Summer 2024

An Assessment of Functional Characteristics in Macroinvertebrates and Fishes in the Lower Ogeechee River

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AN ASSESSMENT OF FUNCTIONAL CHARACTERISTICS IN MACROINVERTEBRATES AND FISHES IN THE LOWER OGEECHEE RIVER

by

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(Under the Direction of J. Checo Colón–Gaud)

ABSTRACT

The southeastern United States is a hotspot for aquatic biodiversity; yet this region is also considered vulnerable to climate and land–use changes. The Ogeechee River is an unimpeded blackwater river in Georgia that drains into the Atlantic Ocean and a unique ecosystem due to the preservation of its natural state; Historically, research conducted in the river establishes a baseline for long-term ecological studies. The aim of this study is to compare aquatic macroinvertebrate and fish community composition data collected in 2014 to 2017 to a recently collected dataset from 2023 and document temporal changes. Water quality monitoring was performed throughout the year either daily or monthly dependent upon site. Aquatic macroinvertebrates and fishes were collected seasonally using standardized methods. Macroinvertebrates were assessed using rapid bioassessment protocols (RBP), permutational multivariate analysis of variance (PERMANOVA), and non–metric multidimensional scaling (NMDS) plots based on abundance and functional traits. Fishes were assessed using the index of biotic integrity (IBI), PERMANOVA, and NMDS based on abundance and trophic characteristics. Macroinvertebrate and fish communities improved in RBP and IBI scores, respectively in 2023 compared to 2014–2017. Macroinvertebrate communities differed across years and seasons, including differences between seasonal communities within a single year. Macroinvertebrate relative abundance appears to be influenced by seasonal flood pulse patterns. Site-specific macroinvertebrate communities sampled in 2023 were similar within the community; however, the 2023 communities were different from the historical dataset. Fish communities differed across sampling years with partial overlap in relative abundances between sites. The community abundance and feeding guild abundance differed in community composition in 2014 samples compared to all other years. The results from this study emphasize the importance of community analysis over time. Long-term datasets like the one generated in this study can provide meaningful insights for conservation scientists.

INDEX WORDS: Aquatic ecology, Aquatic macroinvertebrates, Conservation, Freshwater fish, Functional traits, Ogeechee River

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by

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B.S., Wayne State University, 2021

A Thesis Submitted to the Graduate Faculty of Georgia Southern University

in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

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Electronic Version Approved:

July 2024

DEDICATION

To my partner, Daniel E. Ricalde Herrmann for his unwavering support and belief in me. To my family members who have supported me throughout my journey. In remembrance of my Papaw who was the one who took me fishing and taught me to respect aquatic life.

ACKNOWLEDGMENTS

The first person I would like to thank is Dr. Checo Colón–Gaud. I would not be here if it were not for a fateful conversation with Dr. Checo that helped to bring me to Georgia and allow me to collaborate with graduate students. This opportunity allowed me to formulate my own research proposal, meet wonderful people who helped shape me and turn me into the scientist I am today. He has supported me for years through multiple different programs and shaped me into the confident, knowledgeable mentor and researcher that I am today. I will forever be grateful for the mentorship I have received through Dr. Checo.

I would also like to thank Dr. Donna Kashian at Wayne State University. She took a chance on me as an undergraduate researcher and gave me the opportunities that led me to meet Dr. Checo and come to Georgia Southern. Dr. Kashian encouraged me to apply for the National Science Foundation funded Instars program through the Society for Freshwater Science. This is where I met Dr. Checo and many other wonderful mentors and fellow students. This also led me to join the Emerge program which was a more comprehensive year-round program for underrepresented students and early career professionals. I would like to thank the mentors from the program and the fellow friends I have made along the way through the program. Your support is paramount, and I am grateful to have met all of you.

I would like to thank Dr. Steve Vives for all the support he has given me. Dr. Vives is an important contributor in my fish research and analysis. He has also taken great care in showing me support through many challenging times during my graduate school studies. I would also like to thank Dr. Jamie Roberts as well for his outstanding support and teaching. Dr. Roberts taught me much about fish prior to joining the graduate program and that led me to wanting to incorporate fish into my research project. Dr. Aaron Schrey is on my thesis committee and has helped me find interest in learning a different approach towards conservation studies. I hope to take what I have learned from him and incorporate it into future projects. The last professor I would like to thank is Dr. Dmitry Apanaskevich.

Dmitry assisted me with my more difficult aquatic macroinvertebrate identifications that needed a more powerful microscope.

The research would not have existed without the support of the Ogeechee Riverkeeper. I would like to specifically thank Damon Mullis, Meaghan Walsh Gerard, and Melanie Sparrow for their support and mentorship throughout the Ogeechee Riverkeeper Fellowship. I want to give a special acknowledgement to Kris Howard. Kris braved many days through both chilly, high–water scenarios and blistering summer days with me. We had days that were beyond unordinary out in the field; however, we persevered no matter the circumstances. I also want to thank my peers who got a chance to assist me with my research: Maricela Alaniz, Natalie Boydstun, Houston Chandler, Juan Jeronimo, Raymond Kidder, Patrick Lewis, and Hillary Sklar.

I would also like to thank my father, Jeff McKeon, and second mother, Mary McKeon, for their support and love. You are always there for me when I need it most. My sisters, Nicole Gahns, Emaly McKeon, Katey McKeon, and Christina Smith have helped encourage me to follow my dreams. My mother, Michelle Blanton–McKeon, who raised me and told me to do what I want most in life. And Dr. Daniel E. Ricalde Herrmann, my partner and confidant. We have supported each other through our respective academic journeys, and I am now proud to be able to call you doctor. Thank you so much for all your support.

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CHAPTER 1

INTRODUCTION

Ogeechee River Background

The Ogeechee River is a 6th-order blackwater river in southeastern Georgia that drains over 14,000 total km^2 into the Atlantic Ocean (Benke & Meyer 1988; Meyer et al. 1997). The area falls within the subtropical climate zone and experiences a four-season weather pattern. Stained blackwater of the Ogeechee River comes from tannins released from dissolved organic matter and typically results in a lowering of pH (Meyer 1990). The upper watershed is in the Piedmont ecoregion and flows into the Southeastern Plains and finally to the Southern Coastal Plain ecoregions where it drains into the Atlantic Ocean. Low elevation in the Southeastern Plains and Southern Coastal Plain allows the river to have a large flood plain after significant rainfall.

Much of the riparian zone in the Ogeechee River contains forest cover and lies at low elevation due to being in both the Southern Plains and the Southeastern Coastal Plains (Griffith et al. 2001). In these regions, forest communities primarily consist of baldcypress (*Taxodium distichum*), swamp blackgum (*Nyssa sylvatica*), and willow (*Salix spp.*) (Pulliam 1993; Meyer et al. 1997). The meandering of the main channel causes undercutting resulting in trees on the banks falling into the river; meanwhile, these trees remain rooted in the bank and create stable structures underneath the water (Sigafoos 1964; Keller & Swanson 1979; Wallace & Benke 1984). Fallen trees also create secure habitats for larval and smaller fishes to seek cover and important feeding habitats for many fish communities (Benke et al. 1985).

The river bottom consists of sandy sediments between 5 to 10 meters in depth with underlying igneous and metamorphic rock deposits (Gillespie et al. 1985; Meyer 1992). Amorphous detritus, a primary food source for aquatic macroinvertebrates, is carried into the main channel during periods of floodplain inundation (Wallace et al. 1987; Wainright et al. 1992). The transport of sandy sediment during periods of inundation and flooding causes organic matter to become buried over time (Meyer et al. 1997).

However, this amorphous detritus is continually replaced through the flood plain and not a limiting factor in secondary production (Benke & Wallace 2015).

The river is unimpeded except for one low head dam near the Hancock/Warren County border, making it a valuable system for research (Benke 1990). The relatively natural flow regime creates productive microhabitats, such as flood plain edges and snags, submerged woody structures (Benke et al. 1984). These snags provide solid structures amongst the relatively sandy bottom of the Ogeechee River (Benke et al. 1985) allowing for macroinvertebrate colonization (Cudney & Wallace 1980; Jacobi & Benke 1991; Benke & Jacobi 1994) and fish refuge (Grossman & Freeman 1987; Scheidegger & Bain 1995; Meyer et al. 1997). These microhabitats have been shown to produce roughly 60% of macroinvertebrate biomass in comparable systems (Benke et al. 1985).

Most streams predictably shift from an overall state of heterotrophy (respiration>photosynthesis) to autotrophy (respiration<photosynthesis) as they increase in stream order (Vannote et al. 1980). The Ogeechee River is unique in that it does not shift in higher orders, maintaining a state of heterotrophy throughout (Meyer 1990). This is due to the high amount of energy inputs from allochthonous (external) sources including headwaters in swampy areas and organic matter collected during floodplain inundation (e.g. leaf litter, woody debris, and dissolved organic matter) (Meyer 1990; Meyer 1994).

The Ogeechee River has been a well-studied river in the southeastern United States due to the nature of the system being preserved and novelty of the river (Leff & Meyer 1991; Meyer et al. 1997; Benke et al. 2001). The nature and habitat of the river create effective microhabitats despite the uniform sandy-bottom sediment. Microhabitats promote diversity amongst organisms within riverine systems (Barber et al. 1973; Allan 1975; Orth & Maughan 1983; Erman & Erman 1984). The Ogeechee River has a very diverse and complex set of communities throughout the river because of the microhabitats that are present (Benke et al. 1985; Jacobi & Benke 1991; Meyer et al. 1997). The mostly unimpeded stretch of the river allows for the natural state of the river to be preserved. This makes the Ogeechee River a novel study site.

Flood Pulse Influence

The seasonal flood pulse, which falls between winter and spring, is an important driver for aquatic macroinvertebrates and fishes that inhabit the river system (Benke et al. 2000; Benke 2001). The river is seasonally inundated between February and April, and less than 10% flooded between the months of August and November (Benke & Meyer 1988). The floodplains are low-lying areas adjacent to a body of water that are subject to this periodic inundation. Floodplains are also described as "aquatic-to-terrestrial transition zones" or "ATTZ" (Junk et al. 1989). Predictable long-term flooding is common amongst high order stream systems (Junk et al. 1989). The predictable flooding during the year promotes higher diversity and keeps the system near an equilibrium (Connell 1978).

Disturbances from the flood pulse allow flood plain habitats to experience transformations as flooding alters the habitat types by adjoining the ATTZ, bringing new debris into the system, and allowing species movement into areas that were previously unavailable (Salo et al. 1986). Inundation allows for extension of habitats into the surrounding floodplain and vernal pool formation as the water recedes that can create microhabitat systems for aquatic organisms. These microhabitats promote colonization of species and refuge for more susceptible species to predation during key growth periods. Higher aquatic macroinvertebrate productivity is observable in floodplains compared to river channels (Gladden & Smock 1990; Smock et al. 1992; Benke 2001). There are also invertebrates that rely on the dry and flooded stages in floodplains for emergence during resting periods (Benigno & Sommer 2008). The flood pulse promotes higher diversity amongst communities, such as fishes (Lowe–McConnell 1975; Welcomme 1985; Dutterer et al. 2013). The flood-pulse advantage contributes to the higher production of fish communities with active floodplain availability compared to those without or blocked by reservoirs (Bayley 1991; Bayley 1995). Floodplains aid in the reproduction, shelter, and food availability of the organisms that utilize this habitat. All these factors allow for diverse communities to form throughout the Ogeechee River.

Conservation Impacts

Aquatic communities in the southeastern United States exhibit some of the highest rates of diversity and endemism in the world (Abell et al. 2000; Collen et al. 2014; Jenkins et al. 2015; Elkins et al. 2019). Aquatic macroinvertebrates are important indicators for water quality and ecosystem health (McDonald et al. 1991; Karr 1999; Kenney et al. 2009). Understanding how these communities interact and change throughout the system and with different environmental impact factors can improve our understanding of freshwater systems. Incomplete life history information makes conservation plans more difficult to create due to a lack of understanding of individual species or genera.

Aquatic macroinvertebrate communities also contain non-insect invertebrate species, such as freshwater mussels. Freshwater mussels are a major group that experiences extreme pressures from anthropogenic impacts, particularly in the southeastern United States (Haag & Williams 2014). Examples of extrinsic factors that increase the risk of mussel extinction include loss of reproductive hosts, habitat alteration and destruction, catchment use, pollution, climate change, and invasive species (Ferreira–Rodríguez et al. 2019). There is currently no key to species of mussels in Georgia and much of their life history is not well understood making conservation efforts difficult.

Over half of all North America's freshwater fish species are found in the southeastern United States (Page & Burr 2011; Elkins et al. 2019). Leading contributors in determining suitable habitat for fishes include water temperature, flow, and geology (Wenger et al. 2008; VanCompernolle et al. 2019; Comte et al. 2021). The southeastern United States has consistently experienced increases in imperilment of freshwater fish species over time (Jelks et al. 2008; Freeman et al. 2017; Elkins et al. 2019; Stowe et al. 2020; Nagy et al. 2024). Atlantic (*Acipenser oxyrhincus oxyrhincus*) and Shortnose sturgeon (*Acipenser brevirostrum*) are the main species of concern in the Ogeechee River and are at a high risk for extirpation (Jager et al. 2013; Fox et al. 2023).

Other aquatic invertebrates, such as insects, are up for debate on whether they are at risk due to anthropogenic impacts and climate change. One study shows that freshwater insect abundances have increased due to legislation across North America and Europe promoting cleaner waterways (van Klink et al. 2020). Another study conducted in Europe suggests that diversity of freshwater insects is increasing; however, abundance of freshwater insects may not be increasing (Pilotto et al. 2020). Studies indicate that anthropogenic impacts can affect diversity and abundance through loss of more sensitive taxa and replacement with tolerant taxa (Dolédec et al. 2006; Clavel et al. 2011; Li et al. 2019; Ge et al. 2022). Recent studies have indicated a loss of biomass and community shifts in freshwater invertebrates within the Ogeechee River (Murray–Stoker et al. 2023). Whether or not aquatic insects are at risk for imperilment and extinction is undetermined.

Thesis Objective

The objective of this study was to use aquatic macroinvertebrates and fish as bioindicators for ecosystem health. Three sites were compared to analogous sites from previous years. Aquatic macroinvertebrates were assessed at Rocky Ford, Highway 301, and I-16 shown in Figure 1. Fishes were assessed at Rocky ford, Oliver, and I-16 due to inaccessibility of the boat ramp at Highway 301, also shown in Figure 1. The study was designed to further understand the relationship between flood pulse hydrology and macroinvertebrate and fish communities in the Ogeechee River. The southeastern United States is a hotspot for biodiversity despite having some of the lowest priorities in national funding when it comes to conservation (Jenkins et al. 2015). This dataset will also be used as a baseline for future studies in the area and as a reference in creating conservation plans.

CHAPTER 2

METHODOLOGY

Site Information

A total of three sites on the main stem of the Ogeechee River were identified for this study (Figure 1; Table 1). The furthest upstream site is located near Rocky Ford, GA (Screven County). The second site is located near Highway 301 on the border of Bulloch and Screven counties. The third site is the furthest downstream near I–16 close to Eden, GA bordering Bryan and Effingham counties.

Rocky Ford falls within Screven County which shows the only decrease in total population of the four counties (Table 2). The population density in Screven County is 8 people per km^2, which is much lower compared to the other three counties at an average of 46 persons per square km (Table 2). The final site at I–16 falls between Bryan and Effingham counties which have experienced the highest population growth across the ten-year period; however, the population densities of each of Bryan, Bulloch, and Screven Counties are similar based on 2020 census data (U.S. Census Bureau 2023). The latter area is the future site for a large industrial complex (Brodmerkel McQuarrie 2023). Urban sprawl from the greater Savannah area and the addition of the industrial site are also creating major housing developments within the surrounding area. The area surrounding this plant is expecting around a 5% increase in population growth rate (Savannah JDA 2023) and potential ecosystem impacts both industrially and through suburbanization (Allan 2004; Faulkner 2004; Burcher & Benfield 2006).

Land usage in the local catchment for each site has shown relatively large shifts in select categories within a recent ten-year period (2011–2021; Figures 2–4; Appendix A). All three sites saw an increase in the amount of emergent herbaceous wetland areas (Figures 2–4). Rocky Ford has seen an increase in development and herbaceous and shrub/scrub habitats (Figure 2). Most losses were caused by deforestation of all types of forests in the area. Highway 301 catchment has experienced some development, but a larger increase in barren land in the area (Figure 3). This area saw decreases in herbaceous and shrub/scrub land cover, and deciduous and mixed forest. The area close to the I–16 site near Eden, Georgia also saw an increase in development in the area, as well as an increase in herbaceous and shrub/scrub habitats (Figure 4). This area had a high amount of deforestation and losses of agricultural area as well (Figure 4).

Water Quality

Point collections of water parameters occurred monthly except in warm months where frequency of collection increased to biweekly at Rocky Ford. Water parameters were collected via a portable Hanna Instrument (HI98494 pH/EC/DO meter) or a YSI ProDSS handheld multiparameter meter. The instruments collected water temperature (°C), dissolved oxygen (% saturation and mg/L), pH, and conductivity (µS/cm). Water parameters were collected passively and continuously at the Highway 301 and I–16 sites by a HOBO pH and temperature logger (MX2501), HOBO freshwater conductivity logger (U24–001), HOBO water level (13ft) data logger (U20L–04), and HOBO dissolved oxygen data logger (U26–001). These units were present at both sites and were able to record values for pH, water temperature, conductivity, depth, and dissolved oxygen at one-hour temporal resolution. Water parameter sensors at Highway 301 were lost due to suspected theft between May and July download events. Subsequent water parameter collection events at the site utilized the same handheld instruments as Rocky Ford. Ensuing samples resumed biweekly until temperatures dropped in September where they were then taken monthly.

Figures 5 A–B, 6 A–B, and 7 A–B contain 2023 and a 10-year comparison average for gage height (m) and discharge rate (m^3/sec) at each site. Highway 301 has been supplemented using the USGS data at Oliver Bridge which is roughly 16 km away. Highway 301 and Oliver are relatively similar in characteristics and habitat between the two sites. The supplemental site data was included to help assess the community makeup and compare each site. Sampling of water parameters occurred on days where the flow rate was low or stable enough to safely traverse the river.

Aquatic Macroinvertebrates

Macroinvertebrate sampling was structured based on Georgia Environmental Protection Division’s standard operating procedures for assessing macroinvertebrate communities in wadeable streams (Georgia EPD 2007). Sampling occurred 100 m upstream of any man-made structures, mostly overpass bridges, in the stream. The side of the river sampled was randomized, unless there were obstructions that limited sampling to a specific side of the river. Samples were taken along a 100-meter stretch using the 20-jab method (Georgia EPD 2007). The 20-jab method consists of positioning a D-frame net into the selected sampling area and jabbing to disturb substrate into the net. The net will be positioned downstream and moved upstream to propel material into the net.

Samples were collected using a D-frame net with a 500 μm mesh. A five-gallon bucket was filled halfway with water to store samples until they were strained through a 500 μm sieve bucket. Large, predatory macroinvertebrates, such as dragonfly or stonefly nymphs, were placed in ethanol to avoid stress predation. The resulting sample was taken to shore, sieved, then rinsed using water from the river. The resulting samples were transferred into jars of ethanol and rinsed using water to ensure the whole sample had been transferred. This also diluted the ethanol to between 70–95%, a standard in macroinvertebrate preservation (Georgia EPD 2007). Ethanol was continuously changed within a week of storage due to dilution over time from water leeching in collected detritus and macroinvertebrates.

Bioassessment protocol requires the main sample be sorted into a smaller, random subsample. The sorting process consisted of randomized sampling using gridded sorting trays and a random number generator (Caton 1991). There were three sorting trays with 15 squares in each tray, totaling 45 possible squares that the random number generator sorted from. A random number was generated, the associated square was illuminated, and visible macroinvertebrates were gathered first. The sample and debris were then taken in small batches and placed into a Petri dish under the dissecting microscope and. Each sample in the Petri dish was disturbed 3 times and re-sorted. The process created a consistent and thorough sorting of the sample. Small collection jars filled with ethanol held the macroinvertebrates collected through randomized sampling. Random sampling continued until the sample tally reached 160 or higher. Large and rare macroinvertebrates were sorted from each tray once the tally had been reached or surpassed. The samples consisted of roughly 200 ± 40 total organisms.

Macroinvertebrates were identified as the lowest practical taxon. Selected organisms were only identified to family level depending on size and lack of diagnostic characters in the immature stages. Organisms such as Oligochaeta and Hirudinea were only identified to subclass level. Taxonomic identification was performed using dichotomous keys from Merritt et al. (2008) and Thorp & Rogers (2010). Macroinvertebrates were measured using an ocular micrometer as they were identified, and a final tally was taken to confirm the total number of identified macroinvertebrates.

Macroinvertebrates were categorized with their functional feeding group (FFG), tolerance value, and habit (Appendix B). These functional traits were found using the GA EPD taxa list (2012). The Merritt, Cummins, and Berg 4th edition (2008) taxa key was referenced when the GA EPD taxa list did not contain necessary trait information. Several taxa did not have definitive trait information in the sources referenced; therefore, these taxa were labeled as unknown in the dataset.

The Georgia multimetric index was calculated for both the Southeastern Plains and the Southern Coastal Plains ecoregions. These subecoregions are important for RBP because they contain region specific metrics that reflect the health of the streams in relation to each subecoregion (GA EPD 2007). The references used were for the Atlantic Southern Loam Plains (65l; Appendix C) and the Sea Islands Flatwoods (75f; Appendix D) subecoregions (Georgia EPD 2007). The reference sites for the Atlantic Southern Loam Plains and Sea Island Flatwoods were taken from unimpaired sites in the subecoregion and calculated to give a water quality range for the area. These references are then used to compare to sample sites and data to give a general idea of how the site compares to other sites within the ecoregion and their water quality. The Rocky Ford site falls into the Southern Loam Plains ecoregion. The I–16 site falls within the Sea Island Flatwoods ecoregion. The Highway 301 site falls into the Southern Loam Plains Ecoregion; however, the Oliver site which was used in the 2014–2017 dataset falls in the Sea

Island Flatwoods ecoregion. The Oliver site is located less than 3km between the border of the Sea Island Flatwoods and the Atlantic Southern Loam Plains ecoregions.

Additional metrics used to characterize biotic communities included the Shannon–Wiener diversity index, abundance, relative abundance, and the Hilsenhoff Biotic Index (Georgia EPD 2007). Permutational multivariate analysis of variance (PERMANOVA) analysis compared each metric for significance $p < 0.05$. The PERMANOVA used in RStudio was created using the Bray–Curtis index with 999 permutations (Bray & Curtis 1957). Non-metric multidimensional scaling (NMDS) plots were created using RStudio from the abundance data to assess changes in sites, season, and over time. These processes utilized RStudio version 4.3.1 (© 2023 The R Foundation for Statistical Computing). Further processes within RStudio involved the metaMDS function and adonis2 function within the vegan package (Oksanen et al. 2015).

Fishes

Fish sampling was comprised of a community assessment based on the electrotaxis standards in the United States Environmental Protection Agency's standard fish sampling protocols for non-wadeable streams (USEPA 2013). Electrofishing is an effective method for fish sampling in areas with extensive snags (O'Neil et al. 2014), such as in the Ogeechee River. Boat electrofishing was used for the procedures based on gage height and discharge rate on the days of sampling. Conductivity measurements were taken prior to beginning the fish sampling to provide starting voltage settings. Fish sampling was performed over a 200 m stretch. The total amount of time electrofishing was two hours. Standard safety protocols were followed for operating boat electrofishing. It should be noted that some species of fish may not be as susceptible to our general voltage usage on the electrofishing boat. Some fishes are more susceptible to low voltage sampling, such as sturgeon and catfishes (Damon–Randall et al. 2010; Bodine et al. 2013).

Fishes were collected by two netters and held in an aerated live-well. The live-well was observed and monitored to confirm recovery. Fish were identified and their standard and total lengths measured before release. Boat electrofishing was conducted in early September for the summer season and late

November for the autumn season. Community assessment consisted of all fish captured. Instead of the Highway 301 crossing, sampling occurred at the middle site deployed from the Oliver Bridge boat ramp because of the inaccessibility of Highway 301. Data collected between 2014 to 2017 were also used for the Oliver Bridge landing. Appendix E contains the species collected during all years and seasons with their feeding guilds, tolerance, and species categories. Inclement weather related to hurricanes disrupted normal sampling frequencies in Summer and Fall 2023 (Figure 5 A–B; Figure 6 A–B; Figure 7 A–B)

The fish community data collected was used to calculate and compare the index of biotic integrity (IBI) (Appendix F). Species richness, abundance, and the Shannon–Weiner Index were also calculated. As with the aquatic macroinvertebrates, PERMANOVA testing was used to compare metrics between sites for fishes (Bray & Curtis 1957). NMDS plots were used to compare the abundance of fishes at each of the sites and for both seasons over time. Box-and-whisker plots were created using metrics for the different sites as well.

The IBI was not formulated to be used in mainstream channels and is not standardized for some of the sites where sampling took place (Georgia DNR 2005a; Georgia DNR 2020). The Rocky Ford site does fall within the southeastern coastal plains and does follow the Atlantic slope drainage basin. The IBI was still used due to the previous use in the study from 2014 to 2016, and to analyze the sample using a standardized test even if not applicable to those sites. The number of anomalies and injuries was left out of the scores due to the already low scoring of samples and the low number of anomalies noticed during each trip either did not reach the threshold or barely reached the threshold in the total samples (Appendix F). No samples reached above 214 specimens per 200m stretch. This brought the score down on every sample. The mainstream channel can be variable in organism collection due to the higher discharge rates sweeping fish away before capture, depth challenges, deep tannin coloration making it hard to see, and large snags ambiguously obscuring some specimen.

