NEKTON COMMUNITY CHARACTERIZATION OF THE LOWER BRAZOS RIVER WITH AN EMPHASIS ON ATLANTIC CROAKER, *MICROPOGONIAS UNDULATUS*, TROPHIC DYNAMICS

by

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MASTERS PROJECT

Presented to the Faculty of

The University of Houston-Clear Lake

In Partial Fulfillment

Of the Requirements

For the Degree

MASTER OF SCIENCE

in Environmental Science

THE UNIVERSITY OF HOUSTON-CLEAR LAKE

MAY, 2019

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Dedication

This manuscript is dedicated to my wonderful wife Shantelle, who provided endless support and encouragement during this process. Also, parents and younger sisters who provided me with perspective, guidance, and a healthy appreciation for nature while growing up.

Acknowledgements

I would like to acknowledge the tremendous amount of effort from the staff at the Environmental Institute of Houston during field collection, data compilation, and data analyses. Thank You.

ABSTRACT

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University of Houston-Clear Lake, 2019

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From December 2016 – October 2017, 50 collections of 150 replicate otter and beam trawls were collected at five different sites, three different seasons, and three different flow tiers along the Brazos river estuary. A total of 96 Atlantic Croaker, *Micropogonias undulatus*, and 40 particulate organic matter (POM) samples were collected and analyzed for $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$. Catch per unit effort (CPUE) and taxa richness, as well as, Atlantic Croaker CPUE were all significantly greater at collection sites nearest the Gulf of Mexico. Collection sites nearest the Gulf of Mexico also displayed significantly enriched $\delta^{13}C$, $\delta^{34}S$, and POM $\delta^{34}S$ levels in Atlantic Croaker tissue (Tables 32 – 33 and 44). The observed patterns in stable isotopes were likely caused by the stratification of the salt wedge caused by variations in freshwater inflow transporting upstream sources of carbon and enriched sources of $\delta^{13}C$, $\delta^{34}S$ derived from tidal transport of marine water and associated sources of carbon and sulfur into the estuary. These findings demonstrate

the strong linkage of freshwater inflow, downstream transport of carbon and nitrogen and estuarine productivity.

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CHAPTER I:

INTRODUCTION

Trophic Ecology of Immature Estuarine Fish

Many marine fish species spawned offshore have a strong connection with nearshore estuarine habitat. The larvae of a variety of species immigrate into estuarine nursery areas where they utilize abundant resources to grow and mature (Hettler and Chester 1990, Patterson and Whitfield 1997). Numerous factors influence immigration, survival, and growth of larvae including freshwater inflow, moon phase and tides, weather, currents, and biological interactions (Hettler and Chester 1990). The availability of suitable zooplankton prey has been identified as a critical factor influencing larval fish survival (Gaughan and Potter 1997, Pepin and Dower 2007). Gaughan and Potter (1997) also observed significant dietary niche overlap between numerous co-occurring larval species in Wilson Inlet, Australia. The occurrence of competition for prey is not a singular coincidence. Atlantic Croaker, *Micropogonias undulatus*, and Spot, *Leiostomus xanthurus*, are common species in the northern Gulf of Mexico that were found to select the copepod prey of highest abundance (Govoni et al. 1986). However, shifts in the timing of development, utilization of various microhabitats, and associated preferences for different size and types of prey by similar sibling species, such as Spot and Atlantic croaker, have been observed and is believed to represent an evolutionary response to competition (Deegan and Thompson 1985). In such cases, characterizing the diet of larval fish is a requisite tool to determine the potential level of competition for prey. This approach can also be used to compare small differences in diet of co-occurring species.

Traditional Gut Content Analysis

Research by Cunjak (1992) compared prey of Atlantic salmon parr, *Salmo salar*, utilizing gut content analysis and determined parr utilizing the riverine portion of the estuary consumed different prey items than parr, of similar size, utilizing more marine portions of the estuary. Atlantic Croaker will also consume different volumes of zooplankton prey based on location and life history (Soto et al. 1998). For example, newly spawned Spot and Atlantic croaker are known to feed primarily on copepod (*Copepoda*) prey, normally selecting for prey based on availability and size (Govoni et al. 1986). This similarity in prey selection also exists between larval Atlantic Croaker and Red Drum, *Sciaenops ocellata*. Soto et al. (1998) found these two species feed on similar copepod prey, however larger Red Drum larvae fed less frequently on copepods and more on mysid shrimps.

In instances where prey items are sufficiently developed and large enough to identify with microscopy, visual gut analysis is the ideal method to characterize the diet of fish, at any life stage. However, in some cases, prey items may be extensively digested or consist of an amalgamation of organic matter. For instance, striped mullet, *Mugil cephalus* are extremely indiscriminate feeders and are known to consume large amounts of indistinguishable benthos and organic matter (Hadwen et al. 2007). In such situations, gut content analysis may fail to characterize the diet since most digested prey lack sufficient characteristics for accurate identification. In addition to the difficulties of prey identification, fish larvae may have empty stomachs due to lack of recent feeding or regurgitation which makes it impossible to identify the diet of a specimen. Research by Soto et al. (1998) determined Atlantic croaker between 8.00 and 9.99 millimeters had a 75% incidence of empty stomachs upon collection. A more robust dietary analysis method needs to be employed. Another major downfall of stomach content analysis is that it can only offer a glimpse of the animal’s recent diet which does not provide information on longer temporal trends in feeding and cannot provide any information on the rate of ingestion and assimilation of food (Créach et al. 1997). In conclusion, although valuable, conventional gut analysis may provide little information on the diet of larval fishes due to the factors listed.

Use of Stable Isotopes in Trophic Studies

A potential solution to problems associated with gut content analysis is provided through the use of stable isotopes, which can be used to estimate assimilation of dietary resources over time and space (Jepsen and Winemiller 2002). Using stable isotope ratios of carbon, nitrogen, and sulfur in the muscle tissues is a very powerful method for distinguishing variation in diet at a coarse scale, the trophic position of organism in an estuary, and potential residency time of the fish in marine versus freshwater (Peterson et al. 1985, Post 2002; Fry and Chumchal 2011). The usefulness of isotopic analysis increases with the use of multiple versus single isotopes. A mass spectrometer is used to accurately measure isotopic composition of the multiple elements, including carbon, sulfur, and nitrogen isotopes which are commonly used in studies of coastal trophic community ecology (Peterson and Fry 1987; Fry 2006).

To standardize the isotopic composition values obtained from mass spectrometry the sample ratios of isotopes are compared to the same ratio in known standards. The most common isotopes used include $^{13}C/^{12}C$, to analyze the primary initial source of primary production within the food web and $^{15}N/^{14}N$, which is used to estimate the primary consumer trophic level and, in some cases, potential human influence on the food web (Bouillon et al. 2002). Sulfur isotopes are more numerous including ^{32}S, ^{33}S, ^{34}S, and ^{36}S (Fry 2006). However, sulfur isotope ratio $^{34}S/^{32}S$, is primarily used to examine the amount of residency or exposure to estuarine waters by migrating fish (Fry and Chumchal 2011).

The standard notation used to describe isotope levels in material is delta (δ). The delta (δ) value is defined as:

$\delta X = [(R_{sample}/R_{standard}) – 1] \times 10^3$

where X = the heavy isotope (^{13}C, ^{15}N, ^{34}S), R = the ratio of the heavy isotope to the light isotope ($^{13}C/^{12}C$, $^{15}N/^{14}N$ or $^{34}S/^{32}S$), in the sample R_{sample} and a standard $R_{standard}$. The delta δX is reported in units of parts per thousand or per mil (‰). In the simplest of terms δX can be described as a “ratio of ratios”, which is linearly proportional to the percent heavy isotope.

Isotopic carbon ratios in the sample are compared to the same ratio contained in the standard PeeDee limestone. Similarly, the ratios of nitrogen isotopes in a sample are compared to the ratios found in atmospheric nitrogen. Finally, the ratios of $^{34}S/^{32}S$ contained are compared to the standard obtained from the Canyon Diablo meteor (Peterson and Fry 1987).

Using these ratios, increases or decreases in isotope concentrations between individual samples, over time and location can be compared. An increase in delta values indicates a greater number of heavy isotopes comprising the sample compared to the standard, whereas a decrease in delta signifies a decrease in the heavy isotopes contained in the sample (Peterson and Fry 1987). The variation in isotopic signatures originates from the chemical properties of the various isotopes. Lighter isotopes react faster during chemical reactions, compared to heavier isotopes of the same element (Peterson and Fry 1987).

Autotroph and heterotroph prey items yield unique isotope values and the variation in these values is used to determine dominant prey constituents (Fry 1984, Boon et al. 1997, Bouillon et al. 2002, Melville and Connolly 2003). For instance, saltmarsh cordgrass, *Spartina alternifora*, will record $\delta^{13}C$ values of -13‰ and upland plants $\delta^{13}C$ values of -28‰ (Peterson and Fry 1987). Naturally occurring atmospheric $\delta^{15}N$ levels are normally near 0‰ (Peterson and Fry 1987). Other sources of nitrogen originating from runoff, discharges, precipitation, or internal cycling of nitrogen can have $\delta^{15}N$ values ranging from -18 to + 8 (Peterson and Fry 1987). Phytoplankton incorporate portions of this nitrogen source and dissolved fractions originating from runoff and biochemical cycling of nitrogen including waste products and decaying organic matter. The resulting δ values of ^{15}N in phytoplankton tissue typically range between +4 to +6 ‰ depending on nitrogen sources and taxonomic group (Wada 1980, Peterson and Fry 1987). Enriched (more positive), depleted (more negative), or equivalent values of $\delta^{15}N$ is used to differentiate changes in nutrient assimilation or diet by primary producers and consumers over time, providing information on trophic interactions that may be difficult or impossible by other means. One of these interactions is the determination of the trophic position of an organism. A consumer will usually have enriched $\delta^{15}N$ values of 3 – 4 ‰ for each successive trophic level (Pepin and Dower 2007, Vander Zanden and Rasmussen 2001).

Sulfur isotopes can also be effective in determining primary contributions to estuarine plant matter or estuarine fish. Sulfates from marine water are enriched in $\delta^{34}S$ and the plankton which consume them reflect this ($\delta^{34}S$ of +21‰) (Peterson and Fry 1987). Upland plants will yield $\delta^{34}S$ values of +5‰ and saltmarsh cordgrass $\delta^{34}S$ values of +3‰ (Peterson et al 1985). These deviations allow for clearer determination of organic sources as constituents in predator diets. A fish consuming larger quantities of estuarine zooplankton will be enriched in $\delta^{34}S$. While a fish that consumed larger quantities of estuarine detrital matter will be more depleted in $\delta^{34}S$.

Trophic Studies in Marine Environments using Stable Isotopes

The use of multiple stable isotope analysis increases the ability to detect variations in diet and the ability to evaluate causes of this variation in comparison to gut analysis. The isotopic composition of an organism strongly resembles the carbon and sulfur composition of prey and primary food chains utilized by the target species. In contrast nitrogen isotopic composition provides information on the trophic level of the target organism. For example, nitrogen δ values are usually enriched about 3 – 5 $^{o}/_{oo}$ for each increase in trophic level (DeNiro and Epstein 1980, Minagawa and Wada 1984, Peterson and Fry 1987, Post 2002). Nitrogen wastes excreted from a consumer are typically depleted in $\delta^{15}N$ compared to the nitrogen sources consumed (DeNiro and Epstein 1980). Those consumers which can consumer larger quantities will also excrete depleted $\delta^{15}N$ in greater quantities and cause an overall enrichment of $\delta^{15}N$ in body tissue. Post (2002) found that surface grazing snails exhibit isotope values associated with the littoral food web which the snails are known to graze. In contrast, sessile, filter feeding, zebra mussel exhibits isotopic signature of the free floating seston community (Post 2002). These examples illustrate the use of isotope analysis to determine variation in diet, as well as, trophic interactions between organisms.

Earlier gut analysis studies have determined that larval fishes generally prey on zooplankton. (Govoni et al.1986, Gaughan and Potter 1997, Nixon and Jones 1997, Soto et al. 1998). More recent studies using isotope analysis of larval and juvenile fish tissue have discovered that some species of fish target herbivorous and carnivorous zooplankton at different rates (Pepin and Dower 2007). Stable isotope analysis has provided researchers with the ability to identify primary prey items that are quickly digested or broken down and impossible to identify using conventional visual gut analysis. D'Ambra et al. (2015) found that age zero juvenile Atlantic bumper, *Chloroscombrus chrysurus,* preyed on the same larger medusa the young larvae had used earlier as shelter. Stable isotope analysis was able to identify the quickly assimilated medusa tissue based on the unique isotopic signature displayed by this prey item (D'Ambra et al. 2015). The use of stable isotope analysis also facilitates the detection of diet variation based on space, or habitat preference. The ability to detect these fluctuations in fish diet is the motivation behind implementing the analysis in the current study.

Another important application of isotope analysis is the capability to determine trophic level variation over wide ranges of habitats (Melville and Connolly 2003, Post 2002). Nitrogen isotope ratios in consumers are a primary method of determining trophic level. Minagawa and Wada (1984) reported nitrogen enrichment of +10 – 15 $^{o}/_{oo}$ for predators 3 to 4 successive trophic levels higher. The enriched nitrogen isotope values represent a placement of the consumer at a higher level in the trophic structure of the ecosystem. Paterson and Whitfield (1997), found that ichthyofauna that fed in deeper water had more depleted ^{13}C values than fish feeding on littoral prey sources. Although this variation in ^{13}C concentration may be less useful in the determination of trophic variation, this data when combined with other isotope ratios provides useful data in describing variation in diet associated with spatial patterns in distribution. Two fish species, *Acanthopagrus asutalis* and *Sillago ciliata* were studied in a variety of locations in an Australian estuary. Analyses of their stable isotope ratios in conjunction with individual habitat use observations were used to describe how these two species utilized specific mangrove, seagrass, and particulate organic matter as primary sources of carbon (Melville and Connolly 2003). Stable isotope analysis provides a powerful tool for describing changes in diet and trophic linkages of nekton over a wide range of spatial scales and varying environmental condition including freshwater inflow into estuaries.

Objectives

The Brazos River is located in south central Texas and discharges into the Gulf of Mexico near Freeport (Figure 1). The Brazos River is the largest (118,000 km^2) watershed in Texas (Phillips 2006). As well as transporting a considerable volume of fresh water, the Brazos River also deposits more sediment into the Gulf of Mexico than any other fresh water source in Texas (Rodriguez et al. 2000). Anderson et al. (1983) characterized a freshwater portion of the Brazos River located 1,120 river kilometers (rkm) upstream from the mouth as having low turbidity and sheltering a variety of fish species.

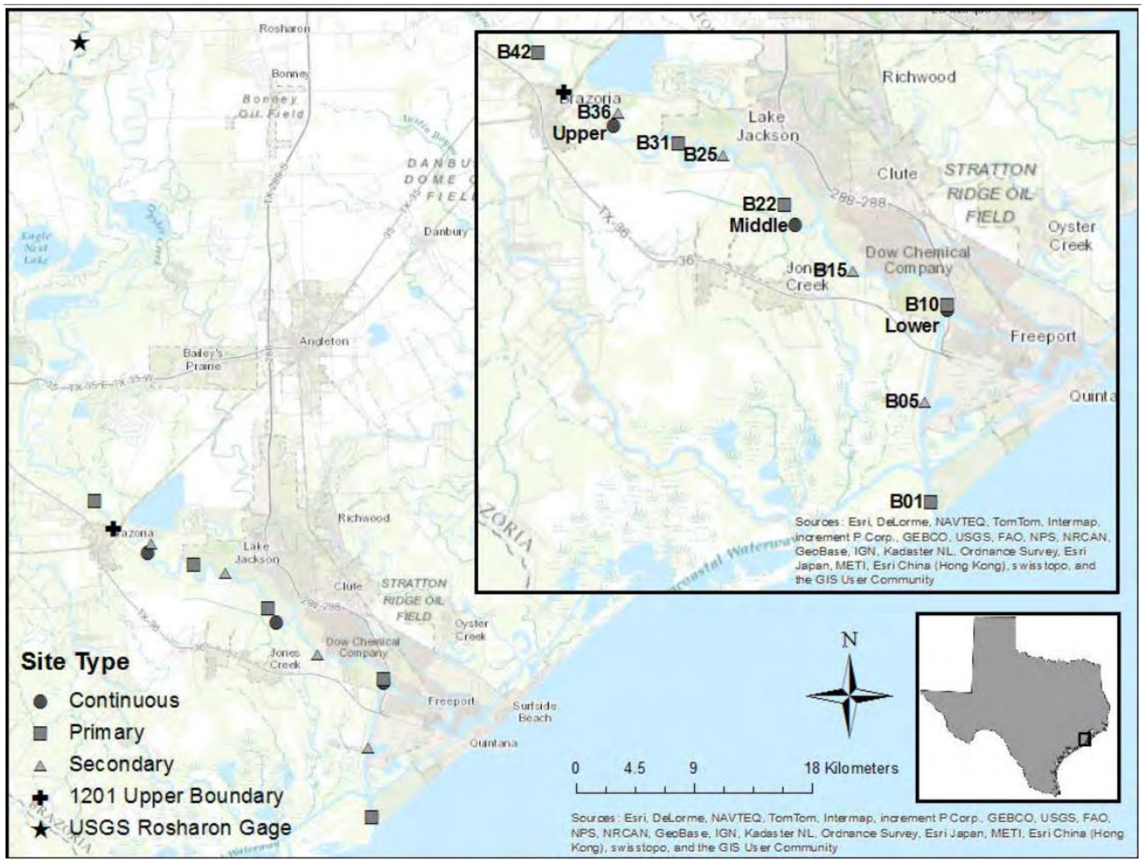

Figure 1. Location of Brazos River mouth and all trawl and water quality sampling sites. Only data from "Primary" sites was used in this manuscript. Continuous: sites which measured data continuously with use of dissolved oxygen and conductivity HOBO data loggers, as well as, TROLL data loggers measuring ambient barometric pressure and subsurface pressure. Primary: sites sampled in-situ during each collection date with Otter and Beam Trawl, YSI data Sonde, and surface water collection. Secondary: sites sampled in situ during each collection date with YSI data Sonde. 1201 Upper Boundary*:* upriver 40.2 km from the mouth of the Brazos River, TCEQ delineates this portion of the river 1201. USGS Rosharon Gage: USGS continuous monitoring gage used for collecting river discharge data between in situ collection days.

The fish and nekton community inhabiting the lower 36.2 river kilometers (rkm) of the Brazos River, otherwise known as the estuarine or tidal zone, was the focus of the current study. This area is legally described as Segment 1201, Brazos River Tidal (TCEQ 2012). Some species of nekton taxa found within the estuarine zone may also occur further upstream. Nekton are defined as those fish and invertebrates with the ability to swim independently against water currents. Anderson et al. (1983) sampled the Brazos

River fish community approximately 1,120 rkm upstream of the river mouth and reported catches of Inland Silversides, *Menidia Beryllina,* a fish found in both estuarine and fresh water environments. A previous study conducted by Texas Park and Wildlife Department (TPWD) on the Brazos River sampled six sites, from the mouth to a point 40.2 rkm upstream (Johnson 1977). The study collected estuarine fish and invertebrates, representing a variety of life stages, at all sampled sites in the lower Brazos River (Johnson 1977). The Environmental Institute of Houston (EIH), collected larval estuarine fish during in a 9-month study in 2014 (Miller 2014) at the same locations previously surveyed by Johnson (1977).

The Atlantic Croaker, *Micropogonias undulatus* is a common estuarine fish species of commercial and recreational importance. Atlantic Croaker is an abundant marine species ranging from the coast of New York, south to Florida, and the northern Gulf of Mexico (Ross 1988, ASMFC 1993, Nixon and Jones 1997). Adults spawn offshore, and the subsequent larvae recruit into Gulf coast estuaries, including the tidal portion of the Brazos River, where maturation and growth occur (Johnson 1978, Soto et al. 1998, Miller 2014). There is a roughly 20-day lag between adult spawning and larval recruitment to estuaries (Nixon and Jones 1997). Larvae feed on zooplankton, primarily copepods, to grow between 0.2 – 0.4 millimeters per day (Nixon and Jones 1997). The previously documented occurrence of Atlantic Croaker larvae, in relatively large numbers, within the lower 40.2 kilometers of the Brazos River make this species an ideal candidate for examining the relationship of stable isotope variation in tissue, with changes in flow regime, position in the river, seasonality, and stage of development (Miller 2014). This provides an opportunity to examine ontogenic changes in the diet and trophic position of this species as it grows and migrates within the estuary.

Although estuarine fishes have been collected in the Brazos River, no studies have characterized the diet of any estuarine species with the purpose of determining the relative contribution of marine and terrestrial/fresh water carbon sources to their diet. This is important since human population growth will likely lead to increased future demand for freshwater, increased diversions and resulting reductions in freshwater inflow estuaries (TWDB 2017). This would alter the relative and absolute amounts of sediment, carbon, and nutrients discharged into estuaries with potential changes in overall productivity and isotopic composition (Alber 2002).

The primary objective of this study was to characterize the stable isotope values of carbon, nitrogen, and sulfur in Atlantic croaker. A secondary objective is to characterize the stable isotope values using the same elements for potential prey items of Atlantic croaker including, small nekton, zooplankton and suspended particulate organic matter (POM) in the water column. The third objective was to describe the overall catch per unit effort and diversity of the nekton sampled at each site, as well as, analyze selected environmental variables associated with or influence by freshwater inflow and their potential influence on nekton community composition. The final objective was to estimate likely trophic pathways utilized by Atlantic croaker within the Brazos River while evaluating other factors such as distance upstream, size, discharge, and season. Where feasible these data were compared to other historical data sets that include this species.

CHAPTER II:

METHODS

Field Collection

Monthly collections of Atlantic croaker larvae and juveniles, small nekton small nekton, zooplankton, and suspended organic matter was collected at five sampling sites in the Brazos River from December 2016 to October 2017. A collection was defined as the three replicate samples taken with a gear type, from a site, and on each sampling date. Sites ranged from 1.0 km to 42 km up river and are labeled B01, B10, B22, B31, or B42 (Figure 1). All five sampling sites were previously sampled during past studies quantifying nekton diversity in the Brazos River (Johnson 1977, Miller 2014). During those studies young-of-year Atlantic Croaker were collected using a 6.4 mm nylon mesh Renfro beam trawl and/or a 3.1 m wide otter trawl equipped with 38.2 mm nylon stretch mesh (Renfro 1963). Both trawls were pulled upstream at each of the five sites. Three otter trawl replicates were collected at each site. Each 5-minute replicate tow was towed at 2.5 knots in the river thalweg. Three beam trawl replicates samples were collected at each site. Each replicate tow was done at the shoreline in approximately one-meter water depth. Replicate beam trawls were pulled by hand parallel to the shoreline for 15.2-meters. Organisms captured with the beam and otter trawl were identified and enumerated in the field and/or preserved in 10% formalin and site water, or stored in site water and placed on ice.

At each site nekton, zooplankton and surface water samples were also collected. One-liter surface water samples, were collected at each site to obtain samples of suspended detrital material. One small nekton and zooplankton sample was collected at each site using a 1.5-meter-long conical plankton net with a 0.5-meter diameter mouth. The net was constructed of 100 um Nitex mesh and was towed horizontally for a cumulative 10 minutes near the surface at each site concurrently while towing the otter trawl upstream along the thalweg. Small nekton and zooplankton samples were transferred to storage containers, filled with in-situ water, and put on ice. Processing took place within 24 hours of collection in the University of Houston-Clear Lake (UHCL) lab.

