 133), and Jones Bluff (RM 236.2), all of which were installed to assist with navigation of the river by barges and other watercraft and for power generation. Currently, the river is maintained at a 9-foot channel depth by periodic dredging to ensure uninterrupted navigation. The study area is concentrated in the most free-flowing stretch of the Alabama River, below Claiborne Lock and Dam (river mile 72.0) on sand/gravel bar habitat.

Methods

Beginning 28 June 2010, we sampled 19 sand/gravel bars from river mile 22.9 to 72.0 of the Alabama River during June–August and October 2010 (Fig. 1, Appendix 1). Selected sites were sampled during both day and night for diel comparisons, and fall for seasonal comparison (n = 41). We also resampled selected sites during April 2011 (n = 3; Fig. 1, Appendix1). Fishes were collected in these habitats using 15- or 30-m seines (5–10 seine hauls per site). We conducted seining according to techniques described by Murphy and Willis (1996).

Seine selection and length of each sand/gravel bar haul was dictated by the depth of the reach and presence of obstructions, but generally ranged between 30–100 m. We re-sampled selected sites at night and in multiple seasons to monitor diurnal and seasonal assemblage changes (4 diel samples and 8 seasonal samples). After each haul, all fish were identified to species, if possible, and enumerated. Those of conservation concern were recorded and returned to the river. Fish that could not be identified to species in the field were preserved and transported to the Fish Biodiversity Lab for further identification; we first anesthetized these specimens in MS 222 (tricane methanesulfonate) prior to preserving them in a 10% formalin solution.

We evaluated long-term temporal variability among fish assemblage structure by comparing recent collections from this study to significant historic collections (Shepard et al. 2000; Royal D. Suttkus Fish Collection, Tulane Museum of Natural

History, New Orleans, LA). Although both of these researchers used seining (thus sampling gears were equivalent), there was no possible method to standardize effort among the samples. Furthermore, comparisons with Suttkus' early samples are limited because most of the sand/gravel bars he sampled for his long-term study are no longer present. However limited these comparisons to historical data are, an examination of assemblage structure is useful for identifying potential homogenization and other faunal shifts during this time period. Due to potential discrepancies in effort, we used the Jaccard index for comparisons of current to historical fish assemblage structure. This metric does not include abundance, which can be strongly influenced by effort. Current diel and seasonal collections were also made in order to assess fish assemblage change over short time scales. We compared current, replicated samples to validate sampling methods.

Jaccard and Morisita indices of similarity were used to compare collections (Ecological Methodology ver. 7.0). The Morisita index takes species abundance into account, and we used this analysis for comparisons of our samples, which

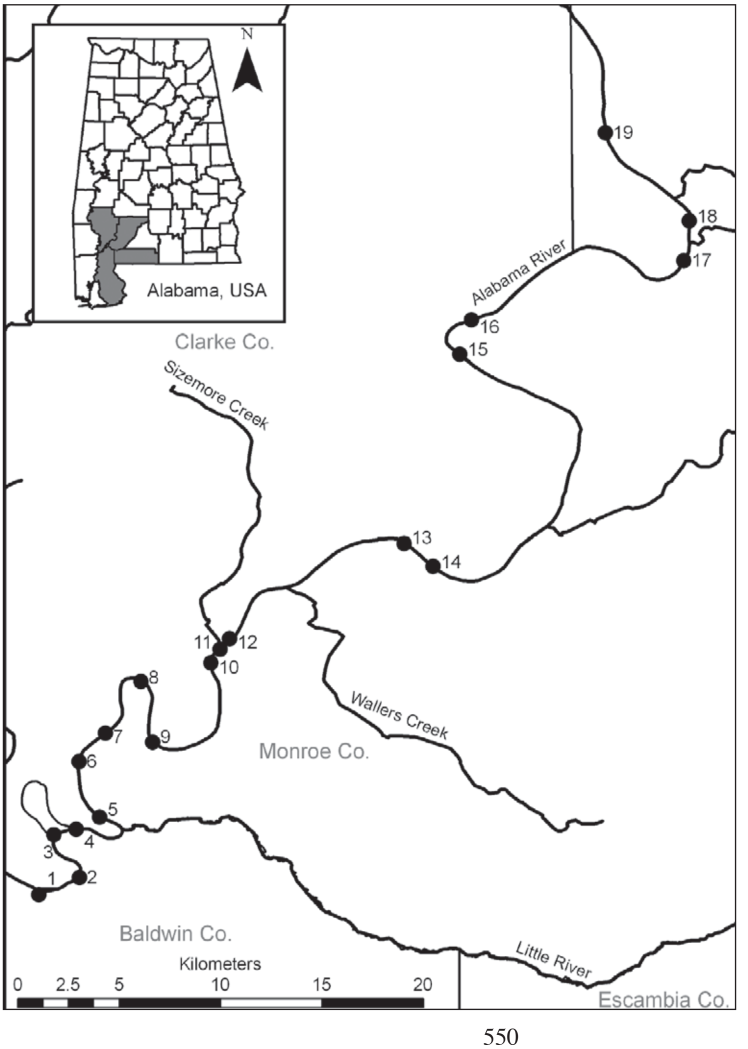

Figure 1. Distribution map of sample sites in the Alabama River and associated tributaries. Site numbers correspond to Appendix 1.

were all collected using the same methodology. The Morisita index is a measure of dispersion and is used to measure overlap among samples:

$$C_D = (2\sum_{i=1}^{s} x_i y_t) / ([D_x + D_y)XY,$$

where x_i is the number of times species i is represented in the total X from one sample, y_i is the number of times species i is represented in the total Y from another sample, and D_x and D_y are Simpson index values for the x and y samples respectively. The index value ranges from 0 to 1. A value 0 indicates no similarity, or shared species, between the collections. A value of 1 indicates complete similarity between the collections (Krebs 1999, Spellerberg 1991).

For historical comparisons, we used the Jaccard index because sampling methods may have differed between current and historical collections, causing fish abundance bias. The Jaccard similarity index is a measure of community similarity and assesses the presence or absence of species:

$$J = \frac{w}{A + B - w},$$

where w is the number of species common to both samples (or community) and A is the number of species in sample one and B is the number of species in sample two. The index value ranges from 0 to 1. A value of 0 indicates no similarity, or shared species, between the collections. A value of 1 indicates complete similarity between the collections (Krebs 1999, Spellerberg 1991).