Historical Dataset

This study is utilizing historical macroinvertebrate community data collected previously (Buchbinder 2019). The resulting dataset will allow comparisons to be drawn to macroinvertebrate communities spatially and temporally. This dataset was comprised of 72 total sampling periods occurring from the years of 2014–2017. Historical samples were collected seasonally using identical methods to those in this study. A total of 34 out of 36 macroinvertebrate samples were used in comparison to the dataset from this study. Morgan's Bridge from the summer of 2014 and Oliver from spring of 2017 did not contain enough macroinvertebrates in the samples to be considered viable for the RBP process. Morgan's Bridge and Oliver in winter of 2016, and Oliver in Summer 2015 are under the 160 minimum for the RBP score; however, they were still analyzed due to the total macroinvertebrate counts only being slightly under the requirement.

The complete historical dataset included six sampling sites; three of which were chosen due to their habitat similarity and proximity to sites utilized in this study. The historical dataset sites of Rocky Ford, Oliver Bridge, and Morgan's Bridge corresponded to the study sites of Rocky Ford, Highway 301, and I–16, respectively. Rocky Ford is in the same location. The Oliver Bridge location is roughly 16.5km downstream of the Highway 301 site and is hydrologically similar. The Morgan's Bridge site is located around 6.75 km downstream of the I–16 site and located on the opposite side of the interstate.

The historical macroinvertebrate and fish datasets were collected as part of a Supplemental Environmental Project in connection with the settlement of an enforcement action taken by the GA EPD (Final Report 2019). Comparisons between historical fish community data and this study will aid in the understanding of fish temporal and spatial patterns in riverine systems. The historical dataset is comprised of samples taken below the Fall Line at 6 sites. Historical samples were collected seasonally; however, comparisons will be made to only summer and autumn sites by calendar date. Site collections ranged from 25 total fish identified up to 535 total fish identified. The historical dataset sites of Rocky Ford, Oliver Bridge, and Morgan's Bridge corresponded to the study sites of Rocky Ford, Oliver Bridge, and I–16.

Permits

Research was conducted under Georgia Southern University IACUC protocol #I23007 for fish community collection in the Ogeechee River (permittee: self) and Georgia DNR Scientific Collections permit #1000545737 (permittee: Dr. Stephen Vives; sub-permitteee: self).

CHAPTER 3

RESULTS

Water Quality

Water quality at each site showed similar trends (Figures 8–10). Mean water temperature was variable between Rocky Ford ($\bar{x}$=18.87, σ_M=1.78, n=14), Highway 301 ($\bar{x}$=15.90, σ_M=1.48, n=19), and I–16 ($\bar{x}$=20.73, σ_M=0.33, n=294). Temperature data reflects expected seasonal patterns for the region with the highest temperatures in the summer and the lowest temperatures in the winter (Figure 8). Notable deviations from expected water temperatures were seen in relation to large storm events which introduced relatively warm precipitation into the system quickly (Figure 8). There was a higher precipitation average in August 2023 than during historical dataset collection years (Appendix G) Decreases in water temperatures coupled with increased gage height and discharge rate can be observed in relation to two hurricanes, Hurricane Idalia and Hurricane Lee, in late August and mid-September respectively (Figures 5–7 A–B; Figure 8).

Average dissolved oxygen (ppm) at the Rocky Ford ($\bar{x}$=6.88, σ_M=0.40, n=14) and I-16 ($\bar{x}$=6.83, σ_M=0.09, n=269) sites were similar (Figure 9). Highway 301 had a slightly lower dissolved oxygen measurement ($\bar{x}$=6.08, σ_M=0.48, n=19; Figure 9). The pH tends to stay between 6 and 7 in the mainstream Ogeechee River. The average pH at Rocky Ford ($\bar{x}$=6.85, σ_M=0.08, n=14), Highway 301 ($\bar{x}$=6.75, σ_M=0.14, n=11), and I-16 ($\bar{x}$=6.89, σ_M=0.02, n=294) was slightly acidic (Figure 10). Conductivity in the mainstream Ogeechee River showed similar averages between Rocky Ford ($\bar{x}$=74.77, σ_M=5.27, n=14) and Highway 301 ($\bar{x}$=77.02, σ_M=4.85, n=11). The I–16 site average was slightly higher ($\bar{x}$=86.20, σ_M=1.26, n=293); however, there are more data points for the site (n=11; n=14; n=293).

Macroinvertebrate Bioassessment

RBP scores were generally higher during the year of the study (2023) in comparison to the historical dataset (2014–2017; Table 3; Appendix H). The RBP scores indicate that no site fell into the very poor condition; however, no patterns were evident when relating RBP ranking to season of collection. Rocky Ford was the only site that has maintained a good status throughout each year. Table 3 shows that Rocky Ford tends to have a lower score in the spring sample season compared to other seasons. The Highway 301 site maintained a good ranking, like Rocky Ford. The Oliver site has had numerous poor stream rankings throughout the years. There was no seasonal pattern to the lower rankings. The I–16 site has a variable change in RBP final score; meanwhile, the score does not fall into the poor ranking. The highest RBP score was the Autumn 2023 I–16 site (92) and the lowest RBP score was the Spring 2016 Rocky Ford site (49). The RBP scores for sample sites in the Atlantic Southern Loam Plains (65l) closely reflect the 65l reference sites scores; conversely, the Sea Island Flatwoods (75f) sample sites tend to show more, and lower variability compared to the 75f reference sites scores (Figure 11).

Overall, Rocky Ford ($\bar{x}$=68.19, σ_M=2.13, n=16) has a higher mean score than the Atlantic Southern Loam Plains 65l reference sites ($\bar{x}$=60.40, σ_M=13.01, n=7) and less variation in scores (Figure 11). The Rocky Ford site has higher Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa ($\bar{x}$=20.38, σ_M=0.53, n=16) and EPT percentage ($\bar{x}$=68.19, σ_M=3.12, n=16) in the samples compared to the reference sites ($\bar{x}$=4.49, σ_M=1.27, n=7; $\bar{x}$=4.43, σ_M=1.48, n=7; Figure 12 A and C). Diptera taxa was much lower than the reference sites due to most Diptera, particularly Chironomidae and Ceratopogonidae, being taxonomically identified to family (Figure 12 B). There was wide variation in percent Trichoptera samples at Rocky Ford (Minimum: 0; Maximum: 12.38; Figure 12 D). The HBI for Rocky Ford ($\bar{x}$=6.13, σ_M=0.13, n=16) and the reference sites ($\bar{x}$=6.29, σ_M=0.40, n=7) are similar (Appendix I) and are representative of the same descriptive category of fair (Appendix J). Rocky Ford ($\bar{x}$=6.44, σ_M=0.58, n=16) has a slightly lower average of predator taxa compared to the reference sites' scores ($\bar{x}$=7.31, σ_M=1.15, n=7; Figure 12 F); adversely, Rocky Ford ($\bar{x}$=7.06, σ_M=0.53, n=16) expresses a higher mean score of clinger taxa compared to the reference sites ($\bar{x}$=6.11, σ_M=1.66, n=7; Figure 12 G).

The Highway 301 site ($\bar{x}$=71, σ_M=5.34, n=4) was comparable in average RBP score to the Rocky Ford site ($\bar{x}$=68.19, σ_M=2.13, n=16) and higher than the reference sites ($\bar{x}$=60.40, σ_M=13.01, n=7; Figure

11). The Highway 301 site expresses the highest EPT taxa ($\bar{x}$=13, σ_M=1.58, n=4) and percent EPT scores ($\bar{x}$=24.75, σ_M=4.11, n=4) in the 65l subecoregion (Figure 12 A and C). The percent Trichoptera mean for Highway 301 ($\bar{x}$=4.99, σ_M=1.60, n=4) was also comparable to the Rocky Ford site ($\bar{x}$=4.58, σ_M=0.89, n=16) and higher than the reference sites scores ($\bar{x}$=2.09, σ_M=0.64, n=7; Figure 12 D). The HBI and predator taxa for the Highway 301 site ($\bar{x}$=5.85, σ_M=0.22, n=4; $\bar{x}$=6.75, σ_M=0.48, n=4) are slightly lower than the reference site scores ($\bar{x}$=6.29, σ_M=0.40, n=7; $\bar{x}$=7.31, σ_M=1.15, n=7; Figure 12 E and F). The clinger taxa for Highway 301 ($\bar{x}$=7.50, σ_M=1.44, n=4) was the highest of the three site scores (Figure 12 G).

The Oliver site has the lowest mean RBP score ($\bar{x}$=70.36, σ_M=4.36, n=11) compared to the other I–16 ($\bar{x}$=79.07, σ_M=2.67, n=14) and the Sea Island Flatwoods 75f reference sites ($\bar{x}$=92.50, σ_M=3.97, n=7; Figure 11). The Oliver site has a lower percent Oligochaeta mean score ($\bar{x}$=1.51, σ_M=0.69, n=11) than the 75f reference sites ($\bar{x}$=3.17, σ_M=1.35, n=7; Figure 13 A). The reference sites for 75f have an extremely low mean score ($\bar{x}$=0.14, σ_M=0.08, n=7) for percentage of Tanypodinae out of the total Chironomidae count (Figure 13 B). On the contrary, the mean score for Oliver ($\bar{x}$=38.37, σ_M=8.42, n=11) was the highest of the three sites observable (Figure 16 B). The tolerant taxa scores for Oliver and I–16 have the same range (4–14); however, the Oliver site has a higher mean score ($\bar{x}$=9.27, σ_M=1.33, n=11; Figure 13 C). The Oliver site also has the highest mean for the percent filterers score ($\bar{x}$=5.93, σ_M=2.36, n=11; Figure 13 D).

The I–16 site has the highest mean RBP score ($\bar{x}$=79.07, σ_M=2.67, n=14) out of the research sample locations, excluding the reference sites (Figure 11). The I–16 site has individual metric scores that fall between the mean scores for the reference sites and Oliver. The mean percent Oligochaeta score for I–16 ($\bar{x}$=2.06, σ_M=1.45, n=14) trends closer to the highest 4th percentile value (2.69) than the median value (0.49; Figure 16 A). The I–16 site scored a higher percentage of Tanypodinae out of the total Chironomidae count ($\bar{x}$=25.90, σ_M=5.01, n=14) like the Highway 301 site ($\bar{x}$=38.37, σ_M=8.42, n=11;

Figure 13 B). The I–16 site contains mean score between the other two sites for both tolerant taxa ($\bar{x}$=7.73, σ_M=0.69, n=14) and percent filterer ($\bar{x}$=4.05, σ_M=1.01, n=14) as well (Figure 13 C–D).

The mean average HBI by site for Rocky Ford ($\bar{x}$=6.13, σ_M=0.13, n=16), Highway 301/Oliver ($\bar{x}$=6.06, σ_M=0.19, n=15), and the I-16 sites ($\bar{x}$=6.08, σ_M=0.19, n=15) was very similar (Figure 14). All three sites are categorized by Hilsenhoff's biotic index to be of fair water quality and a degree of fairly significant organic pollution (Hilsenhoff 1987; Appendix J). The HBI scores by season are somewhat similar with winter being lower than the other seasons (Figure 15). Winter ($\bar{x}$=5.57, σ_M=0.19, n=12) has a lower mean than spring ($\bar{x}$=6.24, σ_M=0.18, n=11), summer ($\bar{x}$=6.32, σ_M=0.17, n=11), and autumn ($\bar{x}$=6.26, σ_M=0.17, n=12); however, the seasons are still categorized with fair water quality and a degree of fairly significant organic pollution. The HBI was also categorized by year shows a general trend of the HBI reducing over time (Figure 16). 2014 ($\bar{x}$=6.35, σ_M=0.16, n=8) was close to the fairly poor cutoff, reducing the HBI score in 2015 ($\bar{x}$=6.17, σ_M=0.23, n=12), and 2016 ($\bar{x}$=6.17, σ_M=0.22, n=12), and 2023 ($\bar{x}$=5.72, σ_M=0.10, n=12) displaying the lowest mean HBI score. The 2017 ($\bar{x}$=6.82, σ_M=0.02, n=2) year was an outlier due to the low number of sample size not giving an accurate representation of HBI for the year.

Macroinvertebrate Communities

Significant ($p < 0.05$) relative abundance PERMANOVA calculations were observed in season, year, and season*year for aquatic macroinvertebrate communities (Table 4). Site and subsequent variable comparison tests did not contain significant p-values. The macroinvertebrate communities by season represent two distinct communities that occur in winter and spring, and summer and autumn (Figure 17). The macroinvertebrate communities by year convey the 2023 community sampling events forming a distinct set of samples when compared to the historical dataset (Figure 18). The 2023 NMDS shows clustering of samples within the same year and little to no community similarities to the historical dataset samples. The clustering of macroinvertebrate communities by year and season for 2023 was also observed (Appendix K).

Macroinvertebrate communities for functional feeding group relative abundance convey significance ($p < 0.05$) observed in season, year, and season*year (Table 5). The FFG abundance shows sequential rotation in communities by season (Figure 19). The FFG macroinvertebrate community for 2023 expresses more similarities in abundance amongst samples within the same year compared to the historical dataset (2014–2017; Figure 20). The historical dataset presents more dissimilarity amongst the FFG communities per year (Figure 20). The macroinvertebrate FFG communities for 2023 by year and season are clustered together where the historical dataset appears widespread (Appendix L).

The macroinvertebrate habit relative abundance identified significance ($p < 0.05$) in season, year, and season*year (Table 6). Seasonal habit abundance has tight clustering near the center between all seasons; however, there was wide variation throughout most seasons (Figure 21). The macroinvertebrate FFG relative abundance has a similar clustering of the 2023 dataset and a wider range through the historical dataset (Figure 22). The tight clustering of the 2023 habit macroinvertebrate communities shows relative dissimilarity to the historical dataset based on season and year (Appendix M).

Fish Bioassessment

Rocky Ford has variable IBI rankings within the historical dataset and the 2023 dataset (Table 7). The lowest IBI rankings are found in summer (21) and autumn (24) of 2014. There was an increase in score in the following year of 2015. The summer 2016 score increases greatly to 44 and decreases in 2023 to 30. The scores in autumn for 2016 (28) and 2023 (30) both decrease and receive a poor ranking compared to 2015 (34) which received a fair ranking.

The IBI metrics for Oliver and I-16 showed a trend of increasing in metric score over time (Table 7). Oliver for summer of 2023 was lower than other scores; however, it maintains a fair ranking compared with other seasons. The only exception to the fair ranking was autumn of 2014 in the historical dataset. Oliver decreased in score in summer 2023 due to the decline in benthic invertivore species over time, decline in native centrarchid species over time, and increase in top predator percentage during the summer sampling (Appendix N). The loss of benthic invertivore species was observable comparing the historical dataset to the 2023 dataset at all three sites (Appendix N).

I-16 was determined to have a very poor ranking in 2014 in both seasons and has increased to a poor ranking in over time (Table 7). This was the only site that has a steady increase in score throughout the historical dataset to the 2023 dataset sequentially during both seasons. The I-16 site has an increase in number of native insectivorous cyprinids in 2023 compared to historical data (Appendix N). The 2023 site contains more consistent variation in fishes captured that raised the IBI score including tolerant species, benthic fluvial species, and insectivorous cyprinid species which also increased evenness scores (Appendix N).

Fish Communities

Fish communities change in composition yearly (Table 8). There was some dissimilarity amongst the 2023 and historical dataset (2014–2016) (Figure 23). The historical dataset was more dissimilar amongst years. The 2014 sample community was almost distinctly different from all other samples (Figure 23). The 2023 community shares some similarity to the 2014 and 2016 communities, but none to the 2015 community (Figure 23). Fish communities' feeding guilds are different by year (Table 9; Figure 24). The 2023 dataset expresses similarities with the 2015 and 2016 communities based on feeding guild (Figure 24). The 2014 sample contains observable dissimilarity amongst the community samples (Figure 24).

CHAPTER 4

DISCUSSION

Water Quality

Water temperature did show expected seasonal variation throughout the year with some variation during hurricane events that effected Georgia (Figure 8). Long-term datasets can help build a wider viewpoint of how external factors affect water quality throughout time. These datasets would make it possible to observe when and how these catastrophic events affect the system and how regular seasonal variability may change throughout time. This may also help in the assessment of climate change variables on water quality through time (Scarsbrook et al. 2003; Edmonds et al. 2022; Muthukrishnan et al. 2022).

Blackwater rivers typically display low dissolved oxygen concentrations (Meyer et al. 1997). This phenomenon was reflected through DO fluctuations between 6 and 7 ppm (Figure 9). The receding of floodplains to mainstream river leads to an influx of particulate organic matter (POM) into the system (Edwards & Meyer 1987a; Cuffney 1988; Junk et al. 1989). The process of the receding floodplains aids in the addition of allochthonous inputs into the system throughout the year. This leads to a higher respiration rate than photosynthesis causing the system to be heterotrophic throughout the whole of the river (Edwards & Meyer 1987a; Meyer 1990; Meyer et al. 1997). The majority (91%) of the respiration in the Ogeechee River is accounted for in higher order streams (4^{th} –6^{th}) where the study sites are located below the Fall Line (Meyer and Edwards 1990; Meyer et al. 1997).

The pH range (5.65–7.73) denotes the slightly acidic and neutral pH variability the mainstream Ogeechee River has for a blackwater river (Figure 10). This is unique amongst blackwater rivers and is due to carbonate-rich water from a limestone spring input from Magnolia Springs State Park (Meyer et al. 1997). The lowest pH samples could have been due to influence from Hurricane Idalia passing over as a tropical storm in the sample area. Previous studies lend support to hurricanes causing quick decline of pH levels in other blackwater rivers and freshwater ecosystems (Cai et al. 2013; Schafer et al. 2020). The pH tends to level out within a few days, which was also observed (Figure 10). The I–16 site is also the closest site to the mouth of the river making it more susceptible to sea water influx from catastrophic storm events. There is a lack in understanding how catastrophic events, like hurricanes, affect freshwater systems, but see citations (Roman et al 1994; Mallin & Corbett 2006; Patrick et al. 2020). Long-term datasets could provide a better understanding of how freshwater ecosystems respond throughout time to these events.

The sites follow a longitudinal gradient towards the Atlantic Ocean. These three sites are sequential through the river; consequently, the sites are somewhat close in proximity and may influence each other pertaining to the River Continuum Concept and temporal patterns (Vannote et al. 1980). The similarities between each site are observable (Figures 8–10). The trends for pH, DO, and water temperature follow very similar patterns even with varying numbers of plot points at Rocky Ford (n=14), Highway 301 (n=17), and the I–16 site (n=294).

Macroinvertebrate Assessment

RBP scores can change depending on the year and seasonality the samples. This is due to the emergence of mayflies in the spring season (Benke & Wallace 2015). Mayflies found in the study tend to be univoltine, one brood of offspring each year, and emerge in mid-April to early-June (Merritt et al. 2008). The next brood would be absent from early samples due to the egg and early instars stages being non-existent or unidentifiable in samples. Caddisflies tend to begin pupation in late spring to early summer as well (Merritt et al. 2008). There may be low to zero presence of some species as emergence leads to the absence of species in the system. The egg and early larval and instars periods may misrepresent species as they will be absent or easily missed when assessing samples (Benke & Wallace 2015). EPT taxa may be misrepresented in certain sample seasons due to the reasoning above. This may also lead to a sample that contains an increased number of Diptera during the sorting process because they can be found year-round in samples. Coleoptera, Amphipoda, and Isopoda can be found throughout the year as well.

All metrics for the 65l RBP scores increase the total score apart from the HBI which decreases the RBP score (Appendix B). Indicators that increased the RBP score for sites Highway 301 and Rocky Ford include EPT taxa (Figure 12 A), percent EPT (Figure 12 C), and percent Trichoptera (Figure 12 D).

These RBP metrics contained higher mean scores and ranges when compared to the reference sites. Metrics that decreased the RBP score were the low classifications for Diptera (Figure 12 B). These scores could be amended with a reassessment for lower taxonomic classifications of either tribe or genus if possible. This would raise the number of Diptera taxa and potentially increase the RBP scores for both sites. Mean scores for HBI (Figure 12 E), predator taxa (Figure 12 F), and clinger (Figure 12 G) score were similar to the reference sites. These scores aid in the overall RBP scores for Rocky Ford and Highway 301 expressing similar means to the reference sites.

All individual metrics for the 75f RBP score decrease the final score (Appendix C). Oliver and I–16 have somewhat lower mean scores for percent Oligochaeta than the reference sites (Figure 13 A). On the other hand, I–16 has an outlier (22.08) that brings the average mean higher, and Oliver contains two outliers (5.83; 6.25) that unfortunately brings the mean score up as well. The percent Tanypodinae to total Chironomidae scores (Figure 13 B) and percent filterer scores (Figure 13 D) are much higher than the reference sites and that causes a substantial decrease in total RBP scores (Figure 11). The tolerant taxa mean RBP scores for Oliver and I–16 was comparable to the reference site (Figure 13 C). In total, the research sites from historical and study data tend to have higher mean scores and variations in the individual metrics that overall decrease the RBP scores.

The Atlantic Southern Loam Plains (65l) and the Sea Island Flatwoods (75f) have different index score rankings shown in Appendix H (Middleton 2006, GA EPD 2007). Scores in 65l have a wider range of final RBP scores that are considered good as a narrative description. This may limit the Sea Island Flatwoods sites in the mainstem Ogeechee River. The I-16 ($\bar{x}$=79.07, σ_M=2.67, n=14) site had a higher mean RBP score than Rocky Ford ($\bar{x}$=68.19, σ_M=2.13, n=16) and Highway 301 ($\bar{x}$=71, σ_M=5.34, n=4); however, the site scored in lower descriptive metric because of the descriptions for score rankings (Appendix H). The 65l reference sites (n=5) contained an outlier that brings the RBP scores down. The 75f scores (n=4) in comparison have substantially higher average RBP scores (Minimum: 83; Maximum: 100; $\bar{x}$=92.50, σ_M=3.97, n=7). The RBP references were calculated nearly two decades ago and may need to be reassessed as water quality tends to experience changes through short and long-term situations.

Applying a reassessment of reference sites could change the reference scores for each site and give more accurate data information on site changes over time.

Hilsenhoff's biotic index data suggests each site was comparable in metric score to one another (Figure 14). The Highway 301/Oliver and I–16 box plots are almost identical. The seasonal variation in RBP scores has some changes with the winter HBI mean score being lower than the other three seasons (Figure 15). Winter also has a high variation in HBI scores (Minimum: 4.45; Maximum: 6.75). The general trend for HBI score throughout the year was a decrease in HBI score (Figure 16). All HBI figures represent the water quality description as fair (Figures 14-16).

Macroinvertebrates have complex life cycles that can be further explored through functional characteristics and the ways they relate to their communities (Wallace & Webster 1996). One of the most common functional traits is functional feeding group (Cummins 1973; Cummins & Klug 1979; Wallace & Webster 1996); however, there are many more functional characteristics amongst aquatic macroinvertebrates. The functional traits can be subclassified into physiological (Poff et al. 2006; Vieira et al. 2006; Merritt et al. 2008), morphological (Arnett 2000; Vieira et al. 2006), behavioral (Poff et al. 2006; Vieira 2006), and ecological traits (Poff et al. 2006; Merritt et al. 2008). These functional characteristics have recently been uploaded into an open-source database for ease-of-accessibility (Twardochleb et al. 2021). There are many macroinvertebrates still missing life history data that could aid in the understanding of community composition and interactions during times of stress (Appendix D).

The macroinvertebrate communities by relative abundance denote significance in season, year, and season*year plots, but not site significance (Table 4). There was distinct flood pulse delineation in the macroinvertebrate community by seasonal relative abundance (Figure 17). There was clustering of winter and spring seasons which is when flood plain inundation was observable. The summer and autumn seasons also form two distinct community seasonal plots that are present when temperatures and evapotranspiration are high. The 2023 sample year forms a distinct set of samples with some overlap relating to the 2014 sample year, but no overlap with other sample years (Figure 18). The distribution of season and year expresses clustering of the 2023 samples (Appendix K). Homogeneity in habitat throughout the Ogeechee River in these sites may contribute to the non-significance among sites.

The same significance was also associated with the functional feeding groups (Table 5) and habit (Table 6); however, expressed in different ways. The macroinvertebrate communities' FFG by season rotates sequentially between each season (Figure 19). Seasonal variability may also relate to the emergence patterns of macroinvertebrates throughout the year and their growth patterns. There was more similarity amongst the 2023 macroinvertebrate community FFG compared to the historical dataset (Figure 20). This was further observable with 2023 FFG macroinvertebrate communities clustering by year and season (Appendix L). The macroinvertebrate communities' habit had a similar trend of clustering amongst the 2023 dataset (Figure 20). The historical dataset expresses higher dissimilarity amongst seasons and years compared to 2023 based on macroinvertebrate communities' FFG and habit.

