Persistence of fish assemblages on sand and gravel bar habitat in the Alabama River, Alabama

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
May 7, 2012

Keywords: Fish Assemblage, Gulf Menhaden, Temporal Variability, Invasions

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Abstract

The Alabama River is a biologically diverse system containing over 180 native fishes and at least 33 endemics. Many studies have surveyed species of conservation concern, such as the federally endangered Alabama Sturgeon (*Scaphirhynchus suttkusi)*, Alabama Shad *(Alosa alabamae*), and Crystal Darter (*Crystallaria asprella*), but few have documented entire fish assemblages. Maintaining fish assemblage data is an important process in monitoring species and assemblage composition through time. In this study, I surveyed fish assemblages of sandbar habitat in the lower Alabama River and 9 associated tributaries. Diel and seasonal surveys were conducted along 19 sandbars from Dixie Landing (river mile 22) to Claiborne Lock and Dam (river mile 72). A total of 55 species were recorded in 44 collections during summer, fall, and spring 2010 – 2011. One species of conservation concern, Crystal Darter, was detected during our survey (n = 34). Fish assemblages in tributaries contained percid and cyprinid species not detected in our sandbar collections and clupeid species detected in sandbar samples were absent from tributary collections. Similarity indices were used to compare our data with historical data. Our samples had low similarity to historical samples of R. D. Suttkus and the Geological Survey of Alabama, suggesting fish assemblage shifts. Diel comparisons 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. In 2010, we detected extremely high numbers of Gulf Menhaden (*Brevoortia patronus*) during summer and fall indicating a new distributional record. Gulf Menhaden were collected during summer and fall 2010 collections. However, no Gulf Menhaden were detected during spring 2011 samples. Finally, sandbar area varied from 0.75 - 64.7 acres. Correlation analyses indicate no significant relationship between sandbar proximity or area and species richness, however we suggest ongoing anthropogenic disturbances such as dredging may affect richness among these sites. Data presented in this study suggest temporal shifts in fish assemblage structure. Ongoing habitat alteration on the Alabama River is leading to assemblage homogenization and potential loss of biodiversity. Future monitoring of fish assemblages and their habitats in the Alabama River, downstream of RM 72, is useful and managers and biologists should consider diel and seasonal sampling to accurately document fish species and assemblages.

Acknowledgments

I would first like to thank my advisor, Dr. Carol Johnston, for believing that I could succeed as a graduate student and giving me this opportunity. Her support, guidance, and patience have been invaluable to me. I would also like to thank my committee members, Dr. DeVries, Dr. Hermann, and Mr. Steven Rider for their helpful insight throughout this study. I extend special thanks to Mr. Steve Rider and Mr. Travis Powell for investing their time and resources in me and this project. Without their assistance, much of my field work would not have been possible. Thanks to Jeff Powell for support and funding from the USFWS. I am extremely appreciative of Katie Dowling, Kasie Goodson, and Kyle Bolton for their assistance in the field and sorting fish in the lab. I am tremendously grateful of Dan Holt for his friendship and encouragement during my time in the Fish Biodiversity Lab. Lastly, I am tremendously grateful for my parents, Tim and Annette, my sister Heather, and Amy Rutherford for their love and support during my time as a Graduate Student.

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GSA	Geological Survey of Alabama
SL	Standard Length
RM	River Mile

INTRODUCTION

Anthropogenic changes to aquatic environments often result in alteration of species assemblages causing a decline in biodiversity (Ganasan and Hughes 1998, Poff et al. 2007; Strayer and Dudgeon 2010). In the past, insufficient consideration was given to the biological aspects of aquatic systems after anthropogenic changes were applied. This lack of consideration of the impact of anthropogenic changes is one of the most prominent causes of the recent declines observed in our aquatic systems (Ganasan and Hughes 1998).

Because of our heavy reliance on freshwater for water supply, transportation, agriculture, and recreation, riverine systems are often dammed and channelized, which threatens the integrity of the system (Taylor et al. 2008). Overexploitation of commercial species, water pollution, flow modification, habitat degradation, and invasion of exotic species are major threats now facing freshwater aquatic ecosystems due to anthropogenic actions (Dudgeon et al. 2005). Alteration of spatial variability among habitat patches, which can also be affected by human actions, is another concern for our freshwater aquatic systems. Current research indicates that each of these factors should be addressed when considering the stability of fish assemblages in a freshwater ecosystem.

Aarts et al. (2004) noted that fish species that take advantage of similar habitat formations can be grouped into a functional assemblage. Through monitoring efforts, information on fish assemblages can be collected, including data about the habitat and surrounding ecosystem. These assemblages can serve as indicators of ecological health among riverine and stream ecosystems (Ganasan and Hughes 1998, Aarts et al. 2004).

Fish studies are often focused on single species, but monitoring diversity within entire assemblages can provide information on the status of the ecosystem (Johnston and

Maceina 2009).   Ganason and Hughes (1998) describe seven reasons why fish assemblages are important: "They (i) indicate the cumulative effects of multiple types of anthropogenic disturbances; (ii) integrate the effects of complex and varied stressors on their prey; (iii) provide a relatively long-term record of environmental stress; (iv) integrate broad-scale habitat conditions; (v) are information about their environments, and (vii) are of great interest to persons concerned about losses in biological diversity." In their study, Ganasan and Hughes (1998) used fish assemblage data to develop an index of biological integrity and measure the effects of industrial effluents on the ecosystem. Likewise, there are many, often human-induced, disturbances in addition to industrial effluents that affect these fish communities and the habitats they depend on. These factors include damming, flow modification, and spatial and temporal variability.

Hydrology is the fundamental determinat of both the structure and function of riverine ecosystems (Rypel et al. 2009). Hydrology is most influenced by the construction of dams (Greathouse et al. 2006, Poff et al. 2007). According to Poff et al. (2007), the construction of dams results in the both fragmentation of aquatic habitats and alteration of the natural flow regime, which poses significant threats to native aquatic fauna.

Damming of rivers isolates fish assemblages to fragmented habitats both below and above dams which leaves the assemblages vulnerable to habitat degradation and changes in water quality (Taylor et al. 2008). These isolation events may also have tremendous effects on fluvial fauna that use both upstream and downstream areas as spawning sites (Kondolf and Wolman 1993). Several fish species, such as anadromous and catadromous fishes, use entire aquatic systems from small springs to estuaries throughout their life cycles. Longitudinal connectivity is therefore vital to the long term survival of these species (Freeman et al. 2007). Additionally, some species depend on the preservation of lateral connectivity between the river channel and the floodplain. Many of these species depend on floodplain habitat for spawning areas and long duration flood pulses to ensure limited interruptions to access to these areas (Bunn and Arthington 2002, Freeman et al. 2007).

In addition, damming results in the congestion of sediment flow throughout the lotic system (Kondolf 1997). Most riverine systems transport sediment loads to depositional areas near the sea; however, the construction of dams blocks this movement of sediment (Kondolf 1997). As a result of dam construction, homogenization of aquatic habitat downstream of the structure may occur due to the deposition of sediment which often changes the particle size of the riverbed (Kondolf 1997).

Poff et al. (2007) state that the function of riverine ecosystems and the evolutionary adaptations of riverine biota are strongly driven by dynamic natural disturbance regimes. Dammed rivers, however, are slowly moving away from these natural disturbance regimes due to currently used practices involving predetermined and predictable flow regimes (Poff and Allen 1995; Poff et al. 2007). This can result in physical habitat homogeneity over time. Undammed rivers do not show this trend toward habitat homogeneity. On the contrary, they maintain a broad spectrum of flow regimes which vary across geographic regions (Poff et al. 2007). This results in a largely heterogeneous aquatic environment which has been shown to promote healthy fluvial fish assemblages (Poff and Allen 1995).

Damming of riverine ecosystems has been found to significantly alter natural flow regimes, negatively impacting the native species assemblages (Ward and Stanford 1983, Freeman et al. 2001, Bunn and Arthington 2002). 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.

Travnichek et al. (1995) compared fish assemblage composition in the Tallapoosa River before and after an enhanced flow regime was implemented below the dam of the system. Their results suggested that an enhanced flow regime supports a more abundant and diverse fish assemblage including fluvial species. This gives support to the idea that flow regimes are directly related to fish biodiversity in a riverine system.

Grabowski and Isely (2007) conducted a study with Robust Redhorse (*Moxostoma robustum*) in the Savannah River. They found that 50% of observed nest sites were de-watered or left in no-flow conditions for several days due to anthropogenic-induced fluctuations in water levels. They hypothesize that this phenomenon may be widespread in regulated rivers, thereby placing shallow-water species such as the Robust Redhorse in peril due to the alteration of flow.

The invasion and success of various exotic and introduced species in riverine systems is also facilitated by alterations in natural flow regimes (Bunn and Arthington 2002). Taylor et al. (2008) conducted a study on the Tennessee-Tombigbee to examine how the alteration of natural flow affected the fish assemblages of the system. They found that altered flow (post-Tennessee-Tombigbee Waterway construction) had resulted in increased numbers of invasive species, one being the Mississippi Silverside (*Menidia audens*).

In addition to damming, periodic dredging of the riverbed is often conducted to maintain navigable river channels. These activities are undertaken with beneficial objectives; however, significant ecological effects have been documented (Paukert et al. 2008, Licursi and Gomez 2009).

Licursi and Gomez (2009) define two types of disturbances from dredging: (i) the abstraction and disruption of substrate and (ii) the generation of chemical changes in the water column. 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 adequate flow (Padmalal et al. 2008, Paukert 2008). The disruption of sediment causes an increase of nutrients (soluble phosphorus) and toxic substances in the water column which can cause changes in aquatic assemblages (Lewis et al. 2001, Licursi and Gomez 2009).

In addition to effects resulting from damming, flow alteration, and dredging other factors often affect fish assemblages among a particular habitat structure. Jackson et al. (2001) examined the roles of biotic, abiotic, and spatial factors on fish assemblages. The authors noted the importance of spatial factors among community dynamics and the importance spatial variation serves in species diversity and community structure. Hargrave and Taylor (2010) suggested that spatial variation may also result in variable environmental conditions throughout a riverine system such as water temperature, dissolved oxygen levels, and water salinity. They recommend that future studies examine variation in fish assemblage structure over spatial gradients in order to differentiate between influences resulting from human activities and those natural to the system. They also suggest that spatial variability of habitat is likely to interact with temporal variability of fish assemblages, both diel and seasonal, potentially resulting in more stable assemblages over time (Jackson et al. 2001, Hargrave and Taylor 2010).

Studies have been conducted noting significant relationships of diel variation of fish assemblages among their associated habitats (Arrington and Winemiller 2003, Hoeinghaus et al. 2003). Diel changes in fish assemblage composition have been documented in a variety of aquatic systems including freshwater riverine (Arrington and Winemiller 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). These factors play important roles individually as well as collectively in the structuring of diel fish assemblages.

In general, fishes are more abundant in higher water temperatures than in lower water temperatures (Gries et al. 1997; Gelos et al. 2010). This is most likely because water temperature has a strong influence on fish metabolism and movement (Gelos et al. 2010). Many current studies are finding that this holds true in daytime hours as well as nighttime (Gries et al. 1997; Gelos et al. 2010). The higher the water temperature, the more fish species are active and abundant (Gries et al. 1997; Gelos et al. 2010). Increases in water temperature may lead to an increase in swimming speed and a higher attack coefficient for predatory species (Gelos et al. 2010). Because water temperatures are generally lower at night, it follows that many species come out at night to avoid predation that could result from higher water temperatures (Gelos et al. 2010).

Water transparency is also an important environmental factor contributing to structural shifts in diel fish assemblages (Gelos et al. 2010). It has been suggested that changes in ambient light concentrations at twilight and dawn trigger changeover in assemblage structure (Arrington and Winemiller 2003). Darkness may serve as a refuge for fish, even at the likely cost of a lower feeding efficiency during the night (Gelos et al. 2010). This is because low water transparency may negatively impact fish that rely on vision when hunting prey (Gelos et al. 2010; Roach and Winemiller 2011). If this is the case, low transparency may also, contrarily, favor fish that use other sensory organs, such as olfactory and tactile organs, to locate prey (Gelos et al. 2010; Roach and Winemiller 2011).

The importance of darkness seems to decrease with decreasing water transparency (Gelos et al. 2010). As the water becomes more turbid, visual-hunters suffer from reduced visibility and become less effective (Gelos et al. 2010). These areas then trend toward safe havens with a reduced predation pressure (Gelos et al. 2010). The same phenomenon has been observed in diel studies where patterns of habitat occupancy and foraging activity are consistent with predator-avoidance (Arrington and Winemiller 2003).

Fishes that move toward shallow water during diurnal periods generally exploit areas such as sandbanks for foraging habitat, and remain in these areas through the night as a shallow-water refuge from predation (Arrington and Winemiller 2003). Assemblage structure is most variable among night samples, and these samples tend to have more individual fishes on average than diurnal samples (Pessanha and Araujo 2003; Arrington and Winemiller 2003). It is believed that these increases in local population are generally caused by an influx of species into shallow water after twilight (Pessanha and Araujo 2003; Arrington and Winemiller 2003).

Resource availability may also play a role in shaping night fish assemblages (Roach and Winemiller 2011). Diel turnover is a type of resource partitioning, when species use the same resources but use them at different times of day (Roach and Winemiller 2011). Many fish species have been found to migrate to shallow areas at night to take advantage of resources that may not be available to them during the daytime hours (Roach and Winemiller 2011). Also, it has been suggested that species migrate to shallow areas at night to avoid predation (Helfman 1981). This indicates that the influence of nocturnal events on temporal structuring within a community may be a response to selection pressures of predators, which are usually most active and successful during the evening hours (Helfman 1981).

Overall, fishes seem to be more active in one of three time periods: day, night, or twilight (Helfman 1981; Gelos, et al. 2010; Roach and Winemiller 2011). Consequently, fish communities can be characterized by their temporal organizational structure (Helfman 1981; Pessanha and Araujo 2003). During twilight, species which are diurnally active and nocturnally active engage in transitional behaviors as they make the shift from foraging to resting behaviors (Helfman 1981). Prior to Helfman's study of twilight activities in 1981, most research in this area was restricted to tropical and marine environments. Since that time many have studied temporal and diel turnover of fishes in temperate freshwater systems. Investigating diel turnover in fish assemblages is important for biologists to effectively characterize assemblage structure and behavior. This also gives managers vital information into the behavior of fish assemblages including migration and fish passage (Baumgartner et al. 2008).

Each of these factors—damming, flow alteration, and spatial and temporal variation—have been shown to have great influences on fish assemblages in riverine systems. To adequately quantify the extent to which each of these factors affects fish assemblages, monitoring efforts are needed. Along the Alabama River, monitoring programs for specific target species such as Alabama Shad (*Alosa alabamae*) and Alabama Sturgeon (*Scaphirhynchus suttkusi*) are well established. However, few recent survey efforts have been aimed at documenting trends in non-game fish assemblages.