Correspondence analysis (CA) was used to compare the collections of sites 1, 8, and 10. These sites were sampled in three seasons. Correspondence analysis is a statistical tool used to test the probability of association between variables in a tabular data set. In this study, CA was used to show how species abundance corresponds to season. We ran CA for this study using PAST (Paleontological Statistics Version 2.13).

We employed ArcGIS to measure spatial parameters of the sand/gravel bar habitats among our sampling area using a projected base layer of the lower Alabama River watershed from Alabamaview.org, and aerial digital ortho quarter quads (DOQQs) of our sampling area (river miles 22.9–72.0). We transferred the projected images (.tiff) to an appropriate coordinate system and digitized the sand/gravel bar habitats into polygons.

Using the spatial analysis tool in ArcGIS, we measured the area (acres and m^2) of each digitized sand/gravel bar, and we measured proximity (m) between neighboring sand/gravel bars with Google Earth (version 6.1.0). Using these data, we estimated spatial relationships between sand/gravel bars and their associated fish assemblages.

Pearson's correlation coefficient and linear regression were used to test the relationship between sandbar proximity or area and species richness. This correlation coefficient can measure the strength of linear dependence between two variables. The coefficient value (r) ranges between -1 and 1. A coefficient value of r = 1 indicates a perfect positive linear relationship between the two variables. A correlation coefficient of r = 0 suggests that no correlation exists between the two variables. A correlation coefficient of r = -1 indicates a perfect negative correlation, or inverse linear relationship, between the two variables (Kachigan 1986).

Results

Collections provided unique records for the Alabama River including *Brevoortia patronus* (Gulf Menhaden), *Fundulus grandis* Baird and Girard (Gulf Killifish) and *Menidia beryllina* (Inland Silverside), all of which are considered primarily marine fishes. Gulf Menhaden, a marine clupeid species not previously recorded from our study area, dominated sand/gravel bar samples. We collected Gulf Menhaden at 12 of 19 sites during our survey (Table 1). The species was absent from the lowermost sample sites of our survey (Table 1, Fig. 1). Numbers of individuals per sample ranged from 1 to over 144,000. Higher numbers were collected in the fall (Table 1). An estimated 393,646 Gulf Menhaden were collected from Alabama River Miles 72–26.3 (Table 1). The presence of such large numbers of one species compounded comparisons, and current comparisons were made with and without Gulf Menhaden included (Tables 2, 3).

Morisita index values differed tremendously when collections with large numbers of Gulf Menhaden were included in the analysis. For example, diel and seasonal comparisons for site 19 exhibited high similarity including Gulf Menhaden, and low similarity excluding Gulf Menhaden. Higher Morisita index values resulted for all seasonal and diel comparisons where Gulf Menhaden were detected and included in the analysis (Table 2).

Table 1. Number of Gulf Menhaden collected in sand/gravel bar samples in the Alabama River in 2010. Site numbers correspond to locality data in Appendix 1 and to Figure 1.

	Summer		Fall	
Site #	Day	Night	Day	Night
19	5649	8159	18,590	495
18	8	0	0	0
17	1	0	0	0
16	4	1	144,464	29,934
15	0	0	109,052	0
14	1	0	0	0
13	1200	0	0	0
12	321	0	0	0
11	16,607	65	420	72
10	2	178	3	36
9	14	0	14,067	0
8	0	0	690	0
7	808	0	2474	0
6	29,195	0	0	0
5	8520	0	0	0
4	2616	0	0	0
3	0	0	0	0
2	0	0	0	0
1	0	0	0	0

Menhaden were collected in both day and night samples (Tables 1, 2). Standard lengths (SL; mm) of preserved menhaden were measured to assess their age classes via length–frequency analysis. While most individuals were age 0 (mean = 54 mm SL, *n* = 94), larval specimens were also collected in summer samples (mean = 21 mm SL, *n* = 13). These lengths fall into year classes described by Lassuy (1983) and Raynie and Shaw (1994). While age-0 individuals dominated fall samples, larger individuals (90–100 mm SL) were present in small numbers (*n* = 10).

Correspondence analyses for the three sites sampled during spring, summer, and fall showed that species compositions showed a strong seasonality to their structures, and spring samples showed low faunal similarity to those from summer and fall seasons (Table 3). Cyprinid species such as *Notropis atherinoides* (Emerald Shiner) and *Notropis edwardraneyi* (Fluvial Shiner) were largely associated with

Table 2. Morisita index values for diel and seasonal comparisons. The index was run for data including and excluding Gulf Menhaden. Index scores below 0.4 are considered as low similarity comparisons, those above 0.6 are judged as highly similar.

		Day vs Night		Summer vs Fall	
Site #		Summer	Fall	Day	Night
19	With menhaden	0.93	0.93	1.00	0.96
	Without menhaden	0.05	0.13	0.25	0.40
16	With menhaden	0.10	1.00	0.06	0.00
	Without menhaden	0.01	0.10	0.63	0.36
8	With menhaden	0.08	0.23	0.98	0.65
	Without menhaden	0.06	0.14	0.03	0.65
13	With menhaden	0.13	0.37	0.05	0.12
	Without menhaden	0.12	0.38	0.05	0.38
10	With menhaden			0.08	
	Without menhaden			0.03	
12	With menhaden			0.56	
	Without menhaden			0.23	
11	With menhaden			0.06	
	Without menhaden			0.30	
7	With menhaden			0.98	
	Without menhaden			0.18	

Table 3. Morisita index values for daytime spring comparisons. The index was run for data including and excluding Gulf Menhaden. Index scores below 0.4 are considered as low similarity comparisons, those above 0.6 are judged as highly similar.

Site #	Spring vs Summer	Spring vs Fall
With Gulf Menhaden		
19	0.001	0.000
168	0.003	0.000
1510	0.084	0.000
Without Gulf Menhaden		
19	0.125	0.051
168	0.003	0.049
1510	0.084	0.309

spring samples (Fig. 2). Centrarchid species such as *Micropterus henshalli* (Alabama Bass), *Micropterus salmoides* (Largemouth Bass), and *Lepomis megalotis* (Longear Sunfish) corresponded to summer sampling (Fig. 2). *Cyprinella venusta* (Blacktail Shiner) showed an association with fall samples.