Fish Assessment

The IBI metrics show variability in the metric data through time at each site. The Rocky Ford 2023 dataset may have experienced unintentional effects due to summer sampling date. The effects of Hurricane Idalia were present during the sampling date (Figure 5 A–B). High water height inundated the floodplain and allowed lateral movement of fish into the floodplain. This may have caused the sample size and composition to change. The sampling dates for Oliver and I–16 was performed on dates between Hurricane Idalia and the storms from Hurricane Lee (Figure 6 A–B & Figure 7 A–B). Overall, there was improvement in IBI metrics in 2023 compared to the historical data; however, the scores still rank mainly in the fair category (Table 7).

The IBI for the Atlantic Slope Drainage Basin was used as a supplemental comparison for this study because it is a standardized procedure near the area of study. Downstream sites in the Lower Ogeechee may not be completely comparable to the Atlantic Slope Drainage Basin IBI calculations; therefore, total scores should be interpreted with caution. The IBI was corrected as needed for the region. General species and characteristics of fishes in these regions will be comparable and can give inferences into community composition for the region. Future studies on reassessment of the data using metrics for the Southeastern Coastal Plain being developed can give further insight into water quality based on IBI metrics for the sites.

There are many species of concern in the Ogeechee River that have little to no records in recent history. Fish like the Shortnose Sturgeon, Atlantic Sturgeon, American Eel, and Robust Redhorse have all been historically noted in the Ogeechee River (Jager et al. 2013; Georgia DNR 2020). American eels have been recorded in the sample datasets, but the others are absent from the historical and recent datasets (Appendix E). Atlantic sturgeons may avoid capture due to the voltage required for capture using electrofishing techniques (Damon–Randall et al. 2010). The robust redhorse was stocked by Georgia DNR from 1997 to 2004 in the Ogeechee River; nonetheless, records following the stocking of these fish in community assessments are rare (Slaughter & Smyrna 2008; Grabowski & Jennings 2009).

There are visible trends among fish community composition changes over time (Table 8; Figure 23). Year*season for fish community abundance had a P-value slightly higher than 0.05 (Table 8). The changes in fish community composition in 2014 may be due to the high amount of generalist species found at the I-16 site. Fish are freer moving than aquatic macroinvertebrates within the river. This allows fish communities in mainstream rivers access to deeper waters and side channel access throughout the year. These community composition changes may be linked to multiple stressors, such as climate change (Lane et al. 2015; Carosi et al. 2019; VanCompernolle et al. 2019), anthropogenic impacts (Esselman et al. 2011; Su et al. 2021), and invasive species (Levine & D'Antonio 2003; Dudgeon et al. 2006; Alexander et al. 2014) amongst other factors.

The mainstem Ogeechee River can have variable discharge rates throughout the year (Figures 5–7 B). Habitat alteration, anthropogenic impacts, and climate change are drivers that can change river discharge rates (Alin et al. 1999; Vörösmarty et al. 2000; Poff et al. 2001; Postel and Richter 2003). Fish communities require a diverse range of habitat types that support runs, riffles, and pools with varying flow rates (Freeman et al. 2001; Poff et al. 2001; Aadland 2011). Species richness and discharge rate have a positive correlation (Oberdorff et al. 1995; Xenopoulos & Lodge 2006). Flooding has seasonal impacts on fish communities that can be drivers for life history traits, such as high flow in spring influencing migratory patterns in fish communities (McCargo & Peterson 2010). Fish assemblages experience changes in life history between periodic, opportunistic, and equilibrium that are influenced by streamflow trends (Winemiller & Rose 1992; Mims & Olden 2012).

Unregulated rivers tend to have variability in year-to-year flow which allows for changes in fish assemblages temporally (Grossman et al. 1982; Schlosser 1985; Sparks 1995; Grossman et al. 1998; Freeman at al. 2001). Instability in intensity and predictability in seasonal streamflow can lead to increased mortality in incubating eggs and developing larval fishes (Mims & Olden 2012; Hitt et al. 2020). Blackwater rivers, such as the Ogeechee River, rely primarily on habitat structure, discharge rates, and stream sizes to drive variation amongst communities (Meffe & Sheldon 1988; Colvin et al. 2020). Short-term effects impact fish communities can allow for habitat movement into the floodplain. The increase in habitable area results in a decrease in the density of fishes in the main channel. The high discharge rate during periods of flooding also causes a decrease in the capture rate effectiveness during sampling (Pierce et al. 1985). Repetition in sampling can help decrease both short-term and long-term variability in sampling efforts.

Conservation Significance

The southeastern United States includes multiple priority ecoregions for freshwater species conservation (Abell et al. 2000; Smith et al. 2002). Aquatic gastropods are a group of organisms threatened worldwide and historically underfunded (Wilcove & Master 2005; Lysne et al. 2008; Johnson et al. 2013; Elkins et al. 2019). Over 70% of freshwater snails in the United States have a status of vulnerable, imperiled, crucially imperiled, or possibly extinct (Wilcove & Master 2005; Collier et al. 2016). Additionally, over 50% of crayfish species in the United States are considered vulnerable, imperiled, crucially imperiled, or possibly extinct (Wilcove & Master 2005; Collier et al. 2016). Nearly half of the world's crayfish species are found in the southeastern United States with nearly one-third of those species imperiled (Taylor et al. 2007; Richman et al. 2015).

The southeastern United States is home to almost 40% of the world's freshwater mussel population and 91% of the United States population (Neves et al. 1997; Graf & Cummings 2007; Elkins et al. 2019). Over 60% of the mussel species found within the United States are listed as vulnerable, imperiled, crucially imperiled, or possibly extinct (Williams et al. 1993; Wilcove & Master 2005). Mussels receive the most funding historically for conservation efforts in the southeast.

Around 40% of freshwater fish in the United States have imperiled status and over a quarter of those fish are found in the southeast (Warren et al. 2000; Jelks et al. 2008; Burkhead 2012). The status assessment of fishes from vulnerable to imperiled or extinct increased at a rate of 75% between 1989 and 1999 (Williams et al. 1989; Warren et al. 2000). Freshwater fishes of Georgia found in the expenditures for 2020 fiscal year for endangered and threatened species contained only 13 species and accounted for less than 0.8% of the total fish budget (US FWS 2020). This lack of funding in other areas is prevalent. Funding for the southeastern United States has been consistently lower despite being a biodiversity hotspot (Elkins et al. 2019).

Multiple drivers affect the decline in freshwater biodiversity (Dudgeon et al. 2006; Strayer & Dudgeon 2010; Reid et al. 2018). Long-term datasets can aid in the understanding of how these drivers affect freshwater communities (Willis & Birks 2006; Willis et al. 2007; Enneson & Litzgus 2008). Utilizing long-term datasets allows researchers to expand upon large-scale spatial and temporal data (Goodman et al. 2015; Edmonds et al. 2022). Long-term datasets from multiple sites can increase the understanding of freshwater communities and help build conservation plans for different regions.

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Table 1: Site information with coordinates and local catchment area.

Site Information	Rocky Ford	Highway 301	I-16
Site Coordinates	32.648975, -81.840760	32.562416, -81.715828	32.150152, -81.401928
Catchment Area (km^2)	135.09	119.08	126.60

Table 2: Census percent change estimates and population density for each bordering county between 2010–2020.

County	Δ% Total Population 2010–2020	Δ% Tot. Pop. Est. 2020–2023	Pop. Density per km^2 (2020)
Bryan	47.9	11.2	40
Bulloch	15.5	5.9	46
Effingham	24.0	10.5	52
Screven	-3.6	0.8	8

Table 3: Rapid bioassessment protocol water quality assessment final scores for each site depending on each year and season. Sample data for Oliver Spring of 2017 and I-16 Summer of 2014 did not have enough macroinvertebrates in the sample and were omitted from the dataset.

	2023	2017	2016	2015	2014
Winter					
RF	73		68	76	66
301/Oliver	56		82	74	89
I-16	79		79	78	78
Spring					
RF	62	64	49	65	
301/Oliver	72	—	90	56	
I-16	91	80	71	62	
Summer					
RF	80		74	63	56
301/Oliver	75		53	69	85
I-16	89		78	91	—
Autumn					
RF	75		81	68	71
301/Oliver	81		64	60	52
I-16	92		62	90	66

Key	Good	Fair	Poor

Table 4: Permutational analysis of variance based on the macroinvertebrate relative abundance. The test compares the communities based on year, season, and site, as well as seasons within each year. Significance is $P < 0.05$. Macroinvertebrates are sorted to the lowest possible taxonomic identification (genus) when possible, to avoid bias.

	DF	**Sum of Squares**	**Mean Sum of Squares**	**Pseudo-F**	**P**
Year	4	2.8051	0.22504	4.2342	0.001
Season	3	2.2122	0.17747	4.4523	0.001
Year*Season	8	2.4791	0.19889	1.8711	0.001
Residual	30	4.9687	0.39861		
Total	45	12.4651	1.00000		
Site	2	0.5450	0.04372	1.1153	0.279
Season	3	2.4916	0.19989	3.3996	0.001
Site*Season	6	1.1221	0.09002	0.7655	0.956
Residual	34	8.3064	0.66638		
Total	45	12.4651	1.00000		
Site	2	0.5450	0.04372	1.0880	0.311
Year	4	2.8183	0.22610	2.8133	0.001
Site*Year	7	1.0878	0.08726	0.6205	1.000
Residual	32	8.0141	0.64292		
Total	45	12.4651	1.00000		

Table 5: Permutational analysis of variance based on the macroinvertebrate functional feeding group relative abundance. The test compares the communities based on year, season, and site, as well as against one another. Significance is P < 0.05. Macroinvertebrates are sorted to the lowest possible taxonomic identification (genus) when possible, to avoid bias.

	DF	**Sum of Squares**	**Mean Sum of Squares**	**Pseudo-F**	**P**
Year	4	0.26823	0.09650	1.9293	0.033
Season	3	0.77963	0.28048	7.4768	0.001
Year*Season	8	0.68906	0.24790	2.4781	0.004
Residual	30	1.04272	0.37513		
Total	45	2.77964	1.00000		
Site	2	0.05513	0.01983	0.5666	0.791
Season	3	0.88034	0.31671	6.0313	0.001
Site*Season	6	0.18993	0.06833	0.6506	0.864
Residual	34	1.65424	0.59513		
Total	45	2.77964	1.00000		
Site	2	0.05513	0.01983	0.4036	0.911
Year	4	0.25906	0.09320	0.9482	0.488
Site*Year	7	0.27972	0.10063	0.5850	0.930
Residual	32	2.18572	0.78633		
Total	45	2.77964	1.00000		

Table 6: Permutational analysis of variance based on the macroinvertebrate habit relative abundance. The test compares the communities based on year, season, and site, as well as against one another. Significance is P < 0.05. Macroinvertebrates are sorted to the lowest possible taxonomic identification (genus) when possible, to avoid bias.

	DF	**Sum of Squares**	**Mean Sum of Squares**	**Pseudo-F**	**P**
Year	4	0.70190	0.22876	4.8916	0.001
Season	3	0.46754	0.15238	4.3445	0.001
Year*Season	8	0.82264	0.26811	2.8665	0.001
Residual	30	1.07618	0.35075		
Total	45	3.06826	1.00000		
Site	2	0.19893	0.06484	1.5739	0.147
Season	3	0.54807	0.17863	2.8908	0.005
Site*Season	6	0.17257	0.05624	0.4551	0.973
Residual	34	2.14868	0.70029		
Total	45	3.06826	1.00000		
Site	2	0.19893	0.06484	1.6007	0.134
Year	4	0.67233	0.21912	2.7048	0.004
Site*Year	7	0.20846	0.06794	0.4792	0.982
Residual	32	1.98853	0.64810		
Total	45	3.06826	1.00000		

Table 7: Fish index of biotic integrity metrics for spring and summer between 2014 and 2016 and 2023.

Summer	**2023**	**2016**	**2015**	**2014**
RF	30	44	36	21
OL	34	40	40	38
I16	32	26	26	20
Autumn	**2023**	**2016**	**2015**	**2014**
RF	30	28	34	24
OL	40	38	34	28
I16	26	26	24	16

Key	Good	Fair	Poor	Very Poor

Table 8: Permutational analysis of variance based on the fish relative abundance. The test compares the communities based on year, season, and site, as well as against one another. Significance is P < 0.05. All fish are identified as species to avoid bias.

	DF	Sum of Squares	Mean Sum of Squares	Pseudo-F	P
Year	3	1.1825	0.28773	3.0578	0.001
Season	1	0.2420	0.05888	1.8773	0.085
Year*Season	3	0.6229	0.15156	1.6107	0.057
Residual	16	2.0625	0.50184		
Total	23	4.1098	1.00000		
Site	2	0.3070	0.07469	0.8140	0.640
Season	1	0.2420	0.05888	1.2834	0.263
Site*Season	2	0.1668	0.04059	0.4423	0.977
Residual	18	3.3940	0.82584		
Total	23	4.1098	1.00000		
Site	2	0.3070	0.07469	0.9266	0.506
Year	3	1.1825	0.28773	2.3796	0.003
Site*Year	6	0.6326	0.15392	0.6365	0.969
Residual	12	1.9877	0.48366		
Total	23	4.1098	1.00000		

Table 9: Permutational analysis of variance based on the fish feeding guild relative abundance. The test compares the communities based on year, season, and site, as well as against one another. Significance is P < 0.05. All fish are identified as species to avoid bias.

	DF	**Sum of Squares**	**Mean Sum of Squares**	**Pseudo-F**	**P**
Year	3	0.49961	0.31068	2.7897	0.018
Season	1	0.05894	0.03665	0.9873	0.390
Year*Season	3	0.09442	0.05871	0.5272	0.857
Residual	16	0.95517	0.59396		
Total	23	1.60814	1.00000		
Site	2	0.21566	0.13410	1.5641	0.178
Season	1	0.05894	0.03665	0.8550	0.459
Site*Season	2	0.09261	0.05759	0.6717	0.665
Residual	18	1.24093	0.77166		
Total	23	1.60814	1.00000		
Site	2	0.21566	0.13410	2.2169	0.078
Year	3	0.49961	0.31068	3.4239	0.010
Site*Year	6	0.30919	0.19227	1.0595	0.399
Residual	12	0.58368	0.36295		
Total	23	1.60814	1.00000		

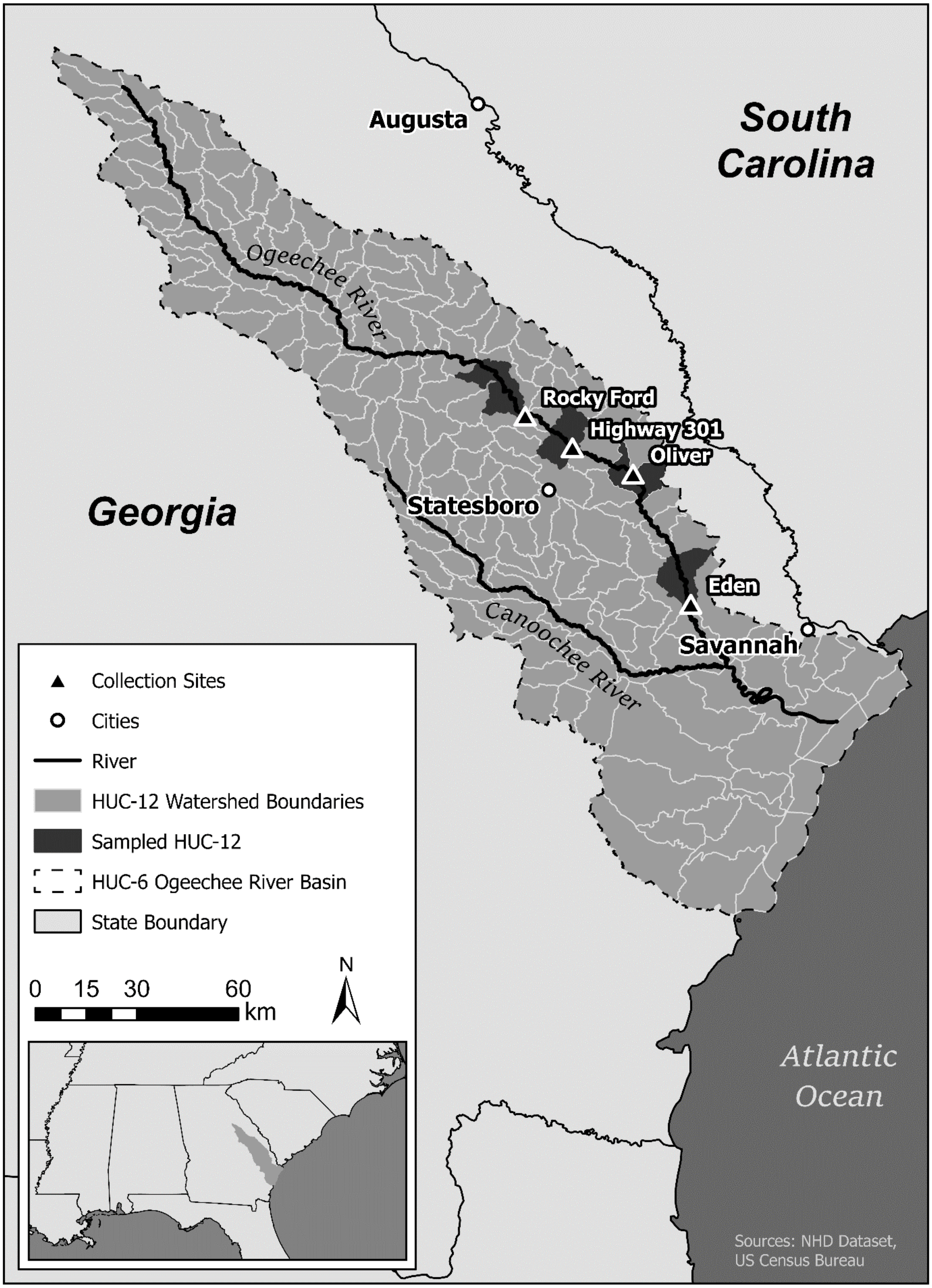


Figure 1: Map of the Ogeechee River watershed with each catchment site highlighted using ArcGIS.

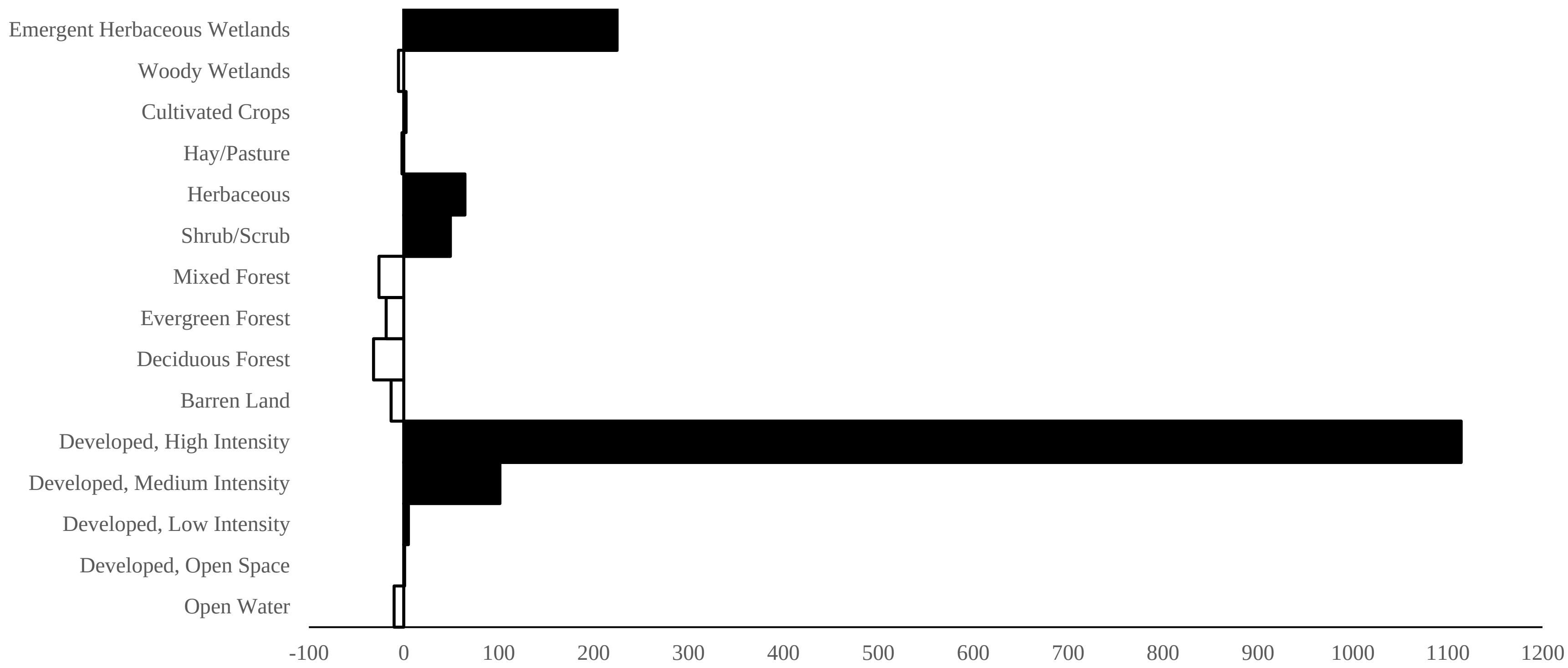


Figure 2: Land usage change between 2011–2021 in the Rocky Ford catchment area.

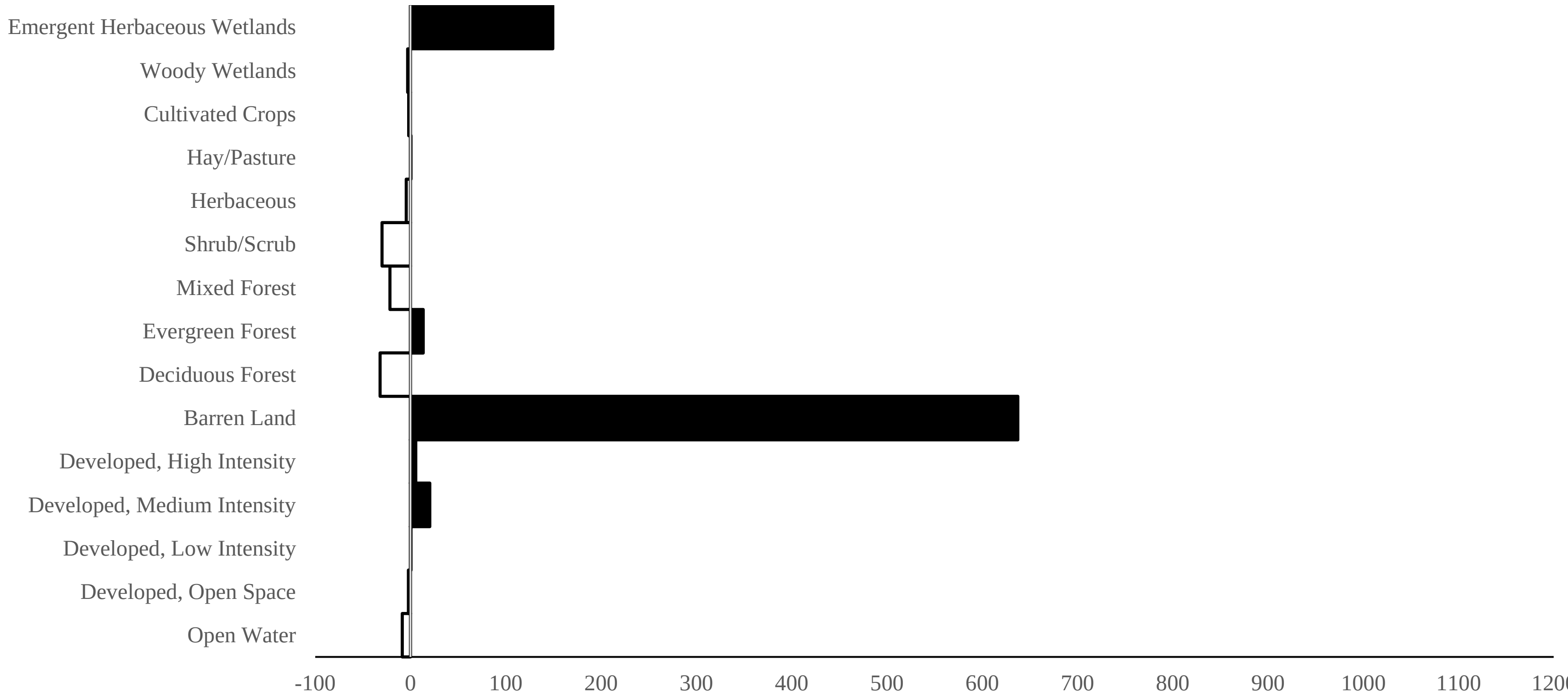


Figure 3: Land usage change between 2011–2021 in the Highway 301 catchment area.