Each water samples were collected with a 1L Nalgene pre-rinsed collection bottle and stored on ice. Water collections were processed within 24 hours at the EIH lab by filtration through 47mm glass fiber filters (GFF) to collect suspended particles from the samples. At each site, water quality parameters such as salinity, dissolved oxygen, and temperature were also measured at the surface and bottom using a model YSI multisensor electronic sonde.

Sample Processing

Each sample was rinsed with deionized water to remove any foreign matter that accumulated during transport from the field. Small nekton and zooplankton samples were filtered through a 75-micron sieve, rinsed with de-ionized water, sorted from the larval fish, and filtered onto a GFF before being dried at 60^{o}C for 8 hours. All larval fish were identified to the lowest taxonomic level. Atlantic Croaker larvae and juveniles were also measured (standard length) and the digestive tract and fins were removed before being stored in 2 mL cryo vials at -80^{o}C prior to being freeze dried. Samples were freeze dried for 48 hours using a Labconco Freezone Freeze Dry System at 0.04mBar and -30 – (-40)^{o}C Specimens of other species of finfish were measured (standard length; mm) and transferred to formalin for 24-48 hours of fixation, followed by ethanol for long term storage.

Stable Isotope Analysis

The GFF with small nekton and zooplankton were dried at 60ºC until reaching a constant mass in approximately 8 hours. Once small nekton and zooplankton on GFF samples were dried each individual GFF and each small nekton/zooplankton sample were stored in 1 mL Nalgene cryovials and shipped to the Texas A&M University Stable Isotopes and Geosciences facility for processing. Following freeze drying, 1 – 4 specimens of Atlantic Croaker, depending on mass, were stored in 1 mL Nalgene cryovials and subsequently shipped to Texas A&M University Stable Isotopes and Geoscience facility for further isotope processing. Unfortunately, at the time of this manuscript processing of the small nekton and zooplankton samples has not been completed. The data from the small nekton and zooplankton analyses will not be included in the remainder of this manuscript.

Processing at Texas A&M Stable Isotopes and Geosciences included grinding of the GFF, small nekton, zooplankton, and fish samples, as well as, weighing the ground samples and loading samples into tin tablets for isotope analysis. The analysis of carbon, nitrogen and sulfur isotopes was conducted using a Delta V Advantage Flash Elemental Analyzer (EA) Isotope Ratio Mass Spectrometer (IRMS), and Delta V Advantage IRMS with GC – Isolink. Ratios were expressed as $^{13}C/^{12}C$, $^{15}N/^{14}N$ and $^{34}S/^{32}S$ as per mil ($^{o}/_{oo}$) concentrations accumulated in tissues of Atlantic Croaker and contained in suspended sediment of water samples. Isotope values from Atlantic Croaker were used to evaluate potential trophic position and sources of carbon and nitrogen in the diet. Isotope measurements of POM were necessary to determine contributions of upstream inputs, such as fertilizer run off, or upland plants/insects. The isotope concentrations were compared to standards, Pee Dee Belemite (carbon), concentration of atmospheric nitrogen, and Diablo Canyon meteorite for sulfur. Using the equation below the delta δ values for carbon-13, nitrogen-15, and sulfur- 34 isotopes can be computed.

$$\delta^{13}C, \delta^{15}N, \text{ or } \delta^{34}S = [(Rsample/Rstandard) - 1] \times 10^3$$

The value for the isotopic ratio of $^{13}C/^{12}C$, $^{15}N/^{14}N$, or $^{34}S/^{32}S$ is represented by R_{sample}. The isotopic ratio of the same isotopes within the recognized standards are denoted by, $R_{standard}$, and $\delta^{13}C$,$\delta\ ^{15}N$, or in units per mil (‰) represents the relative enrichment of the sample with heavier isotopes relative to the respective standard (Jomori et. al. 2008).

Data Analysis

All data was classified by geographic location, season and flow tier. The first group, site, was identified a priori within the study area. The following two groups were identified posteriori and included season and flow tier. The three seasonal delineations used included Winter, Spring, and Summer. Winter was composed of collections during the months December 2016 - January 2017 and included three collections. Spring included March, May, and June 2017 and a total of four collections during this period. Summer included July, September, and October 2017, with three collections. Sampling days were ranked and classified according to daily average flow into three flow tiers. The flow tiers were categorized as Low, Moderate, and High. Low flow included four collections with flow ≤ 3278 cfs. Moderate flows ranged from 3279 – 6122 cfs and included three collections. High flows ranged from 6123 – 9571 cfs and included three collections. In order to properly analyze the influence of seasonal and hydrological factors on nekton community data sampled with otter and shoreline beam trawl samples, total community catch per unit effort, individual taxa catch per unit effort, and taxa richness, were calculated for each gear type by site, season, and flow tier (Table 1-1 and

1-2). Non-transformed CPUE values of each species of nekton were used to calculate Shannon Diversity (H'), and Pielou's Evenness (J) (Appendices 1A and 1B). Going forward within this manuscript the term "Diversity" is henceforth synonymous with Shannon Diversity, and "Evenness" with Pielou's Evenness. Due to the high frequency of zero catches and non-normal distribution, none of the raw CPUE data met normality or equal variance assumptions. For this reason, all CPUE data was transformed using $Log_e(1+X)$ prior to statistical analysis (Clarke et al 2014). One-way analysis of variance (ANOVA) was used to analyze the transformed CPUE data. All diversity and evenness analyses were conducted using one-way ANOVA. Raw taxa richness values were used for analysis. One-way ANOVA was conducted when normality and variance assumptions were met. If taxa richness did not meet the previous assumptions a Kruskal Wallis non-parametric one-way analysis of variance (ANOVA) was used to test for statistically significant differences in median taxa richness between sites, seasons, and flow tiers. If statistically significant differences were found between levels a Dunn's multiple comparison test was then used to conduct pairwise tests (Orlich 2010, Daniel 1990, Dunn 1964). Significant differences were detected when the p-value or corresponding test statistic was ≤ 0.05.

Atlantic Croaker CPUE were also analyzed against site, season, and flow tier. The CPUE values did not meet normality or variance assumptions and were tested with Kruskal Wallis nonparametric one-way ANOVA. Dunn's multiple comparison test was done to conduct pairwise analysis upon significant ANOVA results.

Community similarity and ordination analyses were conducted using the Primer 7 statistics program (Clark and Gorley 2015; Clarke et al. 2014). Analyses were conducted separately for data collected with the otter trawl and beam trawl. CPUE data was transformed with $Log_e(1+X)$, as the data contained numerous zero catch samples. A biological resemblance matrix was constructed consisting of Bray-Curtis Similarity values using the total taxa CPUE from multiple replicate samples during each collection (unique site, date and gear combination). Using the Bray-Curtis similarity function a hierarchical cluster analysis (Cluster) was performed using the group average linkage method to create a dendrogram and the Similarity Profile (SIMPROF) was used to identify significant collection groupings based on these resemblance matrices. The strength of the identified groups was then measured using a cophenetic correlation statistic ranging between 0 and 1. The closer the value to 1 the stronger the likelihood the calculated cluster groupings were not generated by random chance.

Nonmetric multidimensional scaling (nMDS) was used to identify potential gradients in community composition based on collections over a fixed two-dimensional space (Clark and Gorley 2015; Clarke et al. 2014). The nMDS procedure used the biological resemblance matrix to rank similarity values, then plotted the ranks such that the distance between plotted points represented the corresponding similarity between samples in Euclidean distance. A stress test was used to measure the effectiveness of correctly depicting the multivariate distance between collections. The closer the stress statistic value was to 0 the greater the likelihood the ranks plotted were not due to random chance. Similarity Percentages (SIMPER) – species contributions analysis was used to determine the percent similarity of species compositions between sites, seasons, and flow tiers. This analysis documented which species were the primary contributors (≥70%) to the average similarity seen between sites, season, and flows, as well as, which species were the contributors to the dissimilarity when comparing levels of each class variable (i.e. B01 vs B10, low flow vs high flow, or winter vs spring). The Analysis of Similarities (ANOSIM) procedure was also used to test for differences in taxa composition between sites, seasons, and flow tiers. ANOSIM calculated the value ρ

(rho), which ranges between -1 and 1. The closer rho is to 1 the more likely the compared groupings were distinctly different from one another.

Principal Components Analysis (PCA) was to evaluate water quality patterns based on the measured variables. All environmental data was normalized using Primer 7 and then PCA was used to calculate eigenvalues and PCA component scores were generated. Each PCA axis represented linear combinations of the original variables. Data form each collection were plotted on the two PCA axes that explained the greatest amount of the variation in the data. These axes represent potential environmental gradients. The environmental data was also used in two other Primer 7 analyses. The first called RELATE was used to determine how well the environmental variable resemblance matrix "related" to the biological resemblance matrix (i.e. was there a high likelihood the variability seen in the environmental matrix was similar to that in the biological matrix). To do this the procedure calculated the same ρ (rho) statistic as ANOSIM analyses. Environmental data was also used in the BEST analysis. This analysis used the same sample statistic, ρ (rho), as a measure of how well the individual, or group of environmental variables predicted the patterns in the biological data. This differed from the RELATE procedure as BEST provided an individual variable (i.e. salinity) or a combination of variables and a calculated ρ (rho) as to the strength which this variable(s) described the variation in the biological data matrix.

When normality and equal variance assumptions were met, a one-way ANOVA was used to test for differences in $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ from Atlantic Croaker between sites, seasons, flow tiers, and length intervals. Kruskal Wallis non-parametric one-way ANOVA was used when normality and variance conditions were not met. This same methodology was also used in the analysis of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ measurements obtained from POM.

Finally, simple correlation and regression analysis was conducted to determine if there is any association between the occurrence of Atlantic croaker and the measured environmental variables.

CHAPTER III:

RESULTS

Water Quality Monitoring

Flow measurements varied with date and season ranging from 168.09 cfs in the late summer and 9571.57 cfs in the early spring of 2017 (Figure 2). Flow was also seasonally impacted, with the winter and spring months boasting significantly higher flow than the summer months (Table 1) (Figure 3). Salinity showed significant variation over time, space, and sampling depths (Figure 4). Sampling sites B42 and B31 held the lowest salinities with values from 0.23 – 0.44 psu with little variation throughout the profile. Salinities were recorded the highest at site B01 with surface readings ranging from 4.7 – 8.13 psu, and bottom readings from 20.88 - 32.01 psu (Figure 4). Dissolved oxygen showed less variability over time and more variation with depth, with values near 0 mg/L at the bottom of site B22 (Figure 5). Maximum dissolved oxygen was seen near the surface, all sites measuring a value greater than 8 mg/L (Figure 5). Water temperature was highly variable with time and location, and less so, with depth. Coldest temperatures were measured in the winter months, 13.09 ^{o}C at the surface; while the warmest temperatures were measured in late July, and 33.6 ^{o}C at the surface (Figure 6). Site B22 recorded both the highest and lowest pH readings, of all sites, during the study period, 7.11 – 8.13, however the remaining four sites followed similar profile, and seasonal patterns as B22 (Figure 7). Turbidity varied widely over time, space, and depth with all sites showing similar trends with highest Turbidity near the bottom of the profile and the lowest turbidity near the surface (Figure 8).

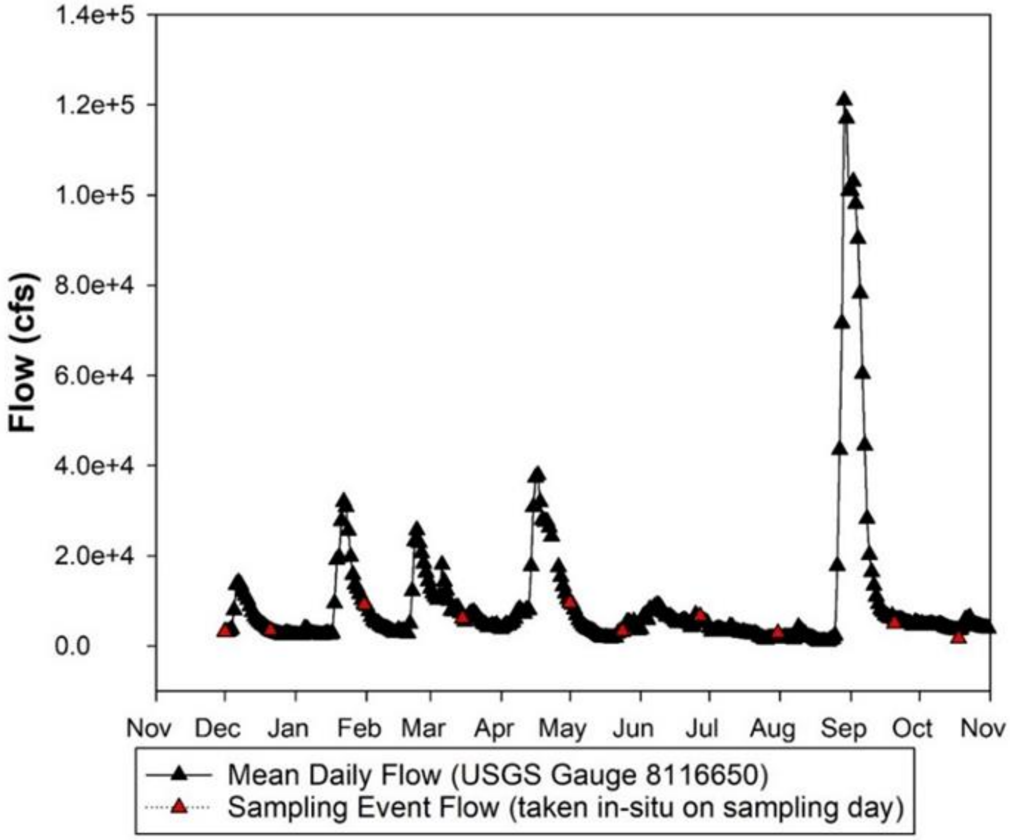

Figure 2. Mean daily and instantaneous in-situ river discharge recorded over the study duration, December 2016 – October 2017 (Sources: USGS gauge 8116650 and instream in situ measurements at B42).

Table 1. *Summary table of results from all statistical tests. Nekton = Large nekton collected with Otter Trawl, KW = Kruskal-Wallis One-Way Analysis of Variance, ANOVA = Analysis of Variance, CPUE = Catch per unit Effort, Rich. = Richness, Diversity = Shannon Diversity, ZPK = Small nekton and Zooplankton collected in Beam Trawl, AC = Atlantic Croaker, Length = 20mm bins.*

Variable (Table 1)	**Levels**	**Test**	**p-value**	**R^2**	**Significance**
Discharge	Season	KW	0.000	NA	Highly
Nekton CPUE	Site	ANOVA	0.001	0	Highly
Nekton Taxa Rich.	Site	ANOVA	0.000	0.59	Highly
Nekton Diversity	Site	ANOVA	0.002	0.25	Highly

Variable (Table 1)	Levels	Test	p-value	R^2	Significance
ZPK CPUE	Season	ANOVA	0.002	0.2	Highly
ZPK Taxa Rich.	Site	KW	0.032	NA	Yes
ZPK Taxa Rich.	Season	KW	0.009	NA	Highly
ZPK Diversity	Site	ANOVA	0.038	0.13	Yes
AC CPUE	Site	KW	0.000	NA	Highly
AC Length	Site	KW	0.000	NA	Highly
AC Length	Season	KW	0.000	NA	Highly
AC Length	Flow Tier	KW	0.000	NA	Highly
AC $\delta^{13}C$	Site	KW	0.000	NA	Highly
AC $\delta^{34}S$	Site	KW	0.001	NA	Highly
AC $\delta^{15}N$	Season	KW	0.004	NA	Highly
AC $\delta^{13}C$	Flow Tier	KW	0.017	NA	Highly
AC $\delta^{34}S$	Flow Tier	KW	0.001	NA	Highly
AC $\delta^{15}N$	Flow Tier	KW	0.034	NA	Yes
AC $\delta^{15}N$	Length	KW	0.000	NA	Highly
POM $\delta^{34}S$	Site	ANOVA	0.001	0.35	Highly
POM $\delta^{13}C$	Season	KW	0.000	NA	Highly
POM $\delta^{15}N$	Season	KW	0.004	NA	Highly
POM $\delta^{34}S$	Season	KW	0.025	NA	Highly
POM $\delta^{13}C$	Flow Tier	ANOVA	0.000	0.31	Highly
POM $\delta^{15}N$	Flow Tier	KW	0.003	NA	Highly
POM $\delta^{34}S$	Flow Tier	ANOVA	0.042	0.11	Yes
Nekton CPUE	Season	ANOVA	0.693	0	No

Variable (Table 1)	**Levels**	**Test**	**p-value**	**R^2**	**Significance**
Nekton CPUE	Flow Tier	ANOVA	0.036	0.16	No
Nekton Taxa Rich.	Season	ANOVA	0.767	0	No
Nekton Taxa Rich.	Flow Tier	ANOVA	0.128	0.05	No
Nekton Diversity	Season	ANOVA	0.806	0	No
Nekton Diversity	Flow Tier	ANOVA	0.204	0.026	No
Nekton Evenness	Site	ANOVA	0.160	0.056	No
Nekton Evenness	Season	ANOVA	0.719	0	No
Nekton Evenness	Flow Tier	ANOVA	0.313	0.008	No
ZPK CPUE	Site	ANOVA	0.434	0	No
ZPK CPUE	Flow Tier	ANOVA	0.096	0.056	No
ZPK Taxa Rich.	Flow Tier	KW	0.114	NA	No
ZPK Diversity	Season	ANOVA	0.057	0.078	No
ZPK Evenness	Season	ANOVA	0.092	0.058	No
ZPK Diversity	Flow Tier	ANOVA	0.518	0	No
ZPK Evenness	Flow Tier	ANOVA	0.915	0	No
ZPK Evenness	Site	ANOVA	0.236	0.035	No
AC $\delta^{13}C$	Season	KW	0.488	NA	No
AC $\delta^{34}S$	Season	KW	0.959	NA	No
AC $\delta^{13}C$	Length	KW	0.249	NA	No
AC $\delta^{34}S$	Length	KW	0.735	NA	No
POM $\delta^{13}C$	Site	KW	0.686	NA	No
POM $\delta^{15}N$	Site	KW	0.873	NA	No

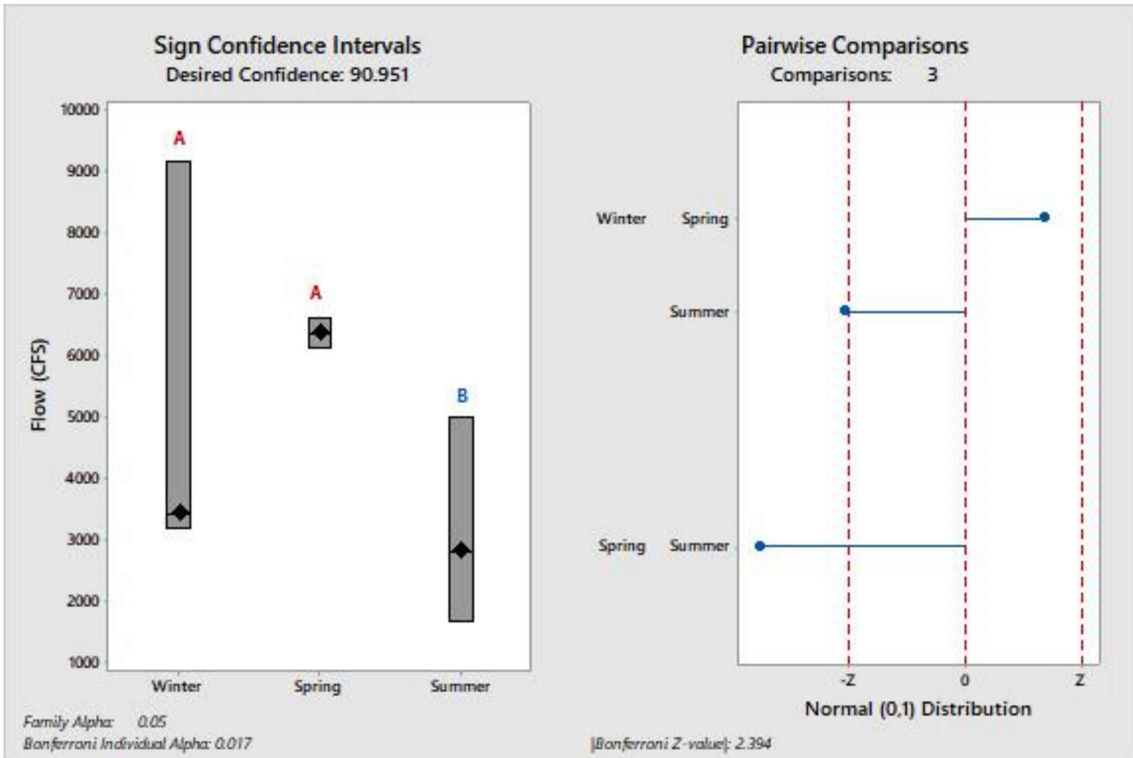

Figure 3. Dunn's multiple Comparison test for significant differences in discharge between seasons. Different letters and colors above bars denote significant groups. The diamond indicates the median flow value and the gray rectangle signifies the 90% confidence interval for the median.

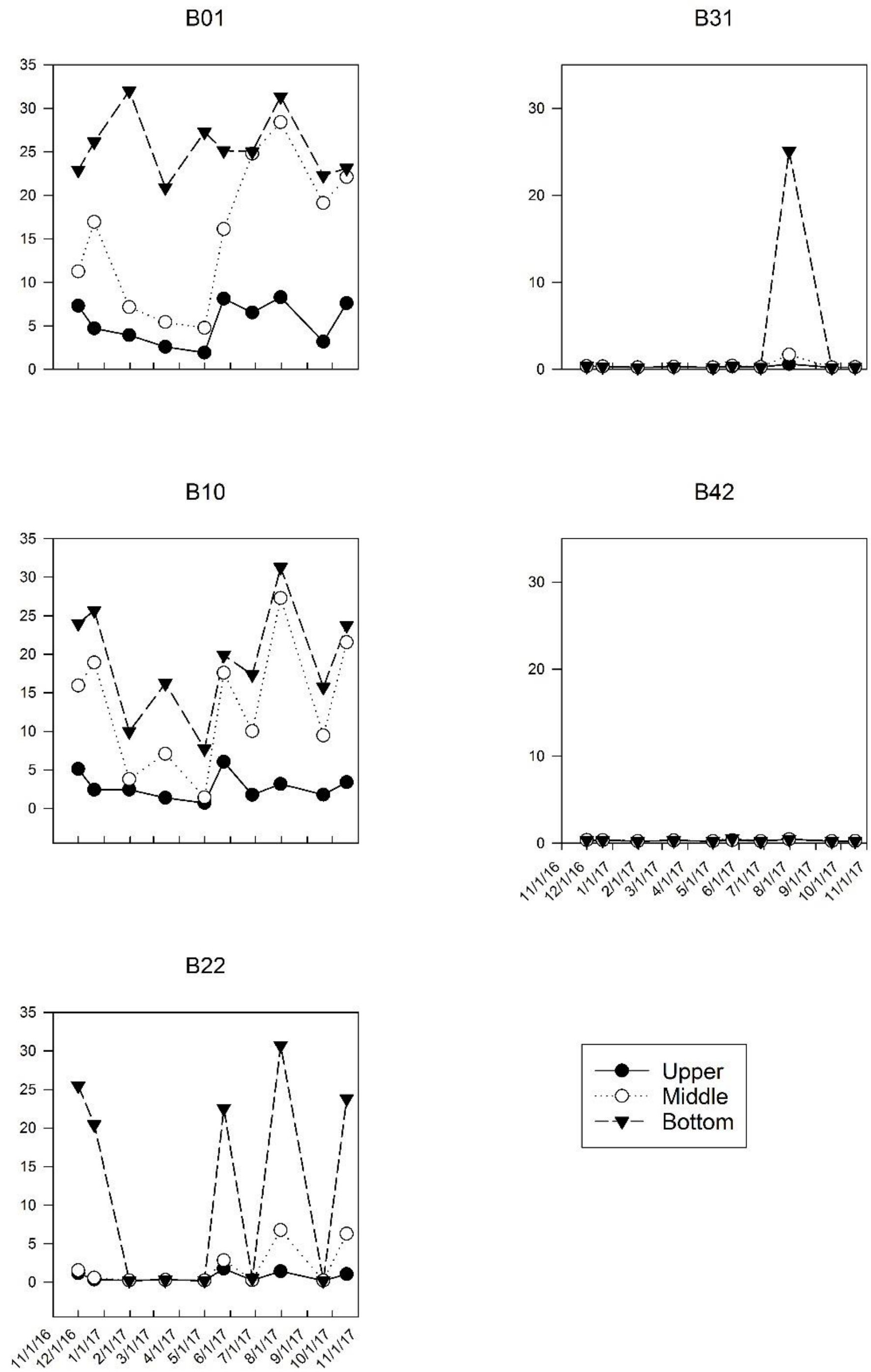

Figure 4. Vertical salinity profiles at each sample site during the study period.