In my study, I examined the persistence of fish assemblages on selected sandbars along the Alabama River, Alabama. My objectives were to: 1) provide current data on fish assemblages found in gravel/sand bar habitat in the Alabama River downstream of river mile 72 (Claiborne lock and dam) and selected associated tributaries, 2) compare current collections along sand/gravel bar habitat to historic collections to evaluate assemblage persistence, 3) assess temporal variability among fish assemblages via diel and seasonal collections and 4) evaluate spatial variability of sand/gravel bar habitat and its influence on fish assemblages.

STUDY AREA

The Alabama River system (including the Tallapoosa, Coosa, and Cahaba subsystems) is in a rich physiographic region and is high in endemism and ichthofauna diversity 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 (*Scaphirhynchus suttkusi*) and Blue Shiner (*Cyprinella caerulea*) (Freeman et al. 2005).

The Alabama River is formed by the confluence of the Coosa and Tallapoosa rivers just north of Montgomery, Alabama. 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), which were installed to assist with navigation of the river by barges and other watercraft and power generation. Currently, the river is maintained at a nine foot channel by periodic dredging activities to ensure uninterrupted navigation.

Due to these circumstances, the natural flow of the river in some areas has been eliminated which has a direct effect on the structure of fish assemblages (Grabowski and Isely 2007). Unfortunately, much of the fish fauna is now limited to fragments of their natural habitats, and long-term datasets for fishes suggest declines in fish species richness over time, potentially due to habitat degradation (Data from Suttkus and Gunning 1964-2000; Freeman et al. 2005).

The study area is concentrated in the most free-flowing stretch of the Alabama River, below Claiborne Lock and Dam (river mile 72.0). Sampling localities focused on sand/gravel bar habitat and the river's associated tributaries where the fauna is poorly described.

MATERIALS AND METHODS

Beginning June 28, 2010, twenty-eight sites (19 sand / gravel bars and 9 tributaries) were sampled from river mile 22.9-72.0 of the Alabama River during June-August and October 2010 (Fig. 1, Appendix 1). Selected sites were sampled during both the day and night, and during the fall (n = 41). Selected sites were re-sampled during April 2011 (Figs. 1 and 2; Appendix 1). Fishes were collected on these habitats using 9 m, 15 m, or 30 m seines (5-10 seine hauls per site). Seining was conducted according to techniques described by Murphy and Willis (1996). Fish collections in tributary sites were made using 3 m seines and backpack electrofisher (Smith and Root ® LR-24 Electrofisher).

Seine selection and length of each sand/gravel bar haul was dictated by depth of the reach and presence of obstructions, but generally ranged between 30 - 100 m. Selected sites were re-sampled 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. All preserved specimens were first anesthetized in MS 222 (tricane methanesulfonate) and preserved in a 10% formalin solution (Boschung and Mayden 2004).

Seine hauls with large numbers of clupeid species were subsampled to approximate total numbers per haul. In these circumstances, individuals were distributed evenly in a square and divided into proportionate fractions until a reasonable subsample could be counted. Subsamples ranged from 1/4 to 1/64 of the total catch. Standard length (SL) of preserved specimens was measured in millimeters (mm) to assess age structure.

Many tributaries of the lower Alabama River have been inadequately sampled. To assist in generating a database with assemblage and habitat information, we collected samples from nine tributaries associated with the Alabama River below Claiborne Lock and Dam. Fish collections in associated tributaries were made using 3 m or 9 m seines and a backpack electrofisher. Tributaries were sampled beginning at the confluence of the tributary to the main stem river. All available mesohabitat types including pool, run, riffle, bank and mid-stream reaches of the tributary were also sampled.

A minimum of ten hauls were made in each of these tributaries. A seine haul was pulled along open habitats such as pools and mid-stream reaches. Riffles, runs, and woody debris were sampled by setting the seine downstream of these habitats and backpack shocking into the seine. Similar to the sand / gravel bar collections, all fish were identified to species and enumerated for each haul. Species easily identified and those of conservation concern were returned to the river. Others were anesthetized in MS222 (tricane methanesulfonate) and preserved in a 10% formalin solution (Boschung and Mayden 2004). Habitat data were taken for all tributaries including stream width (m), depth (m), flow (m/s) and substrate type for each haul.

DATA ANALYSIS

I assessed long-term temporal variability among fish assemblage structure by comparing recent collections from this study to significant historic collections (GSA 1998 Crystal Darter Survey and Royal D. Suttkus 1964-2000). I also compared current diel and seasonal collections in order to assess fish assemblage change over short time scales. Current, replicated samples were compared to validate sampling methods.

Jaccard and Morisita indices of similarity were used to compare collections. These indices were performed using Ecological Methodology software (version needed here). The Morisita index takes species abundance into account, and I used this analysis for comparisons of my samples, which were all collected using the same methodology. The Morisita index $C_D = \frac{2\sum_{i=1}^{S} X_i Y_i}{(D_x + D_y)XY}$ is a measure of dispersion and is used to measure overlap among samples (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. 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 1indicates 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 $J = \frac{w}{A+B-w}$ is a measure of community similarity and assesses the presence or absence of species. J is the index of similarity. 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).

I conducted a Correspondence Analysis (CA) for 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 Correspondence Analysis were used to show how species abundance corresponds to season. Correspondence Analyses for this study were run using PAST (Paleontological Statistics Version 2.13).

I used ArcGIS to measure spatial parameters of the sand / gravel bar habitats among our sampling area. I acquired 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). I then projected these images (.tiff) to an appropriate coordinate system and digitized the sand / gravel bar habitats into polygons (Fig. 3 and 4).

Using the spatial analyst in ArcGIS, I measured area (acres and m^2) of each digitized sand / gravel bar. I used Google Earth (version 6.1.0) to measure proximity (m) between neighboring sand / gravel bars. Using these data, I assessed 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 is used to 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

A total of 57 fish species were collected during the current survey including one species of conservation concern, the Crystal Darter (*Crystallaria asprella*). In all, 34 Crystal Darters were collected in 11 samples (Appendix 2). Collections provided unique records for the Alabama River including Gulf Menhaden (*Brevoortia patronus*), Gulf Killifish (*Fundulus grandis*) and Inland Silverside (*Menidia beryllina*). Tributary collections contained species of percids and cyprinids, such as Weed Shiner (*Notropis* texanus), Coastal Shiner (*Notropis petersoni*) and Bluntnose Darter (*Etheostoma cholorosum*), that were not found in riverine samples. Conversely, many open water species, especially clupeids, were not collected in tributaries.

Sand/gravel bar samples were dominated by Gulf Menhaden, a marine clupeid species which had not been previously recorded from our study area. We collected Gulf Menhaden at 12 of 19 sites during our survey (Table 1; Appendix 2). The species was absent from the lowermost sample sites of our survey (Table 1; Fig. 1; Appendix 2). Numbers of individuals per sample ranged from 1 to over 144,000. Greater 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; Appendix 2). The presence of such large numbers of one species compounded my comparisons, and current comparisons were made with and without Gulf Menhaden included (Tables 2 and 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 1 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).

We collected menhaden in both day and night samples (Tables 1 and 2). Standard lengths (SL mm) of preserved menhaden were measured to assess their age classes. 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 (90-100mm SL) were present in small numbers (n = 10).

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 and 4; Fig. 5). This was true for both summer and fall diel samples (Table 2; Fig. 5). Seasonally, sample similarity varied by site, and night samples tended to be more similar in summer and fall (Table 2). Species such as Blue Catfish (*Ictalurus furcatus*) and Channel Catfish *(Ictalurus punctatus*) were detected in great numbers (n=3,479) during nighttime hours and rarely collected during day samples (n=4) (Table 4). A total of 30 Crystal Darters were collected, 20 during nighttime hours. Mooneye (*Hiodon tergisus*) (n=2), Spotted Gar (*Lepisosteus occulatus*) (n=17), and Longnose Gar (*Lepisosteus osseus*) (n=2) were largely collected during nighttime hours in our diel survey (Table 4). Riverine minnows such as Fluvial Shiner (*Notropis edwardraneyi*) and Silver Chub (*Macrhybopis storeriana*) were also detected in larger numbers during nighttime hours (Table 4).

Correspondence analyses for three sites sampled during spring, summer, and fall show that species associate with season, however this association varied by site (Figs. 6,7,8, and 9). Emerald Shiner (*Notropis atherinoides*) and Fluvial Shiner are largely associated with spring (Figs. 6). Centrarchid species such as Alabama Bass (*Micropterus henshalli*), Largemouth Bass (*Micropterus salmoides*), and Longear Sunfish (*Lepomis megalotis*) correspond to summer (Figs. 6, 7, 8, and 9). Overall, Blacktail Shiner (*Cyprinella venusta*) shows strong associations with fall season; however, this association was variable at sites 8 and 10 (Figs. 7, 8, and 9).

Spring samples varied tremendously from both summer and fall samples (Table 3). Spring collections provided diverse and abundant catches of minnow species such as Emerald Shiner, Silverside Shiner, and Fluvial Shiner; however, fewer individuals were detected in summer and fall collections (Table 4; Figs. 10, 11, 12). Gulf Menhaden persisted in fall samples; however, no Gulf Menhaden were collected during spring sampling efforts.

All five comparisons with historical data indicated low faunal similarity ($J < 0.5$) (Table 5). Current repeated collections at two sites (RM 72 and RM 39.6) resulted in high faunal similarity ($J > 0.9$) (Table 5). Notable changes in species composition in addition to Gulf Menhaden in current collections included the presence of Blacktail Shiners in our samples. Fluvial shiners were much more abundant in previous collections and have declined. A current comparison to a historical collection of Royal D. Suttkus at Alabama River Mile 72, shows notable differences in species detected, especially large river minnows such as Fluvial Shiner, Silver Chub (*Macrhybopsis storeriana*), and

Silverside Shiner. We also collected a greater number of centrarchid species in current collections than were present in historic ones (Table 6; Fig. 13).

Sand/gravel bar surface area varied from 0.75 - 64.7 acres (3,035.14 m^2 – 261,831.61 m^2). Pearson's correlation coefficient ($r = -0.0308$) ($p > 0.05$) show no significant relationship between species richness and sand/gravel bar area (m^2) (Fig. 14). Similarly, no significant relationship was found for richness of fish assemblages and sand/gravel bar proximity to nearest bar ($r = 0.0277$, $p > 0.05$) (Fig. 15).

DISCUSSION

Distributional Records

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 Hogchoker (*Trinectes maculatus*), Southern Flounder *(Paralichthys lethostigma*), Striped Mullet (*Mugil cephalus*), and the Atlantic Needlefish (*Strongylura marina*) (Boschung and Mayden, 2004). This study provided unique, marine distributional records in the Alabama River including Inland Silverside, Gulf Killifish, and Gulf Menhaden. Inland silversides were collected throughout the study area, but largely collected below Claiborne Lock and Dam at Site 1 (RM 72). One Gulf Killifish was also collected at Site 1, October 2011, during an effort to monitor Gulf Menhaden.

Incredibly large numbers of Gulf Menhaden overwhelmed our seine hauls. Similarly, these records affected our comparisons. Statistical tests that were influenced by abundance were run with and without Gulf Menhaden to allow insight into the entire assemblage. Morisita index scores accurately contrasted samples with and without large numbers of Gulf Menhaden; however, excluding Gulf Menhaden in comparisons allowed clearer insight to similarities and differences for the remaining ichthyofauna (Table 2 and 3).

The Gulf Menhaden, is a marine species common to central areas of Gulf of Mexico (Hoese and Moore 1977; McEachran and Fechhelm 1998). Gulf Menhaden 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; Vaughan et al. 2000; Ross 2001).

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 and Tensaw Delta (Lassuy 1983; Mettee et al. 1996; Ross 2001; Boschung and Mayden 2004). Typically, menhaden spawning takes place in the open waters of the Gulf of Mexico in spring and fall (Ahrenholz 1991). Menhaden produce pelagic eggs, which hatch into larvae after approximately 5 days (Raynie and Shaw 1995). Larvae are then carried to inshore marshes via currents 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 (Lassuy 1983; Deegan 1990; Ahrenholz 1991).

As noted, the presence of Gulf Menhaden as far as Alabama River Mile 72 is very unusual. Mettee et al. (1996) recommended future sampling for this species in the lower Alabama River especially during late summer and times of “saltwater intrusion”. 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 (Fore and Baxter 1972; Deegan 1990; 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 1995; Vaughan et al. 2000; Ross 2001), so it seems unlikely that they migrated upstream into the Alabama River.

In this study, age class for Gulf Menhaden was determined using standard length data from subsamples. Other methods, such as otolith analysis, could provide more insight into age and habitat persistence of these individuals. Examination of otolith microstructure is a technique that is widely accepted for aging of fish specimens (Campana and Neilson 1985). Otoliths, or ear bones, are recovered from harvested specimens and used to back-calculate fish age often to a specific spawning date if analysis is performed during the first year of life (Campana and Neilson 1985). Examination of otolith microstructures was not used during this study. Standard Lengths (SL) were recorded and averaged from subsets of voucher Gulf Menhaden. According to a study by Raynie and Shaw (1995), specific age classes of based on otolith data from Gulf Menhaden correspond to ranges of standard lengths. According to their study, collection of standard length data is a viable method by which age of Gulf Menhaden can be estimated, especially during larval and juvenile age classes (Raynie and Shaw 1995).

Diel and Seasonal Fish Assemblages

Night samples show high similarity in summer and fall, but when excluding Gulf Menhaden, diel comparisons exhibit very low similarity (Table 2 and 4). Dissimilarity between diel samples is likely due to high numbers of ictalurid species collected during nighttime hours. These findings are similar to Roach and Winemiller (2011) who studied diel changeover of fish assemblages on sandbanks of the Brazos River, Texas. Roach and Winemiller (2011) found diel changeover was mostly due to ictalurids and palaemonids. The authors explain 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.

Diel turnover can be a type of resource partitioning, when species use 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 where darkness serves as a refugia (Gelos et al. 2010). Changes in water transparency and ambient light concentrations at twilight and dawn trigger changeover in fish assemblage structure (Arrington and Winemiler 2003; Gelos et al. 2010). In our study, cyprinid species (*Macrhybopsis storeriana, Notropis atherinoides, Notropis candidus,* and *Notropis edwardraneyi*) 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.

Seasonal differences varied by site. Some species were detected in greater numbers during fall samples, such as Gulf Menhaden and Crystal Darters. Increased detectability could be due to low water levels in the fall. 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 in environmental condition.

Historical Comparison

Comparison of current and historical collection data can provide vital information relative to species persistence and their ecosystems (Taylor et al. 2008; Johnston and Maceina 2009). Johnston and Maceina (2009) studied fish persistence over time by comparing current collections to historical collections by using statistical methods, including similarity indices. They found that fish assemblages in their study changed significantly over time, including loss of species and homogenization of assemblages. Homogenization is the increased similarity of biotas over time, often caused directly or indirectly by human alteration, and is concerning to biologists because it often results in a decline in biodiversity (McKinney and Lockwood 199; Rahel 2002).