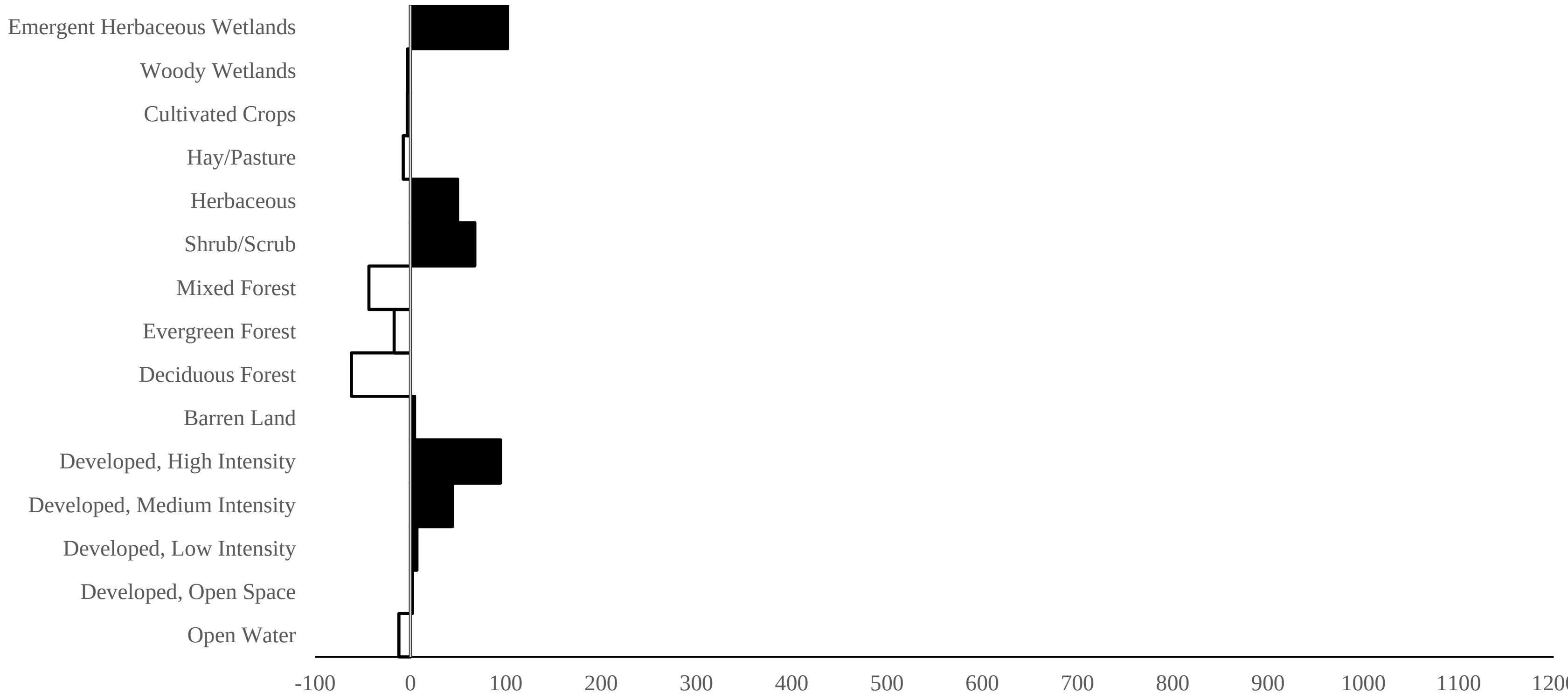
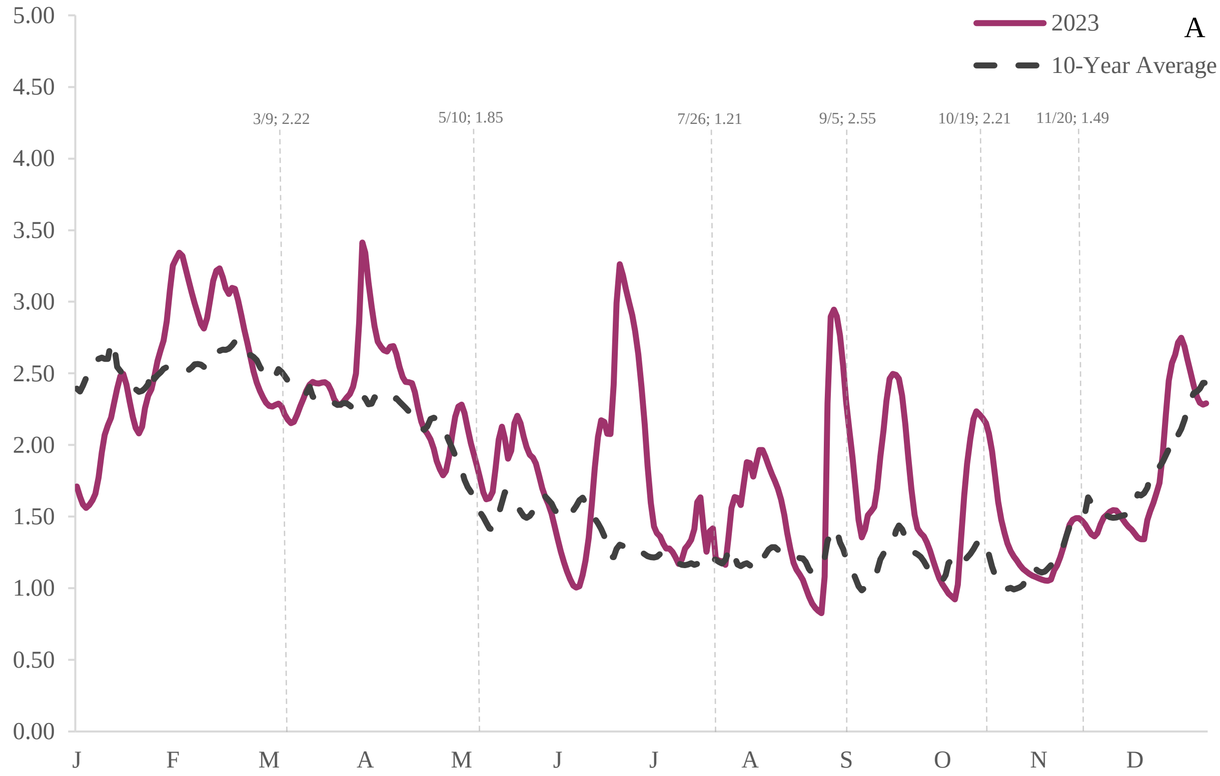


Figure 4: Land usage change between 2011–2021 in the I–16 near Eden, GA catchment area.



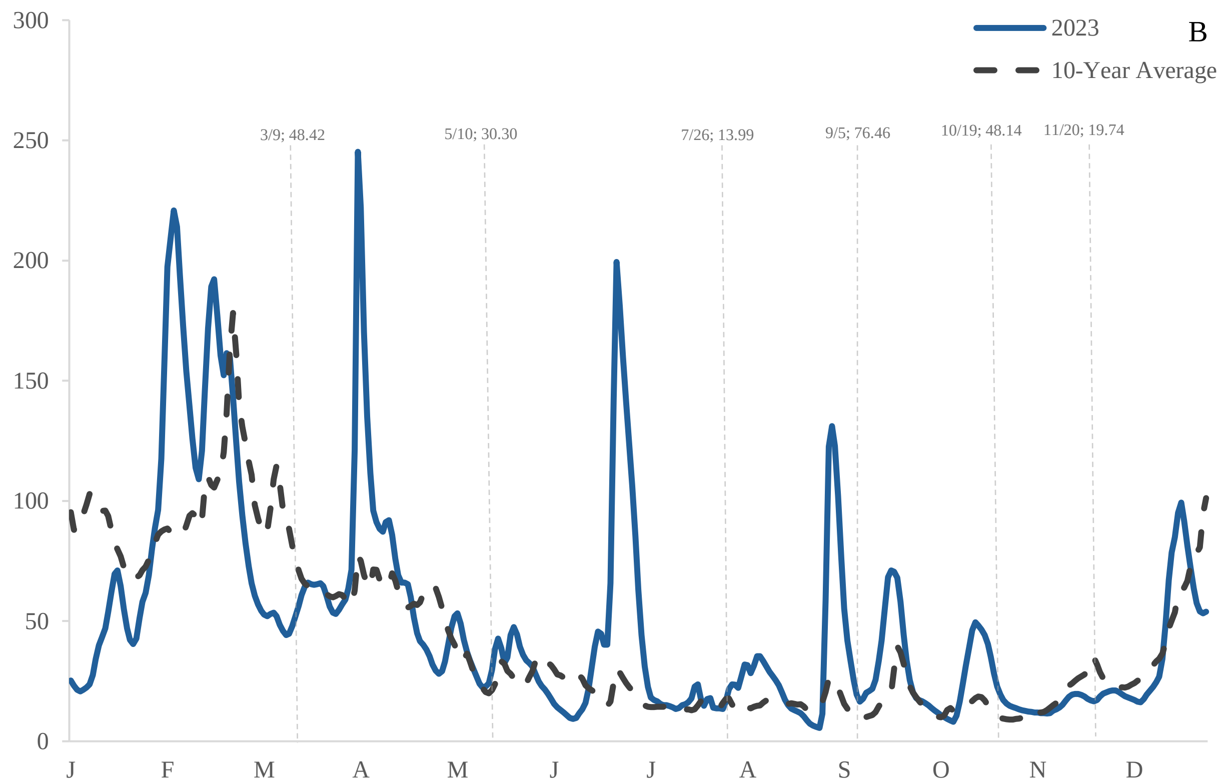


Figure 5 A–B: Rocky Ford USGS daily mean gage height (m) in 2023 compared to a 10-year average (A) and daily discharge rate (m^3/sec) in 2023 compared to a 10-year average (B).

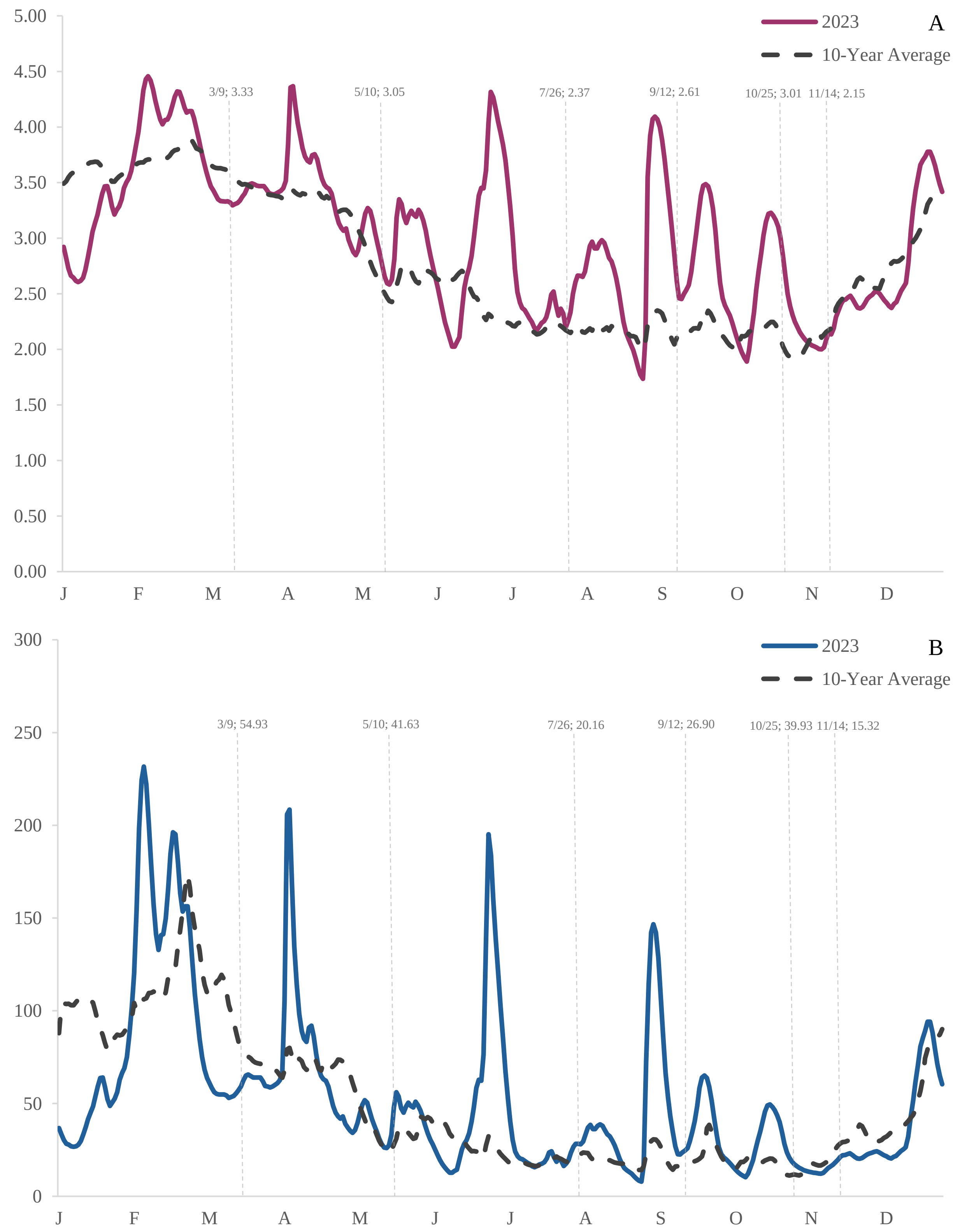


Figure 6 A–B: Oliver Bridge USGS daily mean gage height (m) in 2023 compared to a 10-year average (A) and daily discharge rate (m^3/sec) in 2023 compared to a 10-year average (B).

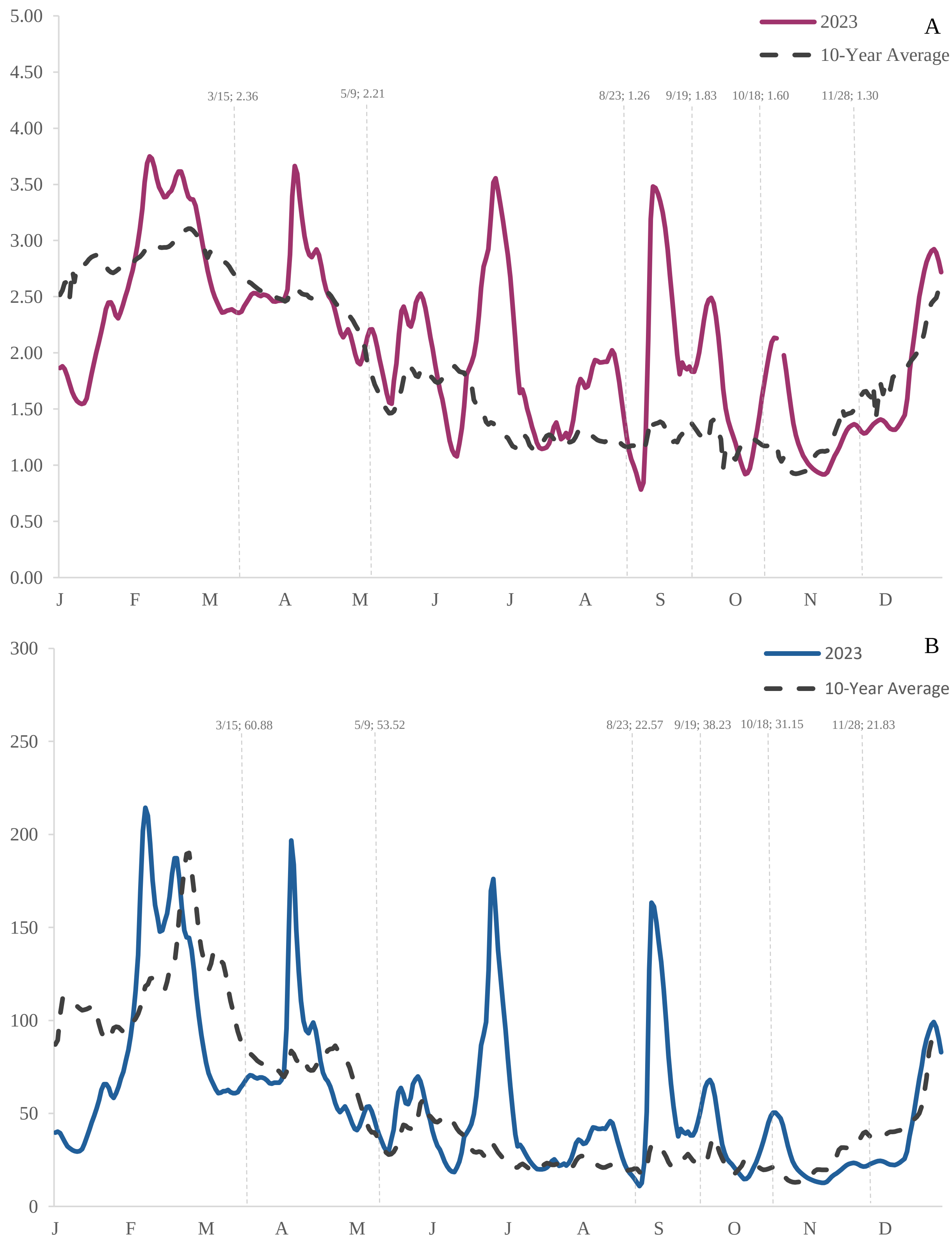


Figure 7 A–B: Near Eden, GA USGS daily mean gage height (m) in 2023 compared to a 10-year average (A) and daily discharge rate (m^3/sec) in 2023 compared to a 10-year average (B).

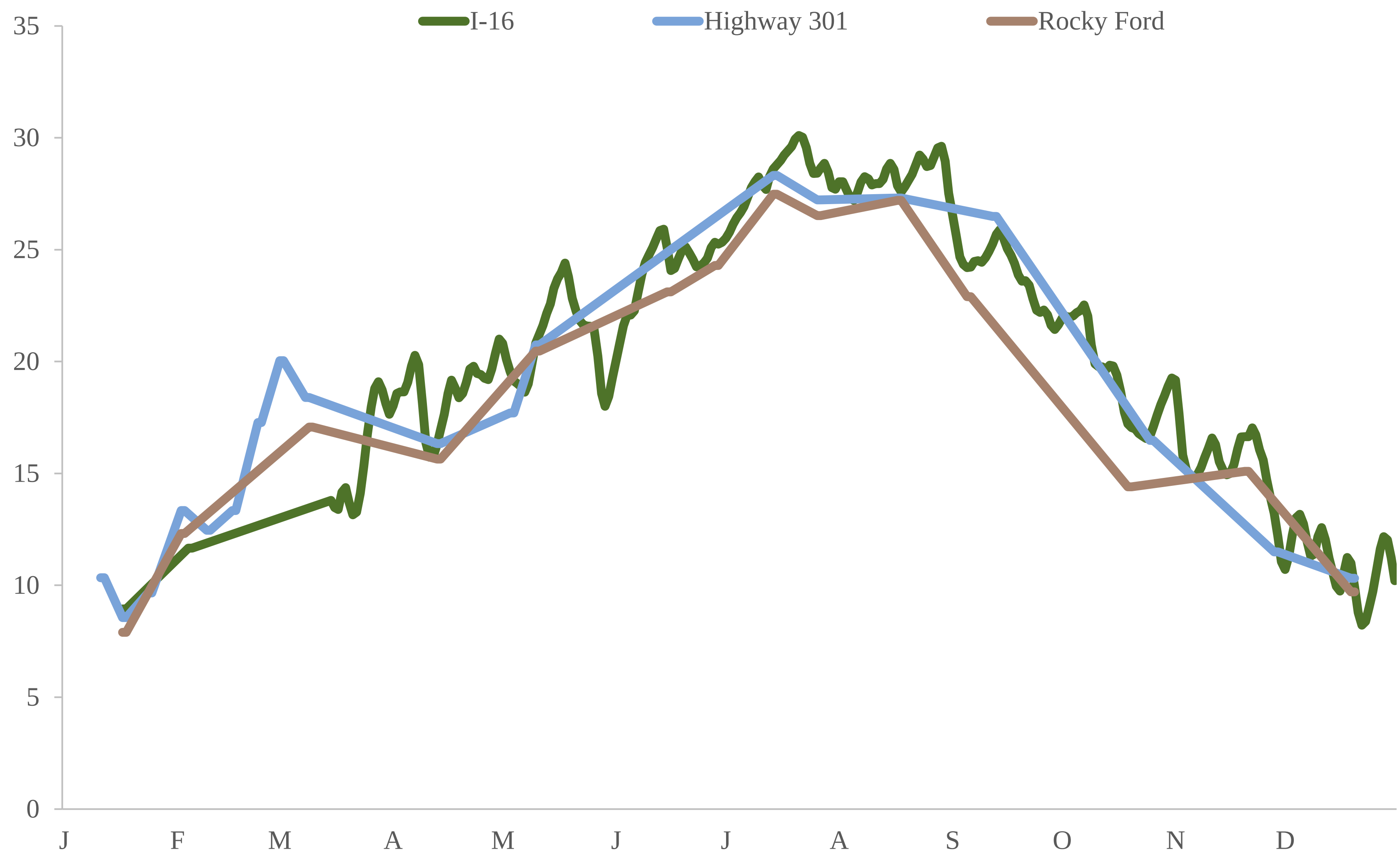


Figure 8: Water temperature (°C) parameters collected at each sample site throughout the year. Hanheld measured data points were taken monthly in cooler months and biweekly in warmer months. The points are non-continuous. The HOBO data was chosen with points at 12:00 GMT –04:00.

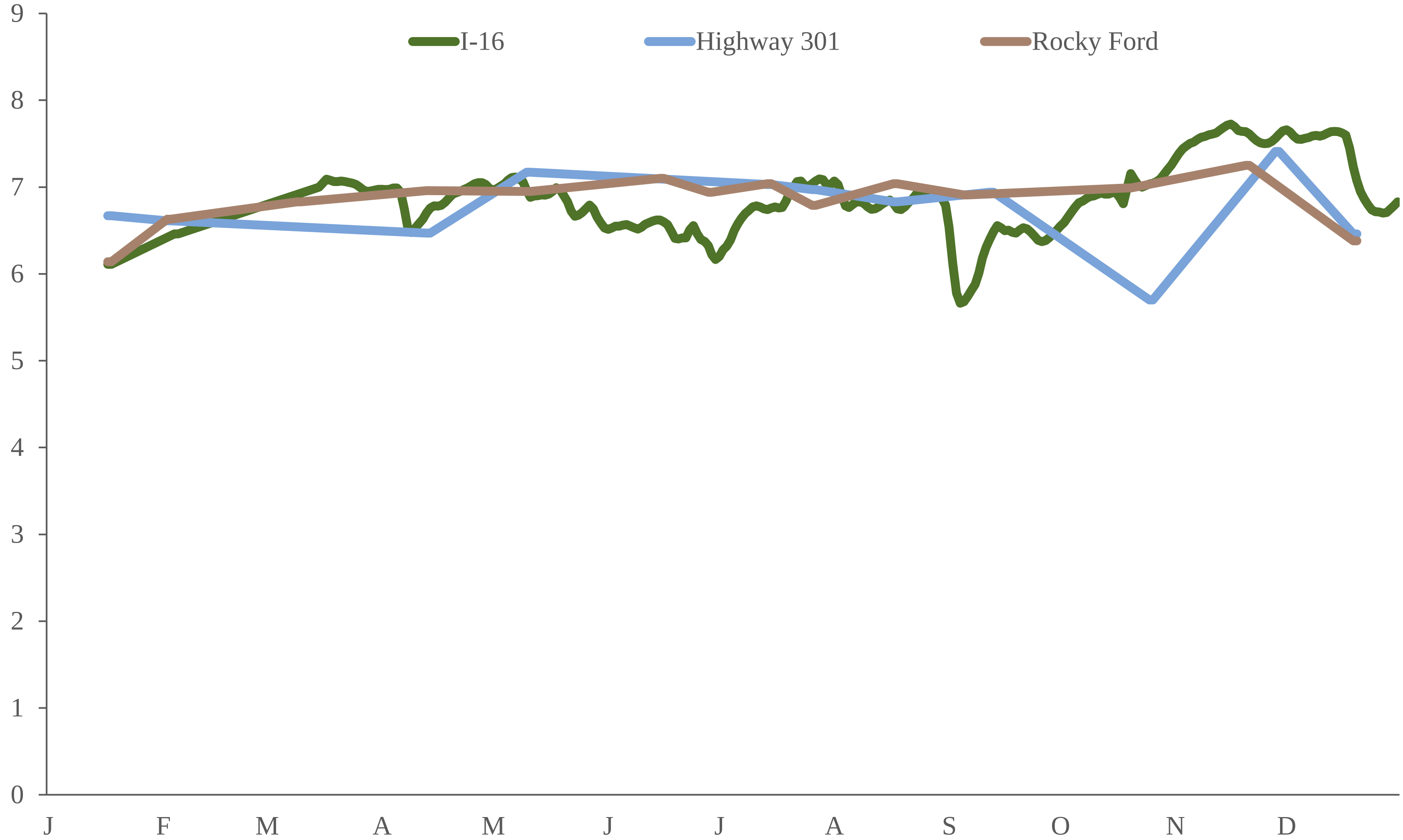


Figure 9: pH parameters collected at each sample site throughout the year. Hanheld measured data points were taken monthly in cooler months and biweekly in warmer months. The points are non-continuous. The HOBO data was chosen with points at 12:00 GMT –04:00.