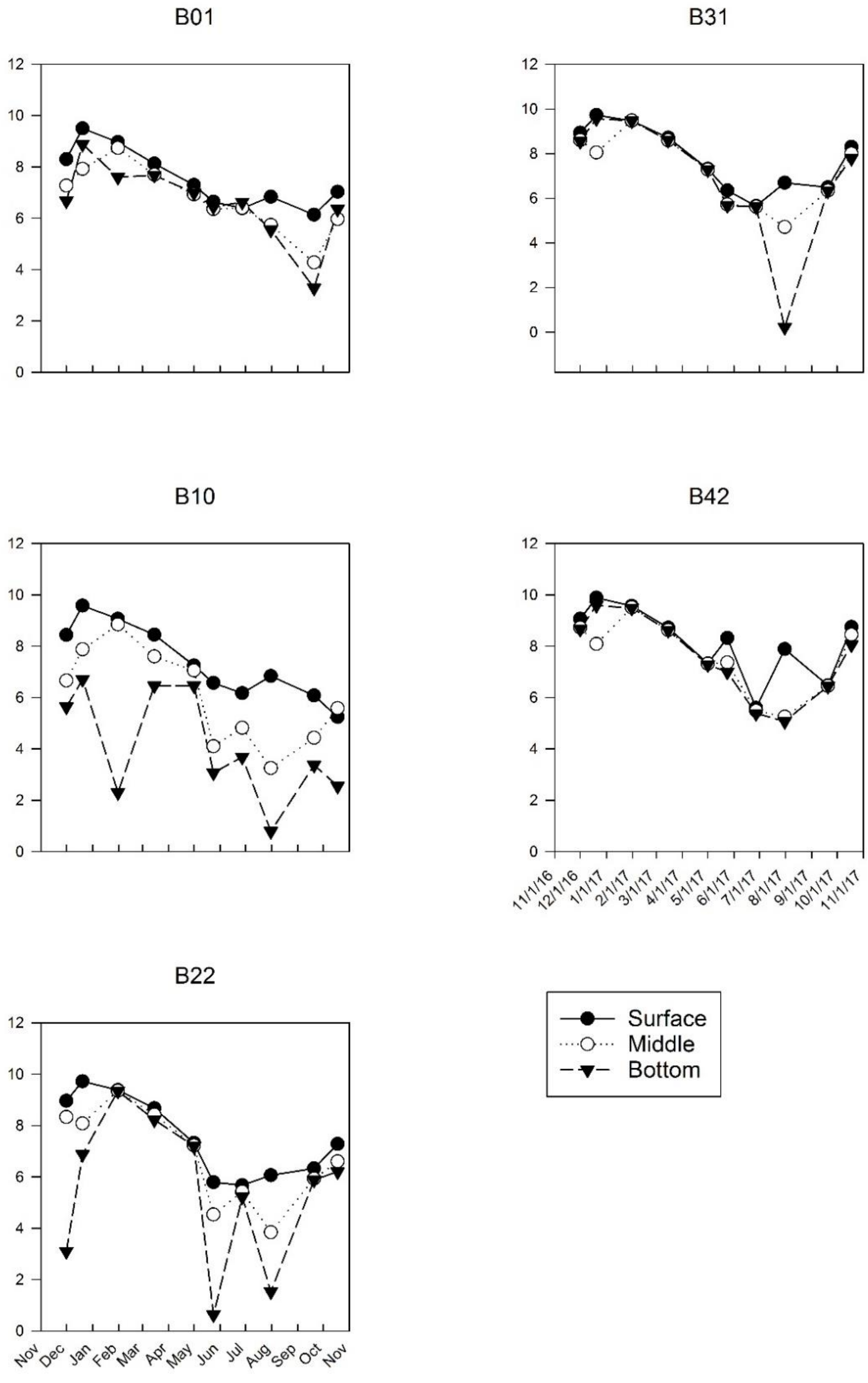

Figure 5. Vertical dissolved oxygen profiles at each sample site during the study period.

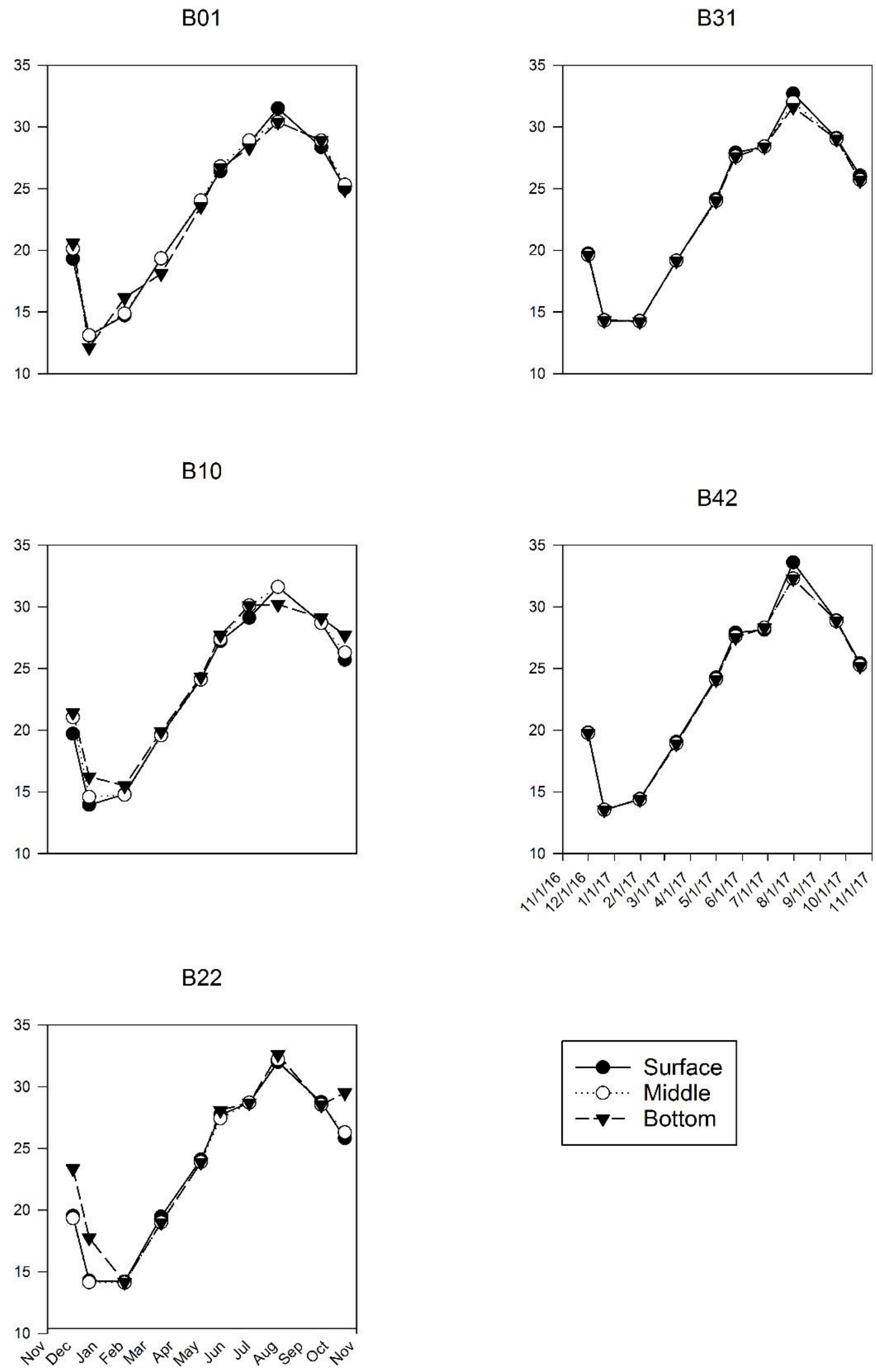

Figure 6. Vertical temperature profiles at each sample site during the study period.

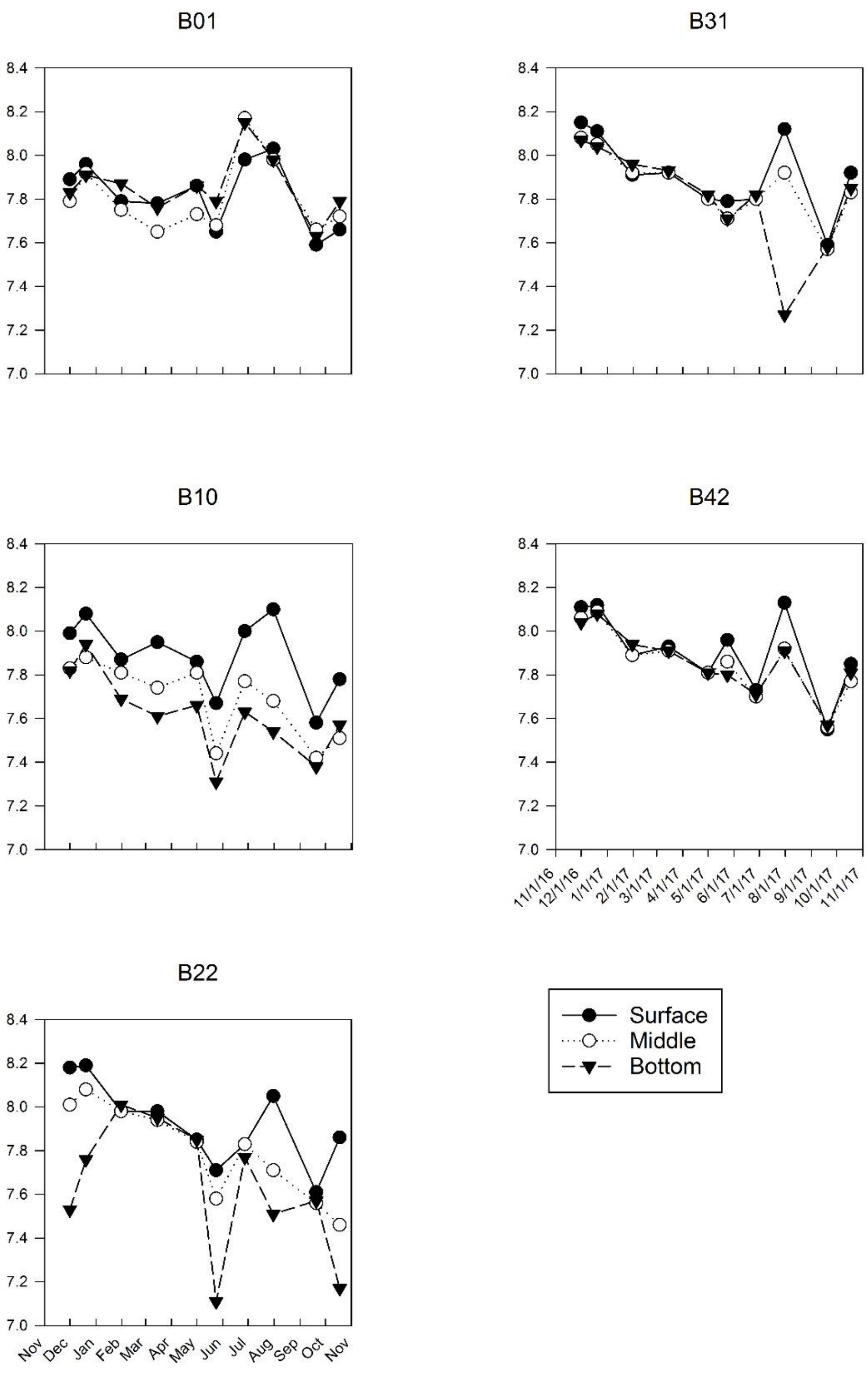

Figure 7. Vertical pH profiles at each sample site during the study period.

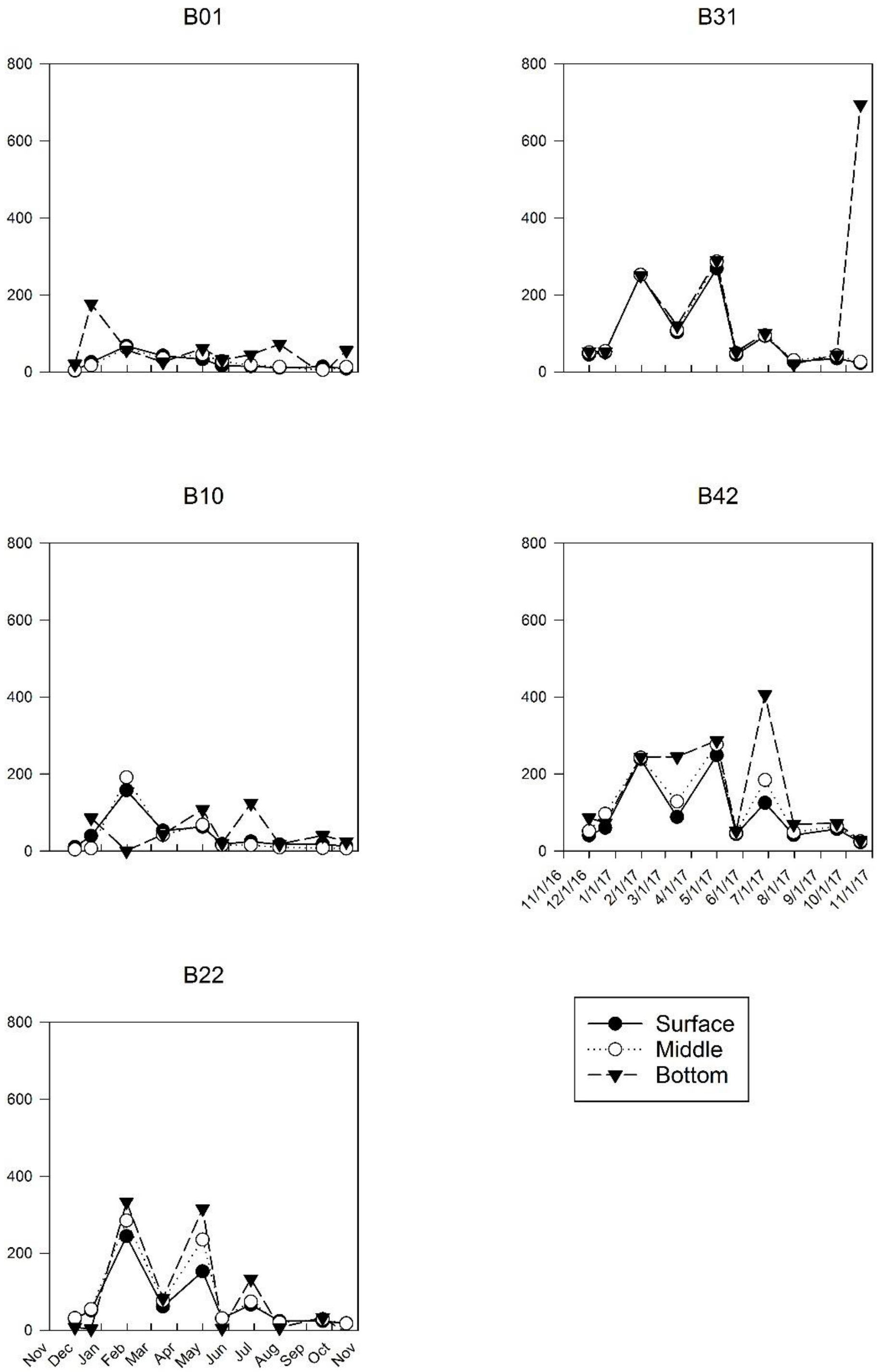

Figure 8. Vertical turbidity profiles at each sample site during the study period.

Principal components analysis was used to display spatiotemporal trends in patterns and interactions of water quality variables graphically, as well as, determine which variables contribute explain the majority of variation between sample sites. Principal components (PC) 1 and 2 had eigenvalues of 3.04 and 1.26 respectively, and explained 61.3% of the variation of the data. The largest coefficient in PC1 was dissolved oxygen, 0.510, followed by pH, 0.457 (Figure 9). Coefficients for PC2 were dominated by depth, -0.599, and temperature, -0.393 (Figure 9).

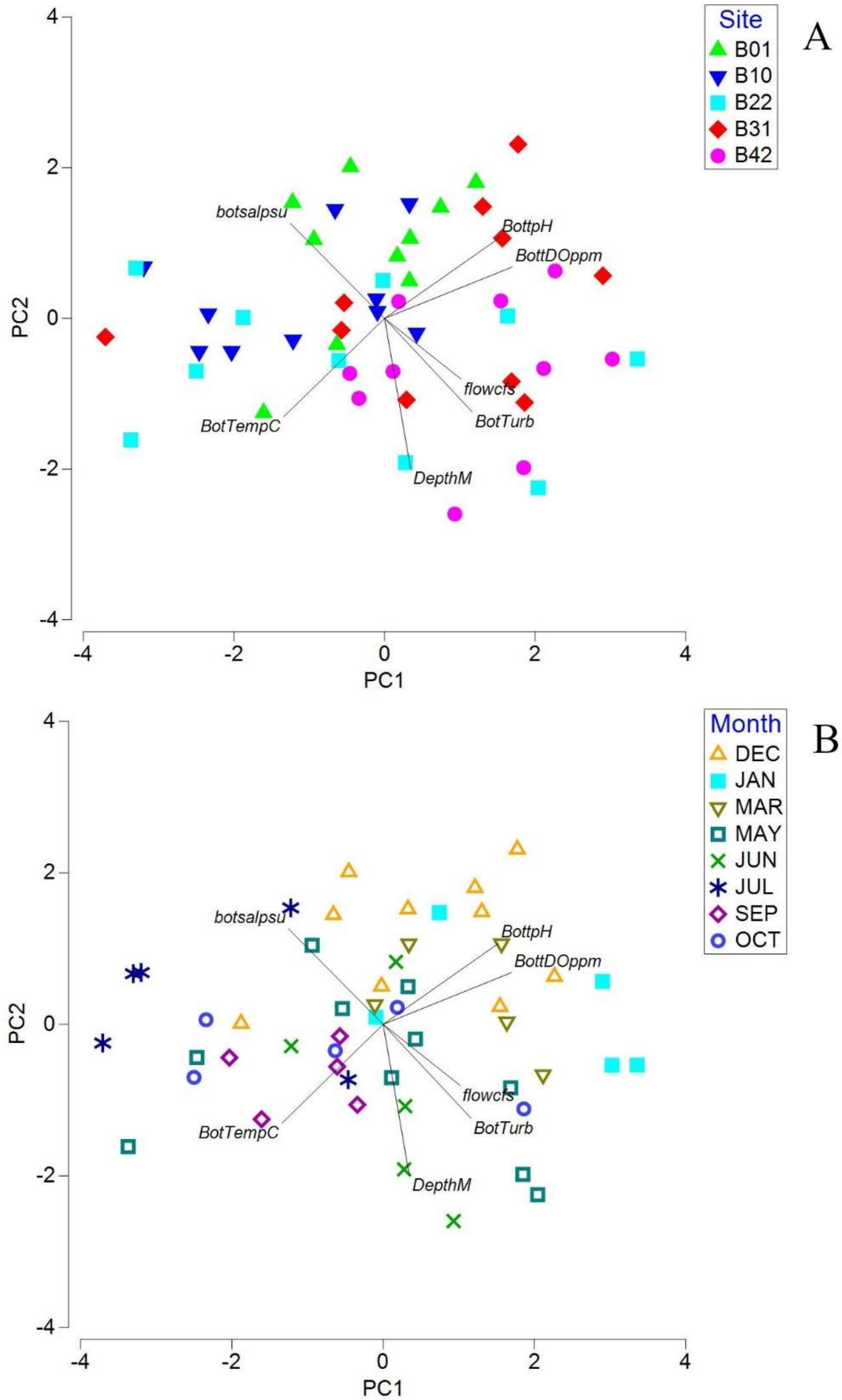

Figure 9. Principal components analysis of normalized bottom water measurements of environmental variables including salinity, temperature, total depth, turbidity, flow, dissolved oxygen, and pH. Collections depicted by site (A) and month (B).

Nekton Collections: Otter Trawl

CPUE and Number of Taxa

From December 2016 through October 2017 a total of 50 trawl collections, consisting of 150 individual replicate tows, were collected at five sites during 10 dates along the lower Brazos River. These collections yielded a total of 11,862 individuals, comprising 45 taxa (Table 1-1). The five most abundant taxa included Atlantic croaker (4,883 individuals), Star Drum, *Bairdiella chrysoura* (2,099 individuals), Blue Catfish, *Ictalurus furcatus* (1,182 individuals), Brown Shrimp, *Farfantepenaeus aztecus* (1,009 individuals), and river shrimp *Macrobranchium* spp., (693 individuals) (Table 1-1).

The highest cumulative number of individuals (6,314) and taxa (14) were captured at site B01 (Table 1-1). Sites B22, B10, B31, and B42 ranked 2nd, 3rd, 4th, and fifth respectively in cumulative CPUE and taxa richness overall (Table 1-1). Seasonally, total cumulative CPUE were greatest during the winter (Dec-Jan) with 5,699 individuals collected, followed by spring (Mar-Jun) and summer (Jul-Oct) (Table 1-1). Cumulative taxa richness was highest during the spring (14 taxa), followed by winter, and summer (Table 1-1).

Statistical Comparisons - CPUE and Number of Taxa

Significant differences in Log transformed catch per unit effort were observed between sites using one-way ANOVA (Table 1). Trawl catch per unit effort at site B01 was significantly higher than B22 and B42 ($P < 0.001$) during the study period (Table 1). One-way ANOVA failed to detect any significant difference in Log transformed catch per unit effort between seasons (Table 1).

Multiple linear regression indicated that flow was the only physical variable that exhibited any significant relationship to Log catch per unit effort ($r^2 = 0.39$, $P = 0.013$). Further testing using one-way ANOVA failed to detect any significant differences in Log catch per unit effort were present when compared to flow tiers (Table 1). However, the weak linear relationship was visibly evident since total CPUE appeared to be greater at low flow compared to moderate and high tiers (Table 1).