Natural habitats have been altered in the Alabama River due to damming and dredging. Many historical sites sampled by Royal D. Suttkus could not be sampled during our study because the gravel/sand bars were no longer present. All five comparisons with historical data indicated low faunal similarity suggesting historic fish assemblage shifts. Rahel (2002) noted that the introduction of cosmopolitan species alone can increase homogenization of an assemblage; however, if that species causes declines in native fauna, the effect is amplified. A classic example is the loss of almost

200 endemic cichlids in Lake Victoria, Africa, due to a species introduction (Kaufman 1992).

The data suggest homogenization among fish assemblages in the Alabama River below RM 72. Notable changes in species composition, in addition to Gulf Menhaden, include the cosmopolitan species Blacktail Shiners. Historically, Royal D. Suttkus did not detect Blacktail Shiners 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.

Habitat Spatial Variability

Sand/gravel bar area and proximity to nearest bar varied greatly. Correlation analysis indicates no significant relationship between sandbar proximity or area and species richness. These results may have shown more significant relationships with a larger sample size. However, I suggest ongoing anthropogenic disturbances such as dredging may affect richness among individual sites.

The Alabama River is affected by periodic dredging activities. The U.S. Army Corps of Engineers oversees dredging on the Alabama River. The riverbed is excavated during these activities and disposed of either outside or within the banks of the river. In-stream sand or gravel extraction and disposal are common practices throughout many river systems. Significant ecological effects have been documented, however (Paukert et al. 2008, Licursi and Gomez 2009).

CONCLUSION

In conclusion, a total of 57 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. Future work monitoring their persistence and abundance in the Alabama River is important for assessing any impacts it may have on the ecosystem and its native fishes. Historically, fish assemblages in sand /gravel bar habit have changed. Results of this study observe changes in native cyprinid abundance and increased presence of Blacktail Shiner and centrarchids. Diel turnover was observed on sand/gravel bar habitats. Most notably were the large numbers of Blue Catfish and Channel Catfish present during nighttime samples. Species corresponded seasonally and was 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. I recommend ongoing monitoring of fish assemblages in the Alabama River, downstream of RM 72. Diel and seasonal sampling is recommended, when possible, to effectively document fish assemblages occupying these sand and gravel bars.

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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 site map (Figure 1).

	SUMMER		FALL	
Site #	**DAY**	**NIGHT**	**DAY**	**NIGHT**
1	5649	8159	18590	495
2	8	0	0	0
3	0	0	0	0
4	1	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	4	1	144464	29934
9	0	0	0	0
10	0	0	109052	0
11	0	0	0	0
12	0	0	0	0
13	1	0	0	0
14	1200	0	0	0
15	321	0	0	0
16	16607	65	420	72
17	0	0	0	0
18	2	178	3	36
19	0	0	0	0
20	14	0	14067	0
21	0	0	690	0
22	808	0	2474	0
23	29195	0	0	0
24	8520	0	0	0
25	2616	0	0	0
26	0	0	0	0
27	0	0	0	0
28	0	0	0	0

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
1	**with menhaden**	**0.93**	**0.93**	**1**	**0.96**
	without menhaden	0.05	0.13	0.25	0.4
8	**with menhaden**	**0.10**	**1.0**	**0.06**	**0.00**
	without menhaden	0.01	0.1	0.63	0.36
16	**with menhaden**	**0.08**	**0.23**	**0.98**	**0.65**
	without menhaden	0.06	0.14	0.03	0.65
18	**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	
20	**with menhaden**			**0.56**	
	without menhaden			0.23	
21	**with menhaden**			**0.06**	
	without menhaden			0.30	
22	**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.

Spring Comparisons		
With *Brevoortia patronus*		
Site #	**Spring vs Summer**	**Spring vs Fall**
1	0.001	0.0002
8	0.003	0.00002
10	0.084	0.0001
Without *Brevoortia patronus*		
Site #	**Spring vs Summer**	**Spring vs Fall**
1	0.125	0.051
8	0.003	0.049
10	0.084	0.309

Table 4. Diel and seasonal collection data for selected sites. Site numbers correspond with Appendix 1; Fig. 1 and 2.

	Site 1					**Site 8**				
	Spring	Summer		Fall		Spring	Summer		Fall	
Species	Day	Day	Night	Day	Night	Day	Day	Night	Day	Night
Polyodon spathula							1			
Atractosteus spatula	1									
Lepisosteus oculatus			13					1		2
Lepisosteus osseus		1			1					
Hiodon tergisus					1			1		
Anchoa mitchilli					2					9
Alosa chrysochloris		2	15	2	4		1			1
Brevoortia patronus		4042	8159	18590	495		4	1	144464	29934
Dorosoma cepedianum		2	25	25	15	1	4	8	29	15
Dorosoma petenense	83		2593	6	41	23		6	3	3
Campostoma oligolepis										1
Cyprinella venusta		9	2	106	1	1	8	1	2	3
Hybognathus nuchalis							3			
Macrhrybopsis aestivalis sp. cf										
Macrhrybopsis storeriana		13	112		7	1		47		19
Notropis atherinoides				8	2	167			2	8
Notropis candidus		30	119		13	2		109		6
Notropis edwardraneyi	9	1		5	38	14				84
Notropis uranoscopus										
Pimephales vigilax										
Carpiodes cyprinus										
Carpiodes velifer				2			2	1		1
Moxostoma poecilurum					1			1		
Ictalurus furcatus			88		16			2		
Ictalurus punctatus			37		41			256		31
Pylodictis 0livaris					1					
Mugil cephalus		4	1	10	3		8	2	2	2
Menidia beryllina			1	1			1			

Table 4 continued. Diel and seasonal data for selected sites.

	Site 1					Site 8				
	Spring	Summer		Fall		Spring	Summer		Fall	
Species	Day	Day	Night	Day	Night	Day	Day	Night	Day	Night
Strongylura marina	73	8	9	1			2			
Gambusia affinis								1		
Gambusia holbrooki										2
Morone chrysops			33	2	11					2
Morone chrysops x saxatilis					2					
Morone mississippiensis			2							
Morone saxatilis		7	104	1	20			22		10
Morone sp. (Hybrid)			1							
Lepomis macrochirus	1	8		9	2		32	13	42	1
Lepomis megalotis		7		1	1		19	1		
Lepomis microlophus							1			
Micropterus henshalli						1	12	2	2	
Micropterus salmoides		4					1			
Pomoxis annularis										
Pomoxis nigromaculatus			1		1			3		
Ammocrypta beanie										
Crystallaria asprella			1	7	6		1		1	2
Percina kathae										
Aplodinotus grunniens							3	66		2
Trinectes maculatus		1		3	42	1	1	3		1

Table 4 continued. Diel and seasonal data for selected sites.

	Site 10			Site 16			
	Spring	Summer	Fall	Summer		Fall	
Species	Day	Day	Day	Day	Night	Day	Night
Polyodon spathula							
Atractosteus spatula							
Lepisosteus oculatus					1		
Lepisosteus osseus					1		
Hiodon tergisus							
Anchoa mitchilli					1		
Alosa chrysochloris		1					
Brevoortia patronus			109052	4328	65	420	72
Dorosoma cepedianum	1	4		6	35		1
Dorosoma petenense				643	50		1
Campostoma oligolepis			1				
Cyprinella venusta	15	41	25	17	10	63	
Hybognathus nuchalis				1			
Macrhrybopsis aestivalis sp. cf							1
Macrhrybopsis storeriana	4		21		82	10	150
Notropis atherinoides	162		9			5	14
Notropis candidus	28				177		39
Notropis edwardraneyi	23		3	1			20
Notropis uranoscopus	1						
Pimephales vigilax					4		1
Carpiodes cyprinus							1
Carpiodes velifer				21	24	13	72
Moxostoma poecilurum							
Ictalurus furcatus					520		21
Ictalurus punctatus			1		469		200
Pylodictis olivaris					1		
Mugil cephalus			5				
Menidia beryllina							

Table 4 continued. Diel and seasonal data for selected sites.

	Site 10			Site 16			
	Spring	Summer	Fall	Summer		Fall	
Species	Day	Day	Day	Day	Night	Day	Night
Strongylura marina			2		1		
Gambusia affinis							
Gambusia holbrooki							
Morone chrysops							
Morone chrysops x saxatilis							
Morone mississippiensis							
Morone saxatilis			2		9		10
Morone sp. (Hybrid)							
Lepomis macrochirus		12	6	10	68		
Lepomis megalotis		4		1			1
Lepomis microlophus							
Micropterus henshalli		7	2	5	4		3
Micropterus salmoides				1			
Pomoxis annularis					2		
Pomoxis nigromaculatus					5		
Ammocrypta beanie		1					
Crystallaria asprella					2	1	9
Percina kathae							
Aplodinotus grunniens				1	34		3
Trinectes maculatus	2			4	22		3

Table 4 continued. Diel and seasonal data for selected sites.

	Site 18				Site 20	
	Summer		Fall		Summer	Fall
Species	Day	Night	Day	Night	Day	Day
Polyodon spathula						
Atractosteus spatula						
Lepisosteus oculatus						
Lepisosteus osseus						
Hiodon tergisus						
Anchoa mitchilli	3	30	322	286		152
Alosa chrysochloris						
Brevoortia patronus	2	178	3	36	14	14067
Dorosoma cepedianum	6	6	1		1	6
Dorosoma petenense	65	59				
Campostoma oligolepis						
Cyprinella venusta		21	7	20	7	7
Hybognathus nuchalis						
Macrhrybopsis aestivalis sp. cf						
Macrhrybopsis storeriana	66	98	7	30	1	22
Notropis atherinoides	31	96	19	8		2
Notropis candidus		16	50	162		21
Notropis edwardraneyi		1	7			50
Notropis uranoscopus						
Pimephales vigilax		1	1	12		
Carpiodes cyprinus		1				
Carpiodes velifer	28	3		5	8	46
Moxostoma poecilurum						
Ictalurus furcatus	1	942		1		
Ictalurus punctatus		102	3	753		10
Pylodictis olivaris						
Mugil cephalus						1
Menidia beryllina				1	1	

Table 4 continued. Diel and seasonal data for selected sites.

	Site 18				**Site 20**	
	Summer		Fall		Summer	Fall
Species	Day	Night	Day	Night	Day	Day
Strongylura marina					3	
Gambusia affinis						
Gambusia holbrooki						
Morone chrysops				2		4
Morone chrysops x saxatilis						
Morone mississippiensis						
Morone saxatilis	1	4			1	8
Morone sp. (Hybrid)						
Lepomis macrochirus	1	1			3	2
Lepomis megalotis						1
Lepomis microlophus						
Micropterus henshalli		1	1		1	
Micropterus salmoides	1	1			3	
Pomoxis annularis						
Pomoxis nigromaculatus				1		1
Ammocrypta beanie						
Crystallaria asprella						
Percina kathae						
Aplodinotus grunniens		4	1			
Trinectes maculatus	2	2	4	40	1	188

Table 4 continued. Diel and seasonal data for selected sites.

	Site 21		Site 22	
	Summer	Fall	Summer	Fall
Species	Day	Day	Day	Day
Polyodon spathula				
Atractosteus spatula				
Lepisosteus oculatus				
Lepisosteus osseus				
Hiodon tergisus				
Anchoa mitchilli		2	3	
Alosa chrysochloris			6	
Brevoortia patronus		690	808	2474
Dorosoma cepedianum	4	6		6
Dorosoma petenense			87	
Campostoma oligolepis				
Cyprinella venusta	2	43	37	30
Hybognathus nuchalis				
Macrhrybopsis aestivalis sp. cf				
Macrhrybopsis storeriana		58	9	166
Notropis atherinoides		7	31	3
Notropis candidus			1	
Notropis edwardraneyi			3	4
Notropis uranoscopus				
Pimephales vigilax				
Carpiodes cyprinus				
Carpiodes velifer	1	130	13	362
Moxostoma poecilurum				
Ictalurus furcatus				
Ictalurus punctatus				1

Table 4 continued. Diel and seasonal data for selected sites.

	Site 21		**Site 22**	
	Summer	Fall	Summer	Fall
Species	Day	Day	Day	Day
Pylodictis olivaris				
Mugil cephalus				
Menidia beryllina				
Strongylura marina			1	1
Gambusia affinis				
Gambusia holbrooki				
Morone chrysops				
Morone chrysops x saxatilis				
Morone mississippiensis				
Morone saxatilis		1		1
Morone sp. (Hybrid)				
Lepomis macrochirus	4	1		
Lepomis megalotis				2
Lepomis microlophus				
Micropterus henshalli	1	2	3	
Micropterus salmoides				
Pomoxis annularis				
Pomoxis nigromaculatus				
Ammocrypta beanie				
Crystallaria asprella				
Percina kathae		1		
Aplodinotus grunniens				6
Trinectes maculatus		14		20

Table 5. Jaccard's index of similarity for current samples vs historical samples from other researchers.

Site	R.D. Suttkus	GSA	AU	Jaccard's Index
Alabama RM 72	Jul-68		Jul-10	**0.23**
Alabama RM 66	Aug-89		Jun-10	**0.15**
Alabama RM 60		Sep-98	Jul-10	**0.16**
Alabama RM 47		Sep-98	Jul-10	**0.33**
Alabama RM 33	Jul-64		Jul-10	**0.11**

AU Repeated Collections: **RM 72 = 0.92**
RM 39.6 = 0.98

Table 6. Comparison of species detected in a historic collection of Royal D. Suttkus 1968 and this study July 2010 at Site 1 (RM 72).