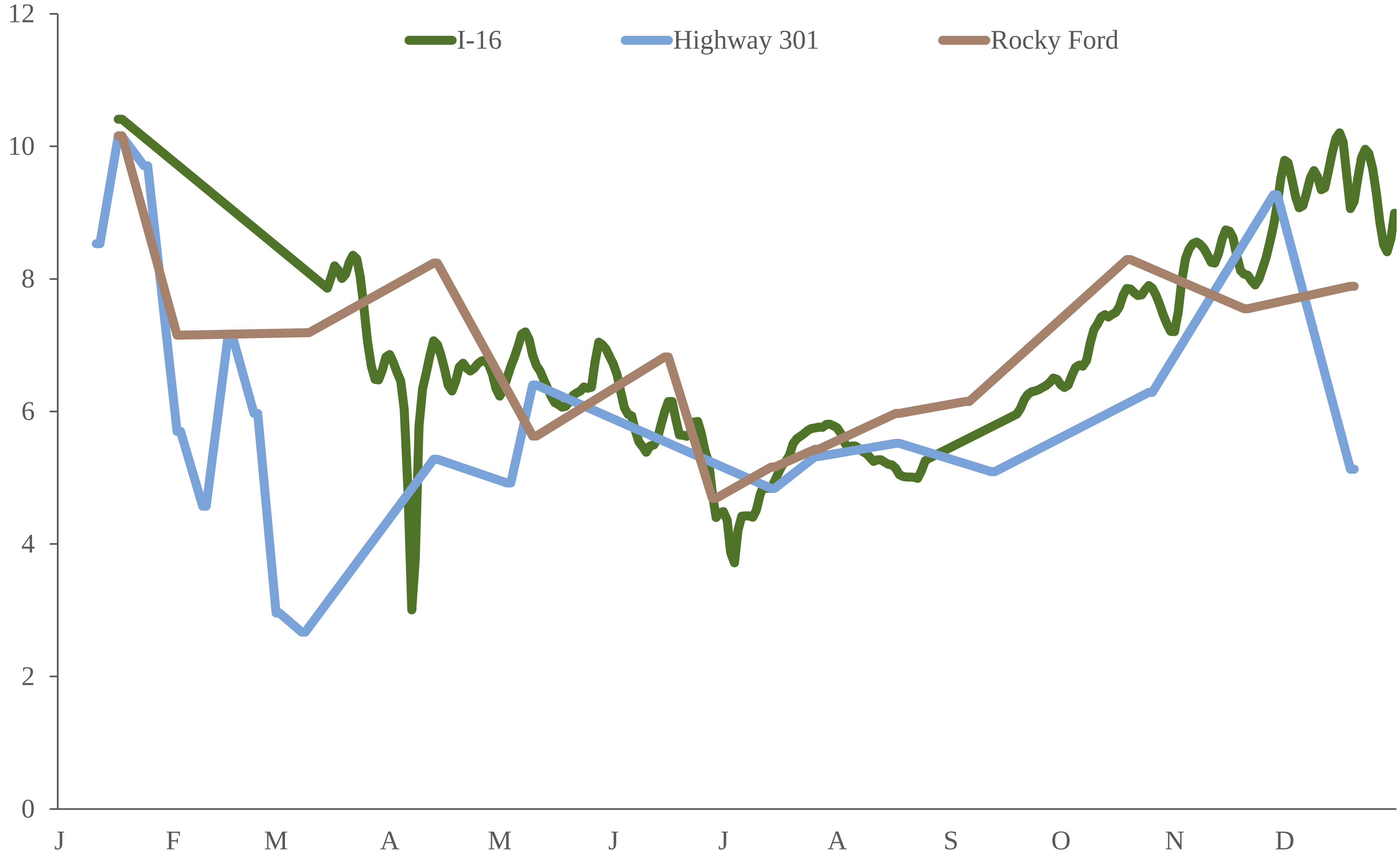


Figure 10: Dissolved oxygen (ppm) parameters collected at each sample site throughout the year. Handheld measured data points were taken monthly in cooler months and biweekly in warmer months. The points are non-continuous. The HOBO data was chosen with points at 12:00 GMT –04:00.

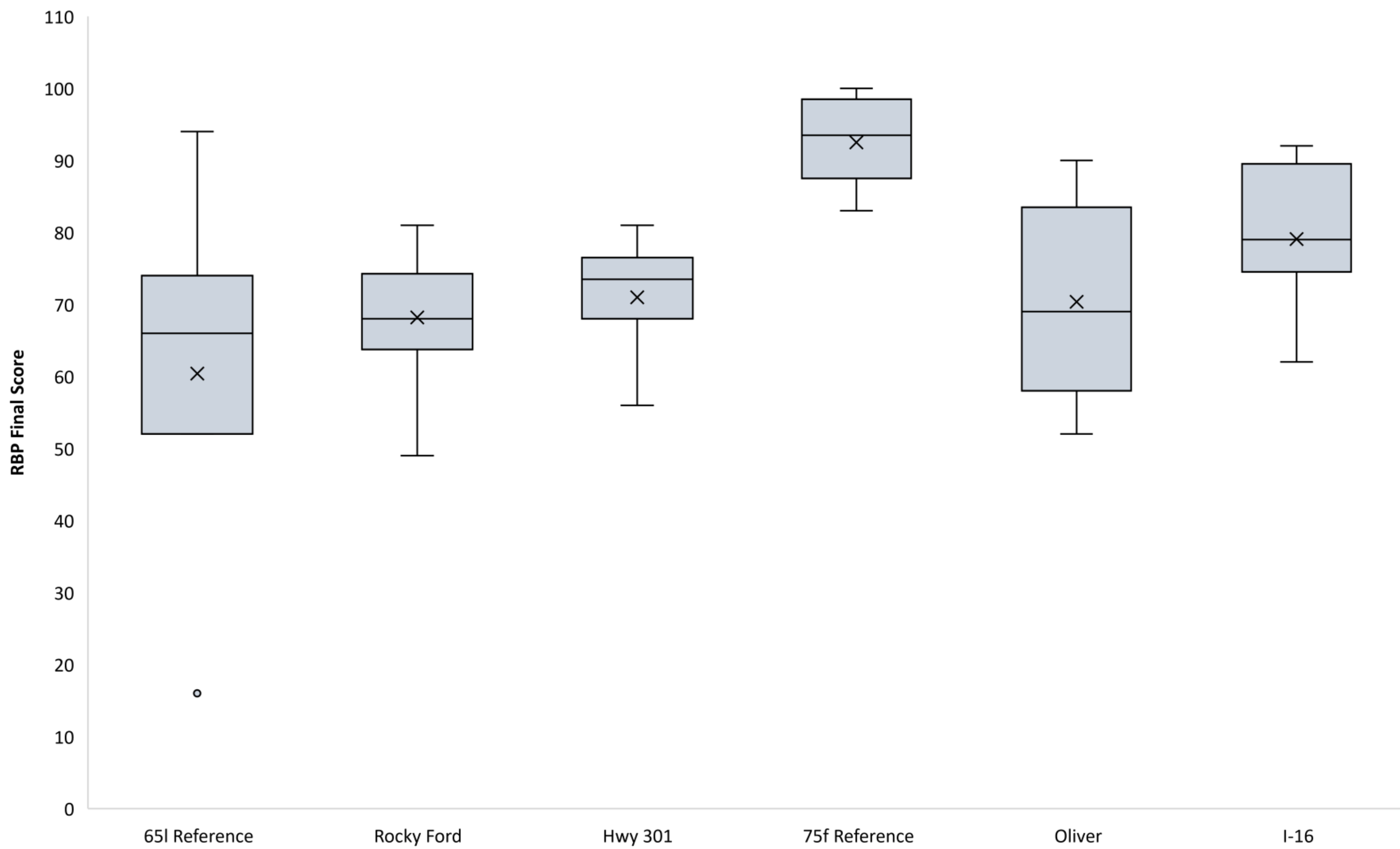
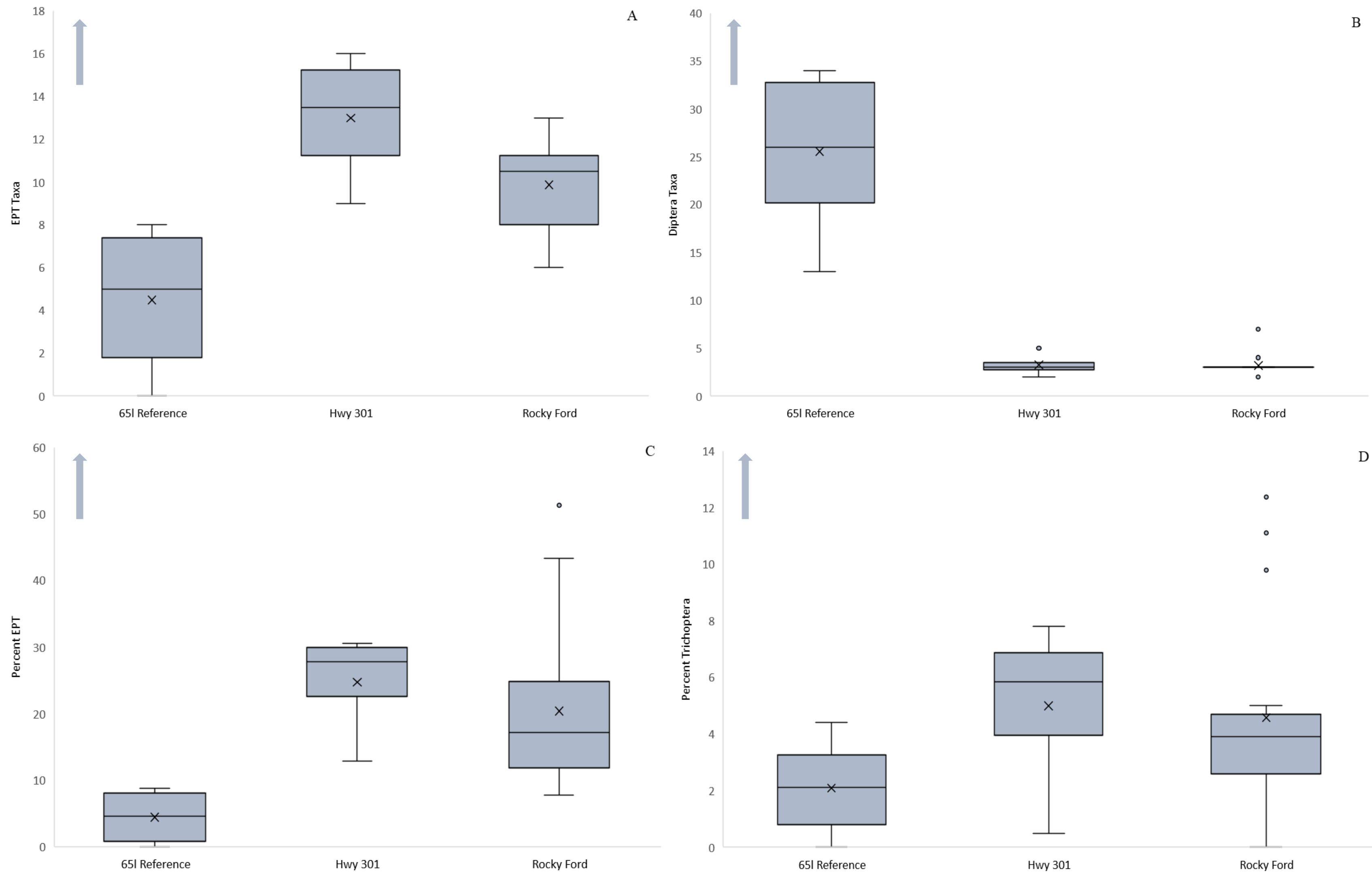


Figure 11: Box plot comparisons of the rapid bioassessment protocol scores for each site with all years and seasons included and their reference site. The dots indicate outlier values. The first and fourth quarter error bars indicate ± SE. The box contains the interquartile range. The line represents the median value. The “X” represents the mean value.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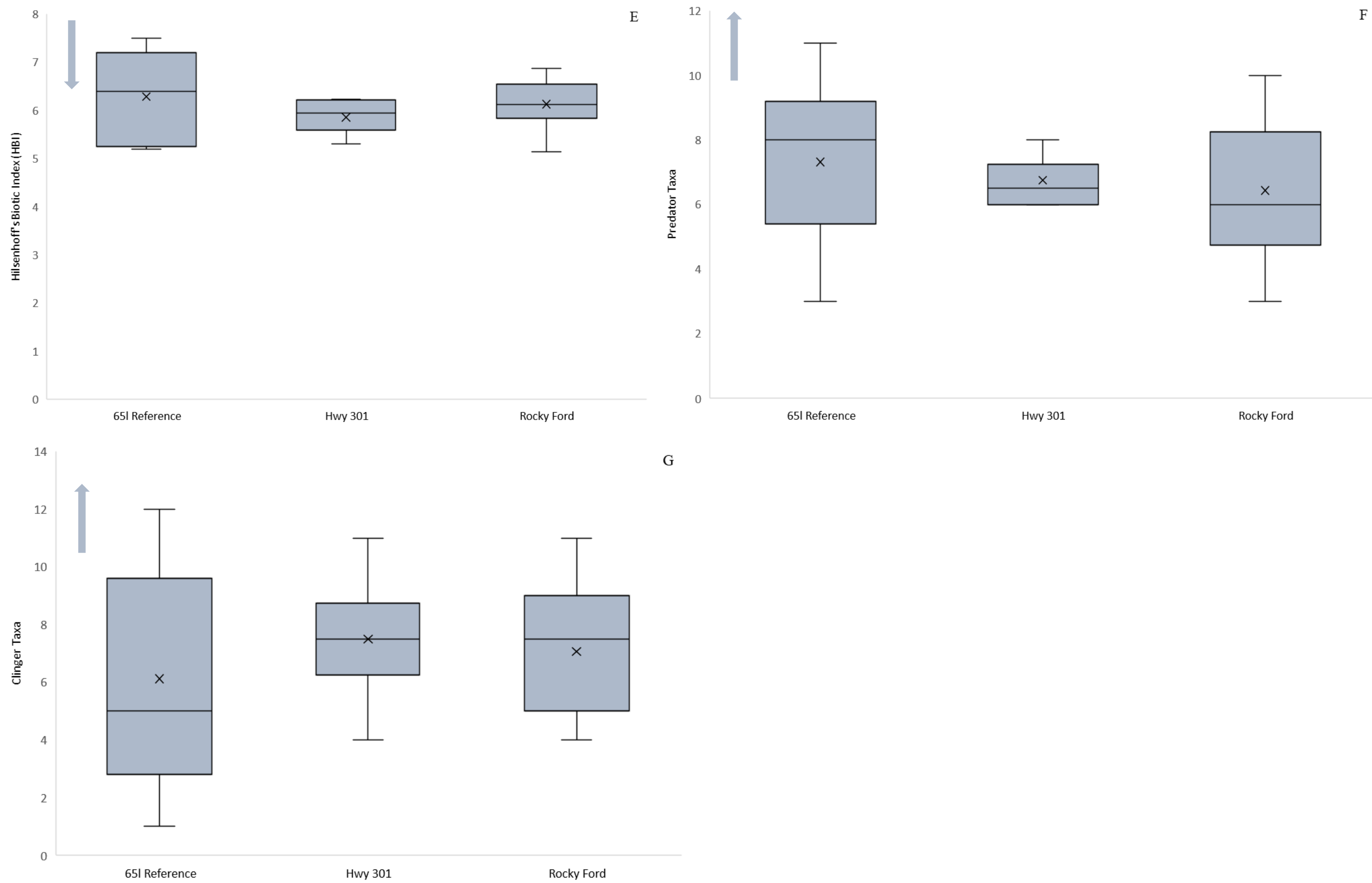


Figure 12 A–G: Box plot comparisons for each mean metric in the Atlantic Southern Loam Plains (65l) rapid bioassessment protocol metrics with reference site metrics included. The dots indicate outlier values. The first and fourth quarter error bars indicate ± SE. The box contains the interquartile range. The line represents the median value. The "X" represents the mean value.

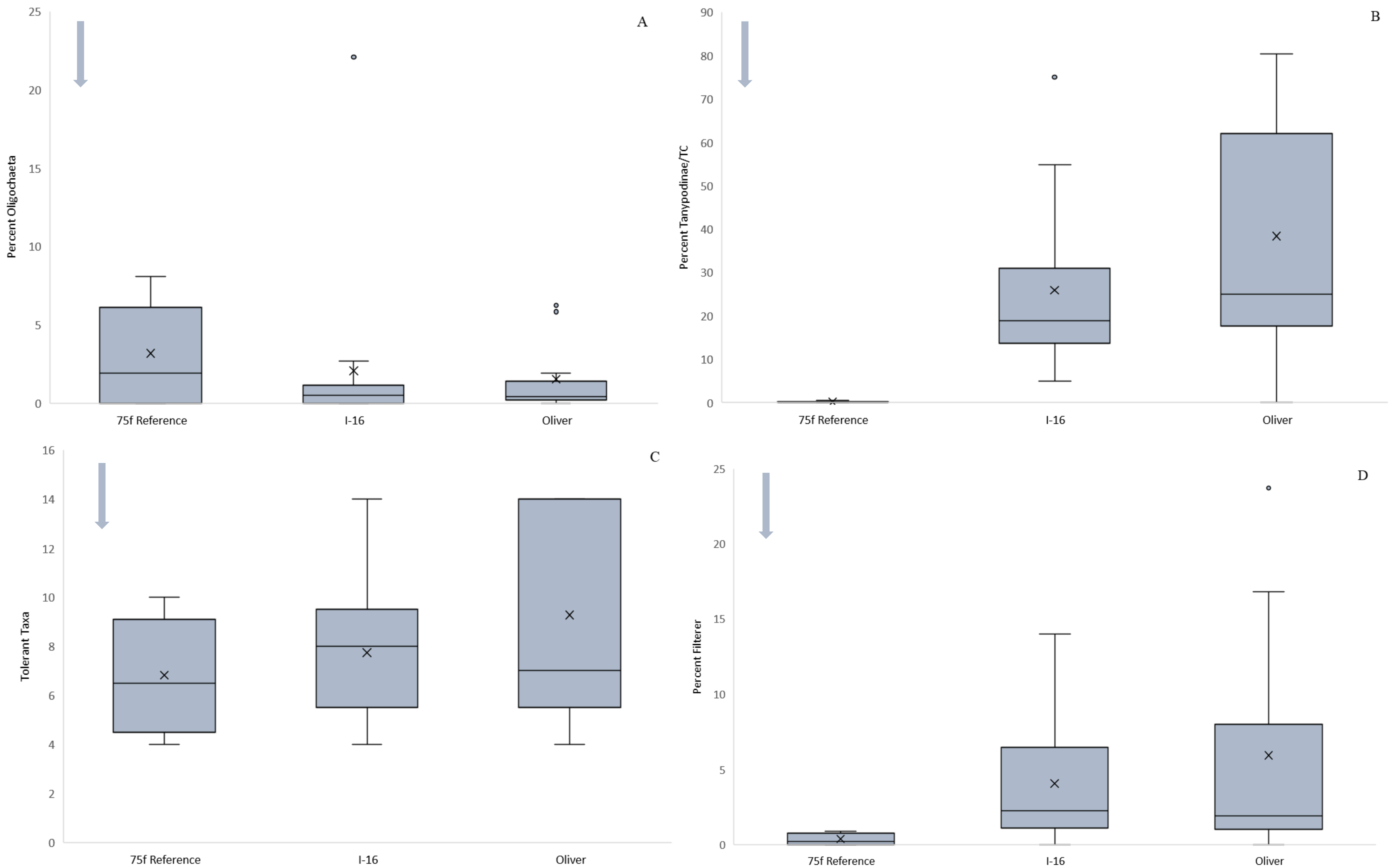


Figure 13 A–D: Box plot comparisons for each mean metric in the Sea Island Flatwoods (75f) rapid bioassessment protocol metrics with reference site metrics included. The dots indicate outlier values. The first and fourth quarter error bars indicate ± SE. The box contains the interquartile range. The line represents the median value. The “X” represents the mean value.

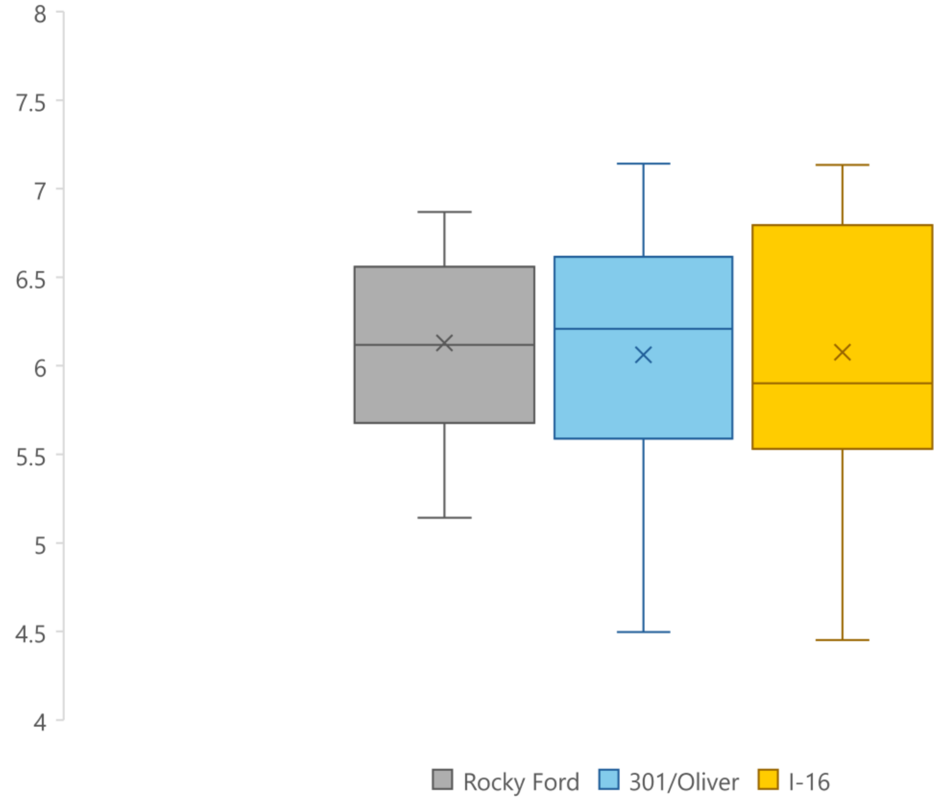


Figure 14: Box plot showing Hilsenhoff's biotic index for each site. The dots indicate outlier values. The first and fourth quarter error bars indicate ± SE. The box contains the interquartile range. The line represents the median value. The "X" represents the mean value.

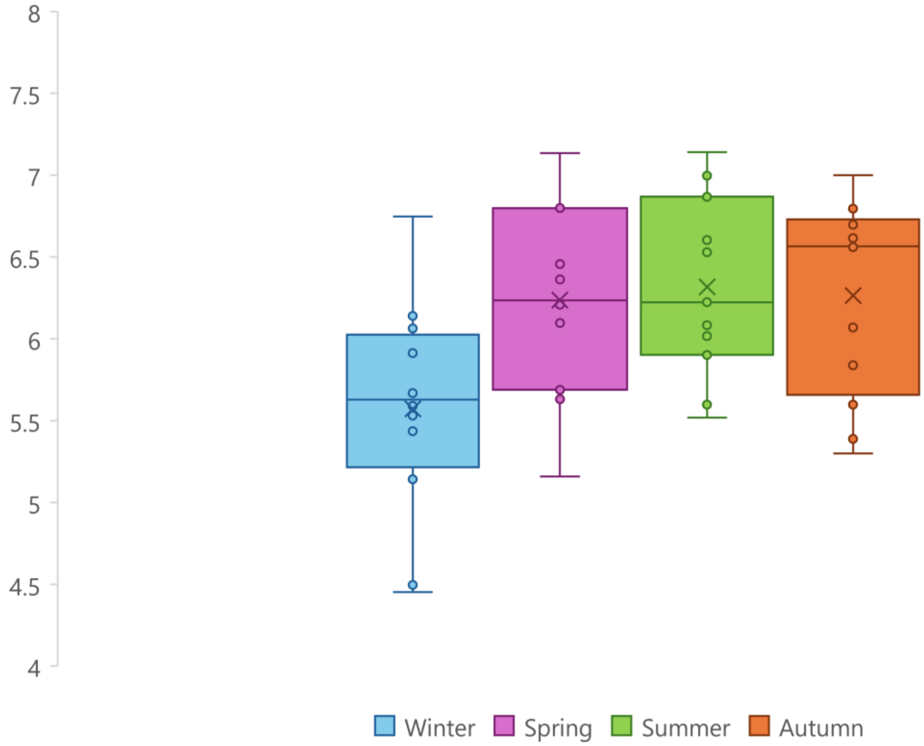


Figure 15: Box plot showing Hilsenhoff's biotic index for each season. The dots indicate outlier values. The first and fourth quarter error bars indicate ± SE. The box contains the interquartile range. The line represents the median value. The "X" represents the mean value.