Taxa richness exhibited patterns similar to Log total CPUE. Significantly more taxa were collected at site B01 than B42, B22, and B31 (P = 0.000) (Table 1). Analysis of taxa richness versus season failed to detect any significant differences. (Table 1). Linear regression analysis detected a significant relationship between taxa richness and discharge (P = 0.043 and r^2 = 0.08). However, one-way ANOVA failed to detect any significant differences in taxa richness between flow tiers (Table 1).

Statistical Summary - Diversity and Evenness

The highest Shannon Diversity (H'), 1.70, was reported at site B10, along with the largest median and mean Shannon Diversity (Table 1-1). Individual maximum Pielou's Evenness (J) of 1.00 were recorded at sites B22 and B42. The highest reported mean and median evenness values, 0.65 and 0.71 respectively were at B10. (Table 1-1).

The highest maximum Shannon diversity (1.70) was recorded during the spring, however the highest calculated average and median Shannon Diversity, 0.88 and 0.92 respectively, occurred during the summer (Table 1-1). Maximum evenness values of 1.00 occurred during summer and winter collections, with the largest calculated average evenness (0.55) occurring during the spring, and the greatest calculated median evenness (0.51) occurring during the summer (Table 1-1).

Statistical Comparison - Diversity

Variation in diversity indices were detected between collection locations. Site B10 had significantly higher average Shannon Diversity than sites B22, B31, and B42 (P = 0.002) (Table 1). Furthermore, no significant differences were detected in Shannon

Diversity between seasons, or flow tiers (Table 1). Pielou's evenness was also calculated between sites, seasons, and flow tier with no significant results detected (Table 1).

Multivariate Nekton Community Analyses

Hierarchical cluster analysis and Similarity Profile (SIMPROF) was performed to determine significant groups of trawl collections based on the relative CPUE of species. A collection consisted of 3 replicate samples at a single site, on a single date. The numbers of specimens per sample were summed for each collection prior to any transformation and subsequent analysis. SIMPROF analysis divided the 50 trawl collections into five significant groups or clusters based on taxa composition (Cophenetic correlation = 0.905, π = 7.35) (Figure 10). To better visualize the cluster groupings nMDS ordination analysis was conducted and a two-dimensional ordination plot based on the ranked differences in similarity was produced (Figure 11). Determining what measured abiotic variables was most correlated with the groupings was accomplished by using PRIMER 7 RELATE and BEST statistical routines. The RELATE results indicated that the resemblance matrices generated from the biological and abiotic variables were similar ($\rho = 0.335$, $P = 0.001$) (Table 2-1). The results of the BEST analysis indicated bottom salinity was the best individual abiotic predictor of variation observed in the trawl nekton resemblance matrix and resulting cluster analysis classification ($\rho = 0.693$, $P = 0.001$) (Table 2-2).

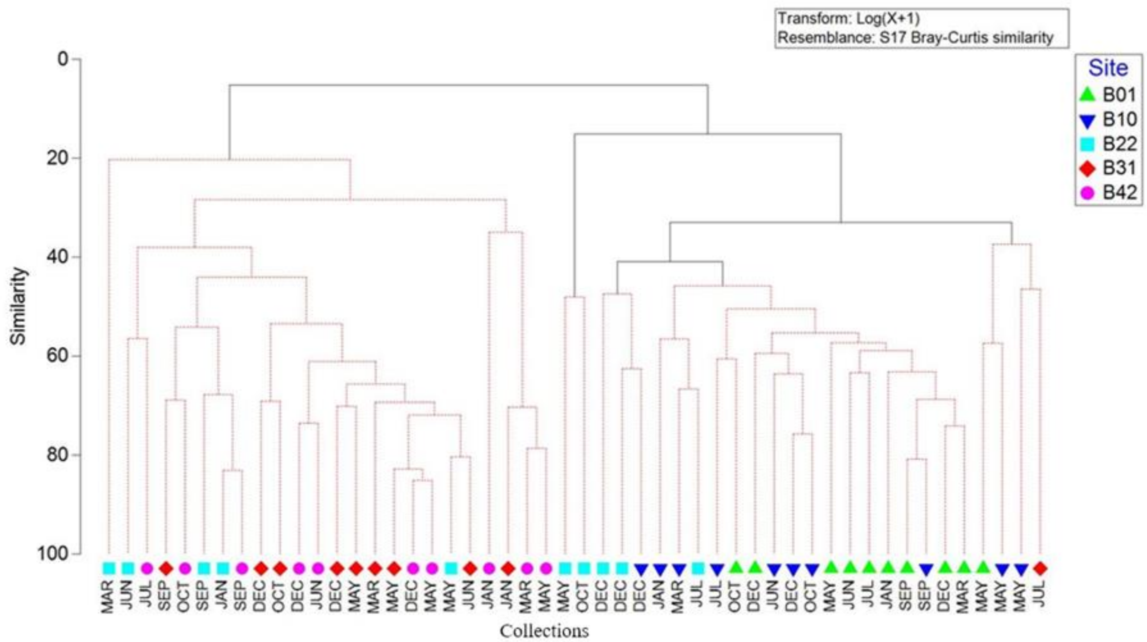

Figure 10. Dendrogram describing the percent similarity of otter trawl collections (samples) based on species composition and CPUE of each collection. The dark blue branches indicate statistically significant groupings of collections.

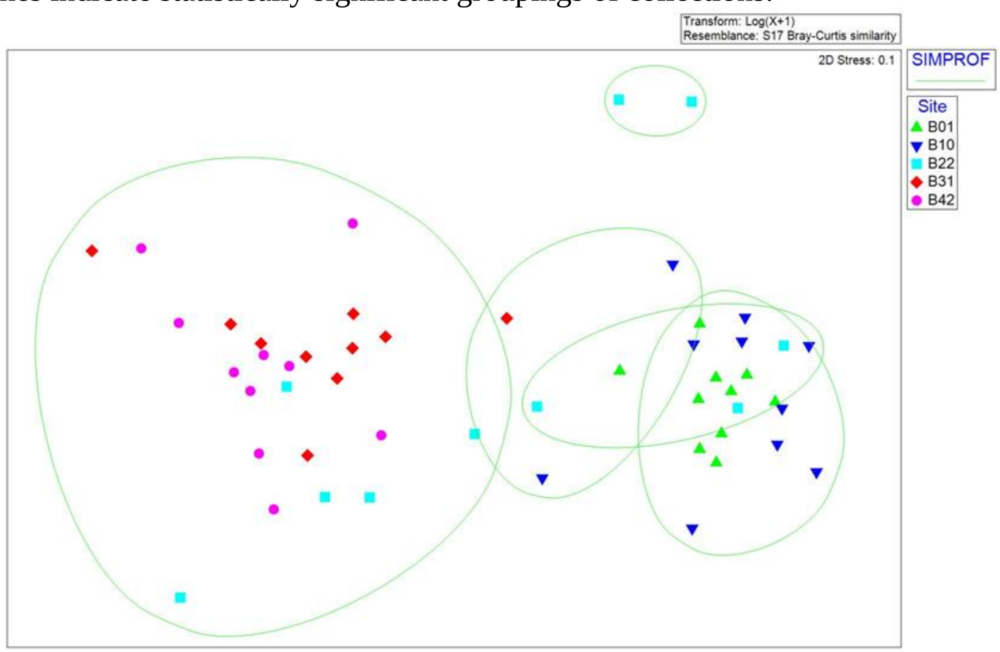

Figure 11. The nMDS ordination of the ranked similarity of 50 otter trawl collections. The green circles represent the SIMPROF generated groupings (clusters) observed in the dendrogram (Figure 10).

Similarity Percentage (SIMPER) analysis was used to identify which species most contributed to the overall similarity within the five sites, three seasons, and three flow tiers. Site B01 exhibited an average similarity of 55.75% between collections and was dominated by Star Drum, *Stellifer lanceolatus* Atlantic Croaker, and White Shrimp, *Litopenaeus setiferus* (Table 2-3). Similarly, Atlantic Croaker, Star Drum, and White Shrimp were the highest contributors to the 40.73% similarity of collections at B10 (Table 2-3). Site B22 recorded the lowest average within group similarity at 17.8% and was primarily influenced by contributions from Blue Catfish, *Ictalurus furcatus*, Atlantic Croaker, and White Shrimp (Table 2-3). Finally, B31 and B42 showed little variability with average similarities of collections recorded at 45.39% and 46.29% with major contributions by both *Macrobranchium* spp. and Blue Catfish at these sites (Table 2-3).

The low, moderate, and high flow tiers were analyzed using SIMPER to identify which species most contributed to overall similarity between collections. Collections taken during a low flow tier exhibited an average similarity of 24.64% over the study duration, with the three largest contributions originating from Blue Catfish, Atlantic Croaker, and White Shrimp (Table 2-4). Blue Catfish and Atlantic Croaker were also the top two species during moderate flow collections contributing 53.21% of the average (20.52%) similarity (Table 2-4). The high flow tier collections exhibited a comparable average within group similarity (24.30%) to the other tiers, however the species contributions were not as similar. Blue Catfish, Macrobranchium Spp., and Blue Crabs, *Callinectes sapidus* contributed a cumulative 74.16% to the within group similarity (Table 2-4). To better graphically distinguish diverging CPUE of various species an nMDS was used to display a two-dimensional ordination based on relative taxa CPUE in relation to flow (Figure 12).

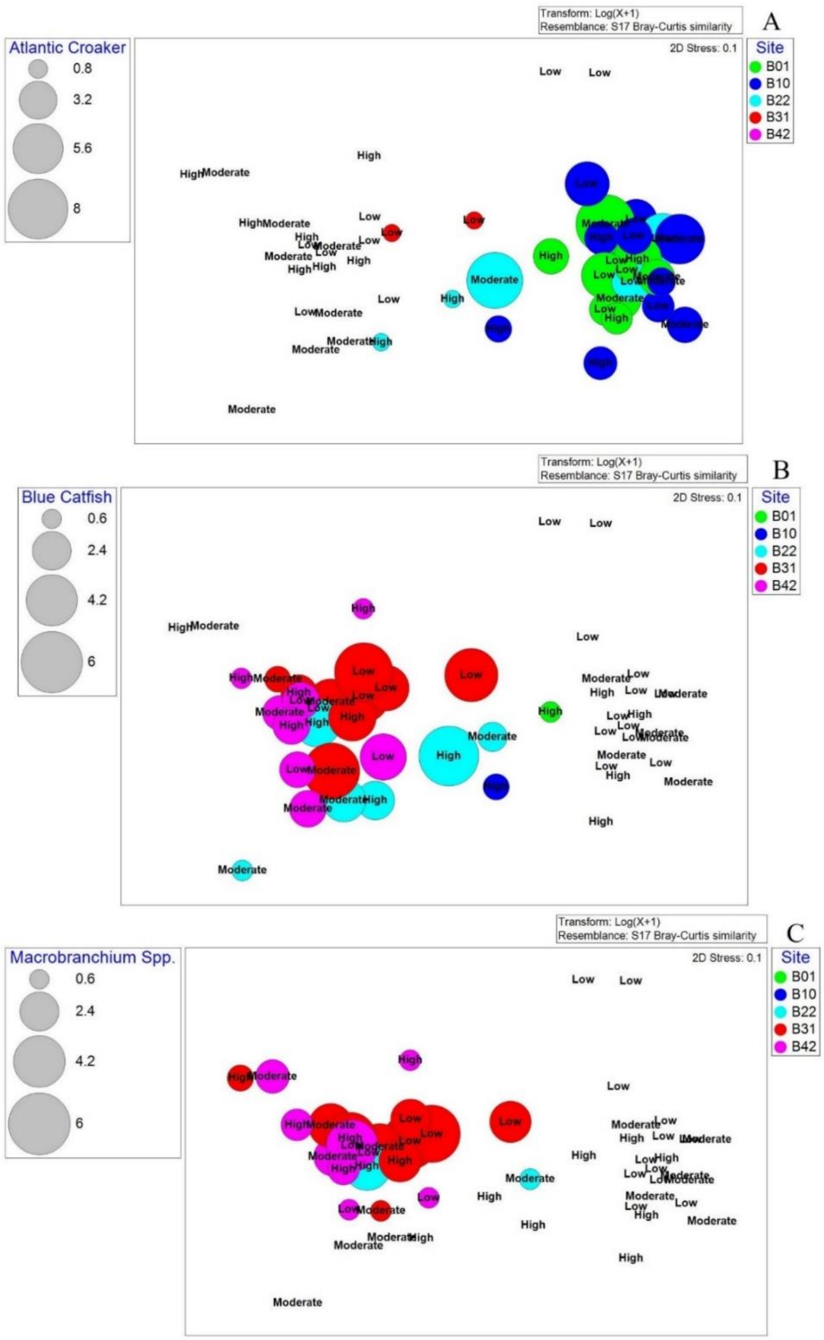

Figure 12. A nMDS ordination plot of three nekton species collected during otter trawl sampling. Atlantic Croaker (A), Blue Catfish (B), and Macrobranchium spp. (C) were all major contributors to average similarity of collections between sites and flow tiers. The terms “Low, Moderate, High” depict the flow tier present during the collection, while the size of the circle represents $Log_e(1+X)$ transformed CPUE, and the color legend the corresponding collection site. Species name is recorded to the left of each plot with corresponding legend illustrating the value of each size circle below the species name.

One-way Analysis of Similarity (ANOSIM) analyses were conducted to test for differences in taxa composition between sites, flow tier, and season. One-way ANOSIM of site produced results supporting the previous CPUE and diversity analyses. Site B01 was highly distinct from B31 and B42 (ρ = 0.97 and 0.99, P = 0.001) (Table 2-6). B10 was also dissimilar from sites B31 and B42 (ρ = 0.93 and 0.97, P = 0.001) (Table 2-6). One-way ANOSIM comparisons of trawl taxa composition failed to detect any significant differences across season and flow tiers (Table 2-7 and 2-8). These results indicate that during the study period spatial variation played a dominant role in taxa CPUE and composition of nekton captured with otter trawls within the Brazos River estuary.

Small Nekton and Zooplankton Collections: Beam Trawl

CPUE and Number of Taxa

The Renfro beam trawl was used to characterize shoreline small nekton and zooplankton communities of the Brazos River. Shoreline sampling collected far fewer individuals than the concurrent otter trawl sampling method. Over the study duration 729 individuals were collected comprising 27 taxa (Table 1-2). Similar to otter trawl collections Atlantic Croaker was the most abundant species collected totaling 184 individuals, followed by *Macrobranchium* Spp., Daggerblade Grass Shrimp, *Palaemonetes pugio*, Striped Mullet, *Mugil cephalus,* and White Shrimp in the top five abundant species (Table 1-4). The taxa collected were in various developmental life stages. Thus, beam trawl collections consisted of fully developed nekton, such as White Shrimp, and numerous zooplankton, including a variety of ichthyoplankton and meroplankton.

The pattern in CPUE and taxa richness collected by the Renfro Beam trawl differed from otter trawl catches. The greatest number of individuals (238) was collected at B42 followed by B01, B22, B10, and B31 (Table 1-2). However, The Renfro Beam trawl collected the greatest number of taxa (8) at B10 followed by B31, B22, B42, and B01 in decreasing order (Table 1-2). Similar to trawl data, the winter season yielded the highest calculated total CPUE of 425 individuals, followed by spring, and summer (Table 1-2). Eight nekton taxa were collected by beam trawl during the winter season, followed by 4 taxa in spring and 4 in the summer seasons (Table 1-2).

Statistical Comparisons – CPUE and Number of Taxa

One-way ANOVA were conducted on $Log_e(1+X)$ transformed values from beam trawl collections. When significant results were detected, a Tukey multiple comparison test was conducted. One-way ANOVA failed to detect any significant differences in CPUE between sites and the flow tiers (Table 1). However, significantly higher CPUE was observed during the winter ($P = 0.002$) versus summer season (Table 1).

Kruskal Wallis one-way ANOVA was used to analyze taxa richness against sites, seasons, and flow tiers. Collections at B01 yielded significantly fewer taxa than collections at B42 ($P = 0.026$) (Table 1) (Figure 13). Winter and spring exhibited greater taxa richness compared to summer ($P = 0.007$) (Table 1) (Figure 14). However, no significant differences were observed when comparing richness with flow tier (Table 1).

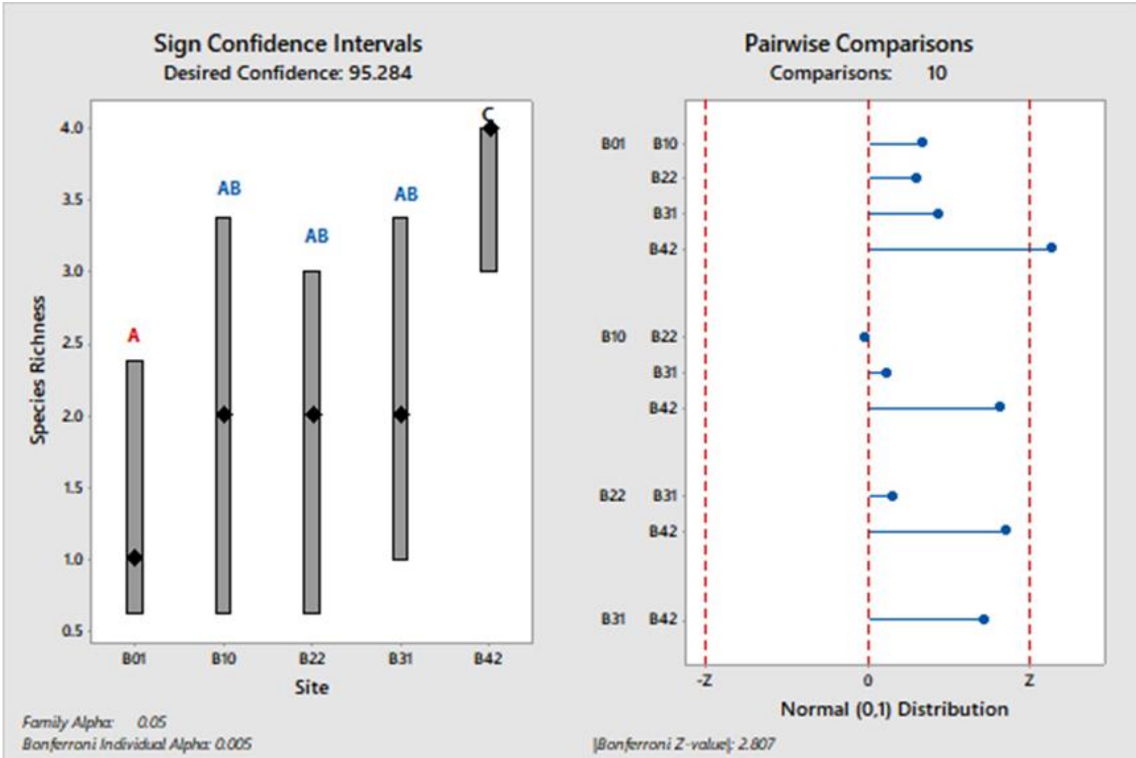

Figure 13. Dunn's multiple Comparison test for significant differences in taxa richness between sites. Different letters and colors above bars denote significant groups. The diamond indicates the median flow value and the gray rectangle signifies the 95% confidence interval for the median.

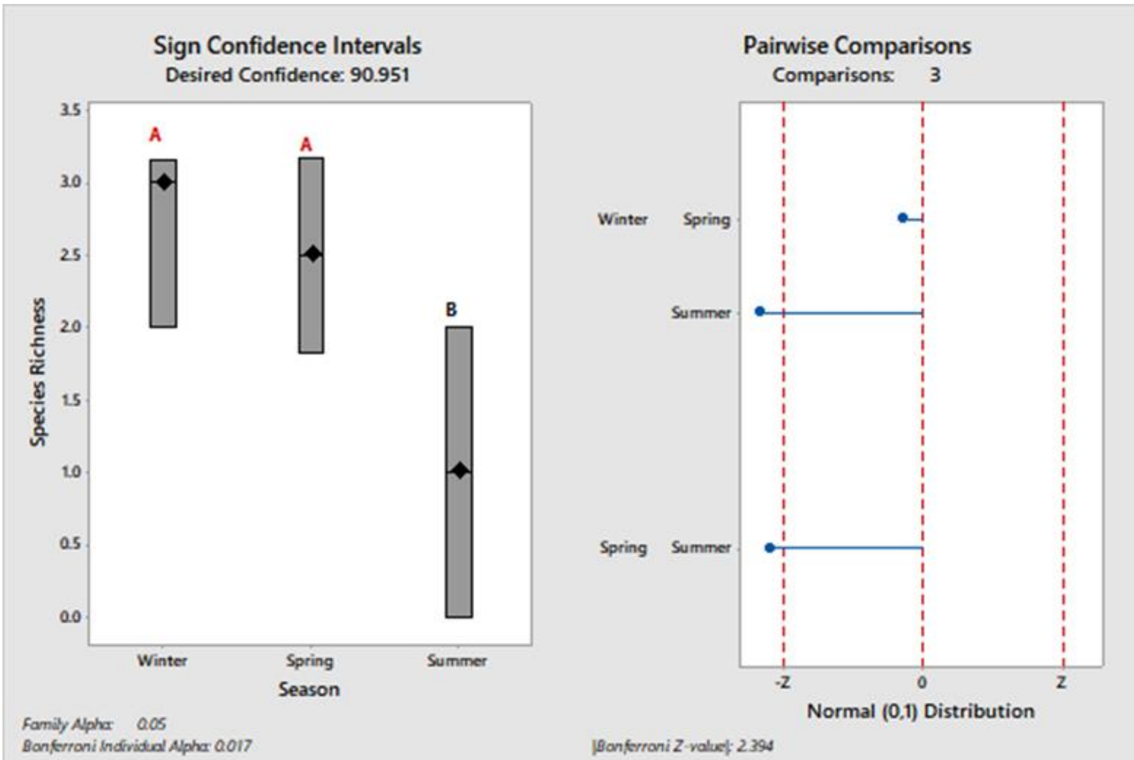

Figure 14. Dunn's multiple Comparison test for significant differences in taxa richness between seasons. Different letters and colors above bars denote significant groups. The diamond indicates the median flow value and the gray rectangle signifies the 90% confidence interval for the median.

Statistical Comparisons – Diversity and Evenness

Diversity and evenness were also used to analyze patterns in taxa assemblage and catch per unit effort from beam trawl samples. When comparing diversity by sites, B01 exhibited a significantly lower diversity than B42 (*P* = 0.038) (Table 1). However, no other significant results were detected when comparing diversity or evenness between seasons (Table 1). One-way ANOVA failed to detect any significant differences in diversity or evenness between flow tiers, as well as, evenness and sites (Table 1).

Multivariate Small Nekton and Zooplankton Community Analyses: Beam Trawl

Hierarchical cluster analysis and SIMPROF failed to detect any significant groups between the 50 beam trawl collections (Cophenetic Correlation = 0.838, π = 0.59) (Figure 15). The RELATE analysis technique detected significant relationships between the biological and environmental resemblance matrices of beam trawl data (ρ = 0.136, *P* = 0.001) (Table 3-1). The BEST analysis revealed the single best environmental variable predicting the variation in the biological data structure was salinity (ρ = 0.213, *P* = 0.001) (Table 3-2). However, temperature, salinity and dissolved oxygen were a stronger combination of predictors of biological data structure (ρ = 0.25, *P* = 0.001) (Table 3-2).