Suttkus July 1968			**AU July 2010**		
Species	**#**	**%**	**Species**	**#**	**%**
Macrhybopsis storeriana	241	49.49	*Brevoortia patronus*	4042	97.66
Ictalurus punctatus	115	23.61	*Notropis candidus*	30	0.72
Notropis edwardraneyi	80	16.43	*Macrhybopsis storeriana*	13	0.31
Morone chrysops	34	6.98	*Cyprinella venusta*	9	0.22
Macrhybopsis aestivalis	4	0.82	*Strongylura marina*	8	0.19
Carpoides velifer	3	0.62	*Lepomis macrochirus*	8	0.19
Hybognathus nuchalis	3	0.62	*Morone saxatilis*	7	0.17
Trinectes maculatus	2	0.41	*Lepomis megalotis*	7	0.17
Pimephales vigilax	1	0.21	*Mugil cephalus*	4	0.10
Notropis texanus	1	0.21	*Micropterus slamoides*	4	0.10
Dorosoma cepedianum	1	0.21	*Alosa chrysochloris*	2	0.05
Notropis candidus	1	0.21	*Dorosoma cepedianum*	2	0.05
Alosa alabamae	1	0.21	*Lepisosteus osseus*	1	0.02
			Notropis edwardraneyi	1	0.02
			Trinectes maculatus	1	0.02

Table 7. Sand/gravel bar area and proximity to nearest bar. Site numbers correspond to Appendix 1

Site	Area (acres)	Area (m^2)	Proximity to Nearest Bar (mi)	Proximity to Nearest Bar (m)
1	22.00	89030.84	3.40	5471.77
2	3.52	14244.93	0.19	305.78
4	0.75	3035.14	0.14	225.31
8	14.50	58679.42	0.26	418.43
10	15.80	63940.33	0.40	643.74
13	16.40	66368.45	0.18	289.68
14	23.50	95101.13	0.18	289.68
15	26.20	106027.64	0.85	1367.94
16	26.20	106027.64	0.26	418.43
18	16.30	65963.76	0.26	418.43
20	21.90	88626.16	1.04	1673.72
21	22.00	89030.84	1.04	1673.72
22	17.20	69605.93	0.41	659.83
23	27.90	112907.29	0.41	659.83
24	20.00	80937.13	0.43	692.02
25	8.10	32779.54	0.04	64.37
26	64.70	261831.61	0.04	64.37
27	20.70	83769.93	0.38	611.55
28	18.90	76485.59	0.56	901.23

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

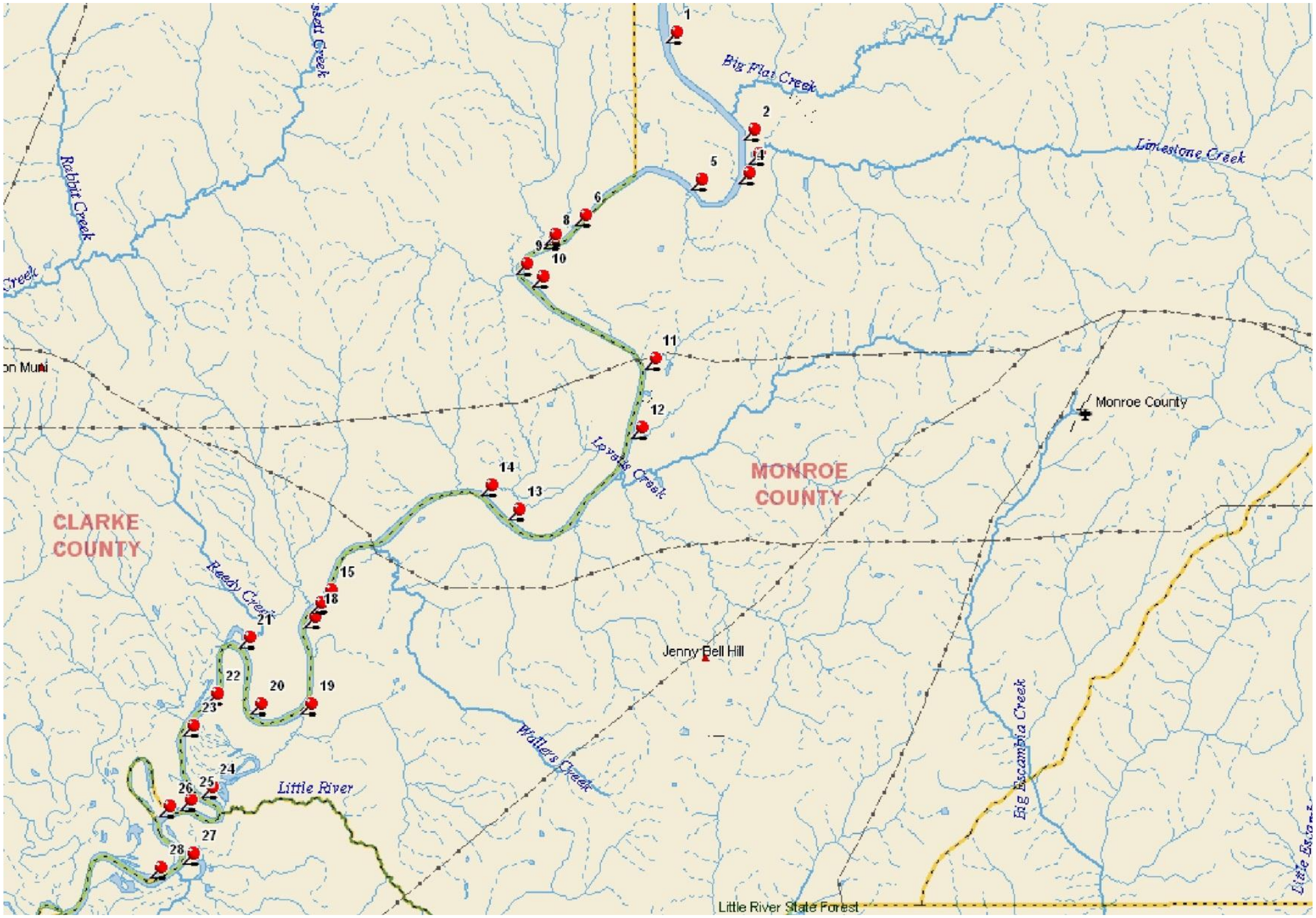


Fig. 2. Diel sample sites (squares) and seasonal sample sites (squares and triangles). Site numbers correspond to Appendix 1.

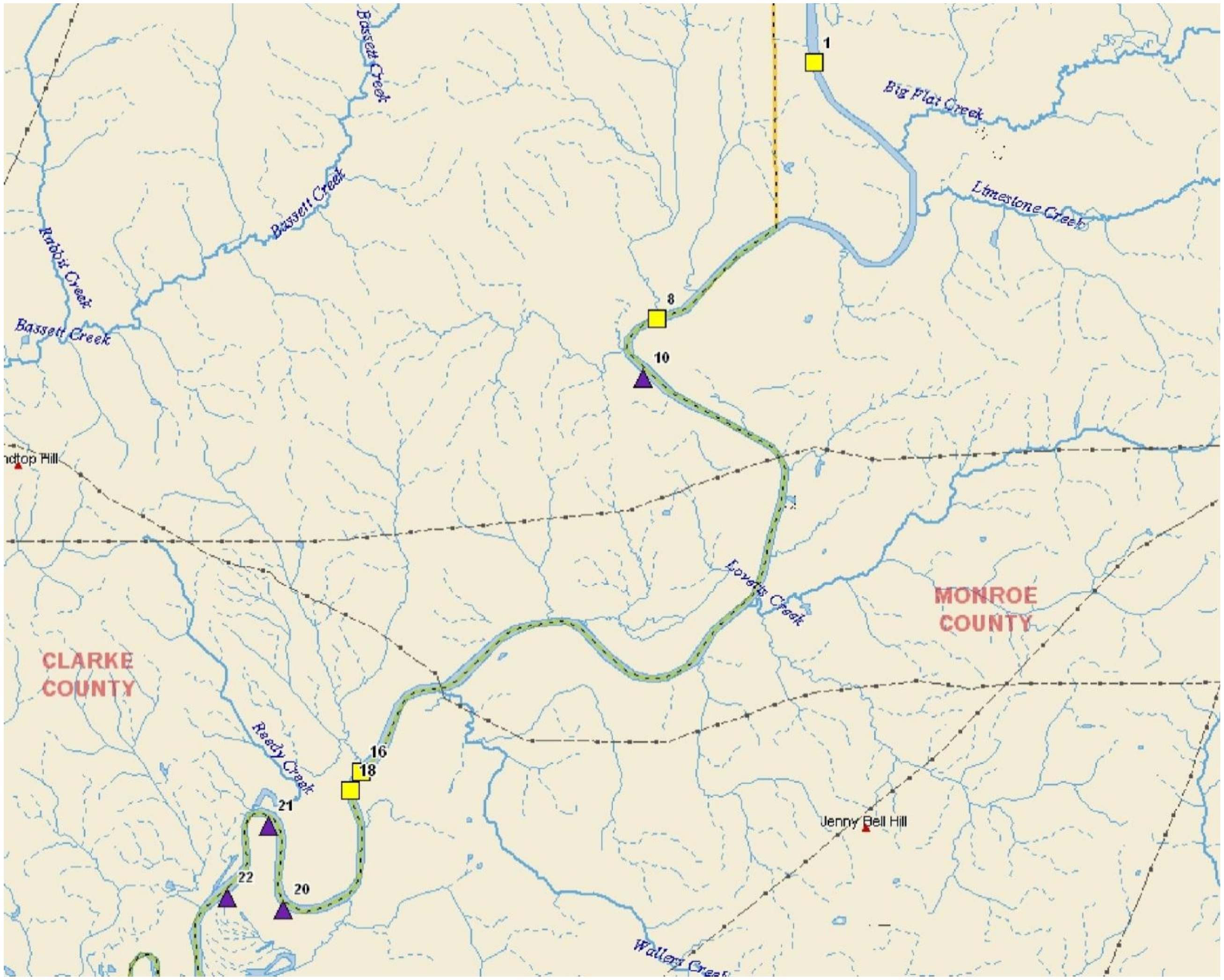


Fig. 3. Example compilation of Digital Ortho Quarter Quads (DOQQs) near Choctaw Bluff (RM 35).

Fig. 4. Example digitized sand/gravel bar habitats into polygons using ArcGIS.

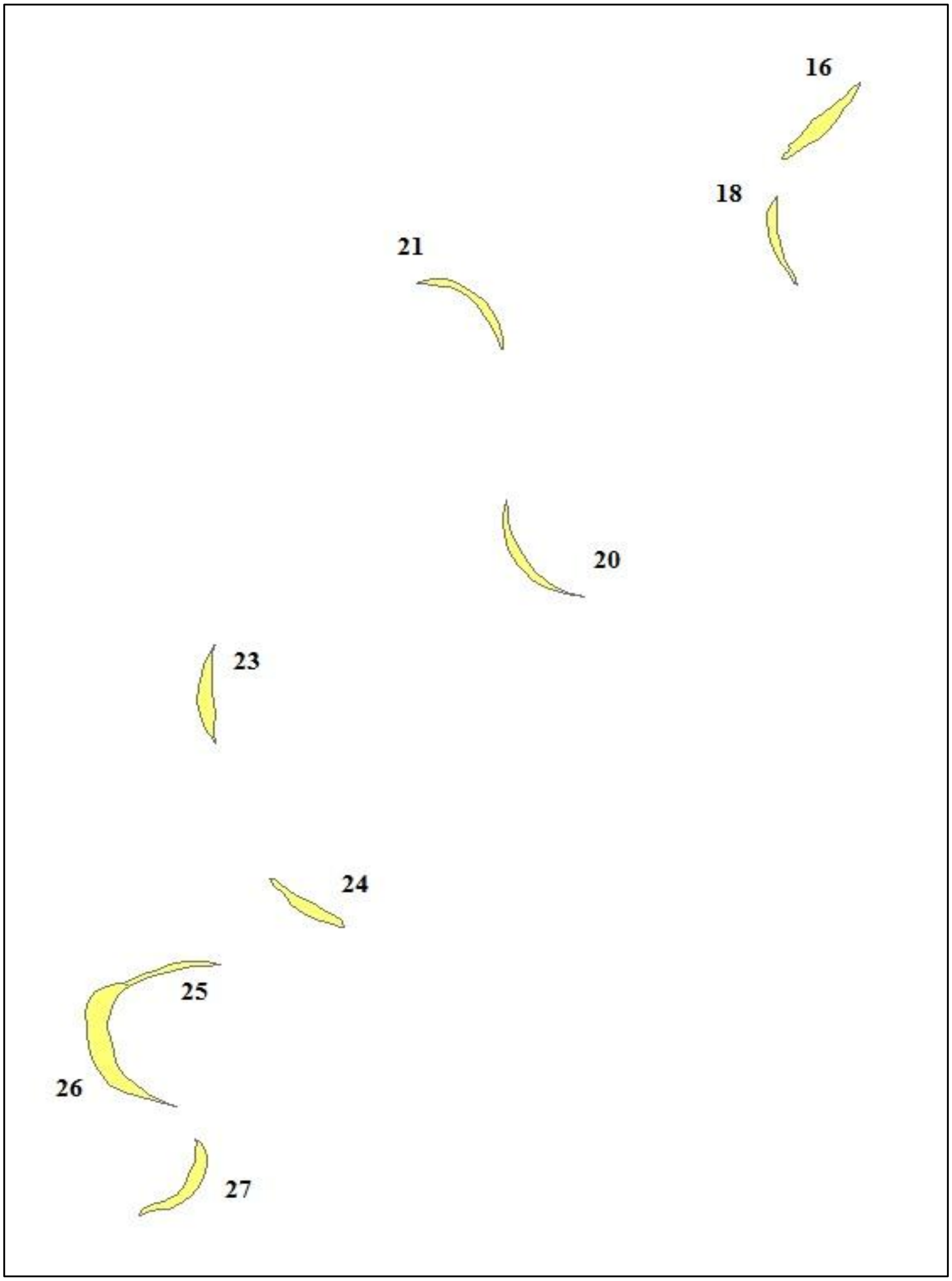


Fig. 5. Species richness of diel collections. Sites correspond with Fig. 2 and Appendix 1.

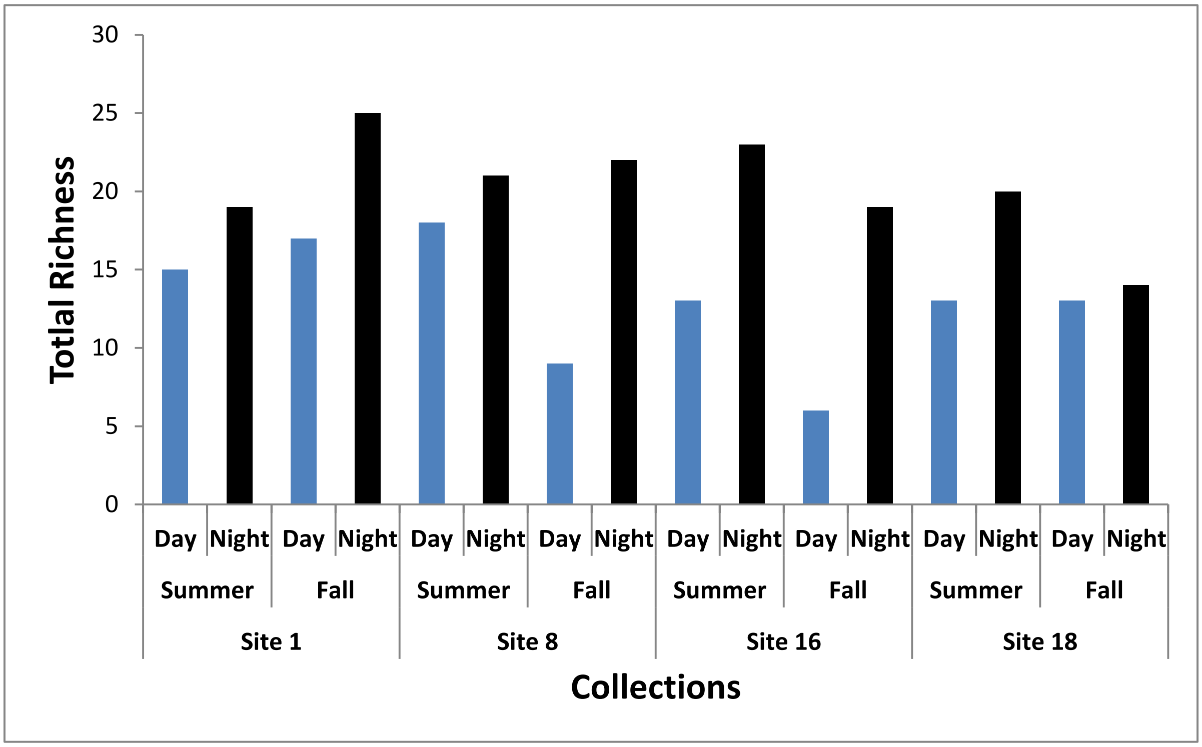


Fig. 6. Correspondence analysis for seasonal collections (Sites 1,8, and 10 combined).