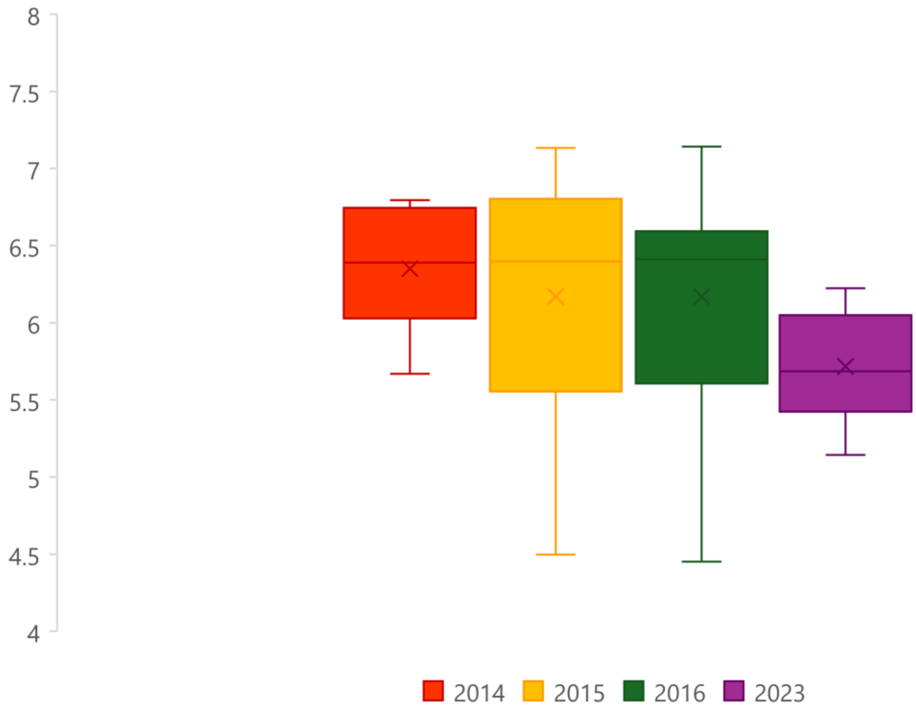


Figure 16: Box plot showing Hilsenhoff's biotic index for each year. 2017 was removed with too low a sample count (n=2). The dots indicate outlier values. The first and fourth quarter error bars indicate ± SE. The box contains the interquartile range. The line represents the median value. The "X" represents the mean value.

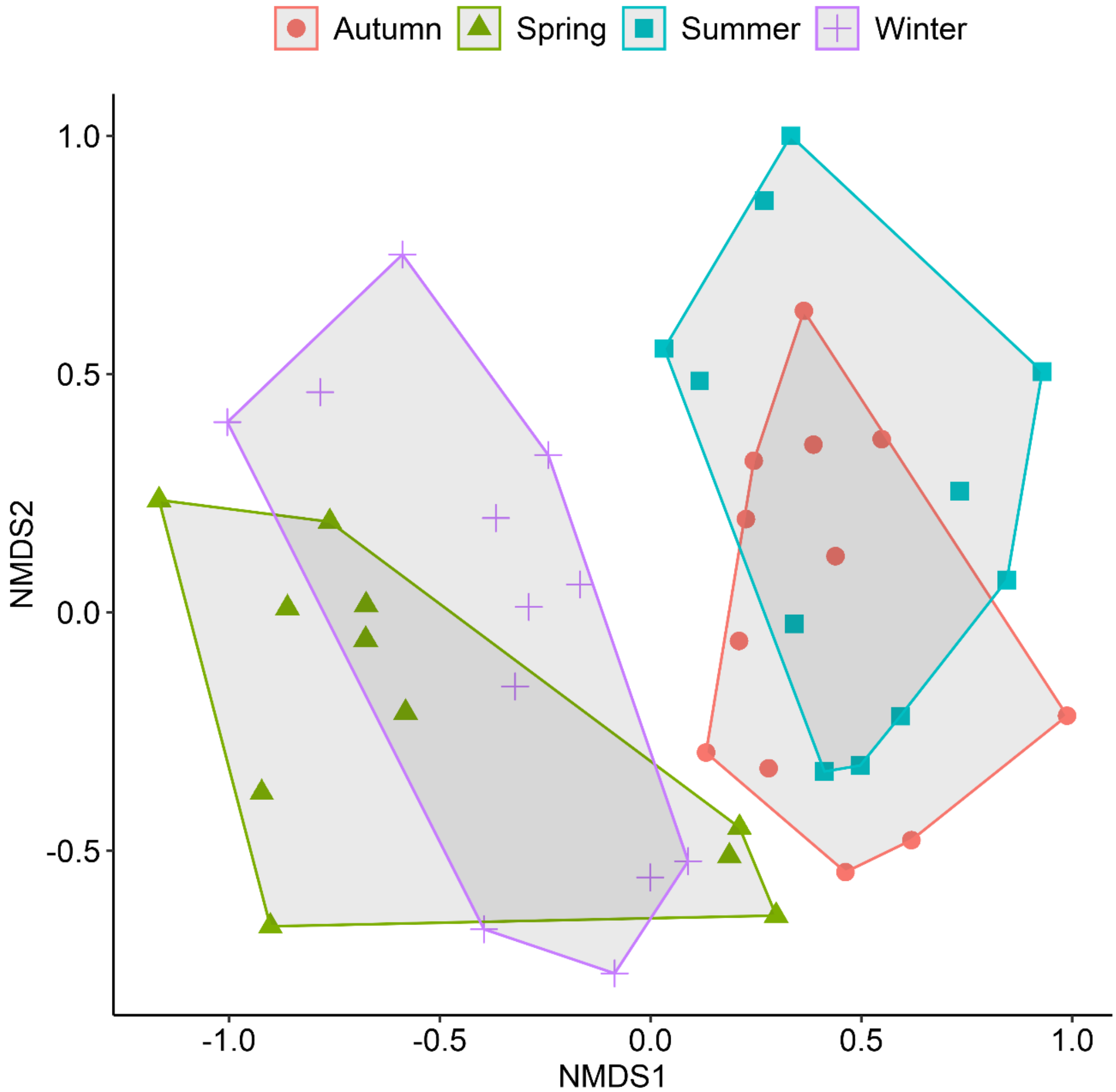


Figure 17: Macroinvertebrate non-metric multidimensional scaling comparing communities seasonally based on relative abundance. 2-dimensional stress = 0.215. Each site is represented by a point on the graph. Seasons are separated by color.

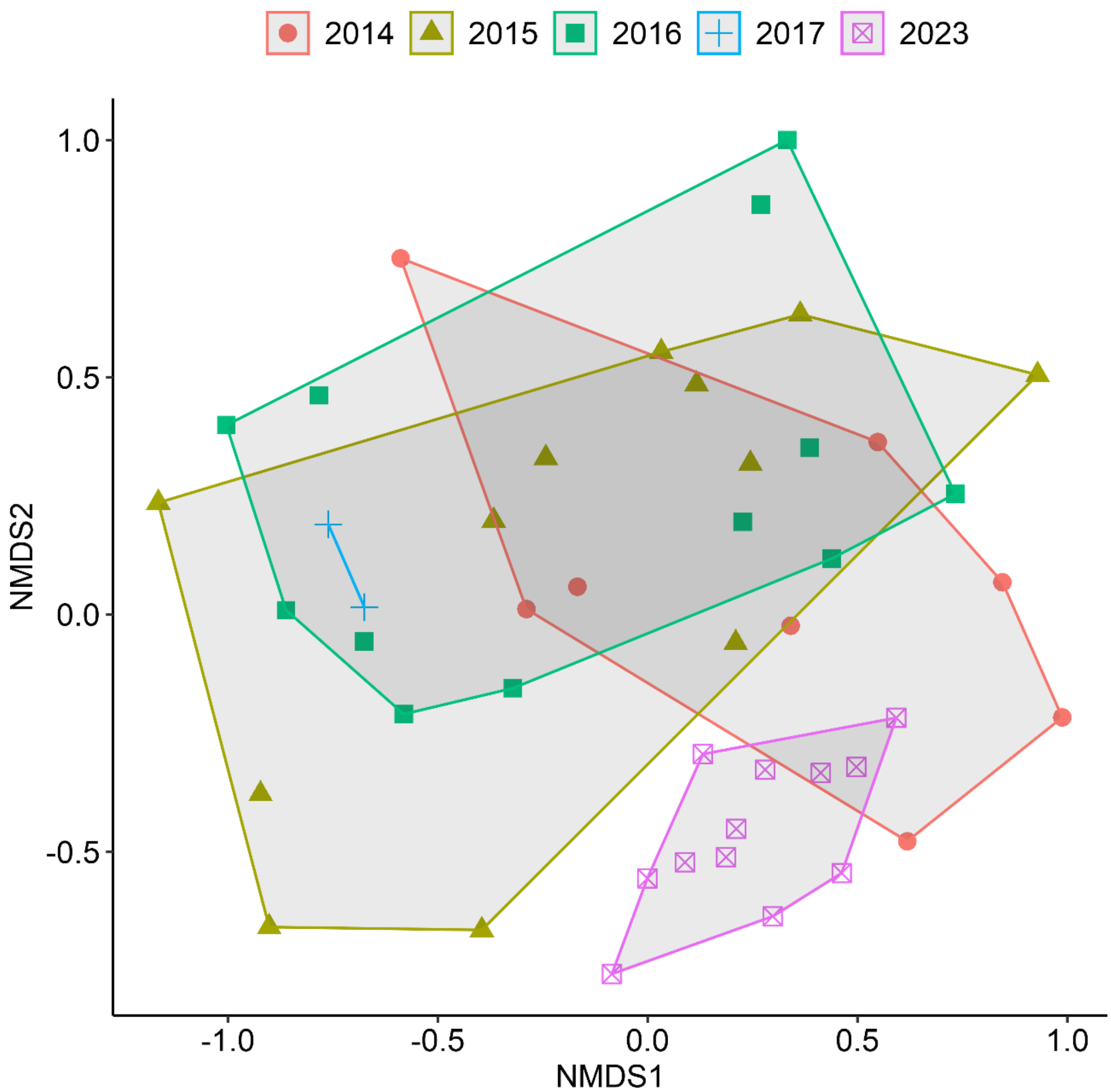


Figure 18: Macroinvertebrate non-metric multidimensional scaling comparing communities yearly based on relative abundance. 2-dimensional stress = 0.215. Each site is represented by a point on the graph. Years are separated by color.

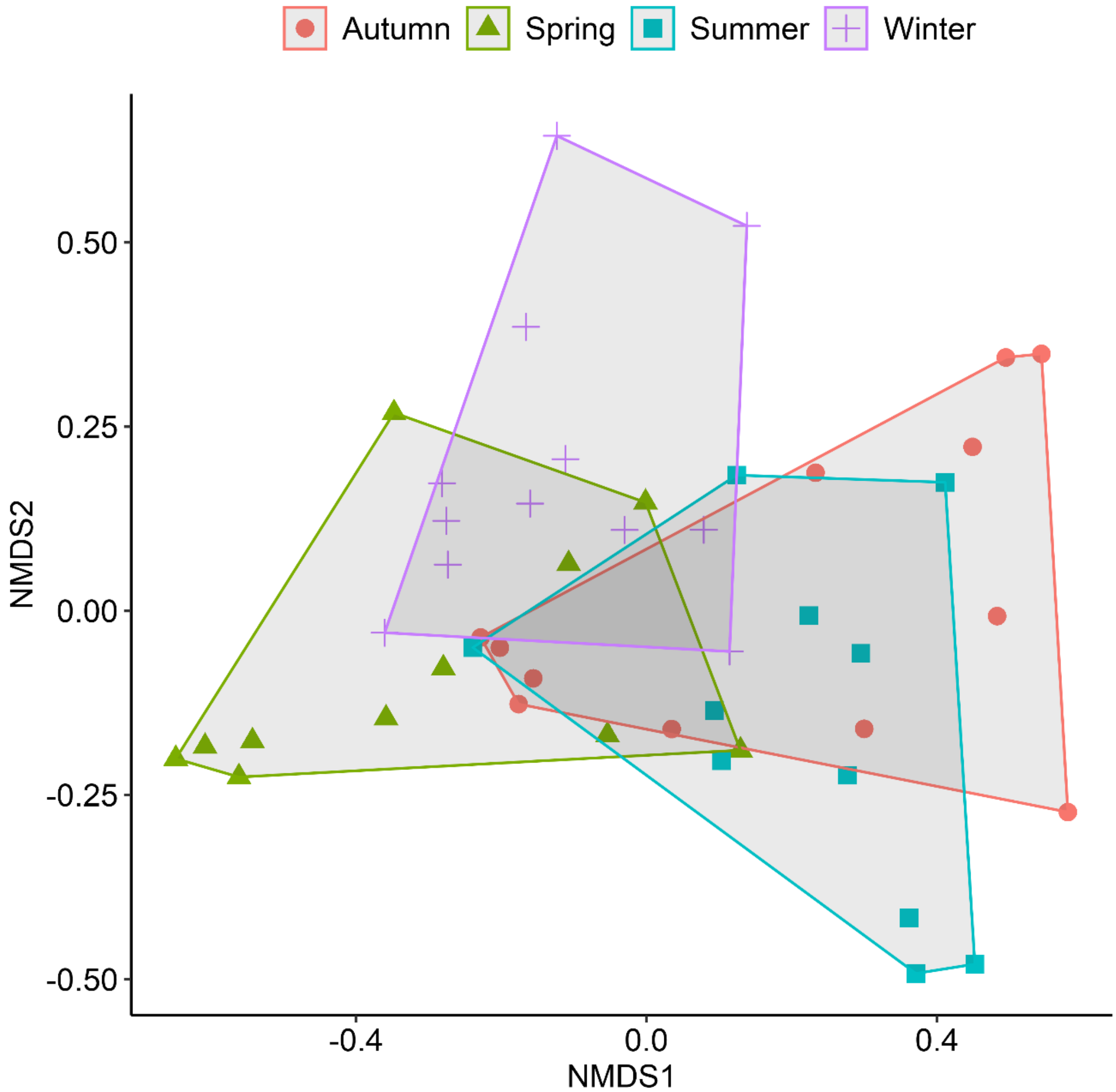


Figure 19: Macroinvertebrate non-metric multidimensional scaling comparing communities seasonally based on functional feeding group relative abundance. 2-dimensional stress = 0.136. Each site is represented by a point on the graph. Seasons are separated by color.

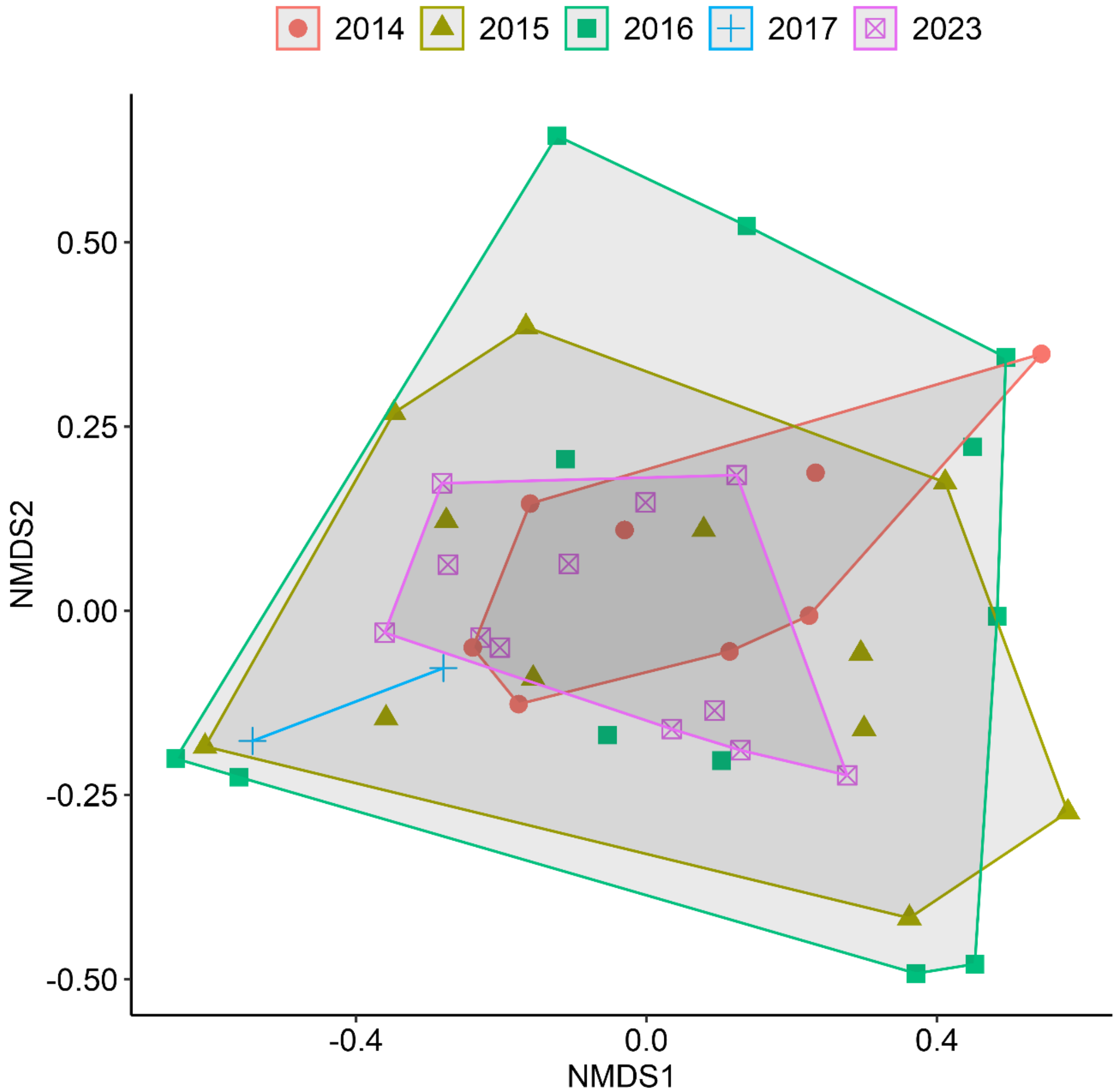


Figure 20: Macroinvertebrate non-metric multidimensional scaling comparing communities yearly based on functional feeding group relative abundance. 2-dimensional stress = 0.136. Each site is represented by a point on the graph. Years are separated by color.

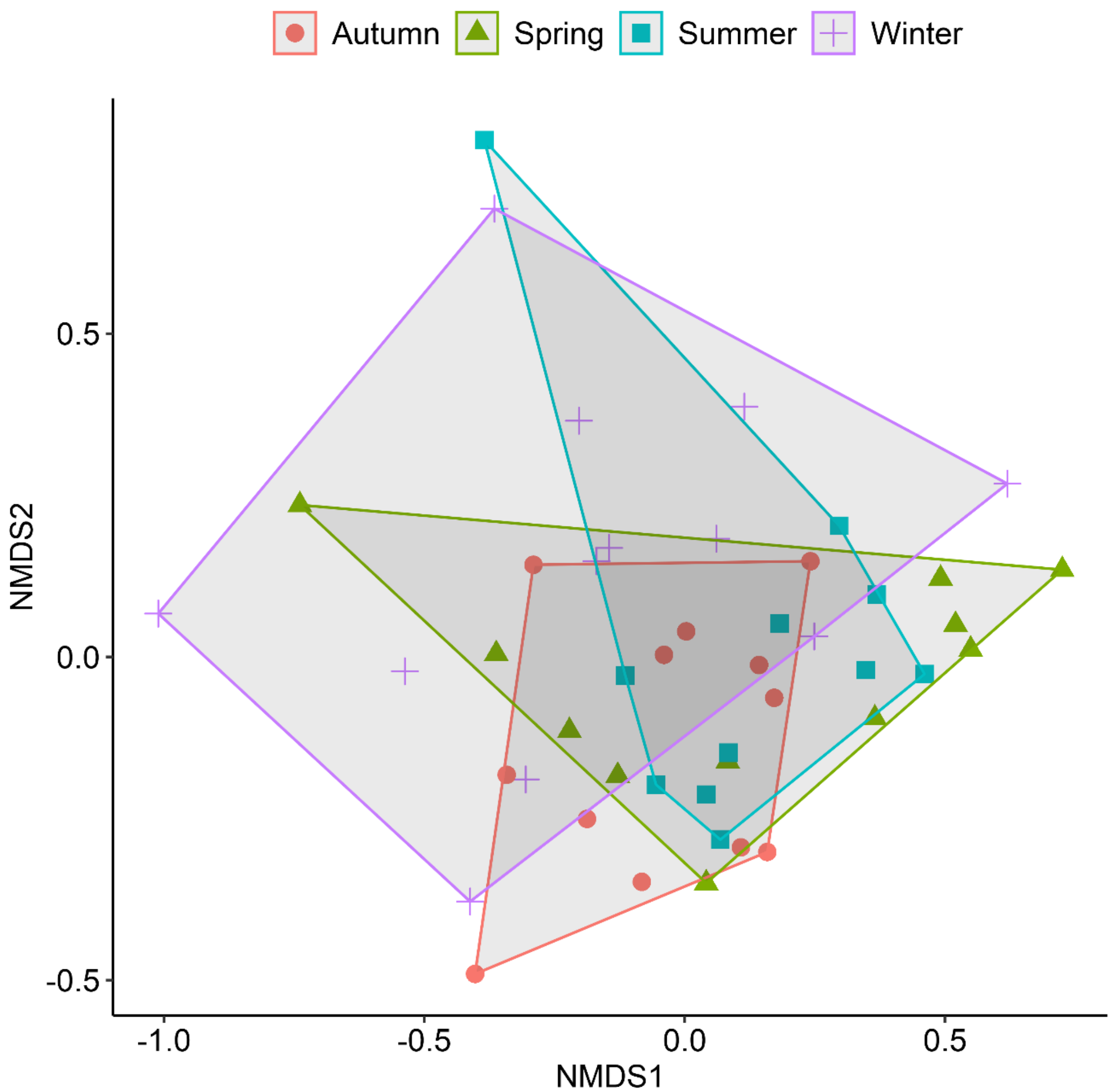


Figure 21: Macroinvertebrate non-metric multidimensional scaling comparing communities seasonally based on habit relative abundance. 2-dimensional stress = 0.149. Each site is represented by a point on the graph. Seasons are separated by color.

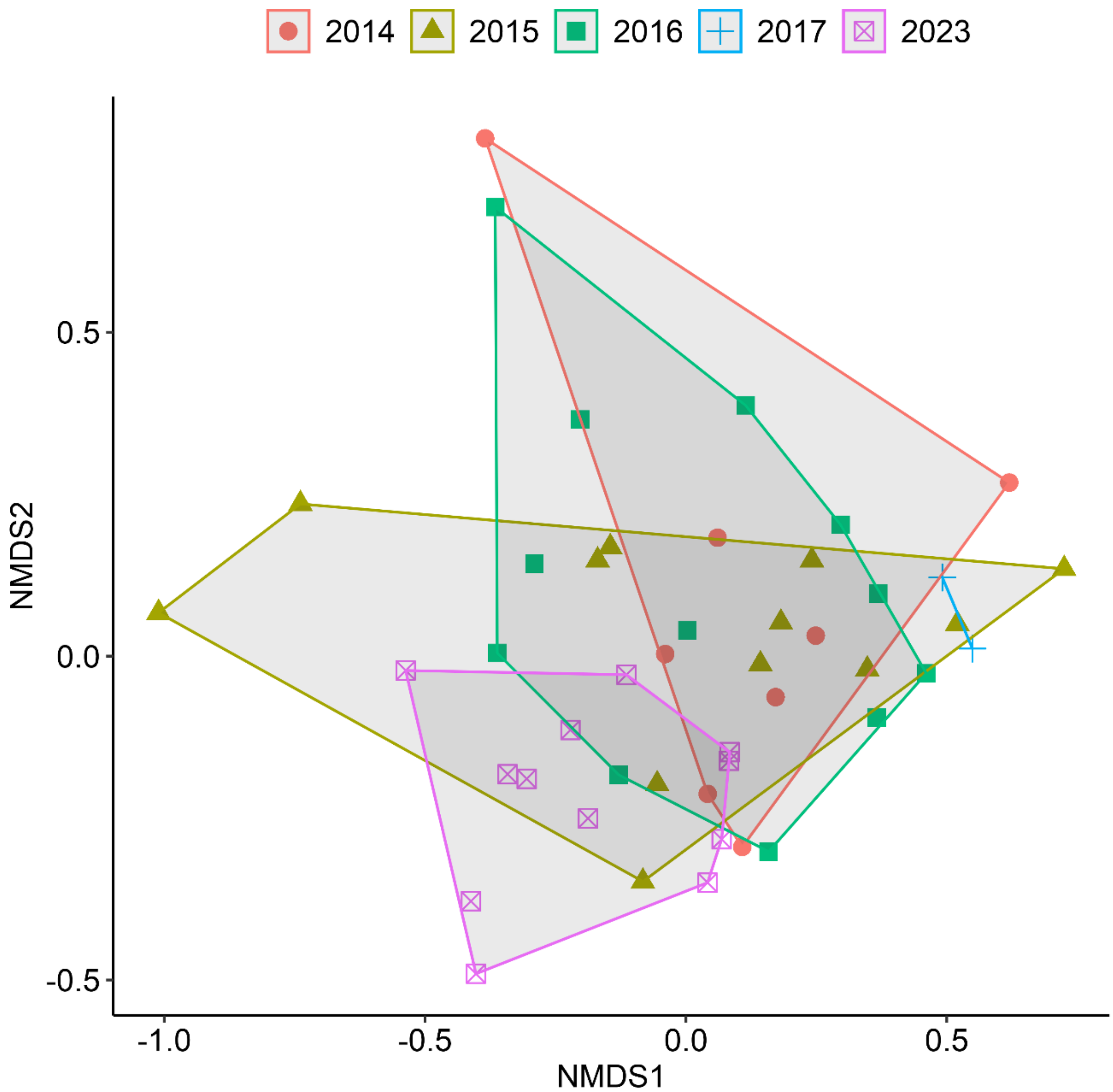


Figure 22: Macroinvertebrate non-metric multidimensional scaling comparing communities yearly based on habit relative abundance. 2-dimensional stress = 0.149. Each site is represented by a point on the graph. Years are separated by color.