Overall, fish assemblages differed between day and night on gravel/sand bar habitat, as indicated by low similarity Morisita index values (excluding Gulf Menhaden; Tables 2, Appendix 2). This pattern was true for both summer and fall diel samples (Table 2). Seasonally, sample similarity varied by site, and night samples tended to be more similar in summer and fall (Table 2). Species such as *Ictalurus furcatus* (Blue Catfish) and *Ictalurus punctatus* (Channel Catfish) were detected in great numbers (n = 3479) during nighttime hours and rarely collected during day samples (n = 4) (Appendix 2). Twenty of the 30 Crystal Darters in the samples were collected during nighttime hours. *Hiodon tergisus* (Mooneye; n = 2), *Lepisosteus occulatus* (Spotted Gar; n = 17), and *Lepisosteus osseus* (Longnose Gar; n = 2) were largely collected during nighttime hours in our diel survey (Appendix 2). Riverine minnows such as Fluvial Shiner and *Macrhybopis storeriana* (Silver Chub) were also detected in larger numbers during nighttime hours (Appendix 2). In general, large numbers of Gulf Menhaden had a negative effect on Shannon diversity and evenness indices (Appendix 2).

All five comparisons with historical data indicated low faunal similarity (J < 0.5; Table 4). Current repeated collections at two sites (RM 72 and RM 39.6) resulted in high faunal similarity (J > 0.9; Table 4). Notable changes in species composition in current collections included, in addition to Gulf Menhaden, the presence of Blacktail Shiners in our samples. Fluvial shiners were more abundant in previous collections and have declined. A current comparison to a historic collection by R.D. Suttkus at Alabama River Mile 72 shows notable differences in species detected, especially large

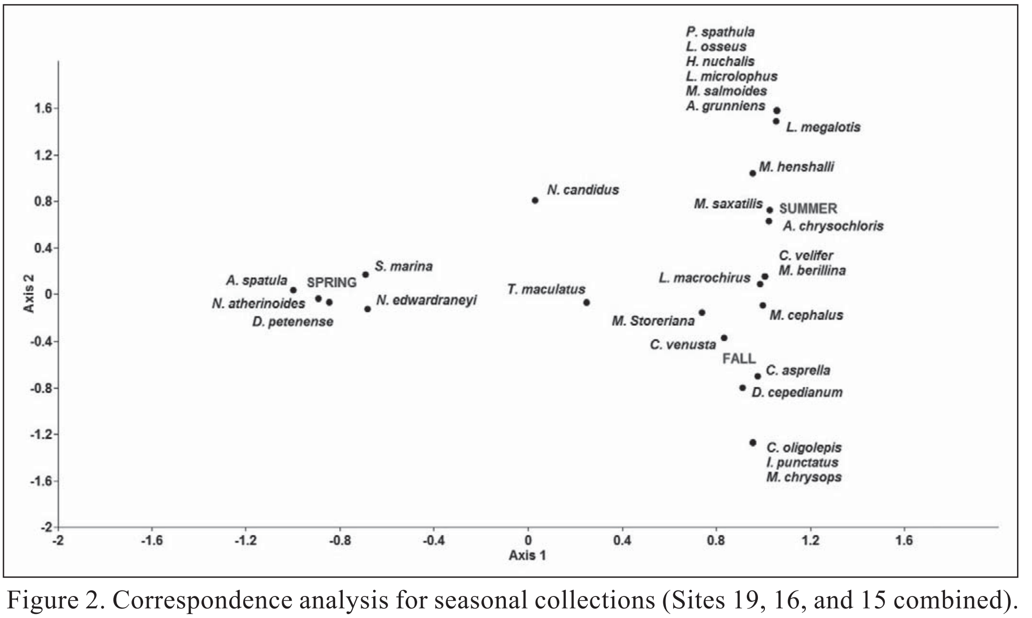

Figure 2. Correspondence analysis for seasonal collections (Sites 19, 16, and 15 combined).

river minnows such as Fluvial Shiner, Silver Chub, and Silverside Shiner. More centrarchid species were also collected in current collections than historic ones.

Fish species richness did not differ by sand/gravel bar size (Fig. 3). There was also no relationship between fish species richness and distance to next sand/gravel bar (Fig. 4).

Discussion

In spite of the limitations with comparisons of current and historical data, some key temporal shifts in fish community structure and diversity were detected, including the reduction of some cyprinid species and the presence of cosmopolitan species in current collections. In addition, seasonal and diel fish assemblage shifts were documented. However, the size and distance between sand/gravel bars seems unrelated to fish assemblage structure. New distributional records of three marine species were also documented (Inland Silverside, Gulf Killifish, and Gulf Menhaden), including large numbers of Gulf Menhaden.

Table 4. Jaccard's index of similarity for current samples vs historical samples from the Alabama River study area from other researchers. GSA = Geological Survey of Alabama and AU = Auburn University (this study).

Site	R.D. Suttkus	GSA	AU	Jaccard's index
Alabama RM 72	July 1968		July 2010	0.23
Alabama RM 66	August 1989		June 2010	0.15
Alabama RM 60		September 1998	July 2010	0.16
Alabama RM 47		September 1998	July 2010	0.33
Alabama RM 33	July 1964		July 2010	0.11

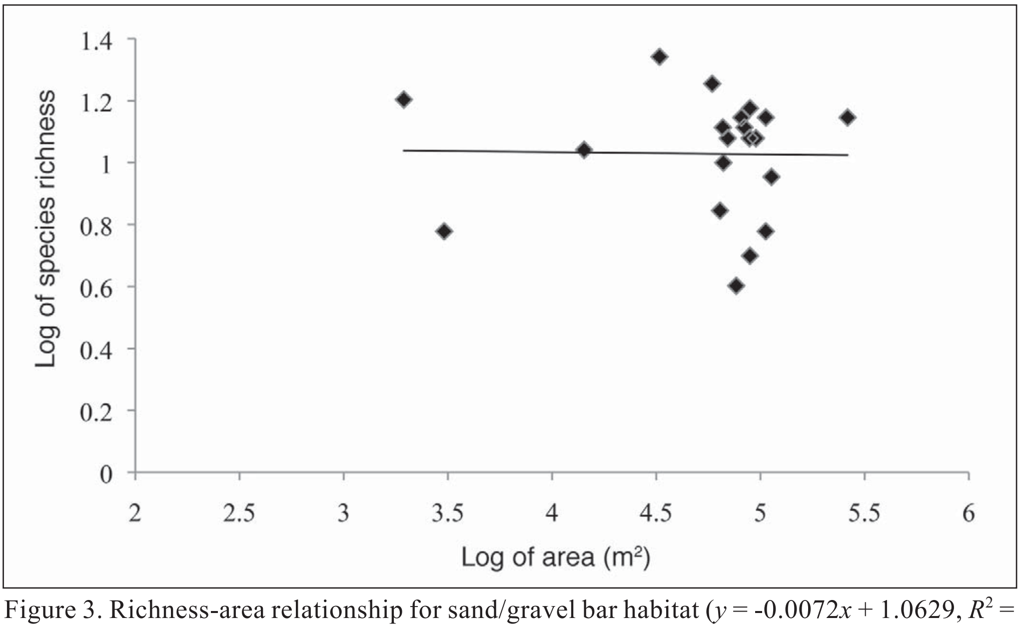

Figure 3. Richness-area relationship for sand/gravel bar habitat (y = -0.0072x + 1.0629, R^2 = 0.00036, P > 0.05).