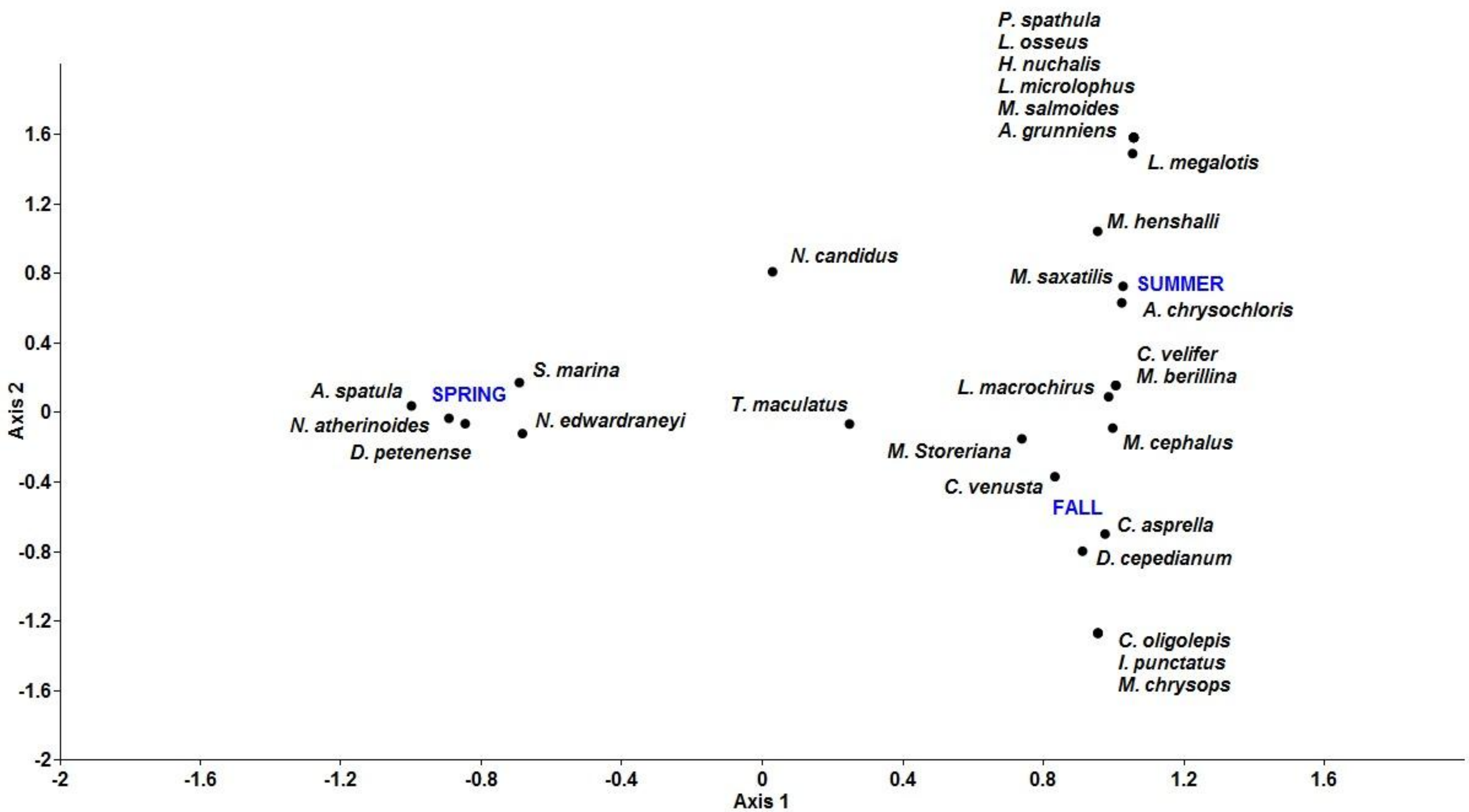


Fig. 7. Site 1 (RM 72) seasonal correspondence analysis.

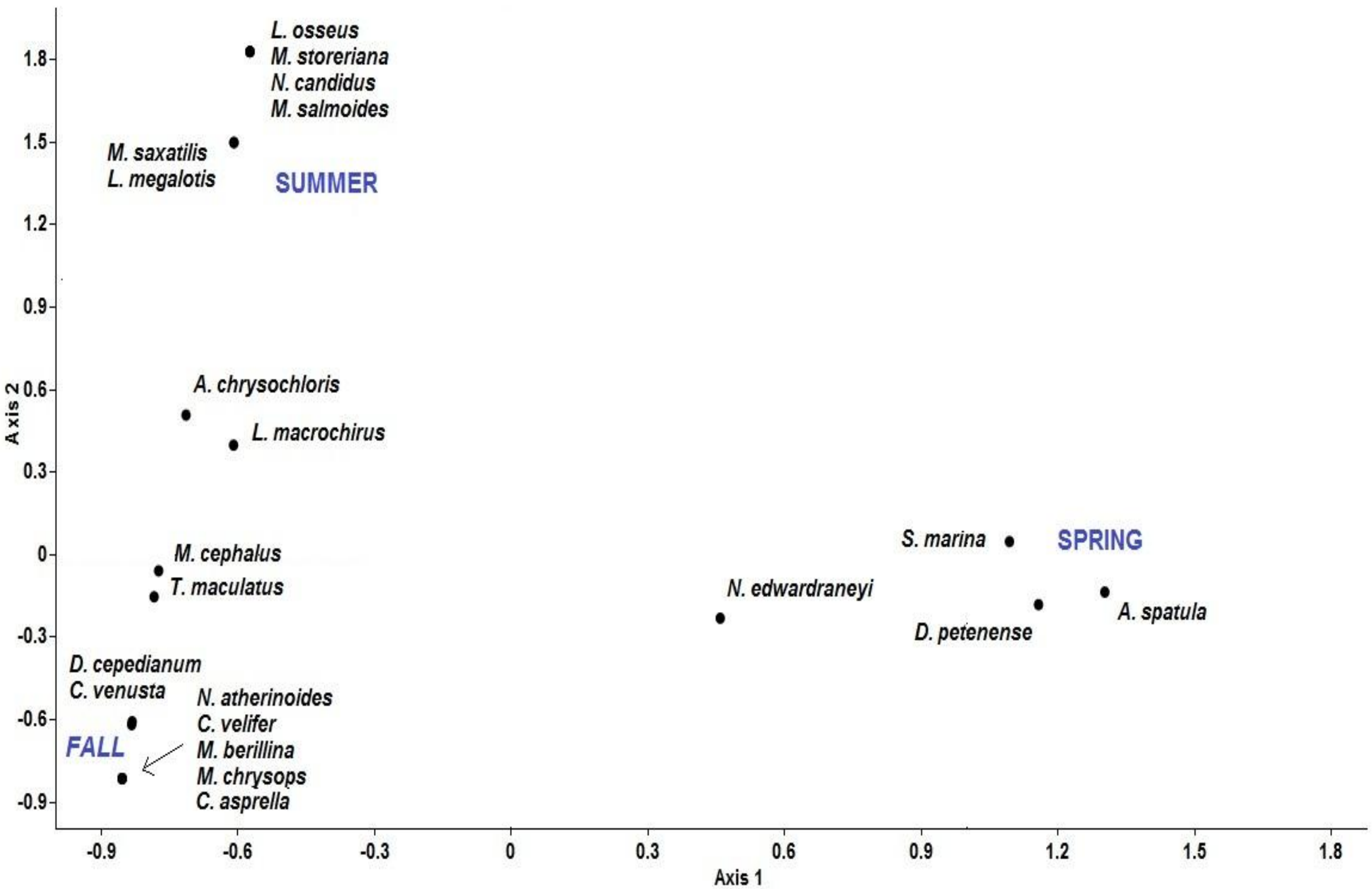


Fig. 8. Site 8 (RM 60) seasonal correspondence analysis.

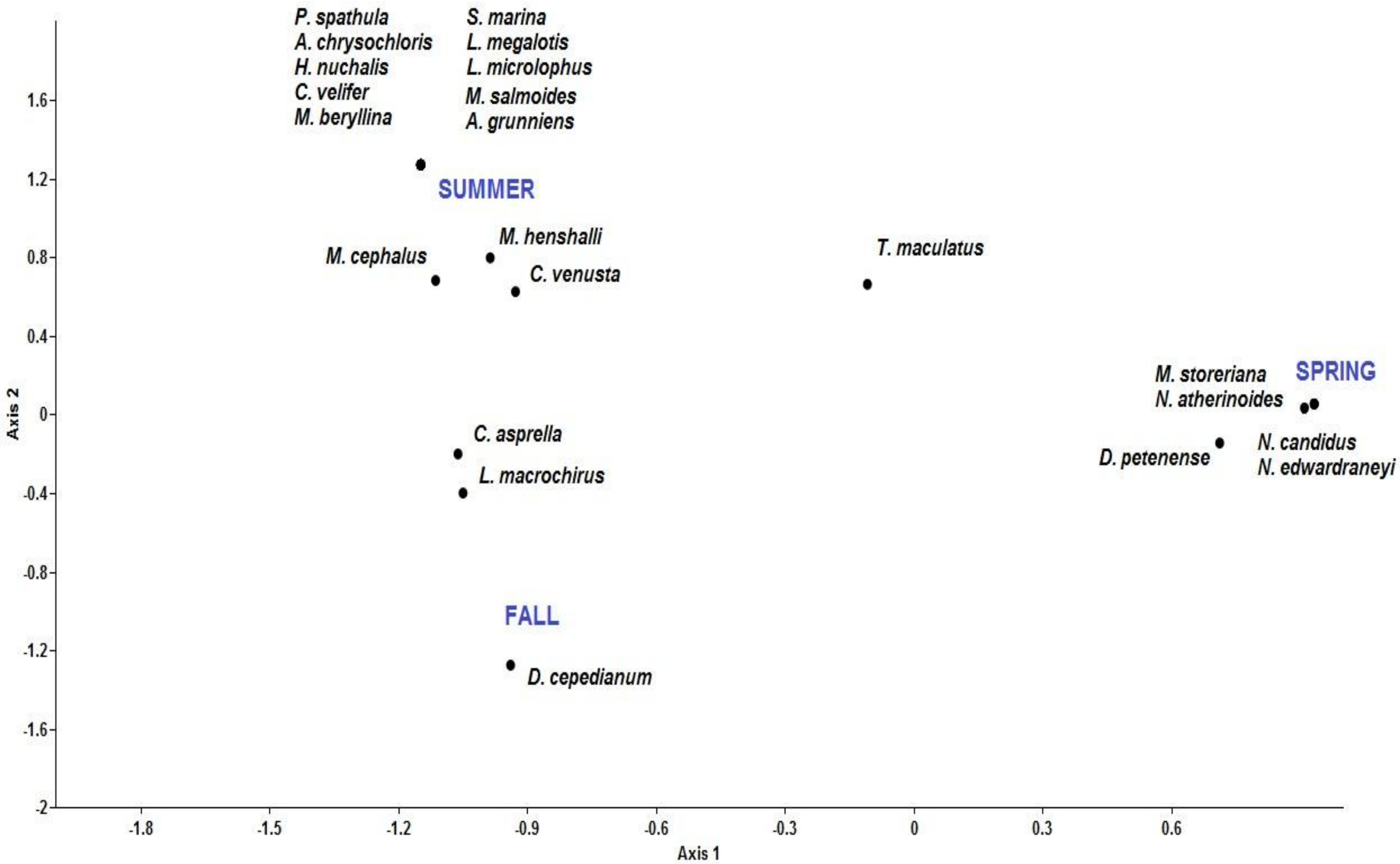


Fig. 9. Site 10 (RM 58.3) seasonal correspondence analysis.

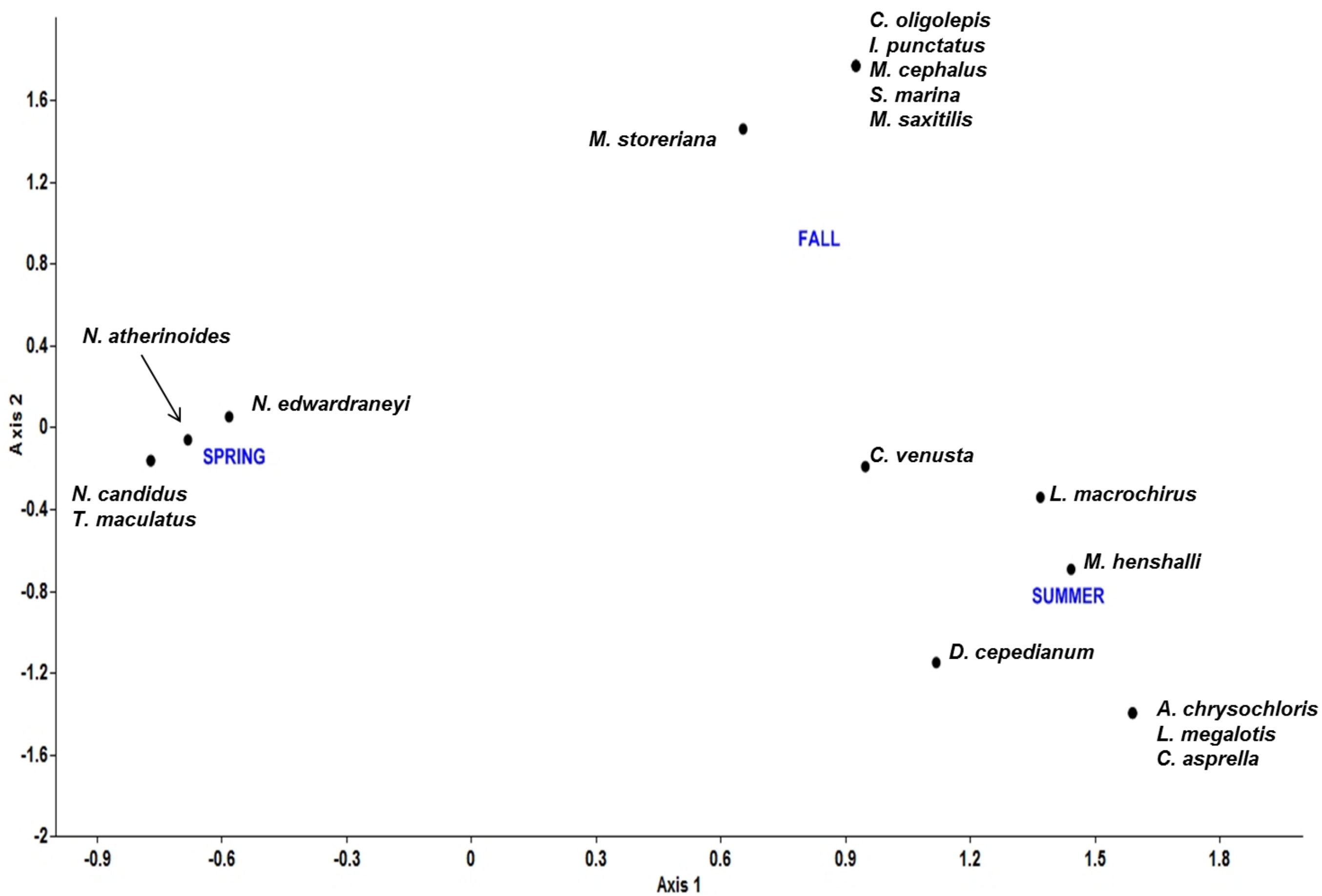


Fig. 10. Seasonal species abundance for site 1 (RM 72).