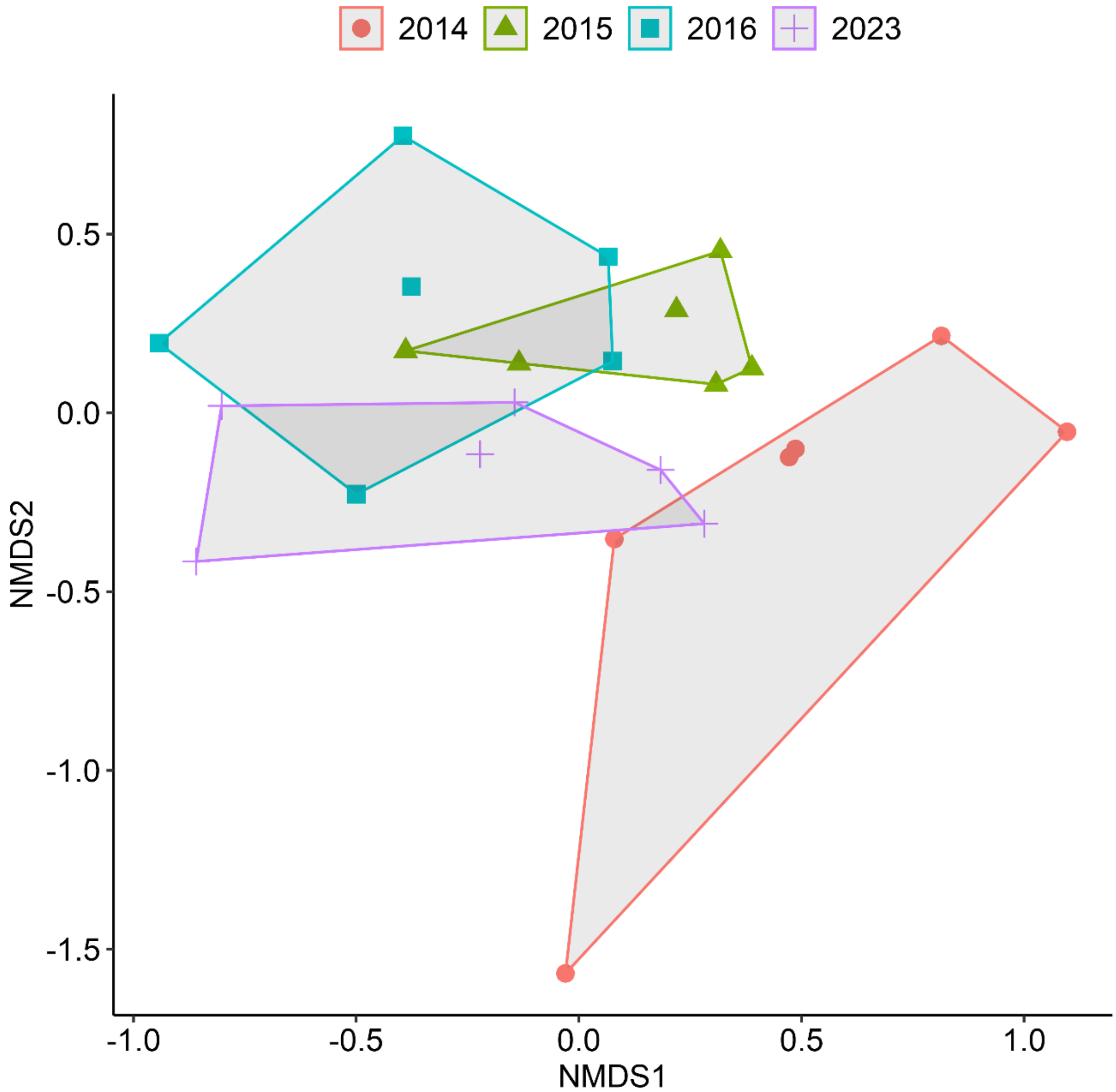


Figure 23: Fish non-metric multidimensional scaling comparing communities yearly based on relative abundance. 2-dimensional stress = 0.136. Each site is represented by a point on the graph. Years are separated by color.

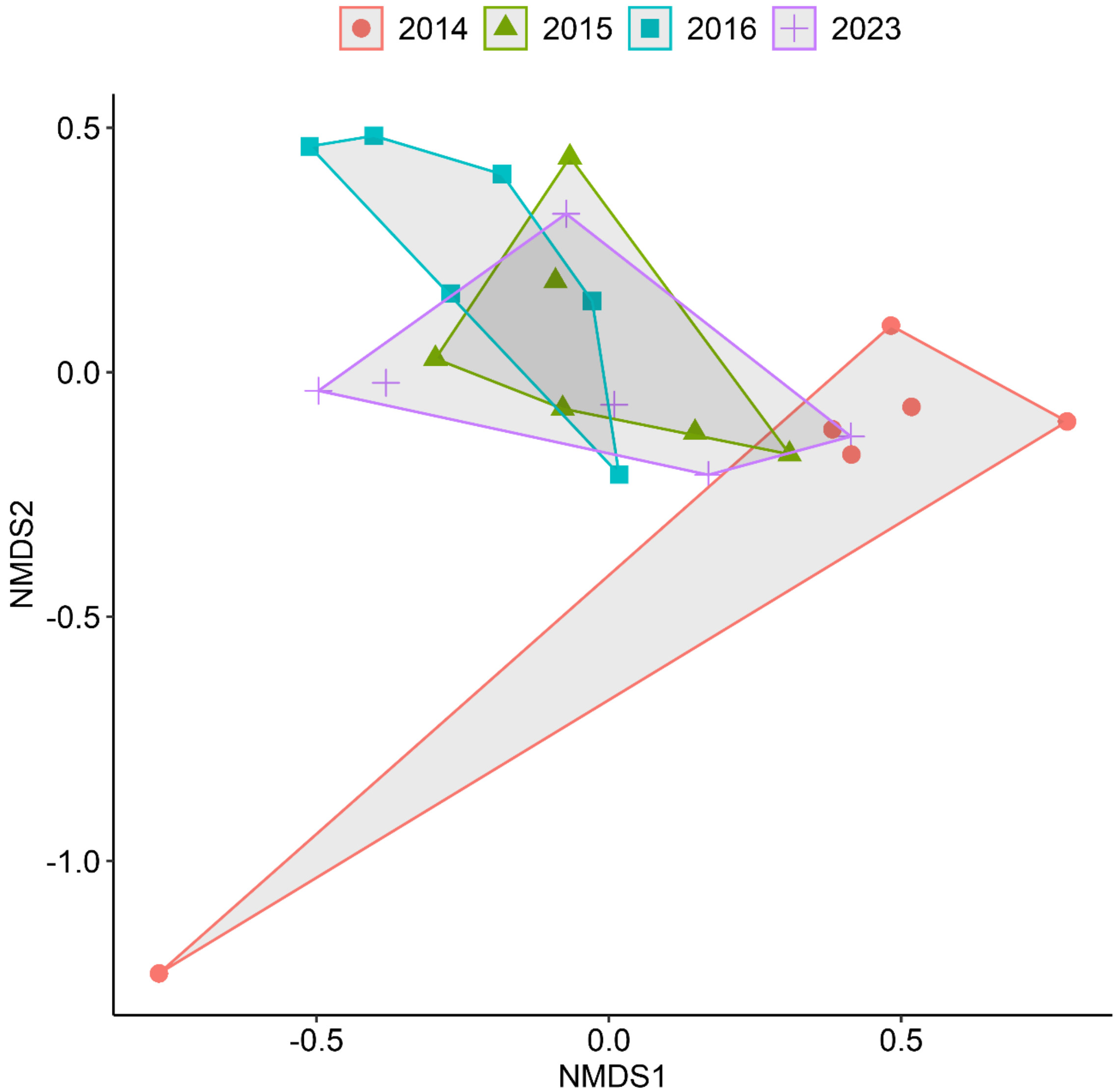


Figure 24: Fish non-metric multidimensional scaling comparing communities yearly based on feeding guild relative abundance. 2-dimensional stress = 0.028. Each site is represented by a point on the graph. Years are separated by color.

APPENDICES

APPENDIX A

Percentage land usage change for each site between 2011 and 2022.

Class Type	Rocky Ford Δ% 2011-2021	Hwy 301 Δ% 2011-2021	Eden Δ% 2011-2021
Open Water	-10	-9	-12
Developed, Open Space	1	-2	2
Developed, Low Intensity	5	0	7
Developed, Medium Intensity	101	20	44
Developed, High Intensity	1114	6	95
Barren Land	-13	637	4
Deciduous Forest	-32	-32	-62
Evergreen Forest	-19	13	-17
Mixed Forest	-26	-22	-44
Shrub/Scrub	49	-30	67
Herbaceous	64	-4	50
Hay/Pasture	-2	0	-8
Cultivated Crops	2	-2	-3
Woody Wetlands	-6	-3	-3
Emergent Herbaceous Wetlands	225	149	102

APPENDIX B

Macroinvertebrate Taxonomic List

Macroinvertebrates were collected using the aquatic dip net 20-jab method (GA EPD 2007). Functional feeding group, habit, and tolerance values were gathered from Merritt et al. (2008) and the Georgia Environmental Protection Division Taxa List (2012).

Phylum	**Class (Subclass)**	**Order (Suborder)**	**Family (Subfamily)**	**Genus**	**FFG**	**Habit**	**Tolerance**
Annelida	– (Oligochaeta)				CG	UN	8.27
	Clitellata (Hirudinea)				PR	UN	10.00
Arthropoda	Arachnida	Trombidiformes	Hydrachnidae		PR	UN	8.00
	Branchiopoda	Ctenopoda	Sididae		CF	UN	8.00
	– (Collembola)	– (Entomobryomorpha)			CG	SK	10.00
	Copepoda				CG	UN	8.00
		Cyclopoida	Cyclopidae		CF	SW	8.00
	Ichthyostraca	Arguloida	Argulidae	*Argulus*	PA	UN	UN
	Insecta	Coleoptera			PR	UN	5.94
			Chrysomelidae		SH	CN	8.00
			Dytiscidae	*Coptotomus*	PR	SW	9.00
				Hydroporus	PR	SW	8.90
				Hydrovatus	PR	UN	7.76
				Laccophilus	PR	UN	10.00
				Liodessus	PR	SW	7.76
				Neoporus	PR	SW	8.90
				Neoporus (adult)	PR	UN	7.76
				Uvarus	PR	SW	7.76
			Elmidae		CG	CN	3.58
				Ancyronyx	OM	CN	6.90
				Ancyronyx (adult)	CG	CN	3.58
				Dubiraphia	CG	UN	6.40
				Dubiraphia (adult)	CG	CN	4.58

		Macronychus	OM	CN	4.70
		Macronychus (adult)	CG	CN	5.58
		Microcylloepus	CG	UN	2.10
		Optioservus	SC	CN	2.70
		Stenelmis	SC	CN	5.40
		Stenelmis (adult)	CG	CN	6.58
	Gyrinidae		PR	SW	5.90
		Dineutus	PR	SW	5.50
		Dineutus (adult)	PR	SW	5.90
		Gyrinus	PR	SW	6.30
		Gyrinus (adult)	PR	SW	5.90
	Haliplidae		UN	SW	8.50
		Peltodytes	SH	UN	8.50
	Hydrophilidae	*Hydrobius*	PR	UN	8.00
		Hydrochara	UN	SW	8.22
	Scirtidae	*Cyphon*	SC	CB	7.00
		Scirtes	PR	SW	8.22
	Staphylinidae (adult)		UN	UN	8.00
Diptera			UN	UN	6.01
	Ceratopogonidae		PR	BU	6.50
	Chironomidae		CG	BU	5.79
	Chironomidae (Tanypodinae)		PR	BU	6.70
	Culicidae		CG	SW	9.55
	Phoridae	*Megaselia*	UN	UN	7.00
	Simulidae		CF	CN	5.07
		Cnephia	CF	CN	4.00
		Simulium	CF	CN	4.40
	Stratiomyidae		CG	SP	7.00
	Tabanidae		PR	SP	8.50
	Tipulidae		SH	BU	5.83
		Dicronata	PR	UN	0.00
		Molophilus	SH	BU	4.00

		Tipula	SH	BU	7.70
	Thaumaleidae		OM	UN	UN
Ephemeroptera			UN	UN	3.60
	Baetidae		CG	SW	4.00
		Baetis	CG	SW	5.39
		Heterocleon	SC	SW	3.60
		Labiobaetis	CG	SW	6.00
		Plauditus	CG	UN	4.00
		Procleon	OM	SW	4.00
		Pseudocentroptiloides	CG	CN	4.00
	Baetiscidae	*Baetisca*	OM	SP	1.87
	Caenidae	*Caenis*	CG	SP	7.60
		Sparabarus	CG	UN	3.00
	Ephemerellidae	*Danella*	CG	UN	1.95
		Ephemerella	CG	CN	1.66
		Eurylophella	SC	CN	2.98
	Ephemeridae	*Hexagenia*	CG	BU	4.70
	Heptageniidae		SC	CN	2.25
		Heptagenia	SC	CN	2.80
		Maccaffertium	OM	CN	3.35
		Stenonema	UN	CN	7.50
	Isonychiidae	*Isonychia*	CF	SW	3.80
	Leptohyphidae		CG	UN	3.70
		Tricorythodes	CG	SP	5.40
	Leptophlebiidae		CG	SW	6.40
		Paraleptophlebia	CG	SW	1.20
		Leptophlebia	CG	SW	6.40
	Metretopodidae	*Siphloplecton*	CG	SW	1.00
	Siphlonuridae	*Siphlonurus*	CG	SW	2.60
Hemiptera	Belostomatidae	*Abedus*	PR	SW	9.80
	Corixidae		PR	SW	9.00
		Hesperocorixia	PR	SW	9.00
		Palmacorixia	PR	SW	5.00
	Gerridae		PR	SK	6.67

		Metrobates	PR	SK	6.67
		Rheumatobates	PR	SK	6.67
		Trepobates	PR	CB	10.00
	Saldidae		PR	CB	10.00
Hymenoptera	Scelionidae		PA	UN	UN
Lepidoptera	Crambidae		SH	CB	3.42
Megaloptera	Corydalidae	*Corydalus*	PR	CN	5.60
Neuroptera	Sisyridae	*Climacia*	PR	CN	6.50
Odonata			PR	UN	7.06
(Anisoptera)	Aeshnidae		PR	CB	7.07
		Boyeria	PR	CB	6.30
		Basiaeschna	PR	CB	7.70
		Nasiaeschna	PR	CB	8.00
	Corduliidae	*Epitheca*	PR	CB	4.00
		Neurocordulia	PR	CB	5.80
	Gomphidae		PR	BU	5.47
		Dromogomphus	PR	BU	6.30
		Erpetogomphus	PR	UN	4.00
		Gomphus	PR	UN	6.20
	Libellulidae	*Dythemis*	PR	SP	9.00
		Libellula	PR	SP	9.80
		Orthemis	PR	SP	9.00
		Perithemis	PR	SP	10.00
	Macromiidae	*Didymops*	PR	SP	5.00
		Macromia	PR	SP	6.70
(Zygoptera)	Calopterygidae	*Calopteryx*	PR	CB	8.30
	Coenagrionidae		PR	CB	9.00
		Argia	PR	CB	6.00
		Chromagrion	PR	CB	6.00
		Enallagma	PR	CB	9.00
Plecoptera			PR	UN	1.87
	Chloroperlidae	*Alloperla*	PR	CN	1.40
	Perlidae		PR	CN	1.00
		Acroneuria	PR	CN	1.36

		Attaneuria	PR	CN	1.00
		Neoperla	PR	CN	1.60
		Perlesta	PR	CN	0.00
	Perlodidae		PR	CN	2.00
		Clioperla	UN	CN	4.80
		Isoperla	PR	CN	2.30
		Malirekus	UN	UN	1.40
	Taeniopterygidae		SH	SP	4.00
		Taeniopteryx	SH	SP	6.30
Trichoptera	Brachycentridae	*Brachycentrus*	CF	CN	2.20
	Hydropsychidae		CF	CN	4.00
		Cheumatopsyche	CF	CN	6.60
		Hydropsyche	CF	CN	3.99
	Hydroptilidae		UN	CB	5.90
		Hydroptila	SC	CN	6.20
		Neotrichia	SC	CN	4.00
		Ochrotrichia	CG	CN	7.20
		Orthotrichia	SC	CN	6.00
		Oxyethira	UN	CB	5.20
		Staciobella	SH	CN	2.00
	Lepidostomatidae	*Lepidostoma*	SH	CB	1.00
	Leptoceridae		CG	CB	3.47
		Ceraclea	CG	CN	2.90
		Nectopsyche	SH	CB	4.07
		Oecetis	PR	CB	5.70
		Triaenodes	SH	CB	3.73
	Limnephilidae	*Ironoquia*	SH	CN	7.30
	Philopotamidae	*Chimarra*	CF	CN	2.80
	Polycentropodidae		CF	CN	4.07
		Cernotina	PR	CN	4.07
		Cyrnellus	CF	CN	7.40
		Neureclipsis	CF	CN	4.40
		Polycentropus	PR	CN	3.50
	Psychomyiidae	*Lype*	SC	BU	4.30

			Uenoidae	*Neophylax*	SC	CN	1.60
	Malacostraca	Amphipoda			CG	UN	7.92
			Crangonyctidae	*Crangonyx*	CG	UN	8.00
			Gammaridae	*Gammarus*	OM	UN	6.90
			Hyalellidae	*Hyalella*	CG	UN	7.90
		Decapoda	Cambaridae		CG	UN	8.10
				Procambarus	UN	UN	9.50
			Palaemonidae	*Palaemonetes*	UN	UN	4.00
		Isopoda			CG	UN	8.55
			Asellidae	Asellus	CG	UN	6.00
				Lirceus	CG	UN	7.70
	Ostracoda				CG	UN	8.00
Mollusca	Bivalvia				CF	UN	6.93
		Sphaeriida	Sphaeridae		CG	UN	7.25
				Eupera	CF	UN	7.25
				Pisidium	CF	UN	6.80
				Sphaerium	CG	UN	7.70
		Unionida	Unionidae	*Elliptio*	CF	UN	3.65
				Villosa	CF	UN	3.65
		Venerida	Cyrenidae	*Corbicula*	CF	UN	6.30
	Gastropoda	Architaenioglossa	Ampullariidae		SC	UN	UN
			Viviparidae	*Campeloma*	SC	UN	6.70
				Viviparus	SC	UN	6.70
		[unranked]	Hydrobiidae		SC	UN	6.50
				Lyogyrus	SC	UN	6.50
		[unranked]	Lymnaeidae	*Pseudosuccinea*	SC	UN	7.20
	(Caenogastropoda)	[unranked]	Pleuroceridae		SC	UN	2.05
				Elimia	SC	UN	2.50
				Pleurocera	SC	UN	3.70
	(Heterobranchia)	[unranked]	Physidae	*Physa*	SC	UN	8.00
			Planorbidae		SC	UN	7.45
			(Ancylinae)		SC	UN	7.10
			(Bulininae)	*Menetus*	UN	UN	8.40
			(Planorbinae)	*Gyralus*	SC	UN	6.25

				Planorbula	SC	UN	7.45
				Promenetus	CG	UN	7.45
Nematoda	Chromadorea				PA	UN	5.00
Platyhelminthes					UN	UN	7.50

APPENDIX C

Georgia Environmental Protection Division (GA EPD) Index 65l – Atlantic Southern Loam Plains

Metrics, metric category, description, and stress responses for the subecoregion 65l according to GA EPD standards (2007).

(Barbour et al. 1999, Gerritsen & Leppo 2000)

Metric	Metric Category	Description	Stress Response
EPT Taxa	Richness	# of Ephemeroptera, Plecoptera, and Trichoptera taxa (not total individuals that are EPT) Lower taxonomic level provides more accuracy	↓
Diptera Taxa	Richness	# of Diptera taxa (not total individuals that are Diptera) Lower taxonomic level provides more accuracy	↓
% EPT	Composition	% EPT = 100 × [n/T] n = Number of individuals in the EPT taxa T = Total individuals in the sample	↓
% Trichoptera	Composition	% EPT = 100 × [n/T] n = Number of individuals in Trichoptera taxa T = Total individuals in the sample	↓
HBI	Tolerance	Hilsenhoff Biotic Index HBI = $\sum \frac{n*t}{N}$ N = Total indiviudals in the sample n = Number of organisms in each taxonomic group t = pollution tolerance score for that taxonomic group	↑
Predator Taxa	Functional Feeding Group	# of Predator taxa Total taxa (not individuals) that fall within the Predator FFG	↓
Clinger Taxa	Habit	# of Clinger taxa Total taxa (not individuals) with the Clinger habit	↓

APPENDIX D

Georgia Environmental Protection Division (GA EPD) Index 75f – Sea Island Flatwoods

Metrics, metric category, description, and stress responses for the subecoregion 75f according to GA EPD standards (2007).

(Barbour et al. 1999)

Metric	Metric Category	Description	Stress Response
% Oligochaeta	Composition	% Oligochaeta = 100 × [n/T] n = Number of individual Oligochaeta T = Total individuals in the sample	↑
% Tanypodinae/Total Chironomidae	Composition	% (Tany/TC) = 100 × [T/C] T = Total individuals in the Tanypodinae family C = Total Chironomidae individuals in the sample	↑
Tolerant Taxa	Tolerance/Intolerance	# of Tolerant taxa (not individuals that are Tolerant) Tolerant individuals have a tolerance value of ≥ 7	↑
% Filterer	Functional Feeding Group	% Filterer = 100 × [n/T] N = Number of individuals with the Filterer habit T = Total individuals in the sample	↑

APPENDIX E

Fish Taxonomic List

Fish collected during the 2014–2017 and 2023 summer and autumn seasonal period using boat electrofishing on the mainstem Ogeechee River. The species feeding guilds, tolerance ranking (if intolerant), and species categories (if applicable) were gathered using the fish list from Georgia Department of Natural Resources (2020). The list is sorted by phylogenetic order.

Scientific Name	**Common Name**	**Family**	**Feeding Guild**	**Tolerance Ranking**	**Species Category**
Lepisosteus osseus	Longnose Gar	Lepisosteidae	CR		
Lepisosteus platyrhincus	Florida Gar	Lepisosteidae	CR		
Amia calva	Bowfin	Amiidae	CR		
Anguilla rostrata	American Eel	Anguillidae	CR		
Alosa sapidissima	American Shad	Alosidae	IN		
Dorosoma cepedianum	Gizzard Shad	Dorosomatidae	OM		
Erimyzon sucetta	Lake Chubsucker	Catostomidae	IN	INT	RBS
Minytrema melanops	Spotted Sucker	Catostomidae	IN		RBS
Moxostoma collapsum	Notchlip Redhorse	Catostomidae	IN		RBS
Moxostoma sp.	Brassy Jumprock	Catostomidae	IN		RBS
Alburnops chalybaeus	Ironcolor Shiner	Leuciscidae	IC	INT	
Alburnops petersoni	Coastal Shiner	Leuciscidae	IC	INT	
Cyprinella leedsi	Bannerfin Shiner	Leuciscidae	IC		SMM
Hudsonius hudsonius	Spottail Shiner	Leuciscidae	IC		SMM
Hybopsis rubifrons	Rosyface Chub	Leuciscidae	IC	HWI	SMM
Notemigonus crysoleucas	Golden Shiner	Leuciscidae	GE		
Notropis maculatus	Taillight Shiner	Leuciscidae	IC	INT	SMM
Opsopoeodus emiliae	Pugnose Minnow	Leuciscidae	IC	INT	
Pteronotropis cummingsae	Dusky Shiner	Leuciscidae	IC		
Ameirus brunneus	Snail Bullhead	Ictaluridae	GE		
Ameirus catus	White Catfish	Ictaluridae	GE		
Ameirus natalis	Yellow Bullhead	Ictaluridae	GE		
Ameirus nebulosus	Brown Bullhead	Ictaluridae	GE		

Ictalurus punctatus	Channel Catfish	Ictaluridae	GE		
Notorus gyrinus	Tadpole Madtom	Ictaluridae	IN	HWI	BI
Notorus leptacanthus	Speckled Madtom	Ictaluridae	IN		BI
Esox niger	Chain Pickerel	Esocidae	CR		
Aphredoderus sayanus	Pirate Perch	Aphredoderidae	IN		
Trinectes maculatus	Hogchoker	Achiridae			
Labidesthes vanhyningi	Green Silverside	Atherinopsidae	IN		
Gambusia holbrooki	Eastern Mosquitofish	Poeciliidae	OM		
Mugil cephalus	Striped Mullet	Mugilidae	DT		
Lepomis auritus	Redbreast Sunfish	Centrarchidae	IN		SF
Lepomis gulosus	Warmouth	Centrarchidae	CR		SF
Lepomis macrochirus	Bluegill	Centrarchidae	IN		SF
Lepomis microlophus	Redear Sunfish	Centrarchidae	IN		SF
Lepomis punctatus	Spotted Sunfish	Centrarchidae	IN		SF
Micropterus salmoides	Largemouth Bass	Centrarchidae	CR		CENT
Pomoxis nigromaculatus	Black Crappie	Centrarchidae	CR		CENT
Etheostoma inscriptum	Turquoise Darter	Percidae	IN	INT	BI
Etheostoma olmstedi	Tessellated Darter	Percidae	IN	INT	BI
Percina nigrofasciata	Blackbanded Darter	Percidae	IN		BI

APPENDIX F

Index of Biotic Integrity (IBI)

The IBI for the Atlantic Slope drainage basin in the Southeastern Plains ecoregion of Georgia was used (GA DNR 2020); however, this study was done in the mainstream channel of the Ogeechee River. The IBI is a measure of response to anthropogenic impacts.