The data suggest some homogenization of the fish assemblage in the Alabama River below RM 72. Natural habitats have been altered in the Alabama River due to damming and dredging, and many historical sites could not be re-sampled during our study because the gravel/sand bars were no longer present. All comparisons with historical data indicated low faunal similarity, suggesting historic fish assemblage shifts. Rahel (2002) noted that invasion by cosmopolitan species alone can increase homogenization of an assemblage; however, if the invading species causes declines in native fauna, the effect is amplified. Notable changes in species composition, in addition to Gulf Menhaden, include the cosmopolitan Blacktail Shiner. Historically, this species was not detected in the study area. Native cyprinids, such as Fluvial Shiners and *Macrhybopsis* sp. were much more abundant in historical collections, and current collections show increased numbers of centrarchids, a group of cosmopolitan species.

Night samples show high similarity in summer and fall, but when excluding Gulf Menhaden, diel comparisons exhibit very low similarity. Dissimilarity between diel samples is likely due to high numbers of ictalurid species collected during nighttime hours. These findings are similar to those of Roach and Winemiller (2011), who studied diel changeover of fish assemblages on sandbanks of the Brazos River, TX. Roach and Winemiller (2011) found diel changeover was mostly due to ictalurids and palaemonids. The authors suggested that these species were moving onto the sandbanks during nighttime hours to forage, but retreated in diurnal hours to more complex habitats to avoid predation.

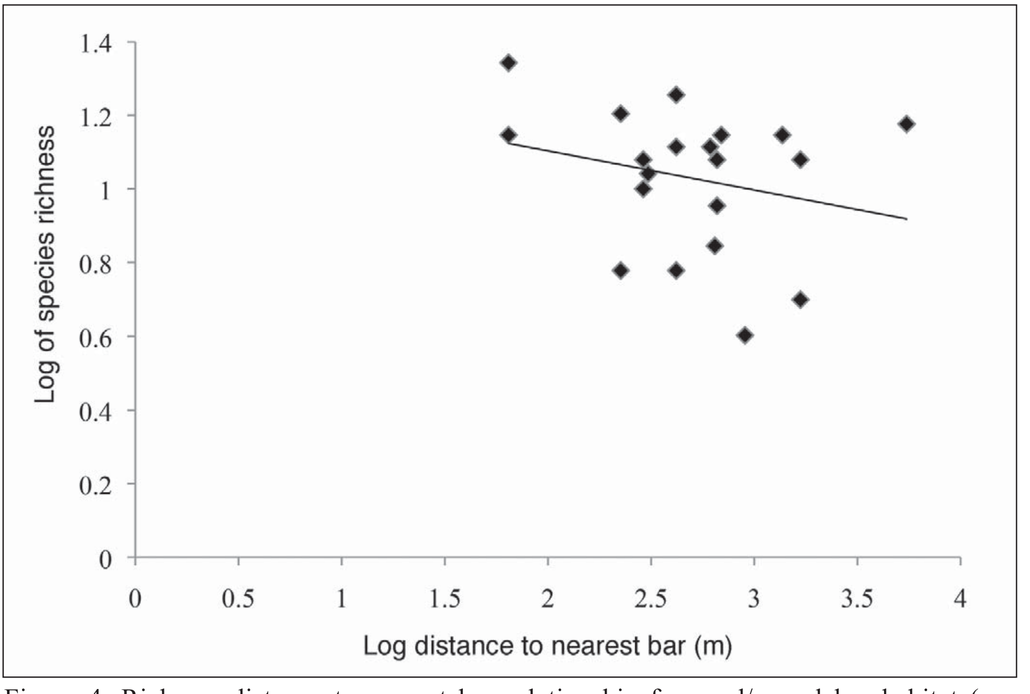

Figure 4. Richness-distance to nearest bar relationship for sand/gravel bar habitat ($y = -0.1063x + 1.3158$, $R^2 = 0.06191$, $P > 0.05$).

Diel turnover is often conceptualized as a form of resource partitioning, when species exploit the same resources but use them at different times of the day (Roach and Winemiller 2011). Predatory species are often more efficient in higher water temperatures and increased water transparency; consequently, lower water temperatures at night lead to many species foraging at night when darkness serves as a refugium (Gelos et al. 2010). Changes in water transparency and ambient light concentrations at twilight and dawn trigger changeover in fish-assemblage structure (Arrington and Winemiller 2003, Gelos et al. 2010). In our study, cyprinid species (Silver Chub, Emerald Shiner, Silverside Shiner, and Fluvial Shiner) were more abundant in night collections. These species could be utilizing sand/gravel bar habitats during nighttime hours to avoid predators such as centrarchids. Contrarily, low transparency may also favor predators that use olfactory and tactile organs to locate prey (Gelos et al. 2010, Roach and Winemiller 2011). Most gar species in our study were collected during nighttime hours, which may reflect this type of resource partitioning.

Fish assemblages varied seasonally. Some species were detected in greater numbers during fall samples, such as Gulf Menhaden and Crystal Darters, which could be due to low water levels. Cyprinid species were most abundant in spring collections and may correspond to increased water levels and lower water temperatures. However, Ostrand and Wilde (2002) found that fish assemblage structure in the upper Brazos River, TX, was influenced more by average environmental conditions of a particular site than seasonal changes overall.

It is not uncommon to find marine species in the Alabama River as far north as Claiborne Lock and Dam (river mile 72.0), including species such as *Trinectes maculatus* (Hogchoker), *Paralichthys lethostigma* Jordan and Gilbert (Southern Flounder), *Mugil cephalus* (Striped Mullet), and *Strongylura marina* (Atlantic Needlefish) (Boschung and Mayden 2004). Inland Silversides were collected throughout the study area, but most were collected below Claiborne Lock and Dam at Site 1 (RM 72). One Gulf Killifish was also collected at Site 1. Large numbers of Gulf Menhaden were collected during this study, and are a new distributional record for the study area (Haley et al. 2010). The exceptionally large numbers of this species affected assemblage eveness.