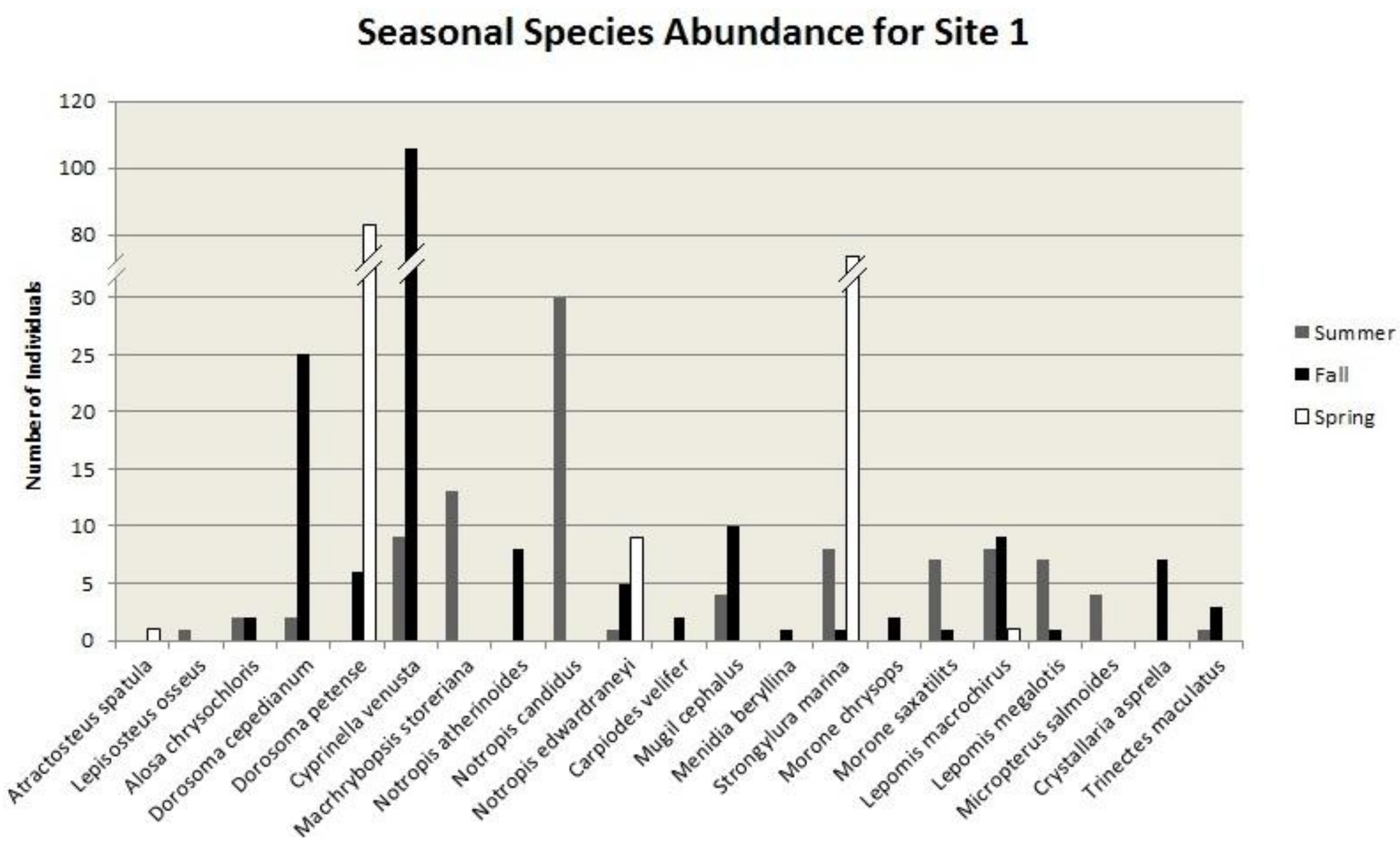


Fig. 11. Seasonal species abundance for site 8 (RM 60).

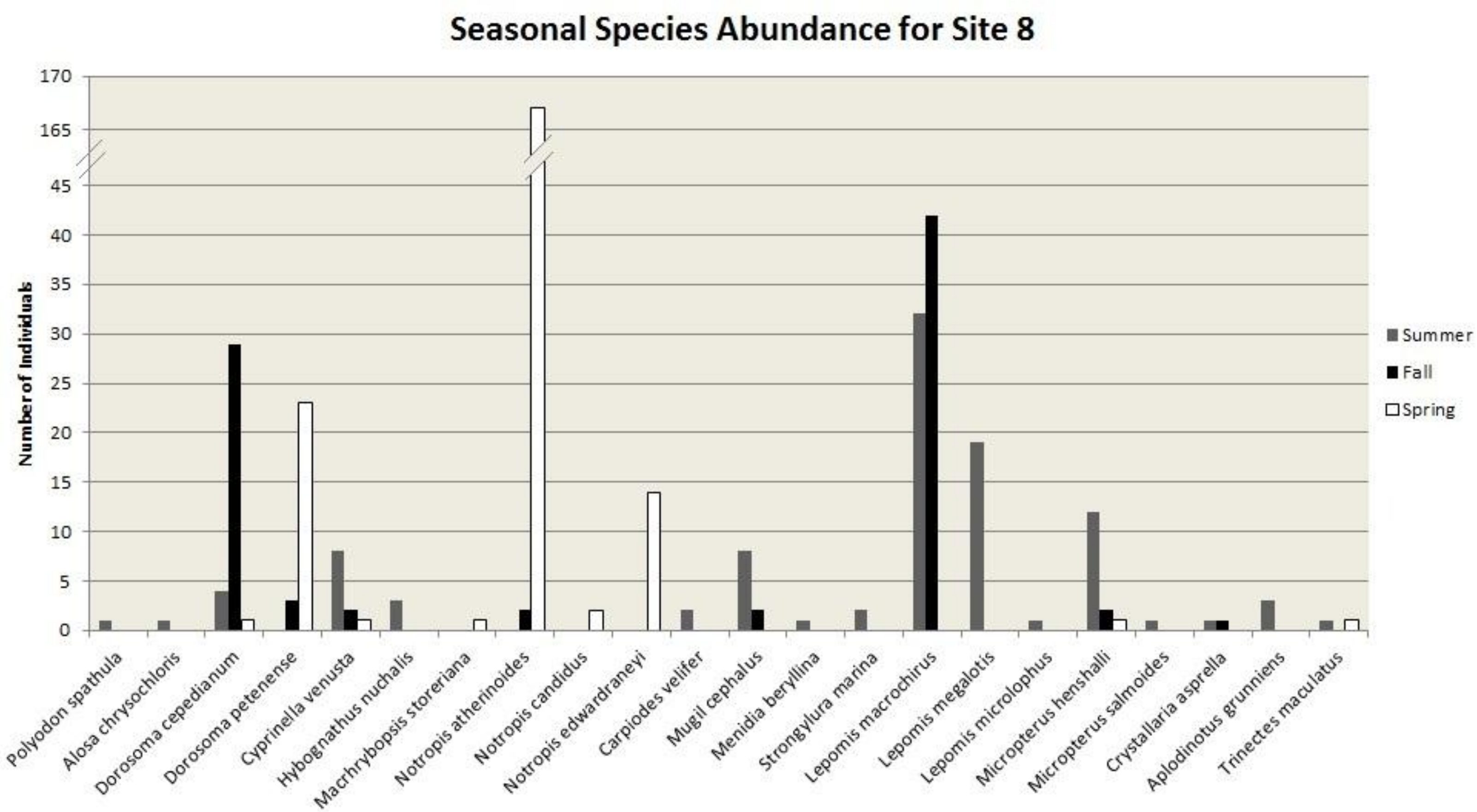


Fig. 12. Seasonal species abundance for site 10 (RM 58.3).

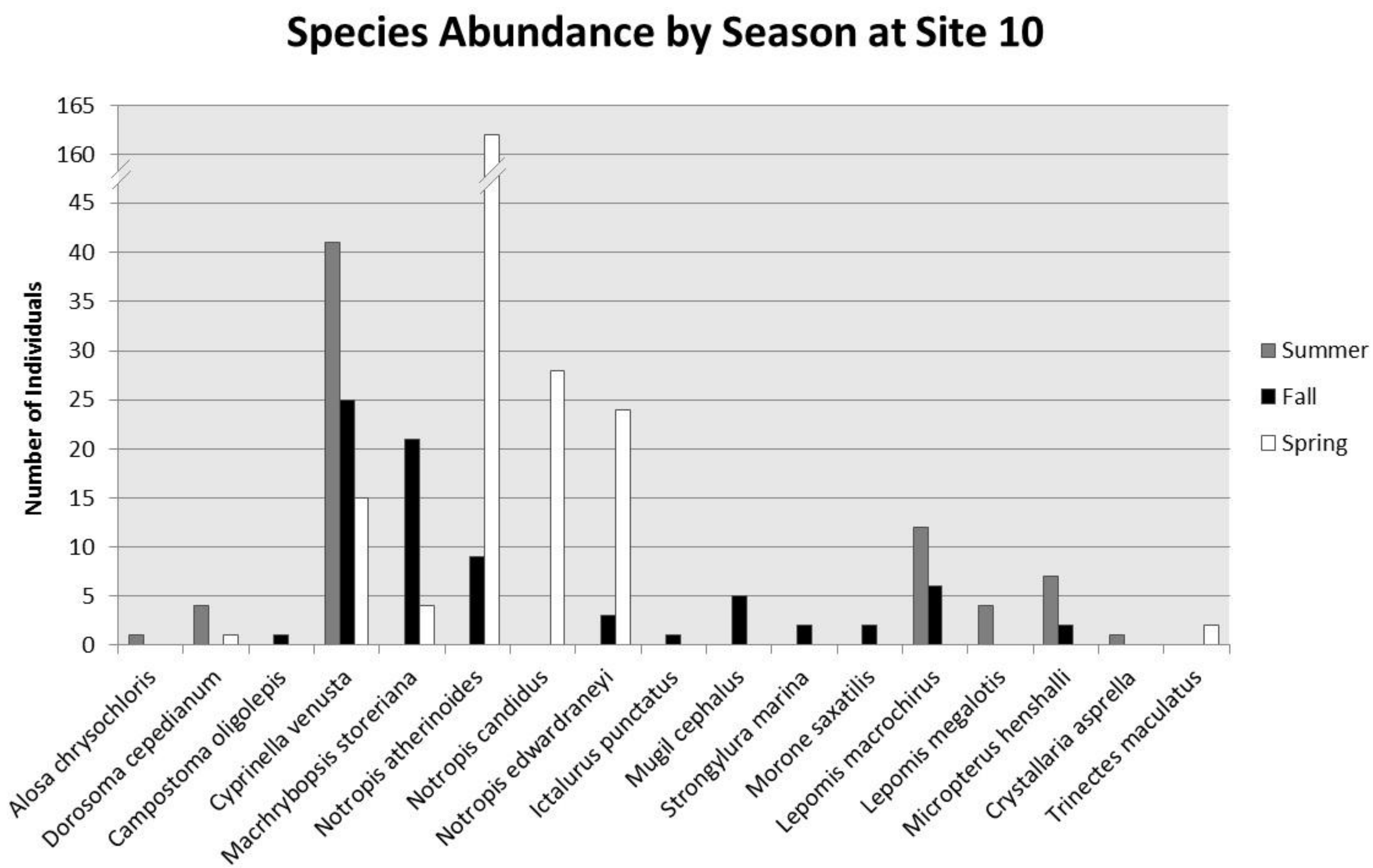
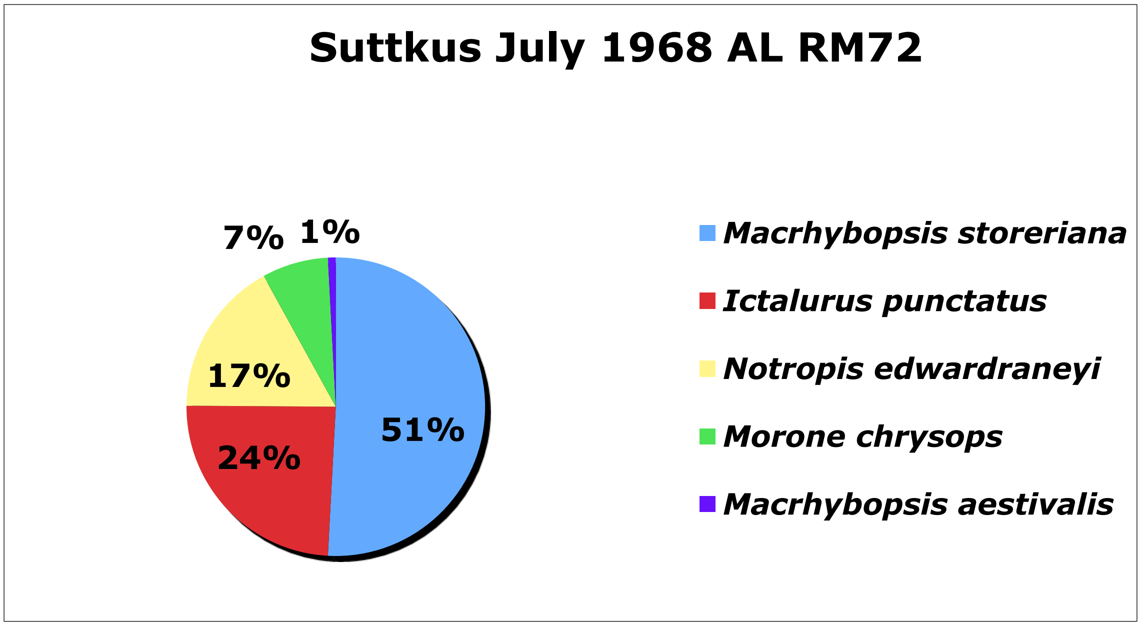


Fig. 13. Historic and current comparison for the top 5 species in each collection.