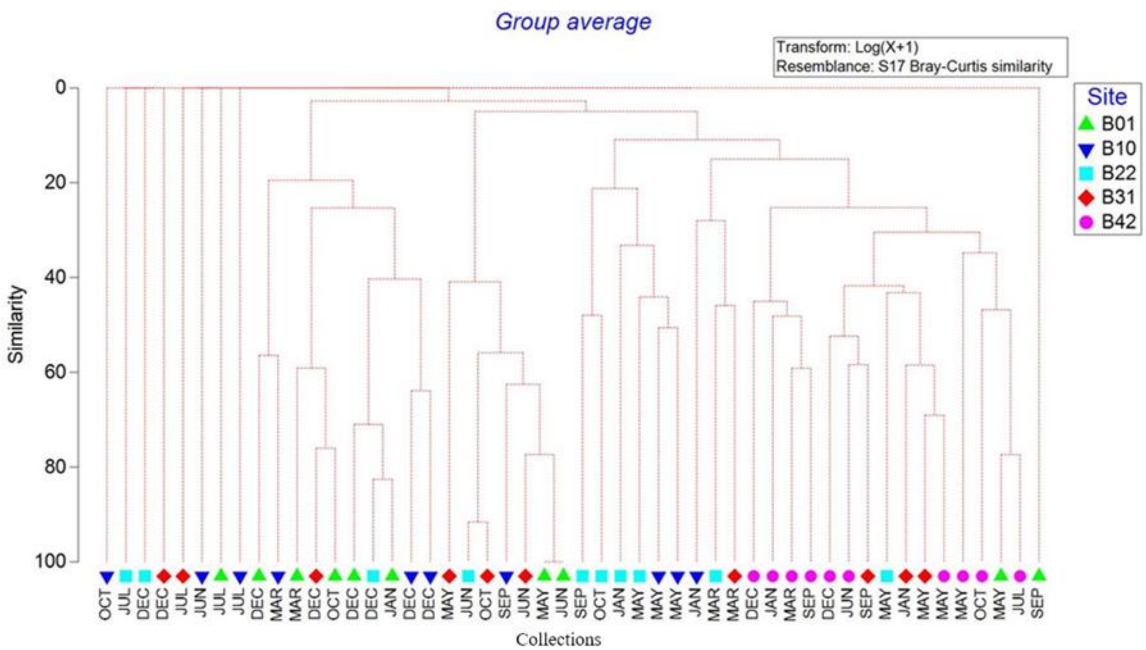

Figure 15. Dendrogram describing the percent similarity of beam trawl collections based on species composition and CPUE of each sample. No significant data clusters were detected in this analysis.

SIMPER analysis was used to identify which taxa most contributed to the overall similarity within the five sites, three seasons, and three flow tiers. Site B42 exhibited the greatest average similarity of 31.97% between collections and was dominated by Daggerblade Grass Shrimp and *Macrobranchium* spp. (Table 3-3). Little variability was displayed from sites B01 and B31 recording 13.35% and 10.48% similarity between collections (Table 3-3). Atlantic Croaker were the largest contributor to similarity of collections at B01, while Bay Anchovy, *Anchoa mitchilli*, and Daggerblade Grass shrimp played the same at site B31. The lowest similarities between site collections were detected at B22 (8.66%) and B10 (4.39%). Blue Crabs and Darter Gobies, *Ctenogobius boleosoma*, were the major contributors to similarity between collections at B22 (Table 3-3).

The low, moderate, and high flow tiers were analyzed using SIMPER to identify which species most contributed to overall similarity between flow tier collections. Collections taken during high flow exhibited the greatest average similarity of 13.03% over the study duration, with the two primary contributors being Daggerblade Grass Shrimp and Bay Anchovy (Table 3-4). Both low and moderate flow tiers exhibited comparable similarity between collections, 6.57% and 6.36% respectively (Table 3-4). The largest contributor to the similarity of collections at both low and moderate flow tiers was Daggerblade Grass Shrimp (Table 3-4).

SIMPER analysis was also used to analyze similarity between collections during the winter, spring, and summer seasons. Spring and winter collections exhibited little variability with average similarity between collections of 17.03% and 13.73% respectively (Table 3-5). Primary contributing species were more variable, spring dominated by Daggerblade Grass Shrimp, *Macrobranchium* spp., and Striped Mullet, while winter was dominated by Atlantic Croaker, White Shrimp, and Ribbon Shiner, *Lythrurus fumeus* (Table 3-5). Summer collections exhibited a lower average similarity (7.78%) between collections and detected only one major contributing taxon, Bay Anchovy (Table 3-5).

One-way ANOSIM analyses were conducted to test taxa composition against sites, flow tier, and season. One-way ANOSIM detected collections at site B01 were significantly distinct from collections at B22 ($\rho = 0.175$, $P = 0.004$) (Table 3-6). Taxa composition in collections from B22 was also significantly distinct from collections at

B31 ($\rho = 0.12$, $P = 0.034$) (Table 3-6). Finally, collections from B42 were significantly distinct from all other sites (Table 3-6). One-way ANOSIM analysis of collections and the three flow tiers exhibited collections from each season to be significantly distinct from one another ($\rho = 0.127$, $P = 0.001$) (Table 3-8). No significantly distinct results were detected when one-way ANOSIM was used to analyze similarities between collections done at the three flow tiers (Table 3-7).

Atlantic Croaker: Otter Trawl

Catch per Unit Effort

Only individuals collected in the otter trawl collections were used for the subsequent analysis of CPUE against site, season, and flow tier. Otter trawls collected 4,833 individuals through the 50 collections. Significant variation in Atlantic Croaker CPUE was seen spatially. Significantly higher CPUE of Atlantic Croaker was observed at sites B01 and B10 ($P = 0.000$) compared to B31 and B42 (Table 1) (Figure 16). Analysis of Atlantic Croaker CPUE with season, as well as, flow yielded no significant results (Table 1).

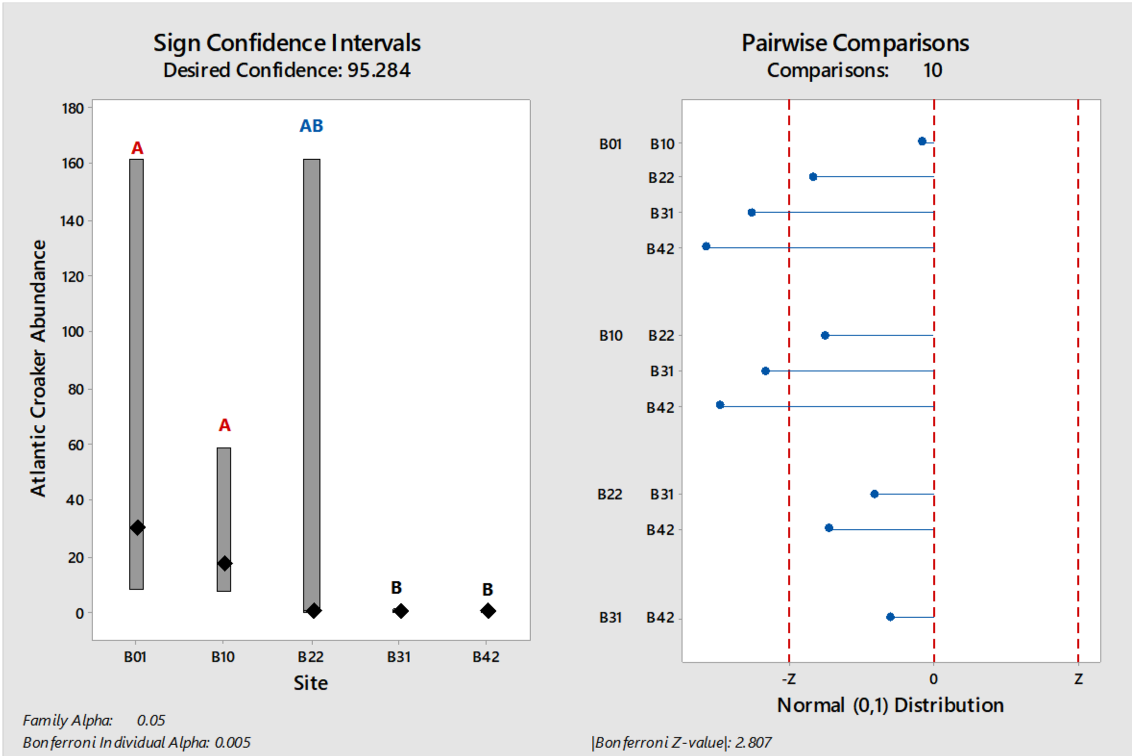

Figure 16. Dunn's multiple comparison test of Atlantic Croaker otter trawl CPUE between collection sites. Gray boxes depict 95% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

Length Analysis

Only Atlantic Croaker collected from otter trawl collections were included in the length analyses, as these individuals were the only specimens measured. Atlantic Croaker collected at B01 and B10 were significantly larger than individuals collected at B22 (*P* = 0.000) (Table 1) (Figure 17). Seasonally, the largest Atlantic Croaker were collected in the summer, followed by spring, and finally winter (*P* = 0.000) (Table 1) (Figure 18). Length exhibited greater variability between flow tiers in comparison to sites and seasons. Significantly larger individuals were collected during low flow collections (*P* = 0.000) followed by the moderate and high flow tier collection (Table 1) (Figure 19).

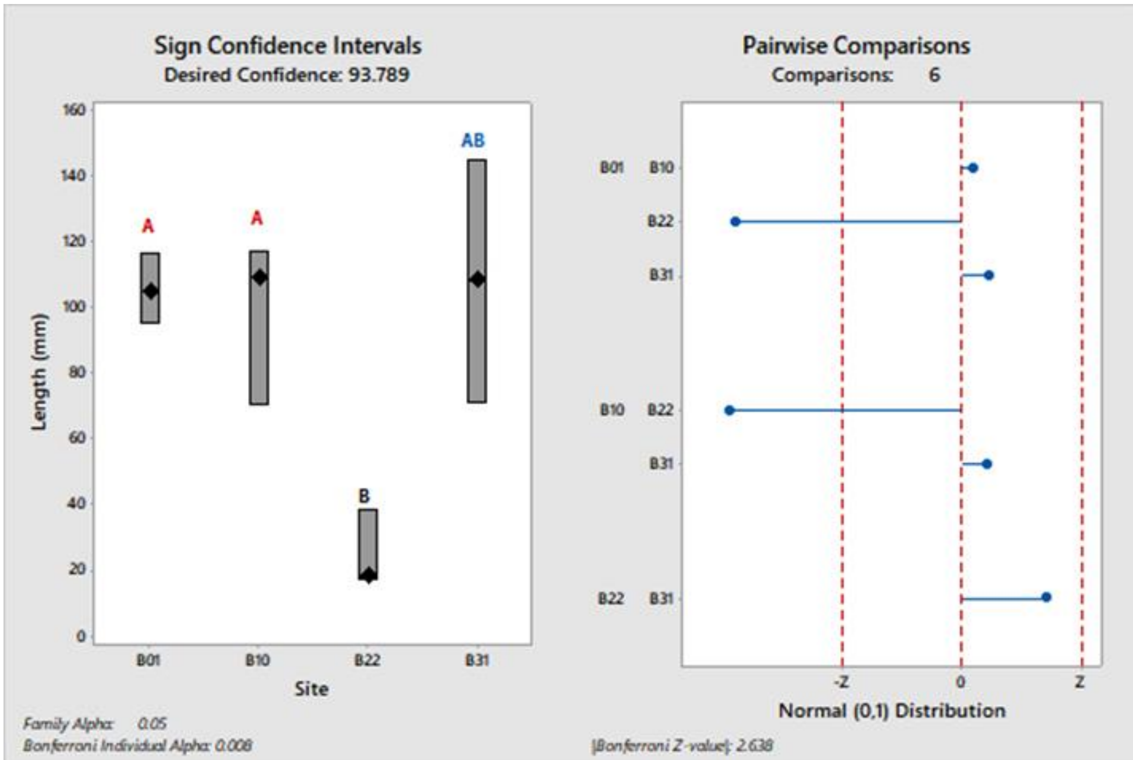

Figure 17 Dunn's multiple comparison test of Atlantic Croaker length between sites. Gray boxes depict 93% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

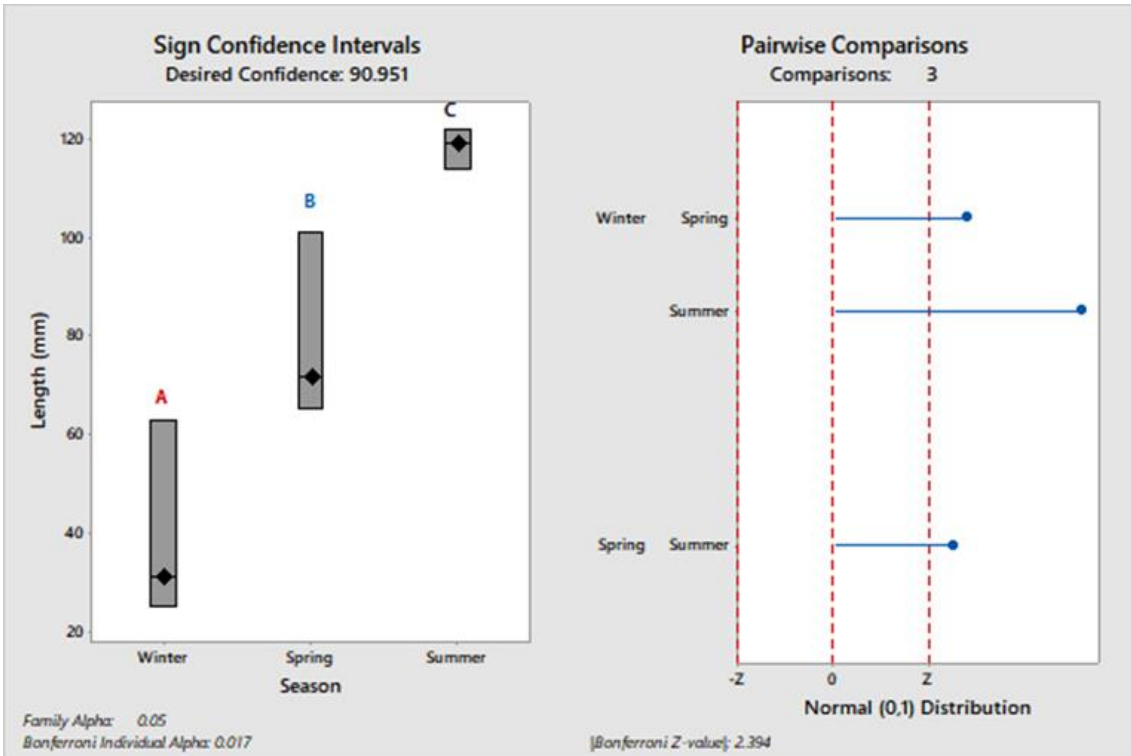

Figure 18. Dunn's multiple comparison test of Atlantic Croaker length between seasons. Gray boxes depict 93% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

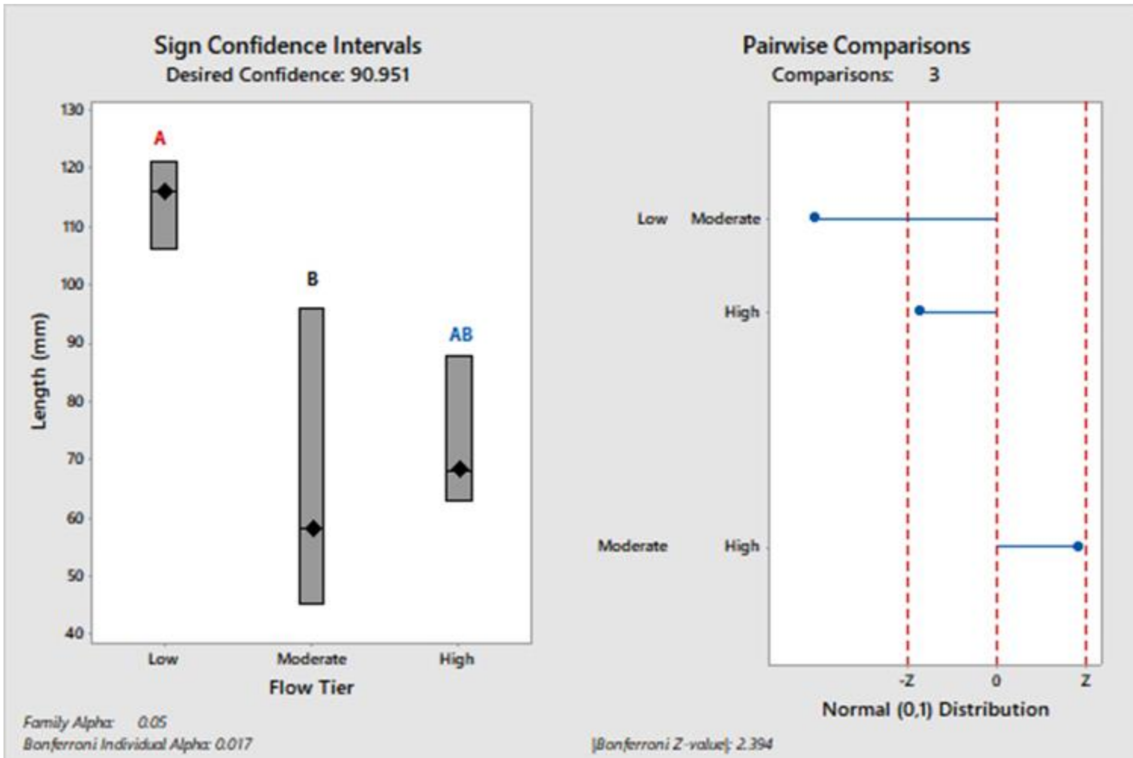

Figure 19. Dunn's multiple comparison test of Atlantic Croaker length between flow tiers. Gray boxes depict 93% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

Stable Isotope Analyses

From December 2016 through September 2017 Atlantic Croaker and water samples were collected and used for analysis of the stable isotopes of Carbon, $^{13}C/^{12}C$, Nitrogen, $^{15}N/^{14}N$, and Sulfur, $^{34}S/^{32}S$ within the lower Brazos River. A total of 96 Atlantic Croaker were collected and tested for $\delta^{13}C$ and $\delta^{15}N$, as well as, 46 of the Atlantic Croaker measured for $\delta^{34}S$ (Table 1-5).

Filtered Particulate Organic Matter (POM) from 40 water samples was tested for stable isotopes of Carbon, $^{13}C/^{12}C$, Nitrogen, $^{15}N/^{14}N$, and Sulfur, $^{34}S/^{32}S$ (Table 1-6). As with Atlantic Croaker, samples were collected from December 2016 through September 2017.

Atlantic Croaker Isotope Analyses

Isotope vs. Isotope Comparisons

Significant negative correlation between C:N ratio and $\delta^{13}C$ indicates the necessity to correct $\delta^{13}C$ values for lipid interaction. In this case, no significant correlation was exhibited in the data and therefore no need to correct for lipid interaction ($P = 0.248$) (Figure 20).

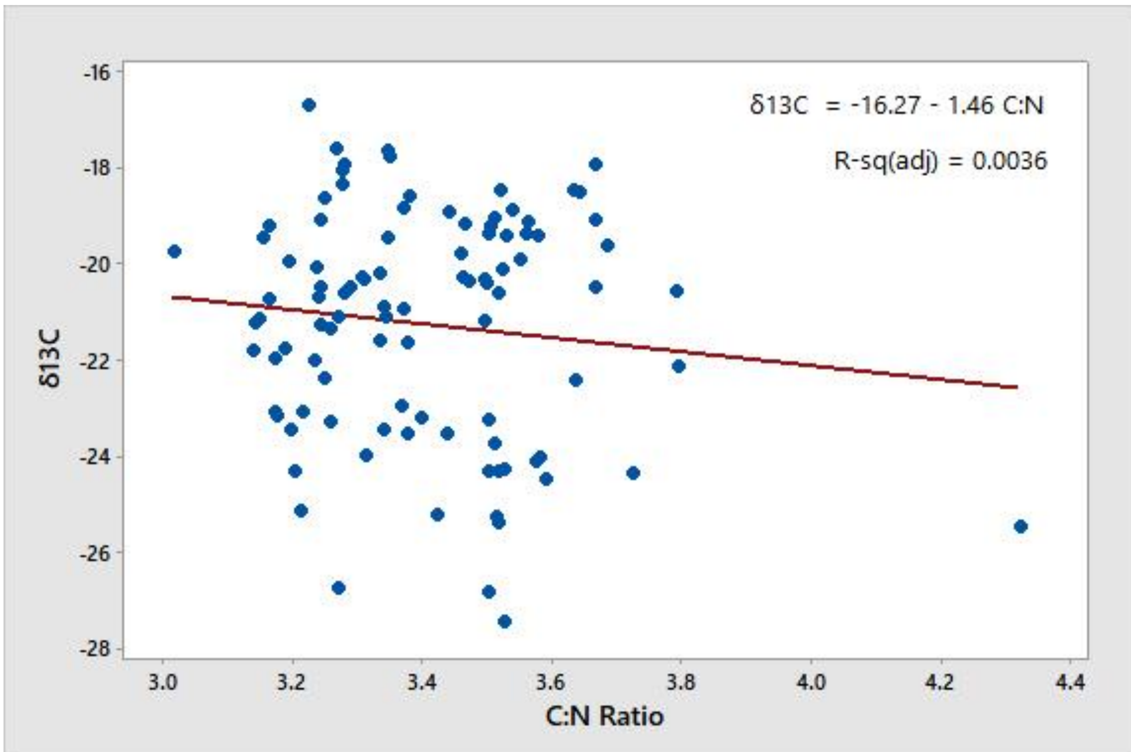

Figure 20. Scatterplot of C:N, by mass, against the $\delta^{13}C$ in 96 Atlantic Croaker. The red line represents the regression equation.

Site Specific Comparisons

Average $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ of Atlantic Croaker and POM were plotted for each site (Figures 21A and 21B). Vales of $\delta^{13}C$ of POM become more depleted the closer collections were to the river mouth (Figure 21A). Atlantic Croaker show the opposite result with $\delta^{13}C$ values more depleted from collections further upstream. This would suggest fish collected further upstream are consuming sources of carbon originating from upstream and/or terrestrial sources. Also, Atlantic Croaker exhibit greater $\delta^{15}N$ than all POM, displaying a distinct increase in trophic levels as expected.