Gulf Menhaden is a marine species common to central areas of the Gulf of Mexico (Hoese and Moore 1977, McEachran and Fechhelm 1998). It is a schooling species and forms large clusters near the surface supporting purse seine fisheries throughout the Gulf of Mexico. The Gulf Menhaden fishery is one of the largest by weight and most valuable in the United States (Christmas et al. 1982, Ross 2001, Vaughan et al. 2000). This commercially important species is tolerant of a wide range of salinities, and can be found from offshore areas of the Gulf of Mexico to the lower reaches of major gulf drainages, including the Tombigbee River and Tensaw Delta (Boschung and Mayden 2004, Lassuy 1983, Mettee et al. 1996, Ross 2001). Typically, spawning takes place in the open waters of the Gulf of Mexico in spring and fall (Ahrenholz 1991). Gulf Menhaden produce pelagic eggs, which hatch into larvae after approximately five days (Raynie and Shaw 1994). Larvae are then carried via currents to inshore marshes where they undergo periods of growth and metamorphosis until they are of juvenile age. As larvae, menhaden selectively consume zooplankton and phytoplankton, and then transition to non-selective filter feeders as adults (Ross 2001). Late-stage larvae and early-stage juveniles spend a variable amount of time in estuarine habitats before migrating offshore into open-ocean habitats (Ahrenholz 1991, Deegan 1990, Lassuy 1983).

Due to their life history, the presence of Gulf Menhaden as far as Alabama River Mile 72 is very unusual. Mettee et al. (1996) recommended sampling for this species in the lower Alabama River during late summer and times of "saltwater intrusion", believing that they might enter these habitats if salinity was high. Although it is noted that the time spent in estuarine habitats is variable for this species, and they often move to nearby areas of lower salinity as growth occurs, we would expect these individuals to migrate back to open sea by fall (Deegan 1990, Fore and Baxter 1972, Raynie and Shaw 1995). Also, the presence of larval individuals may be an indication that Gulf Menhaden spawned in the Alabama River. From 17–24 mm SL, Gulf Menhaden are considered to be larval and rely on offshore currents to carry them to estuarine/marsh habitats (Christmas et al. 1982, Raynie and Shaw 1994, Ross 2001, Vaughan et al. 2000), so it seems unlikely that they migrated upstream into the Alabama River.

Conclusion

In conclusion, a total of 48 species were collected in our Alabama River survey, including unique distributional records such as Gulf Menhaden. The presence of such large numbers of planktivoruos fish in the Alabama River ecosystem is intriguing. A concern is their possible impact on other native clupeid fishes, including the rare Alabama Shad, as well as their effect on the food web. Future work monitoring their persistence and abundance in the Alabama River is important for assessing any impacts they may have on the ecosystem and its native fishes. Results of this study indicate changes in native cyprinid abundance and presence of Blacktail Shiner, and an increase in centrarchids. Diel turnover was observed on sand/gravel bar habitats. Most notable were the large numbers of Blue Catfish and Channel Catfish present during nighttime samples. Species corresponded seasonally and were variable by site.

Ongoing habitat alteration, such as dredging, may have tremendous impacts on the native fauna in the Alabama River. Fish assemblages in our study area are becoming homogenized with potential loss of biodiversity. It is recommended that ongoing monitoring of fish assemblages in the Alabama River downstream of RM 72 be conducted to detect further changes in the fish assemblage. Diel and seasonal sampling is recommended, when possible, to effectively document fish assemblages occupying these sand/gravel bars.

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Appendix 1. Collection locality information for all sites sampled. Collection records include day/night collection, season, GPS of collection site, river mile, site description, date, ambient temperature, and approximate sampling time. Site numbers correspond to Figure 1.

Site	Day/ night	Season	Latitude (°)	Longitude (°)	River Mi.	Site Description	(°C)	Date	Gear used	Begin time	End time
19	Day	Summer	31.606766	87.550967	72.0	Downstream of Claiborne Dam	30.0	6/28/10	50' seine	8:25 AM	9:25 AM
19a	Day	Summer	31.608425	87.551257	72.1	Downstream of Claiborne Dam	32.0	7/8/10	100' seine	9:47 AM	10:50 AM
19b	Night	Summer	31.607965	87.551087	72.0	Downstream of Claiborne Dam	31.2	7/27/10	100' seine	10:15 PM	12:33 AM
19c	Night	Fall	31.607564	87.550947	72.0	Downstream of Claiborne Dam	23.1	10/14/10	100' seine	10:30 PM	12:00 AM
19d	Day	Fall	31.608583	87.550989	72.0	Downstream of Claiborne Dam	24.0	10/15/10	100' seine	1:00 PM	2:20 PM
18	Day	Summer	31.567631	87.513743	68.3	Downstream of paper plant	31.3	6/28/10	100' seine	9:47 AM	10:20 AM
18a	Day	Summer	31.567598	87.513762	68.3	Downstream of paper plant	31.0	7/8/10	30' seine	11:24 AM	12:21 PM
17	Day	Summer	31.549879	87.516141	66.9	Upstream of Hwy 84 bridge	33.0	7/8/10	30' seine	12:45 PM	1:05 PM
17a	Day	Summer	31.547998	87.517645	66.7	At Hwy 84 bridge	33.0	7/8/10	30' seine	1:15 PM	1:45 PM
16	Day	Summer	31.523702	87.610241	60.0	Across from Pigeon Creek	32.0	7/8/10	100' seine	2:06 PM	3:15 PM
16a	Night	Summer	31.523725	87.610925	60.0	Across from Pigeon Creek	31.0	8/2/10	100' seine	10:30 PM	11:45 PM
16b	Nght	Fall	31.523681	87.610989	60.0	Across from Pigeon Creek	23.0	10/14/10	100' seine	8:00 PM	9:26 PM
16c	Day	Fall	31.523841	87.610255	60.0	Across from Pigeon Creek	24.0	10/15/10	100' seine	10:55 AM	12:25 PM
15	Day	Summer	31.508194	87.615469	58.3	Mrs. Grey's Bar right bank (downstream)	32.0	7/8/10	100' seine	3:55 PM	4:55 PM
15a	Day	Fall	31.508480	87.615571	58.3	Mrs. Grey's Bar right bank (downstream)	23.3	10/14/10	100' seine	5:30 PM	6:40 PM
14	Day	Summer	31.382167	87.717499	40.3	Across from Euryka Landing	31.5	7/9/10	100' seine	8:20 AM	9:13 AM
13	Day	Summer	31.371523	87.725739	39.3	Downstream and across from Irvin Creek	31.7	7/9/10	50' seine	9:20 AM	10:15 AM
13a	Night	Summer	31.369525	87.726053	39.2	downstream and across from Irvin Creek	30.6	8/10/10	50' seine	12:05 AM	1:46 AM
13b	Day	Summer	31.369839	87.726100	39.2	Downstream and across from Irvin Creek	32.5	8/10/10	50' seine	11:45 AM	12:16 PM
13c	Night	Fall	31.370694	87.726122	39.2	Downstream and across from Irvin Creek	22.5	10/15/10	50' seine	7:20 PM	8:45 PM
13d	Day	Fall	31.370718	87.726146	39.2	Downstream and across from Irvin Creek	22.1	10/16/10	50' seine	11:16 AM	12:15 PM
12	Day	Summer	31.336299	87.751640	35.4	Choctaw Bluff	33.4	7/9/10	100' seine	10:36 AM	11:20 AM