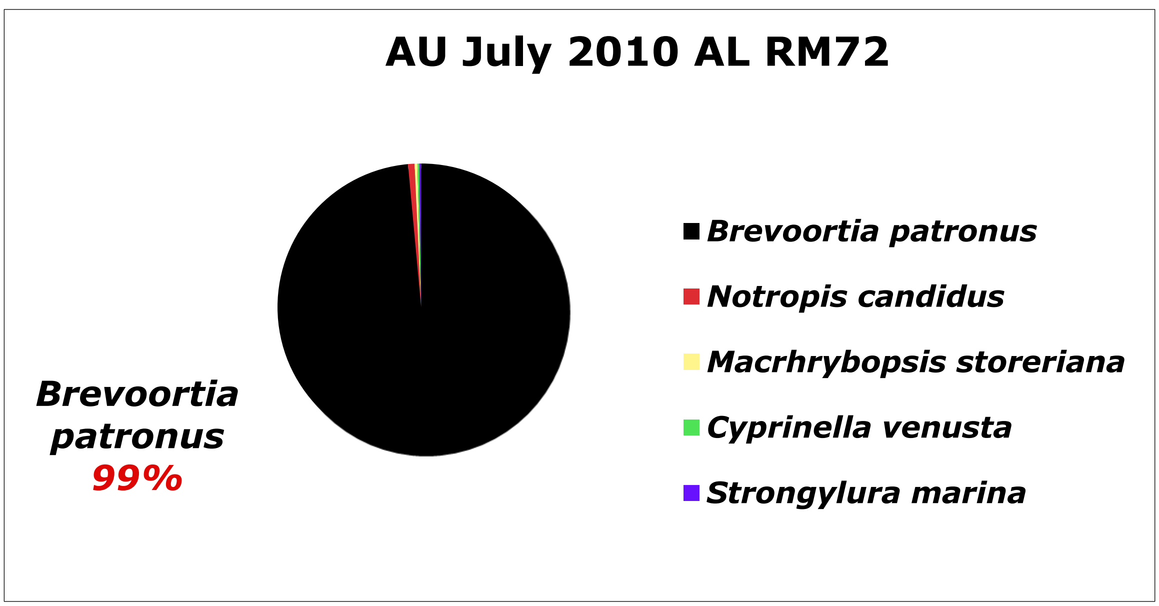


Fig. 14. Richness-area relationship for sand/gravel bar habitat ($p > 0.05$).

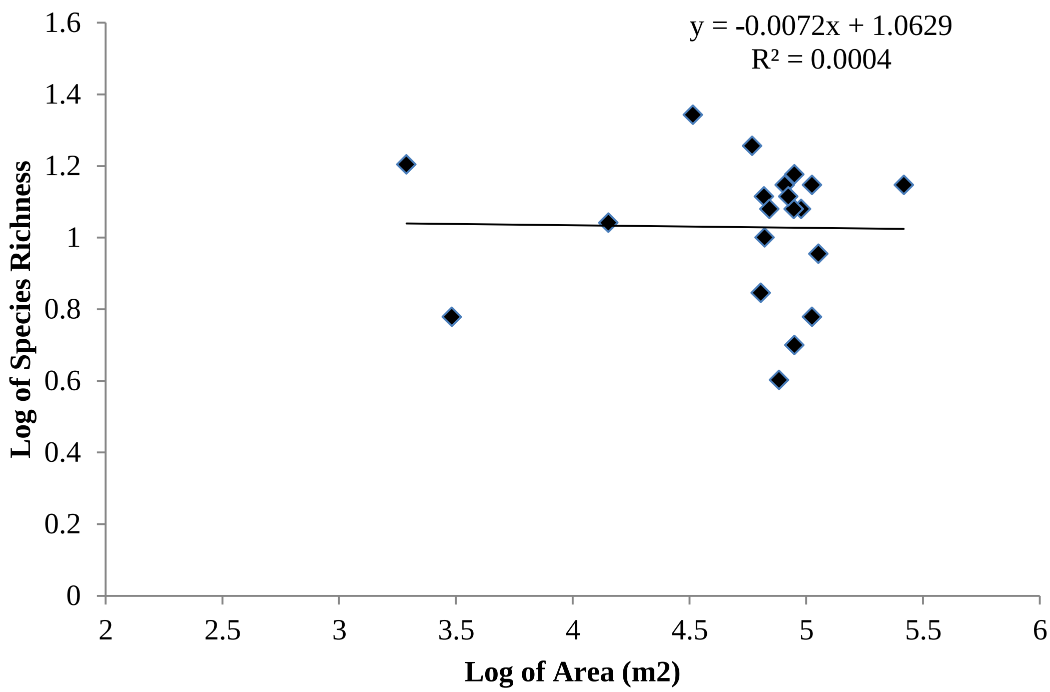
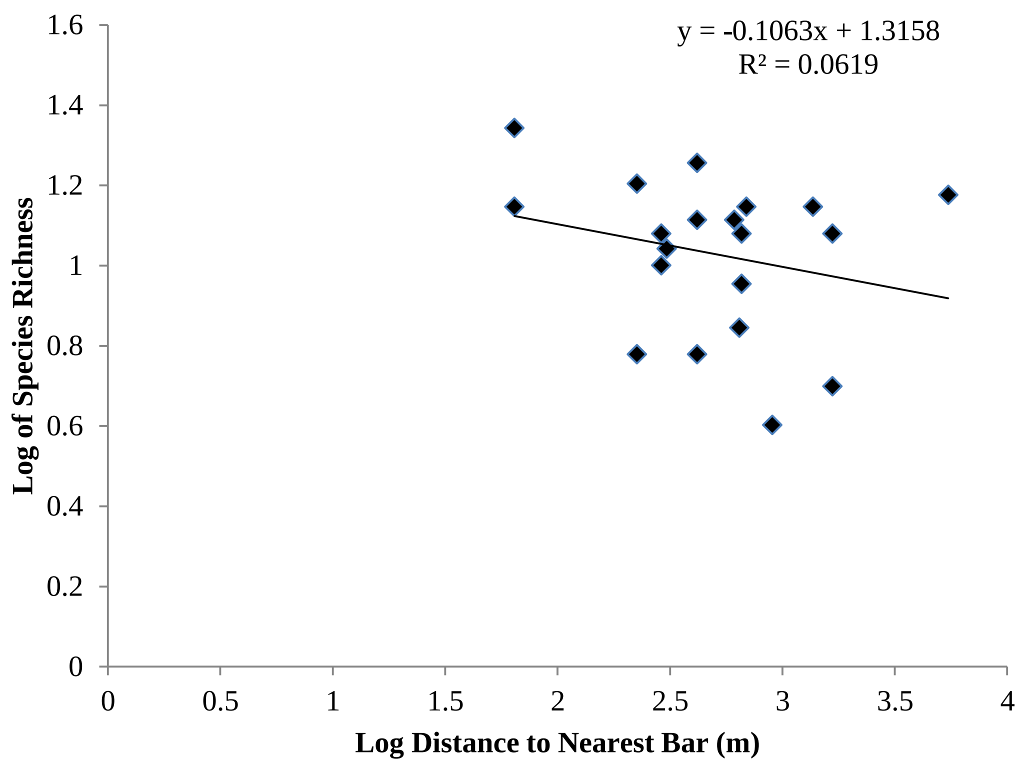


Fig. 15. Richness-distance to nearest bar relationship for sand/gravel bar habitat ($p > 0.05$).



APPENDIX 1

COLLECTION LOCALITIES FOR ALL SITES SAMPLED

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 Figs. 1 and 2.

Site #	Day/ Night	Season	Latitude	Longitude	Al River Mile	Site Description	Date	(°C)	Gear Used	Begin Time	End Time
1	Day	Summer	31.606766	87.550967	72	Sandbar directly below Claiborne Dam	6/28/10	30.0	50' Seine	8:25 AM	9:25 AM
1a	Day	Summer	31.608425	87.551257	72	Sandbar directly below Claiborne Dam	7/8/10	32.0	100' Seine	9:47 AM	10:50 AM
1b	Night	Summer	31.607965	87.551087	72	Sandbar directly below Claiborne Dam	7/27/10	31.2	100' Seine	10:15 PM	12:33 AM
1c	Night	Fall	31.607564	87.550947	72	Sandbar directly below Claiborne Dam	10/14/10	23.1	100' Seine	10:30 PM	12:00 AM
1d	Day	Fall	31.608583	87.550989	72	Sandbar directly below Claiborne Dam	10/15/10	24.0	100' Seine	1:00 PM	2:20 PM
1e	Day	Spring	31.606766	86.550967	72	Sandbar directly below Claiborne Dam	4/13/11	21.0	50’ Seine	2:10 PM	3:00 PM
2	Day	Summer	31.567631	87.513743	68.3	Bar downriver of paper plant	6/28/10	31.3	100' Seine	9:47 AM	10:20 AM
2a	Day	Summer	31.567598	87.513762	68.3	Bar downriver of paper plant	7/8/10	31.0	30' Seine	11:24 AM	12:21 PM
3	Day	Summer	31.557532	87.511109	67.6	Limestone Creek	8/4/10	29.0	30' Seine	1:15 PM	2:10 PM
4	Day	Summer	31.549879	87.516141	66.9	Directly above hwy 84 bridge	7/8/10	33.0	30' Seine	12:45 PM	1:05 PM
4a	Day	Summer	31.547998	87.517645	66.7	Directly below hwy 84 bridge. Small sand bar between jetties	7/8/10	33.0	30' Seine	1:15 PM	1:45 PM
5	Day	Summer	31.54735	87.539022	65.3	Galliard Creek	8/4/10	32.2	10' Seine, Shocker	2:24 PM	3:07 PM
6	Day	Summer	31.532973	87.595281	61	Choctaw Creek	8/5/10	25.5	10' Seine, Shocker	8:15 AM	9:00 AM
7	Day	Summer	31.525333	87.609521	60	Pigeon Creek	8/5/10	26	10' Seine	9:15 AM	10:10 AM

Appendix 1 continued. 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 Figs. 1 and 2.

Site #	**Day /Night**	**Season**	**Latitude**	**Longitude**	**Al River Mile**	**Site Description**	**Date**	**(°C)**	**Gear Used**	**Begin Time**	**End Time**
8	Day	Summer	31.523702	87.610241	60	3 pile Jetty's gravel bar near Nancy Hill Landing across from Pigeon Creek	7/8/10	32.0	100' Seine	2:06 PM	3:15 PM
8a	Night	Summer	31.523725	87.610925	60	3 pile Jetty's gravel bar near Nancy Hill Landing across from Pigeon Creek	8/2/10	31.0	100' Seine	10:30 PM	11:45 PM
8b	Nght	Fall	31.523681	87.610989	60	3 pile Jetty's gravel bar near Nancy Hill Landing across from Pigeon Creek	10/14/10	23.0	100' Seine	8:00 PM	9:26 PM
8c	Day	Fall	31.523841	87.610255	60	3 pile Jetty's gravel bar near Nancy Hill Landing across from Pigeon Creek	10/15/10	24.0	100' Seine	10:55 AM	12:25 PM
8d	Day	Spring	31.523279	87.609126	60	3 pile Jetty's gravel bar near Nancy Hill Landing across from Pigeon Creek	4/13/11	20.8	50’ Seine	12:25 PM	1:05 PM
9	Day	Summer	31.513265	87.623831	59	Cedar Creek	8/5/10	30.7	30' Seine	10:30 AM	11:20 AM
10	Day	Summer	31.508194	87.615469	58.3	Mrs. Grey's Bar right bank (downriver)	7/8/10	32.0	100' Seine	3:55 PM	4:55 PM
10a	Day	Fall	31.50848	87.615571	58.3	Mrs. Grey's Bar right bank (downriver)	10/14/10	23.3	100' Seine	5:30 PM	6:40 PM
10b	Day	Spring	31.507354	87.614888	58.3	Mrs. Grey's Bar right bank (downriver)	4/13/11	20.8	50’ Seine	11:25 AM	12:15 PM
11	Day	Summer	31.475423	87.561345	54.4	Marshall's Creek	8/5/10	26.5	10' Seine, Shocker	12:02 PM	1:15 PM
12	Day	Summer	31.44775	87.56807	52	Hollinger Creek	8/5/10	28	10' Seine, Shocker	1:45 PM	3:00 PM

Appendix 1 continued. 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 Figs. 1 and 2.

Site #	**Day /Night**	**Season**	**Latitude**	**Longitude**	**Al River Mile**	**Site Description**	**Date**	**(°C)**	**Gear Used**	**Begin Time**	**End Time**
13	Day	Summer	31.414326	87.627276	47	Sandbar divided by jetties between Shackleford Bar and English Landing	7/26/10	31.5	30' Seine	10:50 AM	12:20 PM
13a	Day	Summer	31.416228	87.630366	47	Sandbar divided by jetties between Shackleford Bar and English Landing	7/26/10	31.5	50' Seine	10:50 AM	12:20 PM
14	Day	Summer	31.424393	87.640235	46.4	Sandbar / Disposal area between Frenchs Landing and English Landing	7/26/10	31.0	50' Seine	9:00 AM	10:30 AM
15	Day	Summer	31.382167	87.717499	40.3	Sandbar across and downriver from Euryka Landing (Near Irvin Creek)	7/9/10	31.5	100' Seine	8:20 AM	9:13 AM
16	Day	Summer	31.377482	87.721757	39.6	Sandbar near Irvin Creek (Directly above mouth of creek)	7/26/110	34.5	100' Seine	1:52 PM	3:20 PM
16a	Night	Summer	31.380454	87.718138	39.6	Sandbar near Irvin Creek (Directly above mouth of creek)	8/9/10	31.5	100' Seine	8:45 PM	11:55 PM
16b	Day	Summer	31.380648	87.717944	39.6	Sandbar near Irvin Creek (Directly above mouth of creek)	8/10/10	33.5	100' Seine	10:30 AM	11:28 AM
16c	Night	Fall	31.379762	87.718719	39.6	Sandbar near Irvin Creek (Directly above mouth of creek)	10/15/10	21.2	100' Seine	9:00 PM	10:15 PM
16d	Day	Fall	31.379856	87.718624	39.6	Sandbar near Irvin Creek (Directly above mouth of creek)	10/16/10	22.8	100' Seine	10:00 AM	11:15 AM

Appendix 1 continued. 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 Figs. 1 and 2.