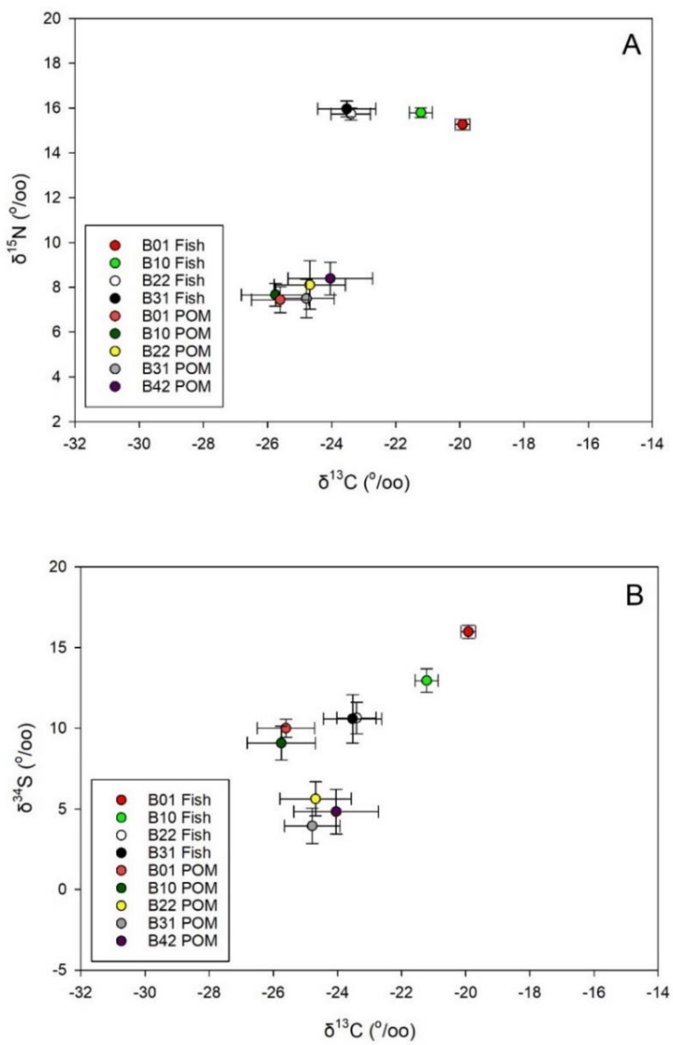

Figure 21. Scatterplot of average Atlantic Croaker and POM isotope values of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ by site. The black lines extending from each mean bubble represent the standard error of the average isotope value at the site. Panel A depicts $\delta^{13}C$ vs $\delta^{15}N$ and Panel B depicts $\delta^{13}C$ vs $\delta^{34}S$.

Kruskal Wallis and Dunn's multiple comparison analysis identified significant variation of Atlantic Croaker $\delta^{13}C$ and $\delta^{34}S$ between sites. Atlantic Croaker collected at site B01 had significantly enriched $\delta^{13}C$ and $\delta^{34}S$ compared to specimens collected at B22 and B31, P = 0.000 and P = 0.001 (Table 1) (Figures 22 and 23). No significant variation in $\delta^{15}N$ values was detected in Atlantic Croaker between sites (Table 1).

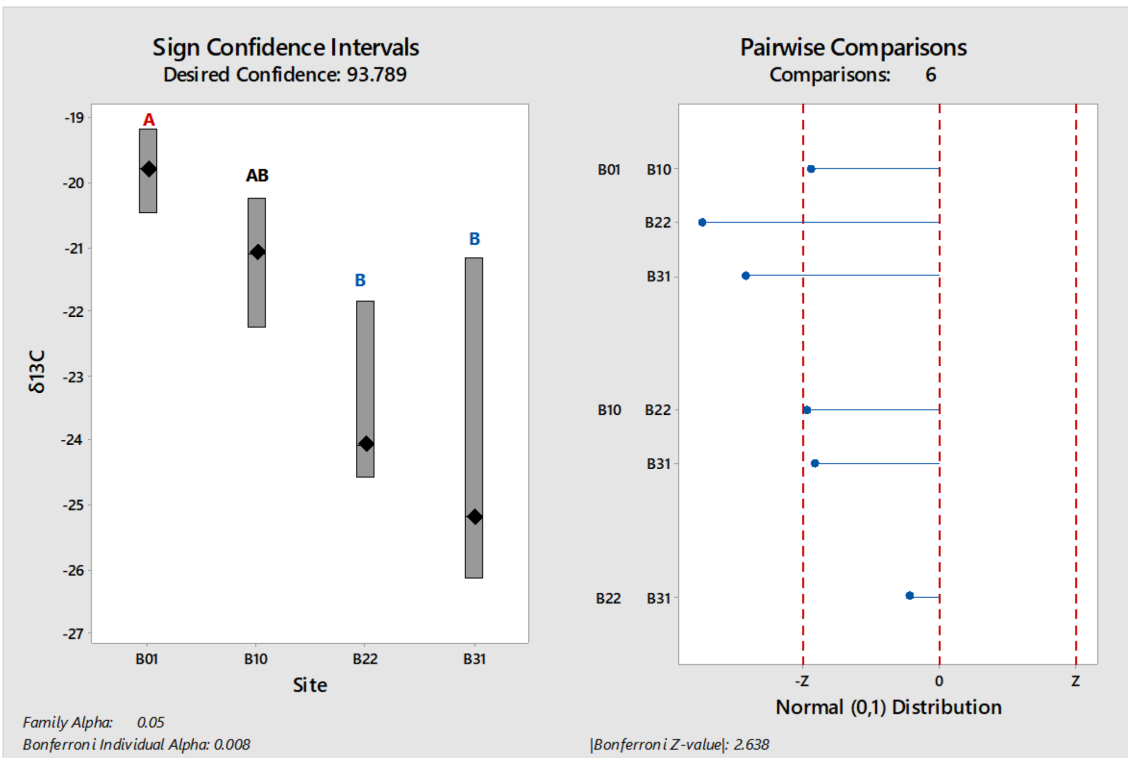

Figure 22. Dunn's multiple comparison test of Atlantic Croaker $\delta^{13}C$ values between sites. Gray boxes depict 93% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

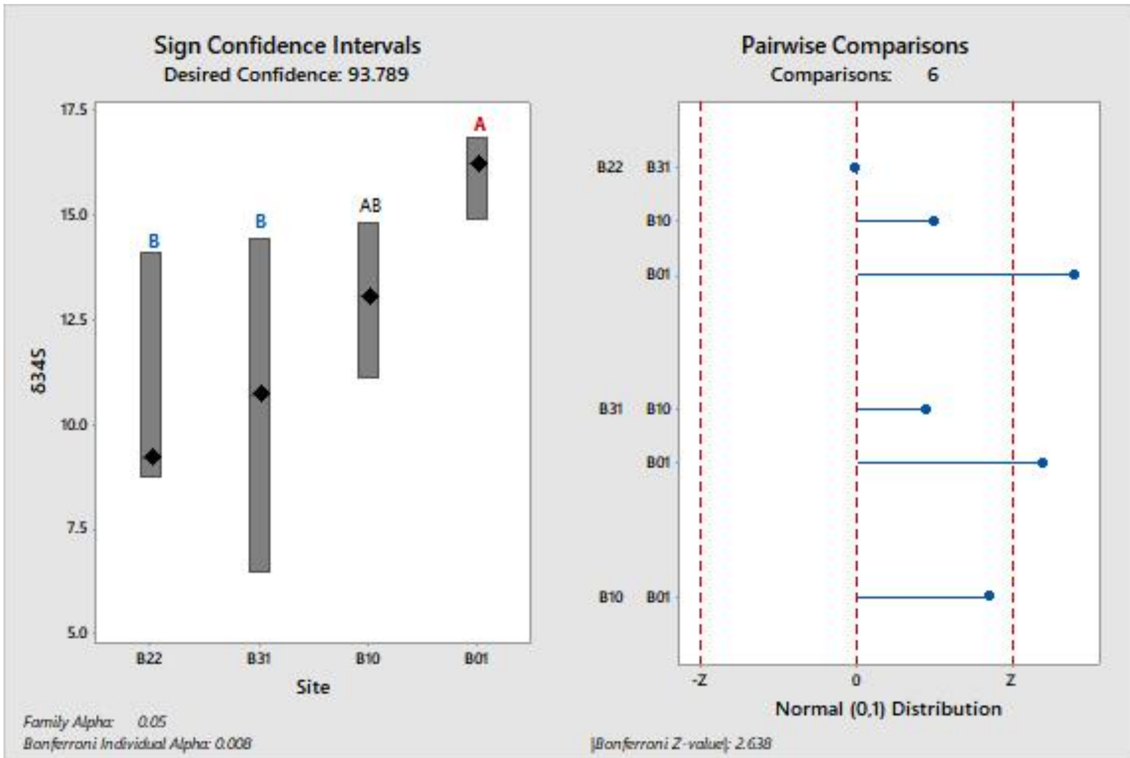

Figure 23. Dunn's multiple comparison test of Atlantic Croaker $\delta^{34}S$ values between sites. Gray boxes depict 93% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

Season Specific Comparisons

The average $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ values were plotted with standard error bars by seasons (Figures 24A and 24B). Values of $\delta^{15}N$ were greater in the summer, likely due to increased irrigation of crops and runoff from nitrogen-based fertilizers which are usually enriched with heavier isotopes (Fry 2006). During the summer $\delta^{34}S$ values were higher, possibly due to decreased flows and increased inundation of seawater which is enriched with heavier isotopes of sulfur.

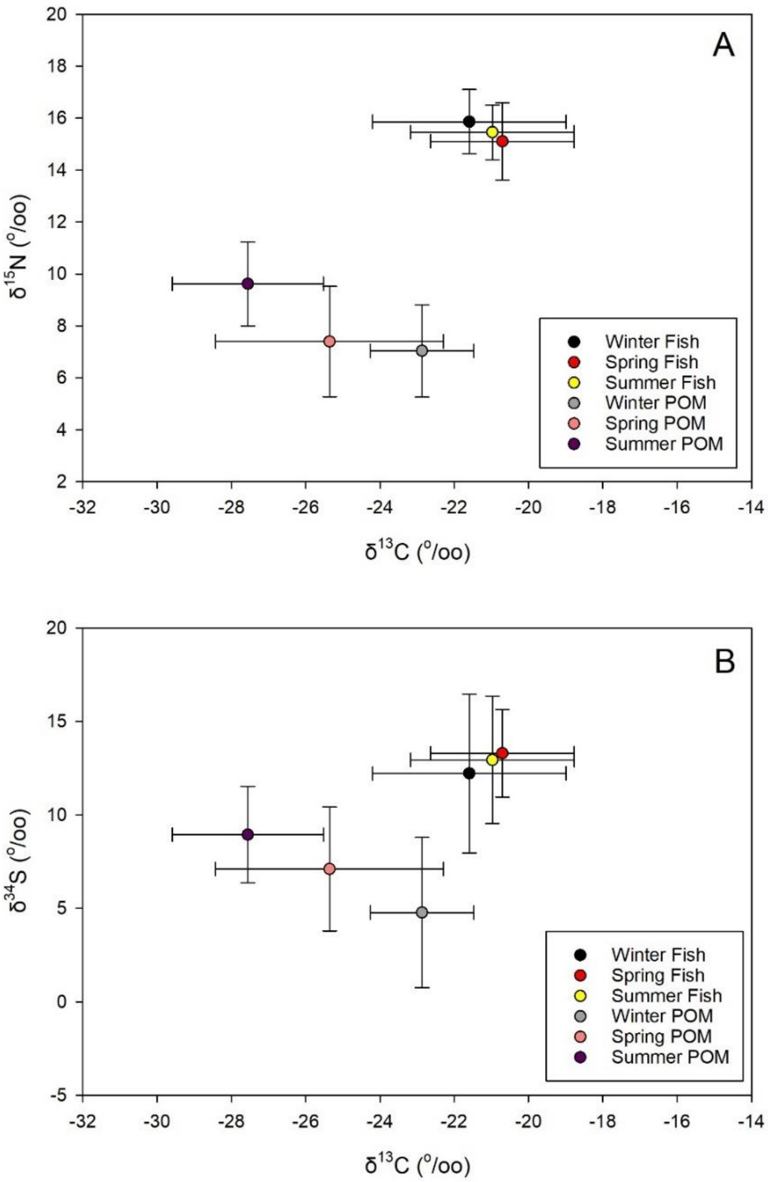

Figure 24. Scatterplot of average Atlantic Croaker and POM isotope values of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ by season. The black lines extending from each average bubble represent the standard error of the average isotope value from that season. Panel A depicts $\delta^{13}C$ vs $\delta^{15}N$ and Panel B depicts $\delta^{13}C$ vs $\delta^{34}S$.

Kruskal Wallis one-way ANOVA detected significant seasonal differences in Atlantic Croaker $\delta^{15}N$ values. Winter Atlantic Croaker collections exhibited significantly higher $\delta^{15}N$ compared to spring collections. ($P = 0.004$) (Table 1) (Figure 25). No significant seasonal groupings were detected in $\delta^{13}C$ and $\delta^{34}S$ values in Atlantic Croaker between seasons (Table 1).

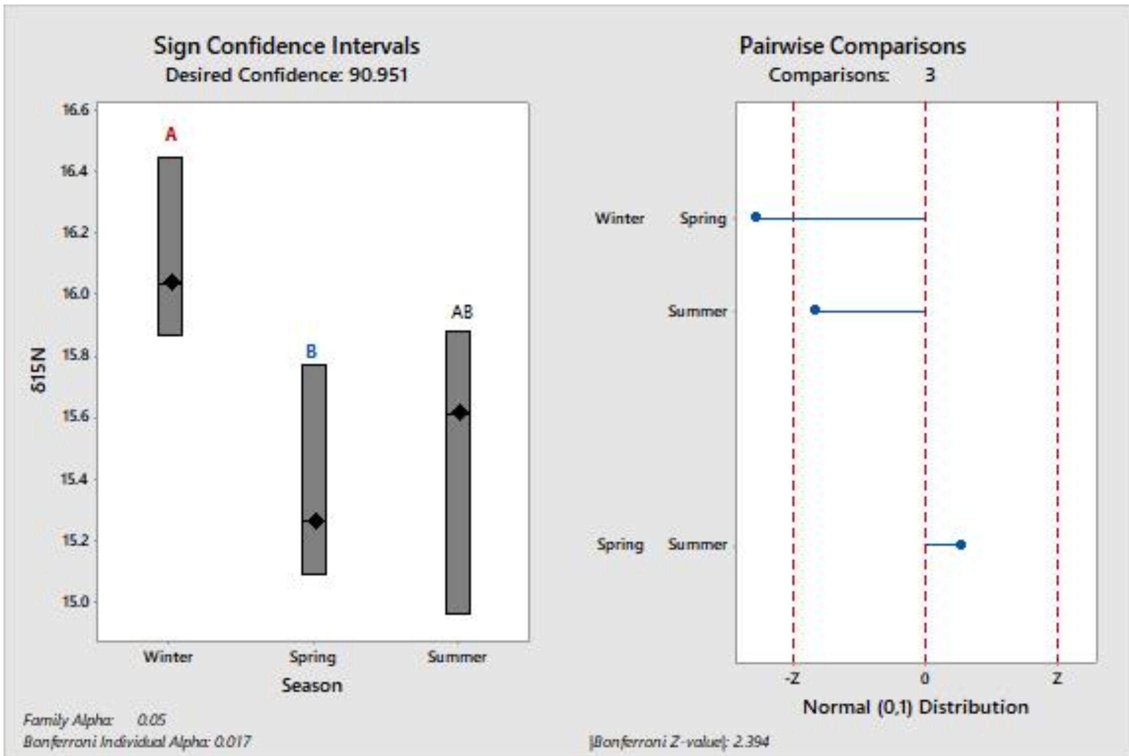

Figure 25. Dunn's multiple comparison test of Atlantic Croaker $\delta^{15}N$ values between seasons. Gray boxes depict 90% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

Flow Specific Comparison

Flow impacted nekton CPUE, as well as, Atlantic Croaker isotope results. Atlantic Croaker collected during moderate flow tiers exhibited enriched $\delta^{13}C$ and $\delta^{34}S$ in comparison to low flow conditions ($P = 0.0055$ and $P = 0.0004$) (Table 1) (Figures 26 and 27). No significant differences in Atlantic Croaker$\delta^{15}N$ values collected during varying flows were detected (Table 1).

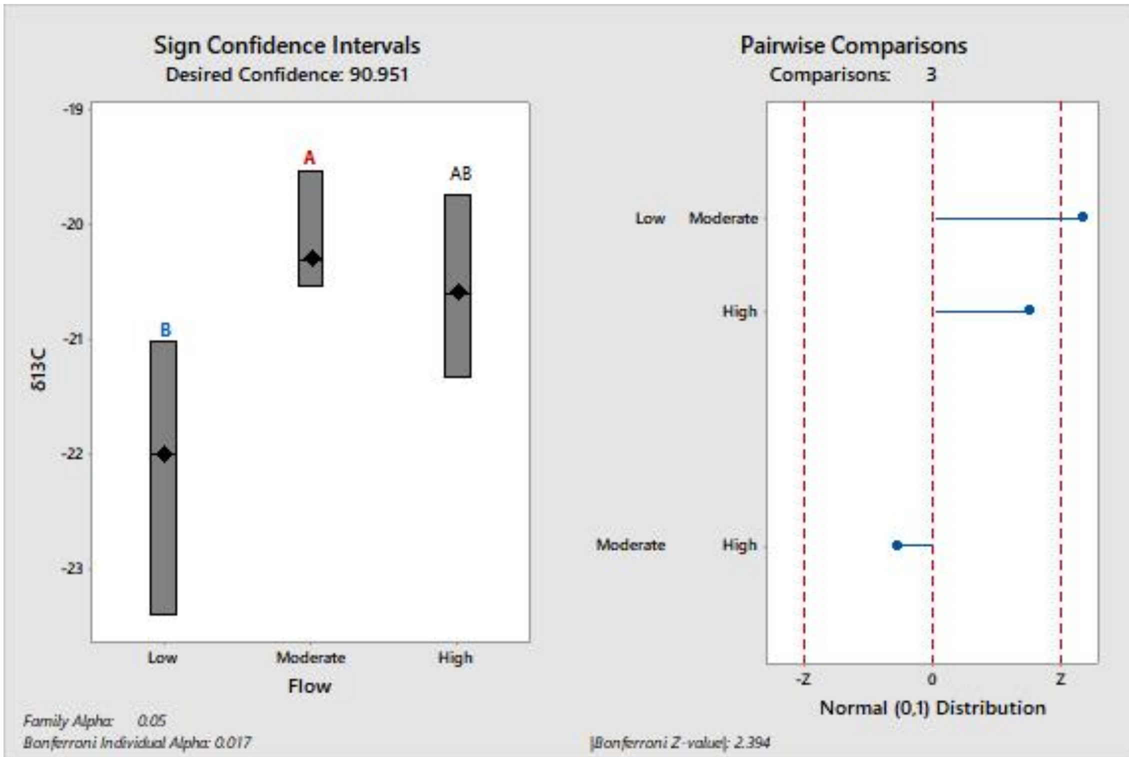

Figure 26. Dunn's multiple comparison test of Atlantic Croaker $\delta^{13}C$ values between flow tiers. Gray boxes depict 90% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

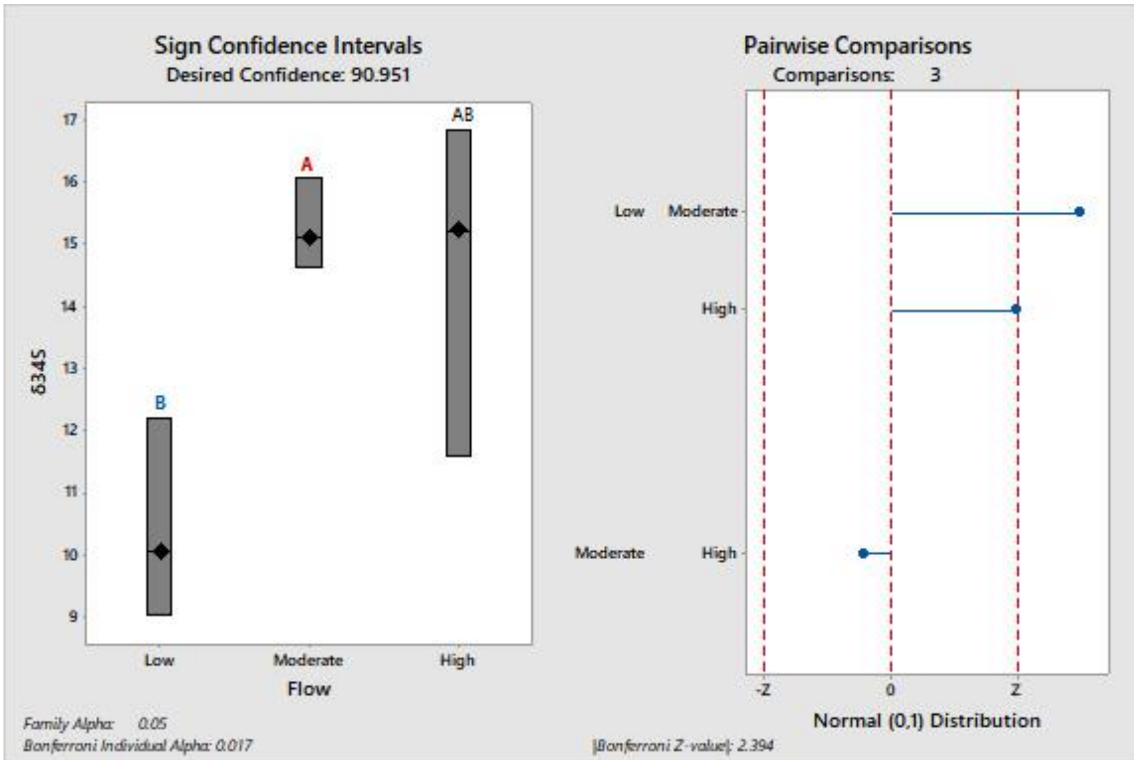

Figure 27. Dunn's multiple comparison test of Atlantic Croaker $\delta^{34}S$ values between flow tiers. Gray boxes depict 90% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

As with seasonality, the overall relationship between flow and isotope measurements was presented in a plot of mean $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ isotope values, with standard error calculations (Figure 28).

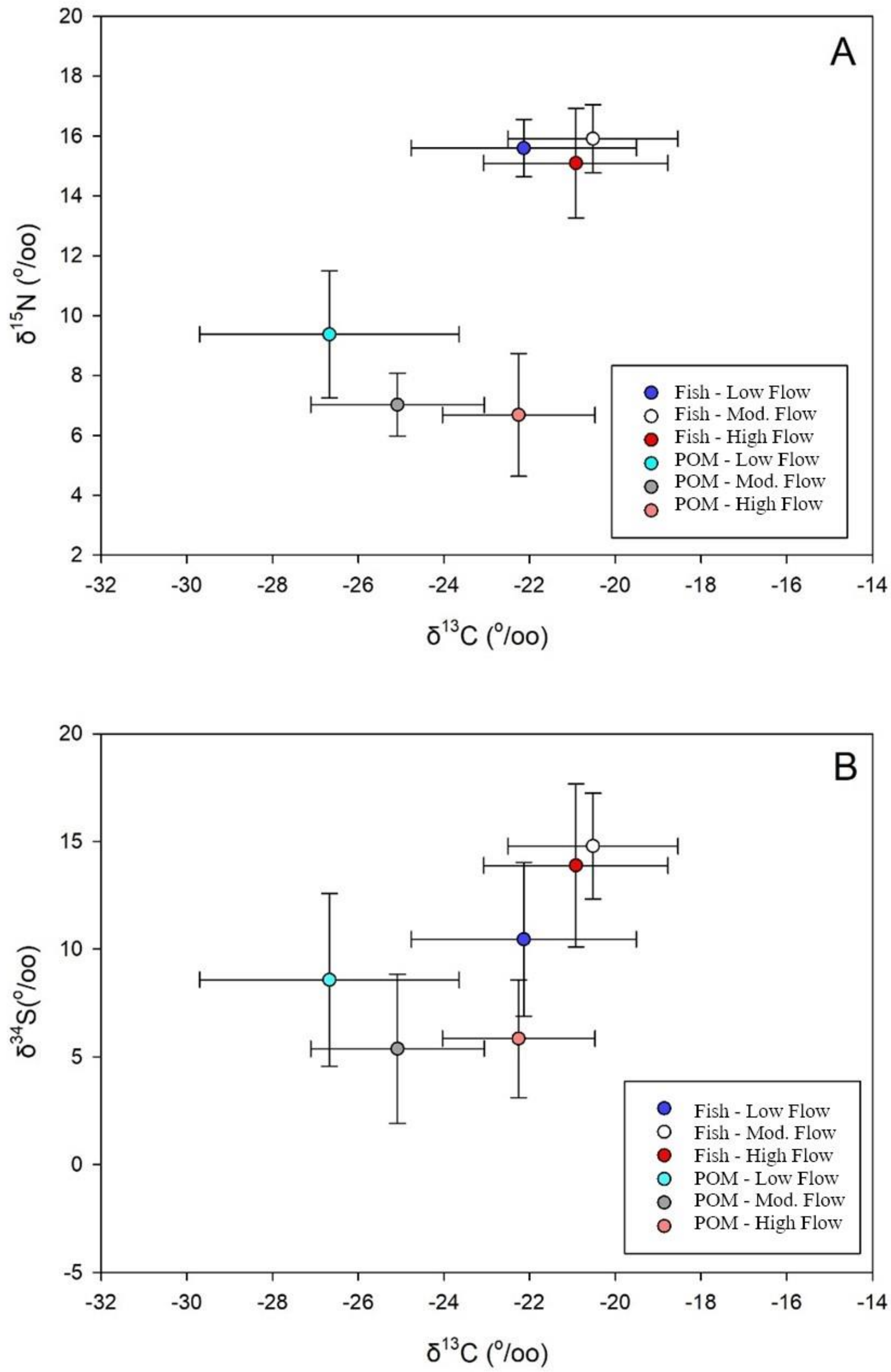

Figure 28. Scatterplot of average Atlantic Croaker and POM isotope values of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ by flow tier. The black lines from each average bubble represent the standard error of the average isotope value for each flow tier. Panel A depicts $\delta^{13}C$ vs $\delta^{15}N$ and panel B depicts $\delta^{13}C$ vs $\delta^{34}S$.