Site	Day/ night	Season	Latitude (°)	Longitude (°)	River Mi.	Site Description	(°C)	Date	Gear used	Begin time	End time
12a	Day	Fall	31.336819	87.752356	35.4	Upstream of Choctaw Bluff	24.0	10/15/10	100' seine	4:45 PM	6:25 PM
11	Day	Summer	31.363272	87.756877	33.3	Choctaw Bluff (east bank)	36.5	7/9/10	100' seine	12:00 PM	12:36 PM
11a	Day	Fall	31.363176	87.755872	33.3	Choctaw Bluff (east bank)	26.2	10/16/10	100' seine	12:55 PM	1:45 PM
10	Day	Summer	31.414326	87.627276	47.0	Shackleford Bar and English Landing	31.5	7/26/10	30' seine	10:50 AM	12:20 PM
10a	Day	Summer	31.416228	87.630366	47.0	Shackleford Bar and English Landing	31.5	7/26/110	50' seine	10:50 AM	12:20 PM
9	Day	Summer	31.424393	87.640235	46.4	Frenchs Landing and English Landing	31.0	7/26/10	50' seine	9:00 AM	10:30 AM
8	Day	Summer	31.377482	87.721757	39.6	Upstream of Irvin Creek	34.5	7/26/110	100' seine	1:52 PM	3:20 PM
8a	Night	Summer	31.380454	87.718138	39.6	Upstream of Irvin Creek	31.5	8/9/10	100' seine	8:45 PM	11:55 PM
8b	Day	Summer	31.380648	87.717944	39.6	Upstream of Irvin Creek	33.5	8/10/10	100' seine	10:30 AM	11:28 AM
8c	Night	Fall	31.379762	87.718719	39.6	Upstream of Irvin Creek	21.2	10/15/10	100' seine	9:00 PM	10:15 PM
8d	Day	Fall	31.379856	87.718624	39.6	Upstream of Irvin Creek	22.8	10/16/10	100' seine	10:00 AM	11:15 AM
7	Day	Summer	31.340333	87.772578	31.6	Sandbar (Island) ≈1.3 mi below Choctaw Bluff	31.4	7/27/10	50' seine	8:49 AM	9:55 AM
7a	Day	Fall	31.339600	87.77209	31.6	Sandbar (Island) ≈1.3 mi below Choctaw Bluff	26.1	10/16/10	100' seine	2:00 PM	3:05 PM
6	Day	Summer	31.327761	87.784254	29.9	0.8 mi downstream from Matthewsons Bar	31.6	7/27/10	100' seine	10:01 AM	11:12 AM
5	Day	Summer	31.303009	87.775094	28.4	Dixie Landing	33.0	7/27/10	100' seine	12:00 PM	1:15 PM
4	Day	Summer	31.297774	87.785475	26.3	Dixie Cutoff and Monroe Point	32.5	7/27/10	100' seine	1:30 PM	3:30 PM
3	Day	Summer	31.295258	87.795414	25.5	Downstream of Monroe Point	34.5	8/2/10	100' seine	10:47 AM	12:24 PM
2	Day	Summer	31.276208	87.784050	24.0	Alabama River Sandbar	33.5	8/2/10	50' seine	1:00 PM	1:45 PM
1	Day	Summer	31.268720	87.802023	22.9	Earl Bar	33.5	8/2/10	50' seine	2:05 PM	2:20 PM

Appendix 2. Diel and seasonal collection data for selected sites. Site numbers correspond with Appendix 1 and Figure 1.

	Site 19 (31.606766°, 87.550967°)					Site 16 (31.523725°, 87.610925°)				
	Spring	Summer		Fall		Spring	Summer		Fall	
Species	Day	Day	Night	Day	Night	Day	Day	Night	Day	Night
Polyodon spathula (Walbaum) (Paddlefish)							1			
Atractosteus spatula (Lacepède) (Alligator Gar)	1									
Lepisosteus oculatus Winchell (Spotted Gar)			13					1		2
Lepisosteus osseus (L.) (Longnose Gar)		1			1					
Hiodon tergisus Lesueur (Mooneye)					1			1		
Anchoa mitchilli (Valenciennes) (Bay Anchovy)					2					9
Alosa chrysochloris (Rafinesque) (Skipjack Herring)		2	15	2	4		1			1
Brevoortia patronus Goode (Gulf Menhaden)		4042	8159	18,590	495		4	1	144,464	29,934
Dorosoma cepedianum (Lesueur) (Gizzard Shad)		2	25	25	15	1	4	8	29	15
Dorosoma petenense (Günther) (Threadfin Shad)	83		2593	6	41	23		6	3	3
Campostoma oligolepis Hubbs and Greene (Largescale Stoneroller)										1
Cyprinella venusta Girard (Blacktail Shiner)		9	2	106	1	1	8	1	2	3
Hybognathus nuchalis Agassiz (Mississippi Silvery Minnow)							3			
Macrhrybopsis aestivalis (Girard) (Speckled Chub)										
Macrhrybopsis storeriana (Kirtland) (Silver Chub)		13	112		7	1		47		19
Notropis atherinoides Rafinesque (Emerald Shiner)				8	2	167			2	8
Notropis candidus Suttkus (Silverside Shiner)		30	119		13	2		109		6
Notropis edwardraneyi Suttkus and Clemmer (Fluvial Shiner)	9	1		5	38	14				84
Notropis uranoscopus Suttkus (Skygazer Shiner)										
Pimephales vigilax Baird and Girard (Bullhead Minnow)										
Carpiodes cyprinus (Lesueur) (Quillback)										
Carpiodes velifer (Rafinesque) (Highfin Carpsucker)				2			2	1		1
Moxostoma poecilurum Jordan (Blacktail Redhorse)					1			1		
Ictalurus furcatus (Lesueur) (Blue Catfish)			88		16			2		
Ictalurus punctatus (Rafinesque) (Channel Catfish)			37		41			256		31