Site #	Day /Night	Season	Latitude	Longitude	Al River Mile	Site Description	Date	(°C)	Gear Used	Begin Time	End Time
17	Day	Summer	31.377019	87.722704	39.8	Sizemore / Irvin Creek	8/6/10	23.5	30', 10' seine, shocker	7:50 AM	9:33 AM
18	Day	Summer	31.371523	87.725739	39.3	Sandbar downriver and opposite of Irvin Creek	7/9/10	31.7	50' Seine	9:20 AM	10:15 AM
18a	Night	Summer	31.369525	87.726053	39.2	Sandbar downriver and opposite of Irvin Creek	8/10/10	30.6	50' Seine	12:05 AM	1:46 AM
18b	Day	Summer	31.369839	87.7261	39.2	Sandbar downriver and opposite of Irvin Creek	8/10/10	32.5	50' Seine	11:45 AM	12:16 PM
18c	Night	Fall	31.370694	87.726122	39.2	Sandbar downriver and opposite of Irvin Creek	10/15/10	22.5	50' Seine	7:20 PM	8:45 PM
18d	Day	Fall	31.370718	87.726146	39.2	Sandbar downriver and opposite of Irvin Creek	10/16/10	22.1	50' Seine	11:16 AM	12:15 PM
19	Day	Summer	31.336516	87.727448	36.9	Potts Bayou	8/6/10	26.5	10' Seine, Shocker	10:15 AM	11:00 AM
20	Day	Summer	31.336299	87.75164	35.4	Sandbar above (upriver) Choctaw Bluff	7/9/10	33.4	100' Seine	10:36 AM	11:20 AM
20a	Day	Fall	31.336819	87.752356	35.4	Sandbar above (upriver) Choctaw Bluff	10/15/10	24.0	100' Seine	4:45 PM	6:25 PM
21	Day	Summer	31.363272	87.756877	33.3	Sandbar across Choctaw Bluff (east bank)	7/9/10	36.5	100' Seine	12:00 PM	12:36 PM
21a	Day	Fall	31.363176	87.755872	33.3	Sandbar across Choctaw Bluff (east bank)	10/16/10	26.2	100' Seine	12:55 PM	1:45 PM
22	Day	Summer	31.340333	87.772578	31.6	Sandbar (Island) ≈ 1.3mi Below Choctaw Bluff	7/27/10	31.4	50' Seine	8:49 AM	9:55 AM
22a	Day	Fall	31.3396	87.77209	31.6	Sandbar (Island) ≈ 1.3mi Below Choctaw Bluff	10/16/10	26.1	100' Seine	2:00 PM	3:05 PM

Appendix 1 continued. 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 Figs. 1 and 2.

Site #	**Day /Night**	**Season**	**Latitude**	**Longitude**	**Al River Mile**	**Site Description**	**Date**	**(°C)**	**Gear Used**	**Begin Time**	**End Time**
23	Day	Summer	31.327761	87.784254	29.9	Sandbar 0.8mi down from Matthewsons Bar	7/27/10	31.6	100' Seine	10:01 AM	11:12 AM
24	Day	Summer	31.303009	87.775094	28.4	Sandbar upriver of Dixie Landing	7/27/10	33.0	100' Seine	12:00 PM	1:15 PM
25	Day	Summer	31.297774	87.785475	26.3	Sandbar near Dixie Cutoff and Monroe Point	7/27/10	32.5	100' Seine	1:30 PM	3:30 PM
26	Day	Summer	31.295258	87.795414	25.5	Sandbar Below Monroe Point	8/2/10	34.5	100' Seine	10:47 AM	12:24 PM
27	Day	Summer	31.276208	87.78405	24	Alabama River Sandbar	8/2/10	33.5	50' Seine	1:00 PM	1:45 PM
28	Day	Summer	31.26872	87.802023	22.9	Earl Bar Sandbar	8/2/10	33.5	50' Seine	2:05 PM	2:20 PM

APPENDIX 2

SPECIES COLLECTED BY SITE FOR ALL SAMPLED SITES

Appendix 2. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #														
Species	**1**	**1a**	**1b**	**1c**	**1d**	**1e**	**2**	**2a**	**3**	**4**	**4a**	**5**	**6**	**7**	**8**
Polyodon spathula															1
Atractosteus spatula						1									
Lepisosteus oculatus			13												
Lepisosteus osseus		1		1											
Hiodon tergisus				1											
Anchoa mitchilli				2				1							
Alosa chrysochloris	1	2	15	4	2		1			1					1
Brevoortia patronus	1607	4042	8159	495	18590			8		1					4
Dorosoma cepedianum	15	2	25	15	25			1						1	4
Dorosoma petenense	21		2593	41	6	83									
Campostoma oligolepis															
Cyprinella venusta	22	9	2	1	106		3	8		18	9	78	16	4	8
Hybognathus nuchalis															3
Macrhrybopsis aestivalis sp. cf															
Macrhrybopsis storeriana	10	13	112	7											
Notropis atherinoides	6			2	8		11	453	9	10		14	10	44	
Notropis candidus	42	30	119	13											
Notropis edwardraneyi		1		38	5	9						13	1		
Notropis petersoni															
Notropis texanus															
Notropis uranoscopus															
Pimephales vigilax															
Semotilus atromaculatus															
Carpiodes cyprinus															
Carpiodes velifer					2										2
Ictiobus bubalus															

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #														
Species	**1**	**1a**	**1b**	**1c**	**1d**	**1e**	**2**	**2a**	**3**	**4**	**4a**	**5**	**6**	**7**	**8**
Moxostoma poecilurum				1											
Ameiurus natalis												1			
Ictalurus furcatus			88	16											
Ictalurus punctatus			37	41											
Pylodictis olivaris				1											
Mugil cephalus		4	1	3	10										8
Menidia beryllina			1		1		1	2							1
Strongylura marina	2	8	9		1	73	1	4		4					2
Gambusia affinis								6			1	2	65		
Gambusia holbrooki															
Morone chrysops			33	11	2										
Morone chrysops x saxatilis				2											
Morone mississippiensis			2												
Morone saxatilis		7	104	20	1										
Morone sp. (Hybrid)			1												
Lepomis macrochirus	1	8		2	9	1	1	3			2	2	10	1	32
Lepomis marginatus															
Lepomis megalotis	3	7		1	1						1	2		1	19
Lepomis microlophus															1
Lepomis miniatus															
Micropterus henshalli	1							2		4	4			1	12
Micropterus salmoides		4						1							1
Pomoxis annularis															
Pomoxis nigromaculatus			1	1											
Ammocrypta beani															
Crystallaria asprella	2		1	6	7										1

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #														
Species	**1**	**1a**	**1b**	**1c**	**1d**	**1e**	**2**	**2a**	**3**	**4**	**4a**	**5**	**6**	**7**	**8**
Etheostoma chlorosoma															
Etheostoma nigrum												1			
Percina kathae															
Aplodinotus grunniens															3
Trinectes maculates		1		42	3										1

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #											
Species	**8a**	**8b**	**8c**	**8d**	**9**	**10**	**10a**	**10b**	**11**	**12**	**13**	**13a**
Polyodon spathula												
Atactosteus spatula												
Lepisosteus oculatus	1	2										
Lepisosteus osseus												
Hiodon tergisus	1											
Anchoa mitchilli		9										46
Alosa chrysochloris		1				1						
Brevoortia patronus	1	29934	144464				109052					1
Dorosoma cepedianum	8	15	29	1		4		1				3
Dorosoma petenense	6	3	3	23							4	
Campostoma oligolepis		1			1		1		5	4		
Cyprinella venusta	1	3	2	1	3	41	25	15	13	2	11	9
Hybognathus nuchalis												
Macrhrybopsis aestivalis sp. cf												
Macrhrybopsis storeriana	47	19		1			21	4	2		2	8
Notropis atherinoides		8	2	167	9		9	162			273	18
Notropis candidus	109	6		2				28	2			
Notropis edwardraneyi		84		14			3	23				3
Notropis petersoni					29					2		
Notropis texanus												
Notropis uranoscopus								1				
Pimephales vigilax												
Semotilus atromaculatus									1			
Carpiodes cyprinus												
Carpiodes velifer	1	1										
Ictiobus bubalus												

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #											
Species	**8a**	**8b**	**8c**	**8d**	**9**	**10**	**10a**	**10b**	**11**	**12**	**13**	**13a**
Moxostoma poecilurum	1				1							
Ameiurus natalis												
Ictalurus furcatus	2											
Ictalurus punctatus	256	31					1		3	1		
Pylodictis olivaris									2	1		
Mugil cephalus	2	2	2				5					
Menidia beryllina												
Strongylura marina							2					
Gambusia affinis	1				9				3	50	1	
Gambusia holbrooki		2										
Morone chrysops		2										
Morone chrysops x saxatilis												1
Morone mississippiensis												
Morone saxatilis	22	10					2		1			1
Morone sp. (Hybrid)												
Lepomis macrochirus	13	1	42		2	12	6		3	10		
Lepomis marginatus												
Lepomis megalotis	1					4			4	4		
Lepomis microlophus												
Lepomis miniatus									2			
Micropterus henshalli	2		2	1		7	2			2	2	
Micropterus salmoides					1				1			
Pomoxis annularis												
Pomoxis nigromaculatus	3									1		
Ammocrypta beani						1						
Crystallaria asprella		2	1									

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #										
Species	**8a**	**8b**	**8c**	**8d**	**9**	**10**	**10a**	**10b**	**11**	**12**	**13**	**13a**
Etheostoma chlorosoma												
Etheostoma nigrum												
Percina kathae												
Aplodinotus grunniens	66	2										
Trinectes maculatus	3	1		1				2				1

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #												
Species	**14**	**15**	**16**	**16a**	**16b**	**16c**	**16d**	**17**	**18**	**18a**	**18b**	**18c**	**18d**
Polyodon spathula													
Atactosteus spatula													
Lepisosteus oculatus				1					2				
Lepisosteus osseus				1									
Hiodon tergisus													
Anchoa mitchilli	1	1		1					22	30	3	286	322
Alosa chrysochloris									1				
Brevoortia patronus	1200	321	12279	65	4328	72	420			178	2	36	3
Dorosoma cepedianum		1	8	35	6	1			5	6	6		1
Dorosoma petenense		28		50	643	1			145	59	65		
Campostoma oligolepis													
Cyprinella venusta	9	46	11	10	17		63	31	14	21	71	20	7
Hybognathus nuchalis					1								
Macrhrybopsis aestivalis sp. cf						1							
Macrhrybopsis storeriana	20	5		82		150	10	100	2	98	66	30	7
Notropis atherinoides	25					14	5	61	1	96	31	8	19
Notropis candidus	91			177		39				16		162	50
Notropis edwardraneyi	2				1	20				1			7
Notropis petersoni													
Notropis texanus								109					
Notropis uranoscopus													
Pimephales vigilax				4		1			8	1		12	1
Semotilus atromaculatus													
Carpiodes cyprinus						1				1			
Carpiodes velifer	1	17		24	21	72	13			3	28	5	
Ictiobus bubalus													

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #												
Species	**14**	**15**	**16**	**16a**	**16b**	**16c**	**16d**	**17**	**18**	**18a**	**18b**	**18c**	**18d**
Moxostoma poecilurum													
Ameiurus natalis													
Ictalurus furcatus				520		21				942	1	1	
Ictalurus punctatus				469		200		1		102		753	3
Pylodictis olivaris				1									
Mugil cephalus		2	2										
Menidia beryllina												1	
Strongylura marina	1			1					1				
Gambusia affinis													
Gambusia holbrooki													
Morone chrysops												2	
Morone chrysops x saxatilis													
Morone mississippiensis													
Morone saxatilis		2		9		10		3		4	1		
Morone sp. (Hybrid)													
Lepomis macrochirus		6	3	68	10			1	5	1	1		
Lepomis marginatus													
Lepomis megalotis	1	1			1	1		2					
Lepomis microlophus													
Lepomis miniatus													
Micropterus henshalli	3	1		4	5	3			7	1			1
Micropterus salmoides		1	3		1				1	1	1		
Pomoxis annularis				2									
Pomoxis nigromaculatus				5								1	
Ammocrypta beani													
Crystallaria asprella				2		9	1						

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #												
Species	**14**	**15**	**16**	**16a**	**16b**	**16c**	**16d**	**17**	**18**	**18a**	**18b**	**18c**	**18d**
Etheostoma chlorosoma								1					
Etheostoma nigrum													
Percina kathae													
Aplodinotus grunniens		1		34	1	3				4			1
Trinectes maculatus		5			22	4	3		1		2	2	40

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #												
Species	**19**	**20**	**20a**	**21**	**21a**	**22**	**22a**	**23**	**24**	**25**	**26**	**27**	**28**
Polyodon spathula													
Atactosteus spatula													
Lepisosteus oculatus													
Lepisosteus osseus													
Hiodon tergisus													
Anchoa mitchilli			152		2	3					1	32	93
Alosa chrysochloris						6				1			
Brevoortia patronus		14	14067		690	808	2474	29195	8520	2616			
Dorosoma cepedianum		1	6	4	6		6		14	36		13	
Dorosoma petenense						87		3	76	273	1320	319	
Campostoma oligolepis													
Cyprinella venusta	22	7	7	2	43	37	30	24	59	26	12	50	1
Hybognathus nuchalis													
Macrhrybopsis aestivalis sp. cf													
Macrhrybopsis storeriana	2	1	22		58	9	166	9	6	60	5	23	
Notropis atherinoides	12		2		7	31	3	2	6	7		8	
Notropis candidus			21			1			2		1	3	
Notropis edwardraneyi			50			3	4			24		3	
Notropis petersoni													
Notropis texanus	29												
Notropis uranoscopus													
Pimephales vigilax													
Semotilus atromaculatus													
Carpiodes cyprinus													
Carpiodes velifer		8	46	1	130	13	362	5	11	97	451	4	
Ictiobus bubalus										1			

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #												
Species	**19**	**20**	**20a**	**21**	**21a**	**22**	**22a**	**23**	**24**	**25**	**26**	**27**	**28**
Moxostoma poecilurum										1			
Ameiurus natalis													
Ictalurus furcatus										2			
Ictalurus punctatus			10				1						
Pylodictis olivaris													
Mugil cephalus			1					1		5	4		
Menidia beryllina		1									2		
Strongylura marina		3				1	1		1	1	1		1
Gambusia affinis													
Gambusia holbrooki													
Morone chrysops			4										
Morone chrysops x saxatilis													
Morone mississippiensis													
Morone saxatilis		1	8		1		1		6	10	3		2
Morone sp. (Hybrid)													
Lepomis macrochirus	4	3	2	4	1				6	13	1		
Lepomis marginatus													
Lepomis megalotis			1				2			8		3	
Lepomis microlophus										1			
Lepomis miniatus													
Micropterus henshalli	1	1		1	2	3		2	5	27	2	2	
Micropterus salmoides		3							2	3	6		
Pomoxis annularis													
Pomoxis nigromaculatus			1										
Ammocrypta beani													
Crystallaria asprella										2			

Appendix 2 continued. Species collected by site. Site numbers correspond to Figs. 1 and 2 as well as Appendix 1. Highlighted site numbers represent tributaries.

	Site #												
Species	**19**	**20**	**20a**	**21**	**21a**	**22**	**22a**	**23**	**24**	**25**	**26**	**27**	**28**
Etheostoma chlorosoma													
Etheostoma nigrum													
Percina kathae					1								
Aplodinotus grunniens							6		4			1	
Trinectes maculatus		1	188		14		20	2		8	6	7	