Metric	**Scoring Criteria**		
Species Richness Metrics	5/3 Breaks		3/1 Breaks
1. Number of native species	y = 6.53x + 8.12 (2.24, 22.8)		y = 4.16x + 5.18 (2.24, 14.5)
2. Number of benthic invertivore species	y = 1.34x + 1.30 (1.52, 3.3)		y = 0.67x + 0.65 (1.52, 1.7)
3. Number of native centrarchid species	y = 2.01x + 3.21 (2.52, 8.3)		y = 1.34x + 2.15 (2.52, 5.5)
4. Number of native insectivorous cyprinid species	y = 1.99x + 0.50 (2.10, 4.7)		y = 0.99x + 0.25 (2.10, 2.3)
5. Number of native round-bodied sucker species	y = 0.92x + 0.65 (2.20, 2.7)		y = 0.46x + 0.32 (2.20, 1.3)
6. Number of Intolerant species	y = 2.18x – 0.59 (1.80, 3.3)		y = 1.09x – 0.29 (1.80, 1.7)
Species Composition Metrics	5	3	1
7. Evenness	≥ 80.1	80.1 ≥ 68.6	< 68.6
8. % of individuals as a *Lepomis* species	≤ 30.3	30.3 ≤ 51.3	> 51.3
9. % of individuals as insectivorous cyprinids	≥ 39.9	39.9 ≥ 19.9	< 19.9
10. % of individuals as top carnivores	≥ 3.8 - ≤ 9.4	≥ 1.9 - < 3.8 > 9.4 - ≤ 11.3	< 1.9 > 11.3
11. % of individuals as benthic fluvial specialist	≥ 21.6	21.6 ≥ 10.8	< 10.8
12. Number of individuals per 200 meters	≥ 457.8	457.8 ≥ 234.5	< 234.5

APPENDIX G

National Oceanic and Atmospheric Administration (NOAA) Precipitation Estimates by County in Georgia

(National Centers for Environmental Information 2024)

NOAA precipitation estimates for each of the counties where the sites border. This supplemental data is meant to estimate rainfall that may fall within the Ogeechee River watershed. Effingham and Screven counties are also shared within the Savannah River watershed.

Year	County	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2014	Bryan	7.01	6.43	8.15	17.45	7.24	9.45	11.48	11.48	18.36	5.03	12.52	10.52	125.12
	Bulloch	6.53	10.46	9.88	15.06	7.65	9.42	14.43	10.97	19.71	4.62	13.94	11.68	134.35
	Effingham	6.73	8.20	8.23	13.84	7.82	9.50	14.83	10.90	17.78	4.42	13.21	10.97	126.43
	Screven	6.63	9.93	9.09	12.55	10.41	9.04	13.77	8.56	15.09	3.66	13.72	10.74	123.19
2015	Bryan	9.25	10.72	6.43	16.81	2.31	12.09	11.20	16.31	7.59	3.96	8.89	6.60	112.16
	Bulloch	8.33	12.45	7.98	16.28	2.11	7.47	6.48	13.21	4.47	5.56	12.29	8.51	105.14
	Effingham	9.60	11.73	6.68	15.65	2.64	10.74	10.03	17.35	6.10	7.54	12.29	8.33	118.68
	Screven	8.66	12.19	9.17	14.50	2.08	7.42	8.20	13.79	6.38	10.31	15.80	10.46	118.96
2016	Bryan	8.10	11.38	9.73	6.43	16.87	16.59	4.45	11.28	15.57	21.21	0.41	15.09	137.11
	Bulloch	8.92	15.49	7.77	5.89	18.16	13.13	5.49	4.47	12.98	13.69	0.66	16.99	123.64
	Effingham	8.76	12.32	9.70	5.16	21.64	14.88	5.36	6.99	15.75	22.56	0.36	14.76	138.24

	Screven	8.31	13.46	6.83	6.22	18.80	11.07	6.81	7.04	13.74	12.09	0.56	16.03	120.96
2017	Bryan	17.83	6.63	1.80	6.96	19.15	13.74	18.34	14.58	14.38	5.44	2.49	6.58	127.92
	Bulloch	14.81	4.24	1.78	6.58	16.74	14.61	14.30	12.83	15.98	5.66	2.11	8.41	118.05
	Effingham	16.26	5.00	1.70	6.99	20.73	13.92	17.15	14.20	16.13	4.65	2.79	7.26	126.78
	Screven	15.82	3.35	2.08	6.07	13.56	13.44	16.00	11.56	14.91	5.74	2.62	9.55	114.7
2023	Bryan	12.19	8.94	9.58	11.73	11.66	17.53	11.84	19.86	7.01	4.47	3.33	12.90	131.04
	Bulloch	13.74	8.86	8.33	13.18	11.91	19.48	15.27	26.72	6.55	5.28	4.11	12.83	146.26
	Effingham	12.65	8.79	7.52	10.39	12.07	19.08	14.81	22.73	5.89	4.62	3.81	12.70	135.06
	Screven	14.78	8.84	7.34	10.39	10.46	16.05	15.04	26.26	6.60	5.94	5.08	11.84	138.62

APPENDIX H

Description of Numeric Ranking for Subecoregions 65l and 75f (Middleton 2006, GA EPD 2007)

65l Atlantic Southern Loam Plains (Vidalia Uplands)				
Index Score	**Numeric Ranking**	**Percentile n = 19**	**Narrative Description**	**Stream Rating**
92 and Above	1	Above 95^{th}	Very Good	A
49–91	2	Below 95^{th}, Above 75^{th}	Good	A
23–48	3	Below 75^{th}, Above 25^{th}	Fair	B
18–22	4	Below 25^{th}, Above 5^{th}	Poor	C
17 and Below	5	Below 5^{th}	Very Poor	C
75l Sea Island Flatwoods				
Index Score	**Numeric Ranking**	**Percentile n = 19**	**Narrative Description**	**Stream Rating**
98 and Above	1	Above 95^{th}	Very Good	A
86–97	2	Below 95^{th}, Above 75^{th}	Good	A
60–85	3	Below 75^{th}, Above 25^{th}	Fair	B
41–59	4	Below 25^{th}, Above 5^{th}	Poor	C
40 and Below	5	Below 5^{th}	Very Poor	C

APPENDIX I

Rapid Bioassessment Protocol (RBP) Metrics for Rocky Ford, Highway 301/Oliver, and I–16/Morgan's Bridge

Constituent metric values and final RBP scores for all study sites.

Atlantic Southern Loam Plains Metrics									
Site	**Season/Year**	**EPT Taxa**	**Diptera Taxa**	**% EPT**	**% Trichoptera**	**HBI**	**Predator Taxa**	**Clinger Taxa**	**Final Score**
Rocky Ford	WI14	11.00	3.00	18.04	9.79	6.06	4.00	5.00	66
	SU14	6.00	3.00	8.48	2.42	6.02	4.00	4.00	56
	AU14	9.00	4.00	12.50	4.58	6.70	7.00	8.00	71
	WI15	13.00	3.00	26.63	3.55	5.91	8.00	9.00	76
	SP15	8.00	3.00	16.24	4.06	6.24	5.00	6.00	65
	SU15	8.00	2.00	7.69	4.14	6.87	5.00	6.00	63
	AU15	7.00	3.00	10.00	3.33	6.57	10.00	5.00	68
	WI16	11.00	3.00	43.33	5.00	6.14	3.00	8.00	68
	SP16	7.00	2.00	18.33	0.00	6.36	4.00	5.00	49
	SU16	11.00	2.00	23.74	11.11	6.53	8.00	9.00	74
	AU16	12.00	3.00	15.83	3.75	5.60	10.00	9.00	81
	SP17	12.00	3.00	13.22	2.64	6.84	5.00	9.00	64
	WI23	12.00	3.00	51.34	4.28	5.14	5.00	6.00	73
	SP23	10.00	3.00	8.08	0.51	6.10	9.00	7.00	62
	SU23	10.00	4.00	24.26	12.38	5.60	9.00	8.00	80

	AU23	11.00	7.00	28.41	1.70	5.39	7.00	11.00	75
Hwy 301	WI23	12.00	2.00	30.52	0.47	5.68	6.00	4.00	56
	SP23	15.00	3.00	12.82	5.13	6.21	7.00	7.00	72
	SU23	9.00	3.00	25.85	7.80	6.22	8.00	8.00	75
	AU23	16.00	5.00	29.80	6.57	5.30	6.00	11.00	81

Sea Island Flatwoods Metrics

Site	Season/Year	% Oligochaeta	% Tanypodinae/Total Chironomidae	Tolerant Taxa	% Filterer	Total Score
Oliver	WI14	0.52	23.71	5.00	1.04	89
	SU14	0.42	10.00	7.00	5.83	85
	AU14	6.25	80.43	14.00	0.00	52
	WI15	0.42	0.00	5.00	23.75	74
	SP15	0.00	69.23	6.00	16.81	56
	SU15	1.92	25.00	14.00	1.92	69
	AU15	0.88	54.84	14.00	2.21	60
	WI16	0.00	22.22	4.00	10.20	82
	SP16	0.42	13.04	6.00	1.67	90
	SU16	5.83	70.59	14.00	0.83	53
	AU16	0.00	52.83	13.00	0.99	64
	SP17	—	—	—	—	—
Morgan’s Bridge	WI14	0.00	45.45	7.00	0.83	78
	SU14	—	—	—	—	—

AU14	22.08	11.54	9.00	7.08	66
WI15	0.00	27.27	10.00	1.82	78
SP15	0.49	75.00	10.00	0.98	62
SU15	0.61	17.65	5.00	1.22	91
AU15	0.53	7.32	5.00	5.85	90
WI16	0.00	17.86	8.00	7.86	79
SP16	0.00	34.78	9.00	7.98	71
SU16	2.69	24.24	8.00	4.84	78
AU16	1.37	54.76	14.00	0.00	62
SP17	0.00	24.14	10.00	0.42	80

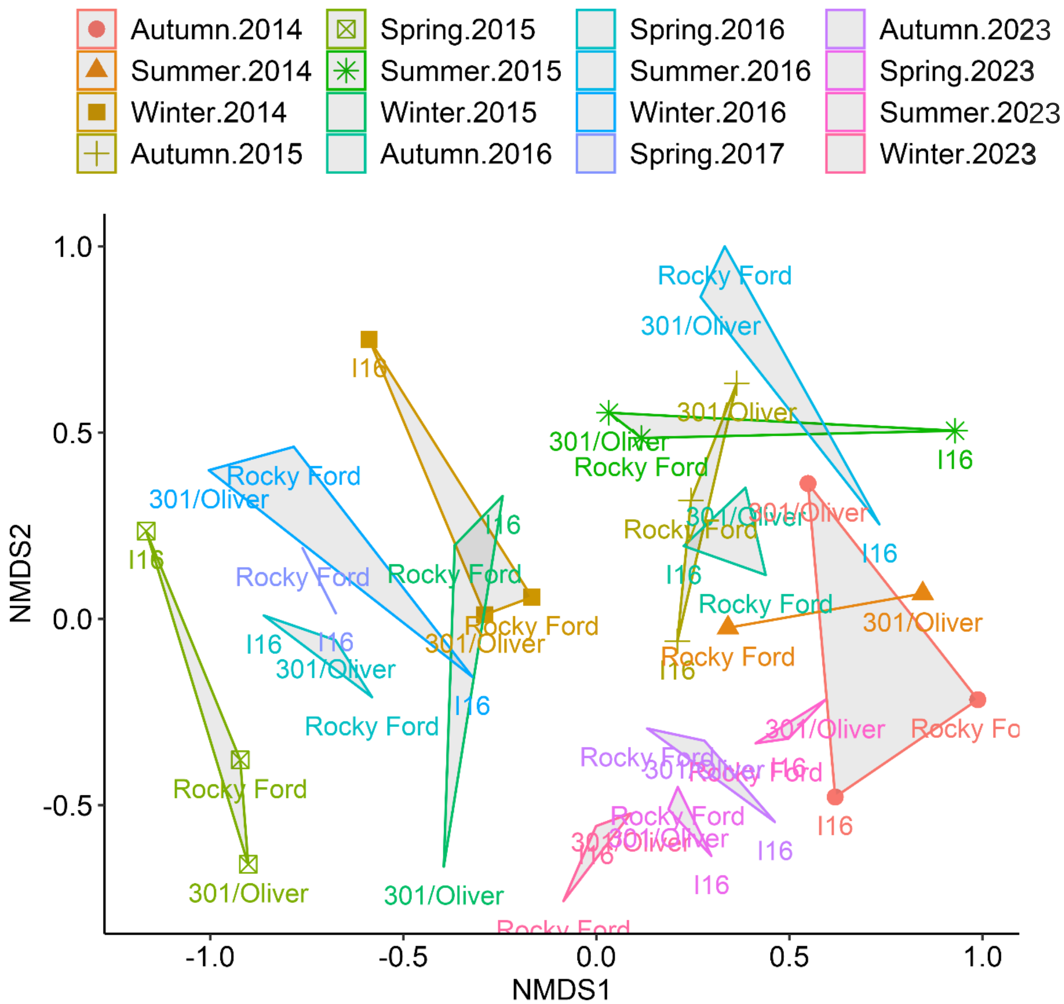
APPENDIX J

Hilsenhoff's Biotix Index Evaluation of Water Quality (Hilsenhoff 1987)

Biotic Index	**Water Quality**	**Degree of Organic Pollution**
0.0–3.50	Excellent	No apparent organic pollution
3.51–4.50	Very Good	Possible slight organic pollution
4.51–5.50	Good	Some organic pollution
5.51–6.50	Fair	Fairly significant organic pollution
6.51–7.50	Fairly Poor	Significant organic pollution
7.51–8.50	Poor	Very significant organic pollution
8.51–10.00	Very Poor	Severe organic pollution

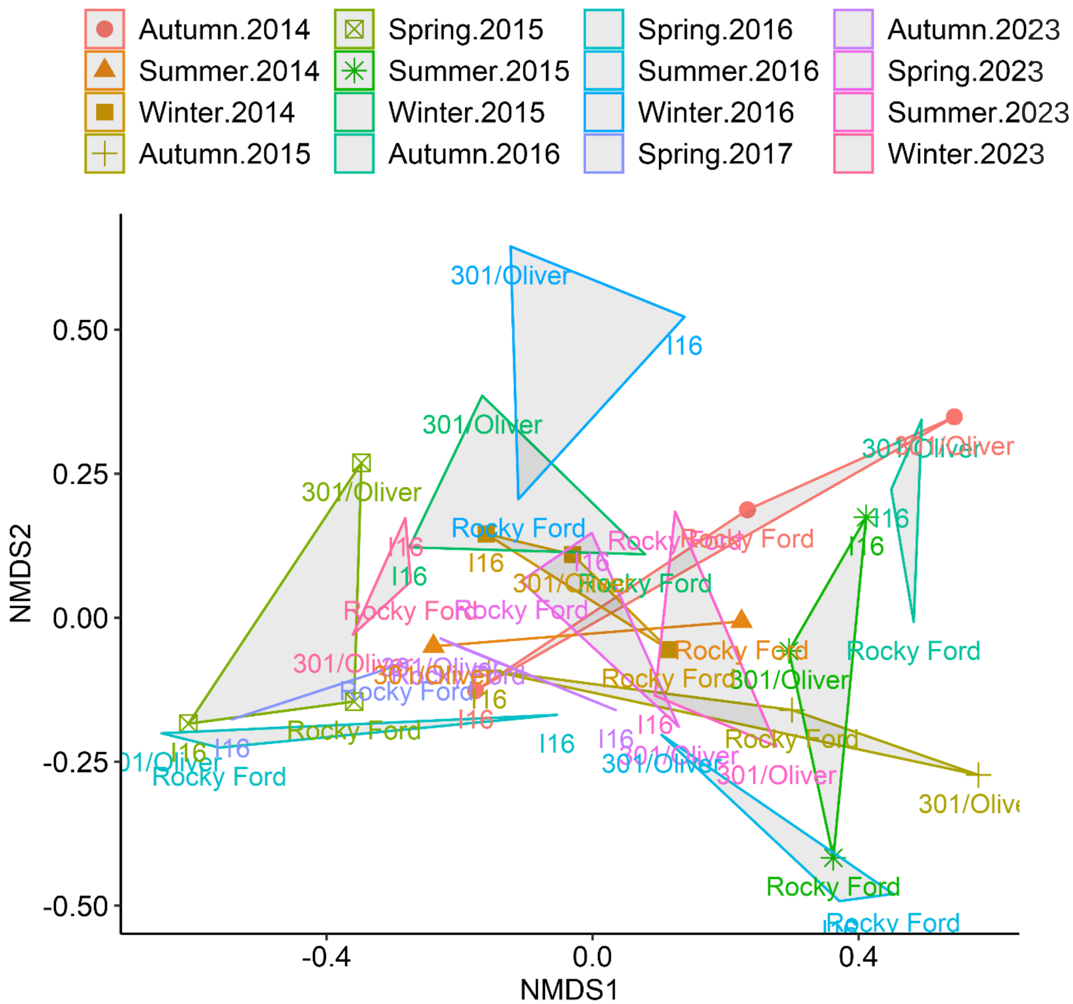
APPENDIX K

Macroinvertebrate non-metric multidimensional scaling comparing communities by year and season based on relative abundance. 2-dimensional stress = 0.215. Each site is represented by a point on the graph. Season and year simultaneously are separated by color.



APPENDIX L

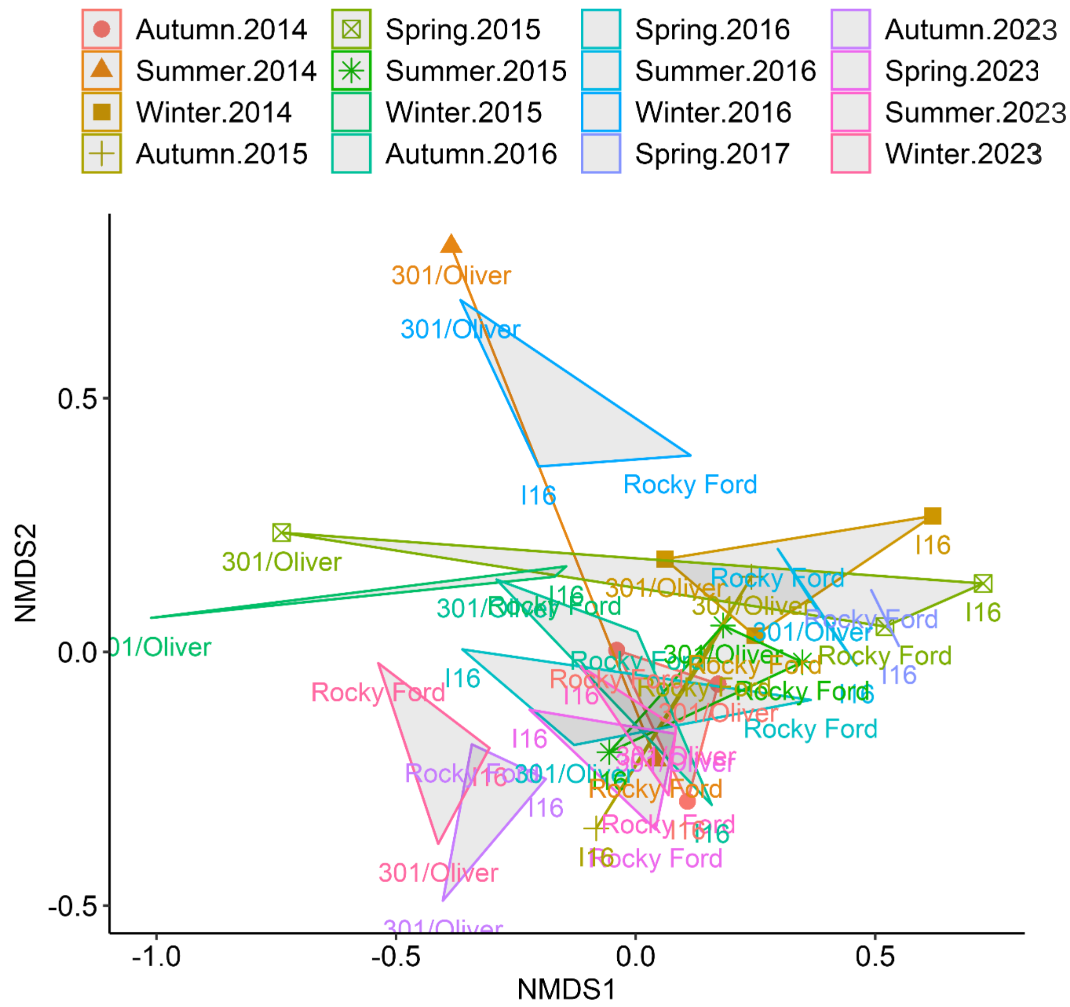
Macroinvertebrate non-metric multidimensional scaling comparing communities by year and season based on functional feeding group abundance. 2-dimensional stress = 0.136. Each site is represented by a point on the graph. Season and year simultaneously are separated by color.



APPENDIX M

Macroinvertebrate non-metric multidimensional scaling comparing communities by year and season based on habit abundance.

2-dimensional stress = 0.149. Each site is represented by a point on the graph. Season and year simultaneously are separated by color.



APPENDIX N

Index of Biotic Integrity (IBI) metrics for Rocky Ford, Oliver, and I–16/Morgan's Bridge

Constituent IBI metrics and final scores for all study sites.

Species is denoted by sp., benthic invertivore is BI, Centrarchid is Cent., Insectivore is IC, Round-bodied Sucker is RBS, Top Carnivore is CR, Individual is Ind, and Morgan's Bridge is MB.

Site	**Season**	**# of Native sp.**	**# of BI Sp.**	**# of Native Cent. Sp.**	**# of Native IC Sp.**	**# of Native RBS Sp.**	**# of Intolerant Sp.**	**Evenness**	**% Lepomis**	**% IC**	**% CR**	**% Benthic Fluvial**	**# of Ind. Per 200m**	**Total score**
Rocky Ford	SU14	10.00	2.00	4.00	0.00	0.00	2.00	68.10	72.90	0.00	4.67	12.15	43.00	21
	AU14	16.00	1.00	4.00	5.00	1.00	4.00	64.40	54.14	11.05	16.02	16.57	72.00	24
	SU15	18.00	1.00	3.00	6.00	1.00	4.00	85.70	21.10	36.70	23.85	32.11	44.00	36
	AU15	16.00	1.00	4.00	4.00	2.00	2.00	81.90	30.00	36.67	11.67	41.67	24.00	34
	SU16	24.00	3.00	5.00	5.00	2.00	5.00	68.20	24.19	52.21	6.78	31.18	136.00	44
	AU16	13.00	0.00	2.00	4.00	1.00	2.00	74.20	9.20	35.63	14.94	59.77	35.00	28
	SU23	13.00	0.00	0.00	3.00	1.00	2.00	88.90	0.00	37.93	31.03	31.03	29.00	30
	AU23	18.00	0.00	5.00	4.00	2.00	3.00	68.30	41.67	9.03	15.97	31.94	144.00	30
Oliver	SU14	14.00	2.00	3.00	5.00	1.00	6.00	82.50	48.00	20.00	4.00	26.00	20.00	38
	AU14	13.00	0.00	6.00	2.00	2.00	2.00	69.10	32.39	8.45	11.27	50.70	28.00	28
	SU15	21.00	2.00	5.00	6.00	1.00	5.00	69.30	31.96	50.65	2.43	37.20	214.00	40
	AU15	16.00	1.00	5.00	4.00	2.00	2.00	84.70	20.83	26.39	26.39	40.28	29.00	34
	SU16	16.00	0.00	3.00	5.00	1.00	4.00	73.70	15.26	62.01	9.09	54.87	123.00	40
	AU16	15.00	1.00	4.00	5.00	1.00	4.00	70.00	9.41	61.18	9.41	24.71	34.00	38
	SU23	18.00	0.00	4.00	4.00	2.00	3.00	82.80	18.84	24.64	20.29	42.03	69.00	34
	AU23	16.00	0.00	3.00	5.00	2.00	3.00	72.40	24.53	45.28	8.18	42.77	159.00	40
I–16/ MB	SU14	7.00	0.00	2.00	1.00	0.00	0.00	86.10	4.00	4.00	20.00	4.00	10.00	20
	AU14	15.00	1.00	5.00	3.00	1.00	1.00	62.60	64.93	8.21	17.91	10.45	54.00	16

SU15	22.00	1.00	6.00	4.00	1.00	3.00	72.30	52.71	18.99	19.38	12.40	103.00	26
AU15	12.00	1.00	4.00	3.00	1.00	2.00	79.80	50.00	12.50	20.00	22.50	16.00	24
SU16	17.00	1.00	5.00	3.00	1.00	2.00	84.10	34.78	17.39	27.54	20.29	28.00	26
AU16	7.00	0.00	3.00	1.00	1.00	0.00	75.70	5.88	44.12	20.59	70.59	14.00	26
SU23	17.00	0.00	2.00	3.00	1.00	2.00	81.80	3.08	36.92	26.15	46.15	65.00	32
AU23	16.00	1.00	2.00	5.00	1.00	3.00	79.60	33.33	14.04	24.56	19.30	57.00	26