Species	Site 19					Site 16				
	Spring	Summer		Fall		Spring	Summer		Fall	
	Day	Day	Night	Day	Night	Day	Day	Night	Day	Night
Pylodictis olivaris (Rafinesque) (Flathead Catfish)					1					
Mugil cephalus L. (Striped Mullet)		4	1	10	3		8	2	2	2
Menidia beryllina (Cope) (Inland Silverside)			1	1			1			
Strongylura marina (Walbaum) (Atlantic Needlefish)	73	8	9	1			2			
Gambusia affinis (Baird and Girard) (Western Mosquitofish)								1		
Gambusia holbrooki Girard (Eastern Mosquitofish)										2
Morone chrysops (Rafinesque) (White Bass)			33	2	11					2
Morone chrysops x *saxatilis*					2					
Morone mississippiensis Jordan and Eigenmann (Yellow Bass)			2							
Morone saxatilis (Walbaum) (Striped Bass)		7	104	1	20			22		10
Morone sp. (hybrid)			1							
Lepomis macrochirus Rafinesque (Bluegill)	1	8		9	2		32	13	42	1
Lepomis megalotis (Rafinesque) (Longear Sunfish)		7		1	1		19	1		
Lepomis microlophus (Günther) (Redear Sunfish)							1			
Micropterus henshalli Hubbs and Bailey (Alabama Bass)						1	12	2	2	
Micropterus salmoides (Lacepède) (Largemouth Bass)		4					1			
Pomoxis annularis Rafinesque (White Crappie)										
Pomoxis nigromaculatus (Lesueur) (Black Crappie)			1		1			3		
Ammocrypta beani Jordan (Naked Sand Darter)										
Crystallaria asprella (Jordan) (Crystal Darter)			1	7	6		1		1	2
Percina kathae Thompson (Mobile Logperch)										
Aplodinotus grunniens Rafinesque (Freshwater Drum)							3	66		2
Trinectes maculatus (Blotch and Schneider) (Hogchoker)		1		3	42	1	1	3		1
Species richness	5	15	13	12	17	9	21	21	9	22
Shannon diversity	0.92	0.16	1.82	2.16	2.22	0.77	2.44	1.68	0.00	2.21
Evenness	0.50	0.07	0.47	0.72	0.54	0.24	0.54	0.25	0.11	0.41

Species	Site 15 (31.50848°, 87.615571°) Spring Day	Site 15 Summer Day	Site 15 Fall Day	Site 8 (31.370718°, 87.726146°) Summer Day	Site 8 Summer Night	Site 8 Fall Day	Site 8 Fall Night
Polyodon spathula (Paddlefish)							
Atractosteus spatula (Alligator Gar)							
Lepisosteus oculatus (Spotted Gar)					1		
Lepisosteus osseus (Longnose Gar)					1		
Hiodon tergisus (Mooneye)							
Anchoa mitchilli (Bay Anchovy)					1		
Alosa chrysochloris (Skipjack Herring)		1					
Brevoortia patronus (Gulf Menhaden)			109,052	4328	65	420	72
Dorosoma cepedianum (Gizzard Shad)	1	4		6	35		1
Dorosoma petenense (Threadfin Shad)				643	50		1
Campostoma oligolepis (Largescale Stoneroller)			1				
Cyprinella venusta (Blacktail Shiner)	15	41	25	17	10	63	
Hybognathus nuchalis (Mississippi Silvery Minnow)				1			
Macrhrybopsis aestivalis (Speckled Chub)							1
Macrhrybopsis storeriana (Silver Chub)	4		21		82	10	150
Notropis atherinoides (Emerald Shiner)	162		9			5	14
Notropis candidus (Silverside Shiner)	28				177		39
Notropis edwardraneyi (Fluvial Shiner)	23		3	1			20
Notropis uranoscopus (Skygazer Shiner)	1						
Pimephales vigilax (Bullhead Minnow)					4		1
Carpiodes cyprinus (Quillback)							1
Carpiodes velifer (Highfin Carpsucker)				21	24	13	72
Moxostoma poecilurum (Blacktail Redhorse)							
Ictalurus furcatus (Blue Catfish)					520		21
Ictalurus punctatus (Channel Catfish)			1		469		200
Pylodictis olivaris (Flathead Catfish)					1		

	Site 15			Site 8			
				Summer		Fall	
Species	Spring Day	Summer Day	Fall Day	Day	Night	Day	Night
Mugil cephalus (Striped Mullet)			5				
Menidia beryllina (Inland Silverside)							
Strongylura marina (Atlantic Needlefish)			2		1		
Gambusia holbrooki (Eastern Mosquitofish)							
Morone chrysops (White Bass)							
Morone chrysops x *saxatilis*							
Morone mississippiensis (Yellow Bass)							
Morone saxatilis (Striped Bass)			2		9		10
Morone sp. (hybrid)							
Lepomis macrochirus (Bluegill)		12	6	10	68		
Lepomis megalotis (Longear Sunfish)		4		1			
Lepomis microlophus (Redear Sunfish)							
Micropterus henshalli Hubbs and Bailey (Alabama Bass)		7	2	5	4		3
Micropterus salmoides (Lacepède) (Largemouth Bass)				1			
Pomoxis annularis (White Crappie)				1			
Pomoxis nigromaculatus (Black Crappie)					2		
Ammocrypta beani (Naked Sand Darter)					5		
Crystallaria asprella (Crystal Darter)		1					
Percina kathae (Mobile Logperch)					2	1	9
Aplodinotus grunniens (Freshwater Drum)				1	34		3
Trinectes maculatus (Hogchoker)	2			4	22		3
Species richness	8	7	12	13	23	6	19
Shannon diversity	1.05	1.29	0.00	0.47	1.93	0.64	1.95
Evenness	0.35	0.52	0.08	0.12	0.30	0.31	0.37