Length Specific Comparisons

Length and age are important factors that can influence the isotopic composition of fish. Regression analysis failed to detect any linear relationship between $\delta^{13}C$. $\delta^{34}S$, and length (*P* = 0.972 and *P* = 0.897), while $\delta^{15}N$ yielded a significant negative relationship with length, *P* = 0.041 (Figures 29 - 31). The Atlantic Croaker collected were also grouped into length bins, where the average $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$ of each bin and standard error was plotted (Figure 32).

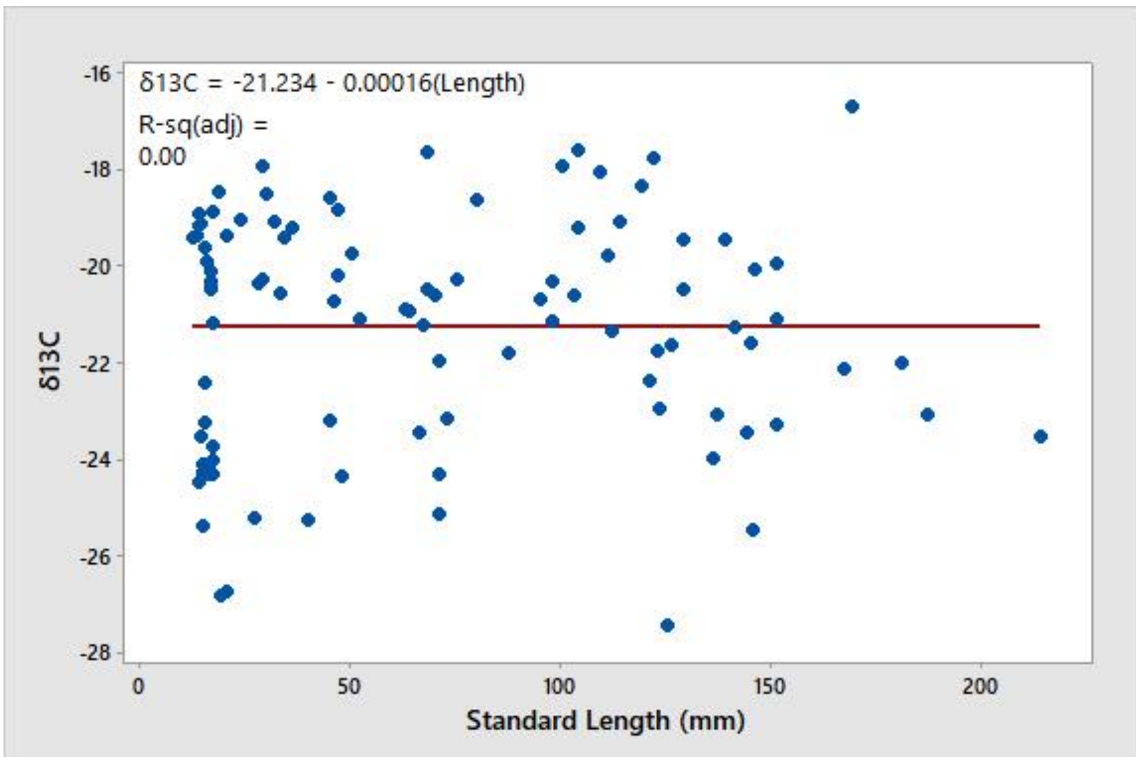

Figure 29. Scatterplot of $\delta^{13}C$ vs Atlantic Croaker standard length. The red line represents the regression equation.

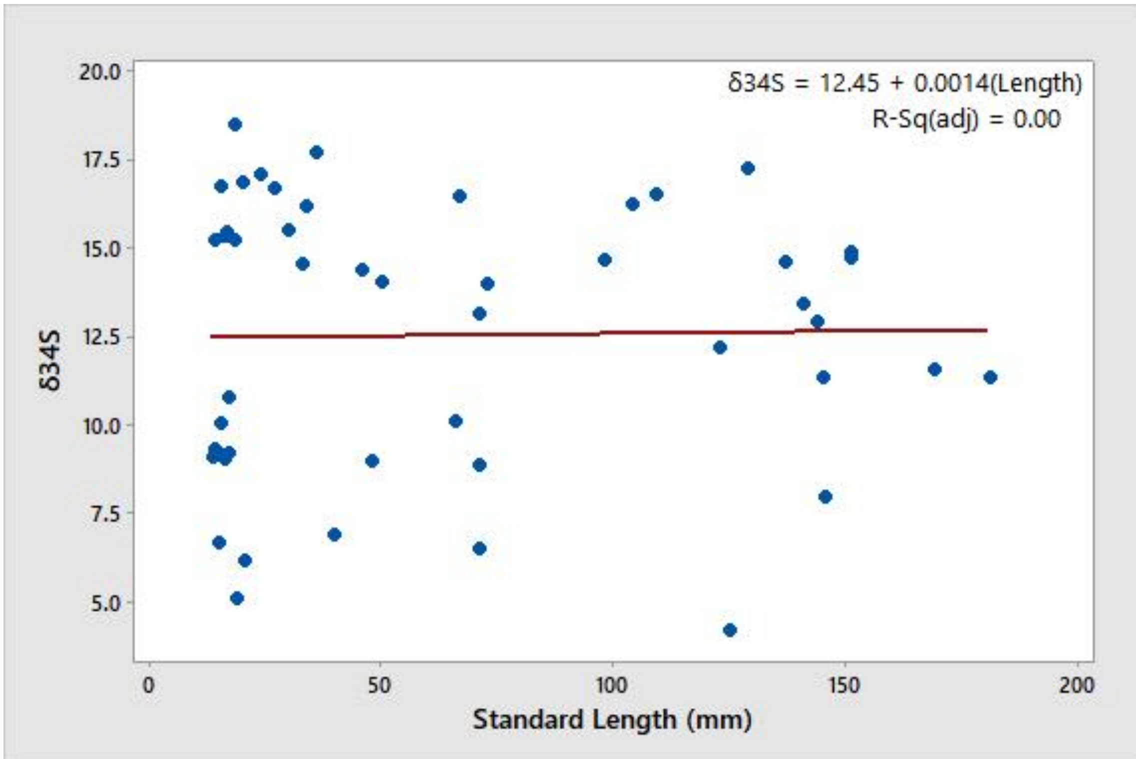

Figure 30. Scatterplot of $\delta^{34}S$ vs Atlantic Croaker standard length. The red line represents the regression equation.

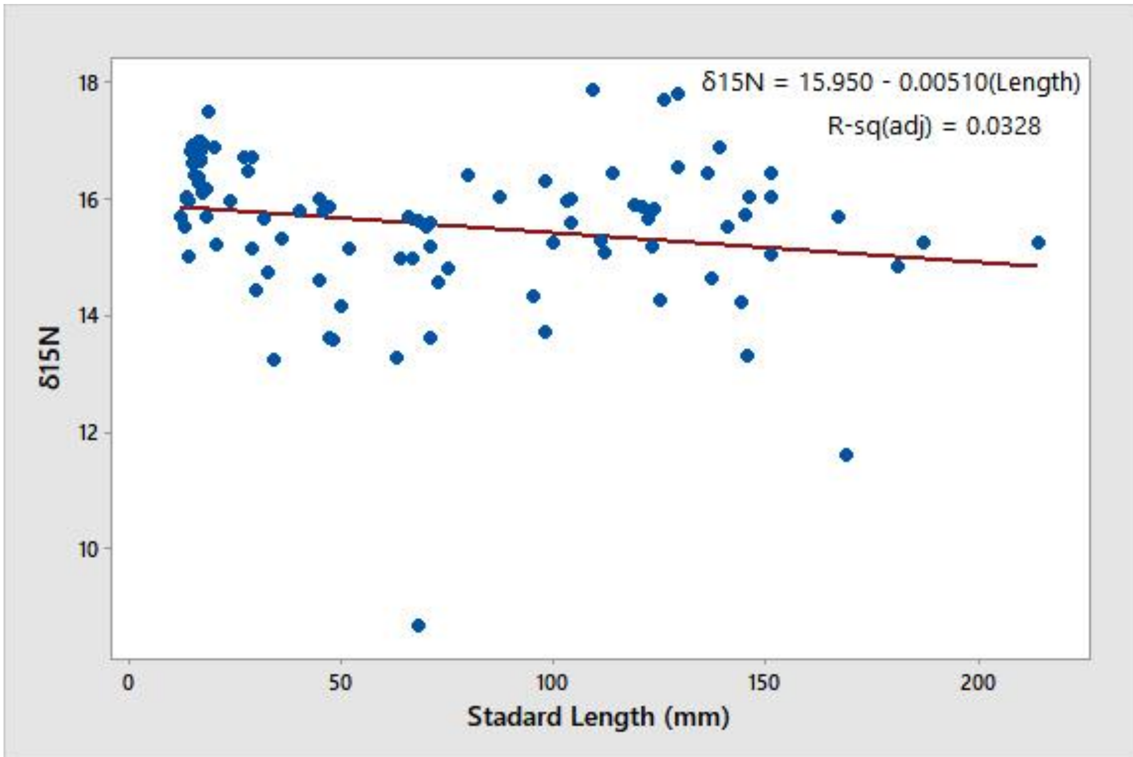

Figure 31. Scatterplot of $\delta^{15}N$ vs Atlantic Croaker standard length. The red line represents the regression equation.

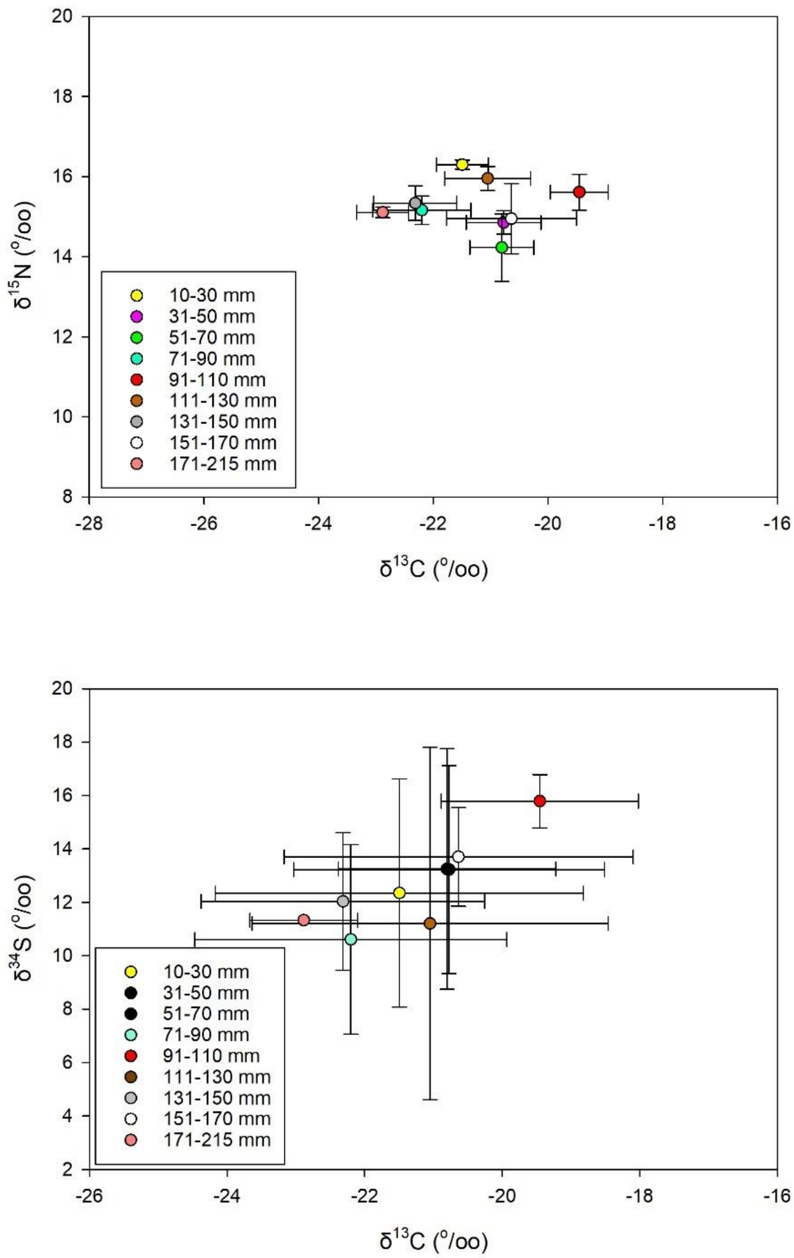

Figure 32. Scatterplot of average $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$ of each Atlantic Croaker length bin. The whiskers coming from each average bubble represent the standard error of the isotope value for the bin.

Kruskal Wallis one-way ANOVA detected no significant differences in $\delta^{13}C$ and $\delta^{34}S$ versus length bins. (Table 1). Recorded values for $\delta^{15}N$ showed the 10-30 mm bin was significantly enriched compared with the 31-50- and 51-70-mm bins, $P = 0.000$ (Table 1) (Figure 33).

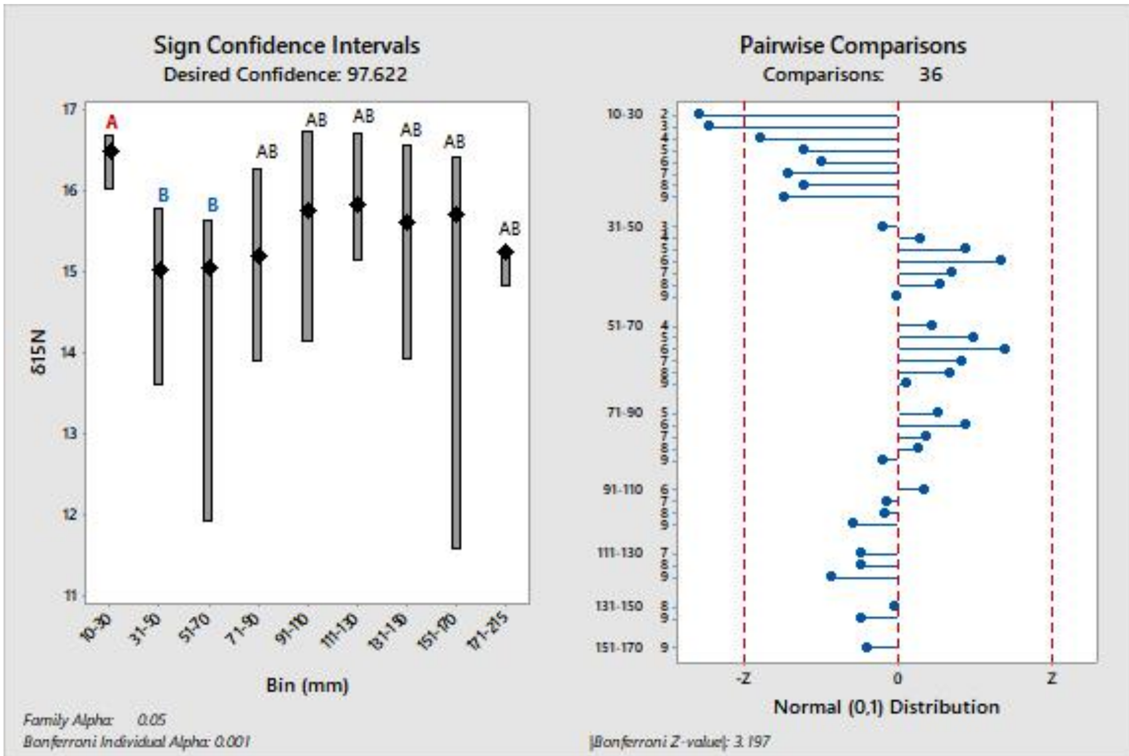

Figure 33. Dunn's multiple comparison test of Atlantic Croaker $\delta^{15}N$ values between length bins. Gray boxes depict 97% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

Particulate Organic Matter (POM) Isotope Analysis

Statistical Comparisons Sites

The results of site-specific comparisons were used to determine impacts of factors such as salinity or location on the $\delta^{13}C$, $\delta^{15}N$, or $\delta^{34}S$ contained in the POM of the water column. Significant differences in isotope readings were detected using one-way ANOVA or Kruskal Wallis one-way ANOVA and Dunn's multiple comparison test when applicable. Site B01 $\delta^{34}S$ was significantly enriched from those of B31 and B42, P = 001 (Table 1). Values of $\delta^{13}C$ and $\delta^{15}N$ did not exhibit any significant differences between sites (Table 1).

Statistical Comparisons – Seasonal Patterns

Similar to nekton, seasonal variation can also have implications on a variety of water quality variables. Kruskal Wallis one-way ANOVA analyses detected significant differences between $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$ and season. The measure of $\delta^{13}C$ was enriched during the winter, when compared to summer and spring, $P = 0.000$ (Table 1) (Figure 34). Values of $\delta^{15}N$ were significantly enriched during the summer in comparison to winter and spring season, $P = 0.004$ (Table 1) (Figure 35). Finally, $\delta^{34}S$ measures were also enriched in summer compared to the winter collections, $P = 0.025$ (Table 1) (Figure 36).

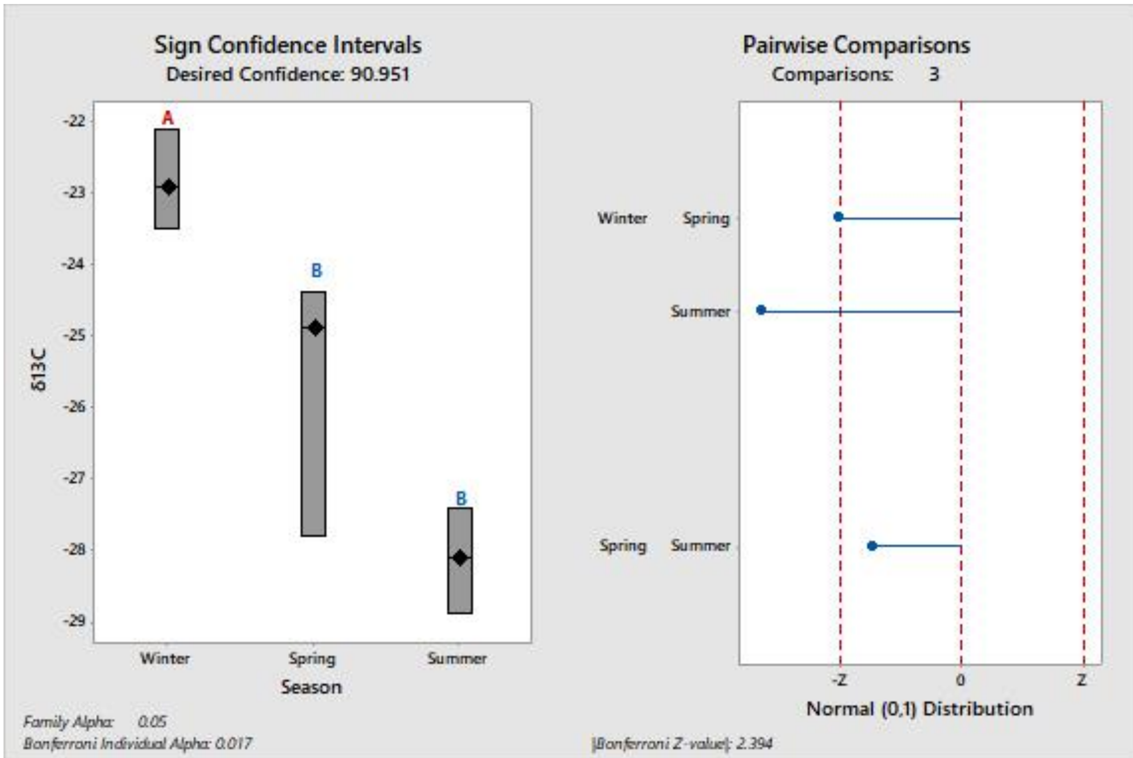

Figure 34. Dunn's multiple comparison test of POM $\delta^{13}C$ values between seasons. Gray boxes depict 90% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

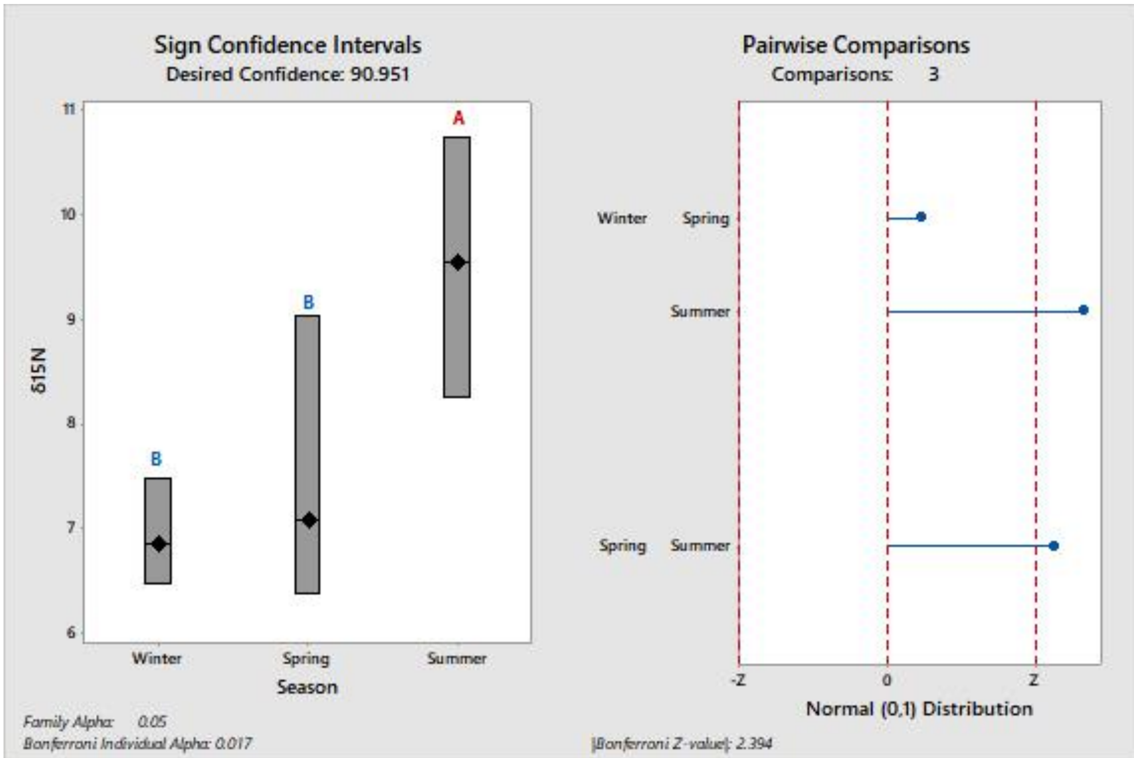

Figure 35. Dunn's multiple comparison test of POM $\delta^{15}N$ values between seasons. Gray boxes depict 90% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