Species	Site 13 (31.380454°, 87.718138°) Summer Day	Site 13 Summer Night	Site 13 Fall Day	Site 13 Fall Night	Site 12 (31.336299°, 87.75164°) Summer Day	Site 12 Fall Day
Polyodon spathula (Paddlefish)						
Atractosteus spatula (Alligator Gar)						
Lepisosteus oculatus (Spotted Gar)						
Lepisosteus osseus (Longnose Gar)						
Hiodon tergisus (Mooneye)						
Anchoa mitchilli (Bay Anchovy)	3	30	322	286		152
Alosa chrysochloris (Skipjack Herring)						
Brevoortia patronus (Gulf Menhaden)	2	178	3	36	14	14,067
Dorosoma cepedianum (Gizzard Shad)	6	6	1		1	6
Dorosoma petenense (Threadfin Shad)	65	59				
Campostoma oligolepis (Largescale Stoneroller)						
Cyprinella venusta (Blacktail Shiner)		21	7	20	7	7
Hybognathus nuchalis (Mississippi Silvery Minnow)						
Macrhrybopsis aestivalis (Speckled Chub)						
Macrhrybopsis storeriana (Silver Chub)	66	98	7	30	1	22
Notropis atherinoides (Emerald Shiner)	31	96	19	8		2
Notropis candidus (Silverside Shiner)		16	50	162		21
Notropis edwardraneyi (Fluvial Shiner)		1	7			50
Notropis uranoscopus (Skygazer Shiner)						
Pimephales vigilax (Bullhead Minnow)		1	1	12		
Carpiodes cyprinus (Quillback)		1				
Carpiodes velifer (Highfin Carpsucker)	28	3		5	8	46
Moxostoma poecilurum (Blacktail Redhorse)						
Ictalurus furcatus (Blue Catfish)	1	942		1		
Ictalurus punctatus (Channel Catfish)		102	3	753		10
Mugil cephalus (Striped Mullet)						1

	Site 13				Site 12	
	Summer		Fall		Summer	Fall
Species	Day	Night	Day	Night	Day	Day
Menidia beryllina (Inland Silverside)				1	1	
Strongylura marina(Atlantic Needlefish)					3	
Gambusia affinis (Western Mosquitofish)						
Gambusia holbrooki (Eastern Mosquitofish)						
Morone chrysops (White Bass)				2		4
Morone chrysops x *saxatilis*						
Morone mississippiensis (Yellow Bass)						
Morone saxatilis (Striped Bass)	1	4			1	8
Morone sp. (hybrid)						
Lepomis macrochirus (Bluegill)	1	1			3	2
Lepomis megalotis (Longear Sunfish)						1
Lepomis microlophus (Redear Sunfish)						
Micropterus henshalli (Alabama Bass)		1	1		1	
Micropterus salmoides (Largemouth Bass)	1	1			3	
Pomoxis annularis (White Crappie)						
Pomoxis nigromaculatus (Black Crappie)				1		1
Ammocrypta beani (Naked Sand Darter)						
Crystallaria asprella (Crystal Darter)						
Percina kathae (Mobile Logperch)						
Aplodinotus grunniens (Freshwater Drum)		4	1			
Trinectes maculatus (Hogchoker)	2	2	4	40	1	188
Species richness	12	20	13	14	12	17
Shannon diversity	1.64	1.48	0.97	1.37	2.03	0.21
Evenness	0.42	0.21	0.20	0.28	0.63	0.07

Species	Site 11 (31.363176°, 87.755872°) Summer Day	Site 11 (31.363176°, 87.755872°) Fall Day	Site 7 (31.3396°, 87.77209°) Summer Day	Site 7 (31.3396°, 87.77209°) Fall Day
Polyodon spathula (Paddlefish)				
Atractosteus spatula (Alligator Gar)				
Lepisosteus oculatus (Spotted Gar)				
Lepisosteus osseus (Longnose Gar)				
Hiodon tergisus (Mooneye)				
Anchoa mitchilli (Bay Anchovy)				
Alosa chrysochloris		2	3	
(Skipjack Herring)			6	
Dorosoma cepedianum (Gizzard Shad)		690	808	2474
Dorosoma petenense (Threadfin Shad)	4	6		6
Campostoma oligolepis (Largescale Stoneroller)			87	
Cyprinella venusta (Blacktail Shiner)				
Hybognathus nuchalis (Mississippi Silvery Minnow)	2	43	37	30
Macrhrybopsis aestivalis (Speckled Chub)				
Macrhrybopsis storeriana (Silver Chub)				
Notropis atherinoides (Emerald Shiner)		58	9	166
Notropis candidus (Silverside Shiner)		7	31	3
Notropis edwardraneyi (Fluvial Shiner)			1	
Notropis uranoscopus (Skygazer Shiner)			3	4
Pimephales vigilax (Bullhead Minnow)				
Carpiodes cyprinus (Quillback)				
Carpiodes velifer (Highfin Carpsucker)				
Moxostoma poecilurum (Blacktail Redhorse)	1	130	13	362
Ictalurus furcatus (Blue Catfish)				
Ictalurus punctatus (Channel Catfish)				1
Pylodictis olivaris (Flathead Catfish)				
Mugil cephalus (Striped Mullet)				

	Site 11		Site 7	
Species	Summer Day	Fall Day	Summer Day	Fall Day
Menidia beryllina (Inland Silverside)				
Strongylura marina (Atlantic Needlefish)				
Gambusia affinis (Western Mosquitofish)				
Gambusia holbrooki (Eastern Mosquitofish)			1	1
Morone chrysops (White Bass)				
Morone chrysops x *saxatilis*				
Morone mississippiensis (Yellow Bass)				
Morone saxatilis (Striped Bass)				
Morone sp. (hybrid)				
Lepomis macrochirus (Bluegill)		1		1
Lepomis megalotis (Longear Sunfish)				
Lepomis microlophus (Redear Sunfish)	4	1		
Micropterus henshalli (Alabama Bass)				2
Micropterus salmoides (Largemouth Bass)				
Pomoxis annularis (White Crappie)	1	2	3	
Pomoxis nigromaculatus (Black Crappie)				
Ammocrypta beani (Naked Sand Darter)				
Crystallaria asprella (Crystal Darter)				
Percina kathae (Mobile Logperch)				
Aplodinotus grunniens (Freshwater Drum)				
Trinectes maculatus (Hogchoker)				
Species richness	5	12	12	13
Shannon diversity	1.44	0.99	0.81	0.71
Evenness	0.84	0.22	0.18	0.15