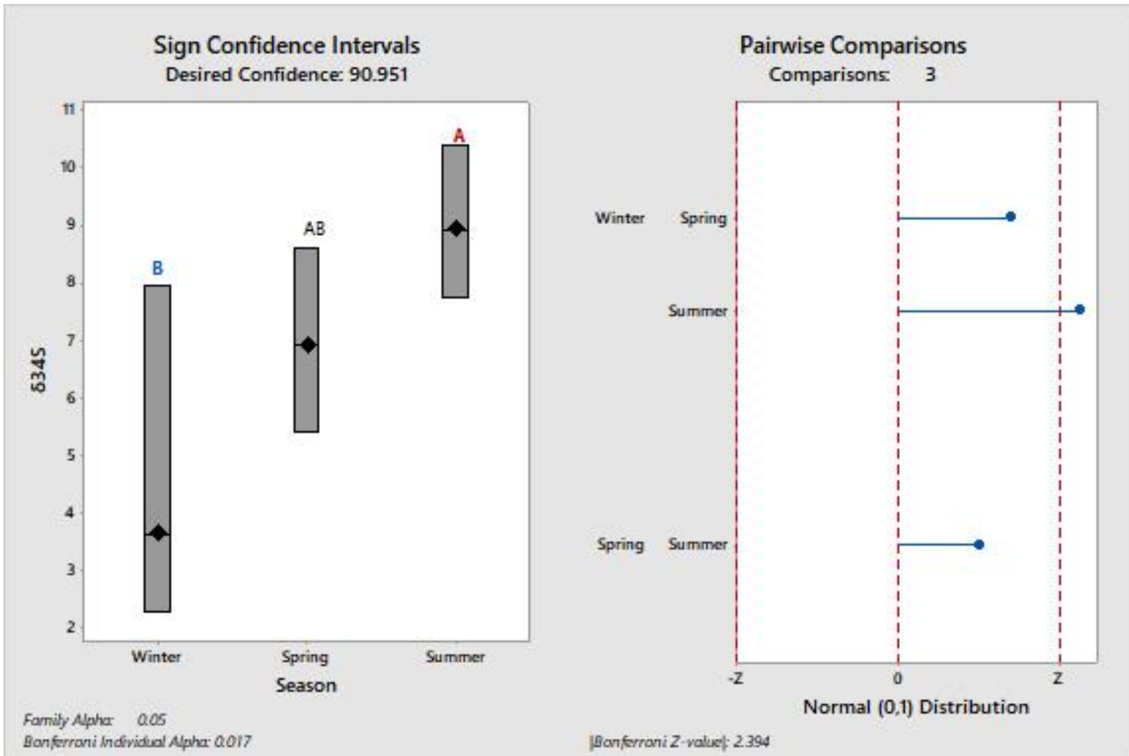

Figure 36. Dunn's multiple comparison test of POM δ^{34}S values between seasons. Gray boxes depict 90% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

Statistical Comparison - Flow

Both river discharge and seasonality can influence cycling and movement of isotopes and their composition in nekton, POM, at the landscape and biological community level. Values of δ^{13}C in POM showed significant differences between flow tier, with high flow enriched compared to moderate flow, P = 0.000, and moderate flow enriched from low flow (Table 1). Results for δ^{15}N diametrically opposed the carbon readings, low flow collections were significantly enriched from both moderate and high flows, P = 0.003(Table 1) (Figure 37). Comparison of δ^{34}S and flow tiers did not detect any significant results (Table 1).

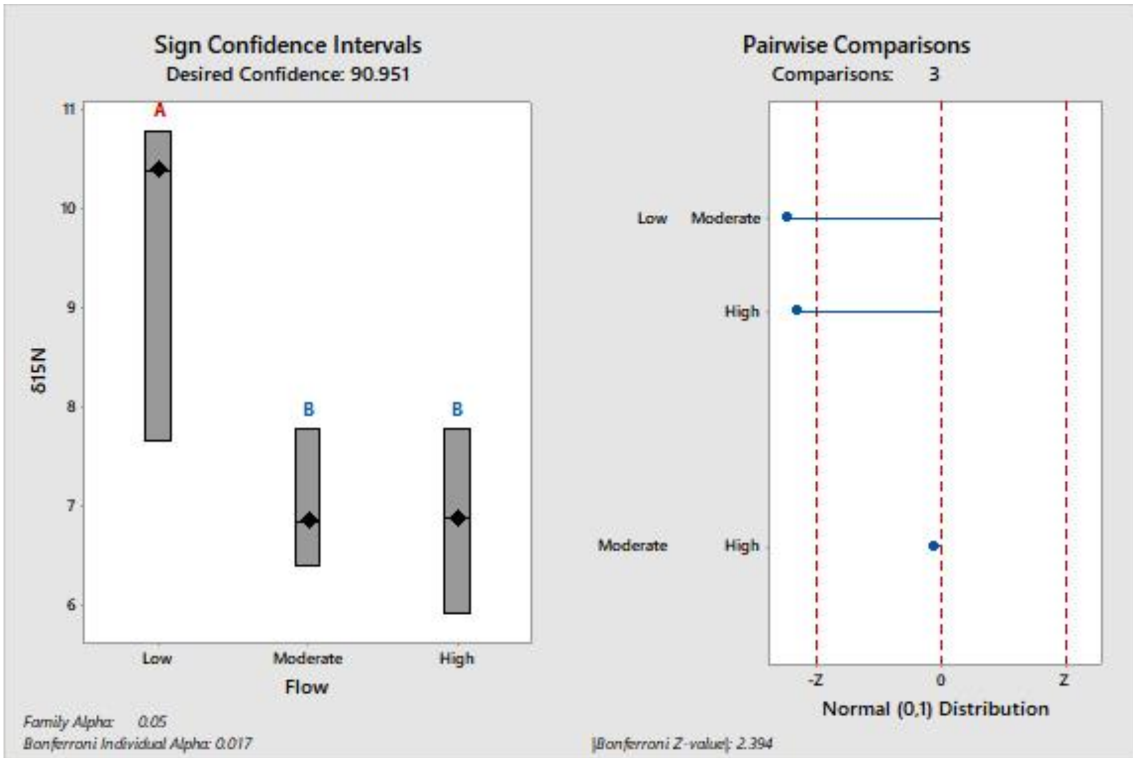

Figure 37. Dunn's multiple comparison test of POM $\delta^{15}N$ values between flow tiers. Gray boxes depict 90% confidence interval for the median, black diamonds are the median CPUE, and the different colored letters are the significant groups.

CHAPTER IV:

DISCUSSION

Otter Trawl Nekton Collections

Relationship of Salinity on Otter Trawl Nekton Community Structure

The importance of river discharge and salinity on the composition and life history of riverine and marine organisms is well documented in the literature (Junk et al 1989, Cunjak 1992, Zeug and Winemiller 2008). However, this study in the Brazos River was unique as flow and salinity both played significant roles in the variation seen in taxa CPUE, diversity, and composition (Table 1). The significant groupings of collections across sites based on taxa composition were likely caused by the influence of varying salinity on individual biota. Salinity was highest at B01 and continued to drop at each successive upstream site (Figure 4). The BEST analysis identified bottom salinity as the best individual and overall measured variable that explained the majority of variation in the biological resemblance matrix of otter trawl biota (Table 2-2). Past studies have also documented salinity as a primary variable impacting estuarine nekton diversity, CPUE, and composition (Cunjak 1992, Chao and Musick 1977). SIMPER analysis also detected that the similarity/dissimilarity, within and between collection sites was primarily driven by changes in the composition and CPUE of marine and fresh water nekton. The best examples of the influence of salinity on taxa composition was observed when comparing the average similarity of sites B01 and B42. Frequently, Site B01 exhibited the highest salinity and the species that contributed the largest percentage (62%) to the average similarity within collections at the site were Star Drum, Atlantic Croaker, and White Shrimp (Table 2-3). In contrast, B42 always exhibited the lowest salinities within the study area and Blue Catfish and *Macrobranchium* spp. contributed 98% to the similarity of the collections at B42 (Table 2-3). The role of salinity being the primary driver in structuring the nekton community is further supported by the observed average dissimilarity (97.49%) between collections at B01 and B42 with Atlantic Croaker, Star Drum, *Macrobranchium* spp., and Blue Catfish cumulatively contributing nearly 50% to this dissimilarity of collections between the sites (Table 1-3).

Relationship of Discharge on Otter Trawl Nekton Community Structure

The lower Brazos River is a dynamic estuarine system due to lack of a large lagoon type estuary and the discharge of the river into the Gulf of Mexico. This leads to a highly variable flow regime that rapidly influences salinity, which in turn impacts the biota. As with traditional river ecology river discharge is traditionally considered to be one of the primary variables responsible for stratifying biological communities in estuaries (Cheshire et al 2015, Zeug and Winemiller 2008, Cunjak 1992). In the lower Brazos however, the salinity was identified as the strongest environmental predictor of variation in the biological resemblance matrix (Table 2-2). However, river discharge was the primary variable responsible for stratifying the salinity within the lower river. Higher discharges migrated the salt wedge closer to the coast and lower discharges allowed the salt wedge to migrate further upstream. No significant differences in CPUE, taxa richness, or diversity were detected in collections taken from different flow tiers. However, low flow tiers had the largest mean CPUE (4.8), diversity (0.91), and taxa richness (7.4) (Tables 4-4, 4-7, and 4-10). Cheshire et al 2015 detected similar results as discharge and relative water level described a significant amount of variation in taxa assemblage in a south Australian estuary. Lower river discharges in the Brazos river allowed more marine nekton to easily enter the estuary and migrate upstream (Figure 12). This increased CPUE, taxa richness, and diversity values during low flow tier collections. Taxa in the Brazos river showed an affinity to certain habitat types and physical variables. However, the taxa also proved resilient, quickly returning to status quo after encountering short term spatial and temporal changes.

Relationship of Seasonality on Otter Trawl Nekton Community Structure

Seasonal changes in water quality variables such as flow, salinity, and temperature were observed during the Brazos river study (Figures 3 - 4, and 6). These changes also contributed to variations detected in the nekton community. No significant differences were detected in mean CPUE, taxa richness, or diversity between collections of different seasons. Collections done during the winter season recorded the largest mean CPUE (4.6) and taxa richness (6.6) results (Tables 4-3 and 4-6). Atlantic Croaker are common in Brazos river collections and the higher CPUE values can be attributed to this species. Winter is the time when the greatest incidence of Atlantic Croaker, and other fish of the Sicaenidae family, spawn and recruit to estuaries (Soto et al. 1998). Previous research, as well as the current study, collected recently spawned Atlantic Croaker, in significant abundance during the winter season (Johnson 1977, Miller 2014). The variation in water quality parameters lead species to emigrate or immigrate during different seasons, which led to small changes in the nekton community throughout the study duration.

Beam Trawl Collections

Relationship of Salinity on the small Nekton/Zooplankton Community Structure

Salinity followed a gradient with the highest values recorded at B01 and the lowest recorded at B42 (Figure 4). The BEST analysis identified surface salinity was the best individual and overall measured variable that explained the majority of the variation in the biological resemblance matrix of beam trawl biota (Table 3-2). No significant differences were detected in CPUE between the collections from different sites. However, B42 had the largest mean CPUE of all sites (2.63) and a significantly greater median taxa richness (4) than B01 (1), $P = 0.038$ (Tables 4-14 and 4-17) (Figure 13). The reason for these results is likely less salinity and more habitat dependent. Previous studies determined river edges with cover recorded greater CPUE and diversity of small nekton and zooplankton than edges without cover (Winemilller 2008, Junk et al 1989, Andersen 1983). Site B42 had more cover along the river in the form of fallen trees and debris than the downstream sites. This allowed for a larger number of small nekton and zooplankton taxa to inhabit these areas. However, salinity did impact the small nekton and zooplankton community composition. ANOSIM analyses detected significant differences in similarity from collections taken at B01 and B42, $P = 0.001$ and $\rho = 0.481$ (Table 3-6). While SIMPER analysis also detected a 95.74% dissimilarity between B01 and B42 collections (Table 3-3). Chao and Musick (1977) determined salinity were a primary variable in structuring changes in community composition and CPUE in nekton. The collection of small marine nekton and zooplankton downstream, coupled with freshwater nekton and zooplankton taxa collected upstream was the reason for these differences in community composition.

Relationship of River Discharge on the small Nekton/Zooplankton Community Structure

No significant differences were detected when CPUE, taxa richness, and diversity were analyzed against collections taken at low, moderate, and high flow tiers. However, taxa richness (3.0) and diversity (0.630) were larger when collected during high flow tier (Table 1). These results contradict previous studies, where an increase in discharge resulted in a decrease in zooplankton diversity (Venkataramana et al 2017, Kaartvedt and Nordby 1992). The previous studies sampled using bongo style plankton nets towed in the centroid of flow, in the mid to upper water column. When discharge increases zooplankton move to deeper depths, as well as, get forced out of the estuary (Kaartvedt and Nordby 1992). This caused fewer zooplankton to be collected without adjusting collection depth. The use of shallow, river edge beam trawl in the Brazos river study allowed for sampling in a more sheltered environment, out of the flow center. Also, the beam trawl targeted small nekton and zooplankton, which the previous studies were not interested in quantifying.

Relationship of Season on the small Nekton/Zooplankton Community Structure

Seasonal variation in water temperature and taxa life history ecology were the primary factors explaining seasonal differences seen in beam trawl CPUE and taxa richness. Significantly lower CPUE (1.057) and taxa richness (1.0) was detected in samples collected during the summer season, P = 0.002 and 0.009 (Table 1). During the summer season, surface water temperature reached and sustained 30^{o}C (Figure 6). Kupchik and Shaw (2016) determined plankton and nekton that inhabited shallow, river edge habitats moved to deeper depths to avoid high temperature stress. This movement likely contributed to the lower CPUE and richness values seen in the summer months. Significant differences in taxa similarity were also detected between the collections taken during each season, P = 0.001 and ρ = 0.123 (Table 3-8). Bay Anchovy contributed 74.33% to the similarity detected in collections taken during the summer months (Table 3-5). This coincides with the early summer spawning and recruitment period of this species (Jung and Houde 2004). Atlantic Croaker and White Shrimp contributed 69.96% to the similarity detected in collections taken during the winter months. The spawning and recruitment period for this species occurs during the winter and spring months (Rivera-Velázquez 2008, White & Chittenden 1976, Juhl et al 1975). Unique life history and variation in water quality played key roles in structuring the small nekton and zooplankton community.

Atlantic Croaker CPUE and Size distribution

Atlantic Croaker were collected at four of five sites throughout the study (Figure 16). Significantly greater median CPUE were detected at sites B01 (30.0) and B10 (17.5), $P = 0.000$ (Table 1) (Figure 16). This is expected because adult Atlantic Croaker prefer higher salinities (Force 2017). No other significant differences in CPUE were detected, however collections during the winter season recorded the largest CPUE (35) of all seasons (Table 4-27). Furthermore, fish collected during the winter season were significantly shorter (31.0) Atlantic Croaker than spring (71.5) and summer (119.0) seasons, $P = 0.000$ (Table 4-33) (Figure 18). The majority of Atlantic Croaker spawning and recruitment occurred during the winter season and increased catch of smaller individuals was the result (White & Chittenden 1976, Juhl et al 1975). Hansen (1965) recorded these smaller individuals migrate further into the estuary than larger adults. Atlantic Croaker demonstrated similar life history and recruitment patterns during the current study. Site B22 recorded the lowest median length (18.0) of all sites where Atlantic Croaker were collected (Table 4-29) (Figure 17).

Stable Isotope Analysis of Atlantic Croaker and Particulate Organic Matter (POM)

Relationship of Location on Atlantic Croaker and POM Isotopes

The flow of organic matter through a food web can be traced using stable isotope measurements from producers and consumers in the food web (Peterson et al 1985). Significantly enriched $\delta^{13}C$ and $\delta^{34}S$ was detected from Atlantic Croaker collected at site B01, $P = 0.000$ and 0.001 respectively (Table 1) (Figures 22 and 23). A general decrease in $\delta^{13}C$ and $\delta^{34}S$ of fish and organic matter was detected with increased distance upriver (Figures 22 and 23). This same relationship was recorded in juvenile fish and organic matter collected in both a Japanese and an Australian estuary (Kiyashko et al 2011, Hadwen et al 2007). The more enriched $\delta^{34}S$ sources from sea water sulfates, and $\delta^{13}C$

from marine organic matter and phytoplankton, lead to enriched $\delta^{13}C$ and $\delta^{34}S$ in Atlantic Croaker collected near the river mouth.

Relationship of Season on Atlantic Croaker and POM Isotopes

No statistically significant differences in nekton CPUE, richness, or diversity were detected in collections from the three seasons (Table 1). However, significant differences in flow were seen with season, along with seasonal variations in $\delta^{15}N$ of Atlantic Croaker and $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ of POM (Table 1) (Figures 3, 25, and 34 – 36). The result of primary interest was the significantly enriched $\delta^{13}C$ of POM (-22.91) from the winter collections, $P = 0.000$ (Table 1) (Figure 34). Harmelin-Vivien et al (2010) found this same result when sampling POM of the Rhone River in coastal France. The cause of the depleted $\delta^{13}C$ values seen in the Rhone River during spring was attributed to the higher concentrations of phytoplankton and the precipitous drop in phytoplankton during the winter caused the enrichment of POM $\delta^{13}C$ measures (Harmelin-Vivien et al 2010). This also seems to explain some variation seen in the Brazos River study as during the winter months primary production slows and likely impacts the $\delta^{13}C$ measurements of POM in the river. POM also recorded significantly enriched $\delta^{34}S$ (8.92) and $\delta^{15}N$ (9.54) during the summer months (Table 1) (Figures 35 and 36). Previous research by Leakey et al (2008) recorded similar results, with fresh water POM $\delta^{34}S$ significantly depleted compared to marine water. River discharge was also significantly lower in summer (2812.91) months, allowing the more saline Gulf water to migrate further up the estuary (Table 1) (Figures 3 and 4). This caused more sites to record enriched $\delta^{34}S$ values during the summer months and thus contributed to the seasonal enrichment observed.

Fish Length and Isotopes

Enriched δ^{15}N from Atlantic Croaker collected during winter collections was unexpected. The mean length of Atlantic Croaker collected during the winter (31.0) was shorter than all other seasons (Table 4-30) (Figure 18). Previous studies have detected more depleted δ^{15}N from smaller individuals and an enrichment in δ^{15}N with increasing length (Pepin and Dower 2007, Fry 2006, Vander Zanden and Rasmussen 2001, Peterson and Fry 1987, Peterson et al. 1985). However, discharge was increased during the winter months (3428.5) and this may transport enriched δ^{15}N runoff from farmlands and homes upstream to the near gulf area (Table 1) (Figure 3). Similar results were recorded in Fry (2006) when artificial enrichment in δ^{15}N was detected due to increased fertilizer runoff into the water body.

Conclusions

Stable isotope analysis is a useful tool for assessing the trophic structure of communities and populations. In the current study it would have been ideal to also utilize stable isotopes measurements from selected Atlantic Croaker prey, however complications with the contract laboratory delayed those results from being available in time for completion of the manuscript. Using predator, prey, and ambient environmental measurements of isotopes would provide a better description of the interactions of Atlantic Croaker, upstream POM and potential prey items, along with actual prey items captured during the study period. Long term monitoring of stable isotopes of POM, invertebrates, and nekton can be used to assess the response of the Brazos River estuary ecosystem to varying amounts of freshwater.

Results of the current study further supported Miller 2014 and Johnson 1977 in the importance of the Brazos River as a habitat for estuarine nekton and zooplankton. Furthermore, pulses in freshwater inflow significantly altered both the salinity and isotopic regimes of the estuary. High discharges were accompanied by a nearly complete exclusion of the salt wedge from the lower Brazos River. The habitat in the lower river became unsuitable for marine nekton in these cases and caused a significant decrease in the number of taxa collected (Table 1).

Fresh water pulses also contained sources of inland carbon and depleted sources of sulfur. Increased discharge pushed out small phytoplankton, causing the pool of carbon to become enriched, as well as, pushing the marine water from the lower river. With this the naturally enriched marine sulfates and zooplankton in the lower river were also forced out to the Gulf, drastically changing the environment of the lower Brazos River.

With the potential for these changes to occur from alterations in discharge, proper management practices need to be adopted in the Brazos River estuary. Monitoring of changes in river discharge are important to help predict both impacts on the nekton community, and the water isotope chemistry. Also, consistent monitoring of the nekton in the lower river using methods such as trawls and gill nets to effectively quantify the nekton community throughout the year. Furthermore, both continuous and consistent long-term monitoring of the water quality variables other than discharge, including temperature, salinity, pH, and dissolved oxygen. Commercially and recreationally important nekton species all use this estuary as an environment to live and mature, immediate notifications to changes in water quality can be vital in maintaining a healthy nekton community. Finally, implementation of a consistent long-term analysis of the isotope values of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ in water particulates, important nekton species, and nekton prey. These analyses provide the data to determine potential impacts of runoff to the lower river, including potential of enriched nitrogen sources from fertilizers, or enriched carbon from increase organic matter. The Brazos River is an important estuary for many species of marine and fresh water nekton and proper management will provide prolonged use of this resource.

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APPENDIX I. NEKTON/ZOOPLANKTON CATCH AND ISOTOPE SUMMARY STATISTICS.

Table 1-1. Otter trawl nekton summary statistics. Cumulative values for each collection are listed.

SAMPLE	DATE	SITE	SEASON	FLOW TIER	TOTAL CPUE	TOTAL TAXA	DIVERSITY (H')	PIELOU'S (J)
B01-D	12/1/2016	B01	WINTER	Low	231	13	1.1	0.4
B10-D	12/1/2016	B10	WINTER	Low	210	9	1.5	0.7
B22-D	12/1/2016	B22	WINTER	Low	391	5	0.5	0.3
B31-D	12/1/2016	B31	WINTER	Low	240	7	0.9	0.5
B42-D	12/1/2016	B42	WINTER	Low	99	3	0.5	0.5
B01-D2	12/20/2016	B01	WINTER	Moderate	2737	13	0.4	0.1
B10-D2	12/20/2016	B10	WINTER	Moderate	318	12	0.7	0.3
B22-D2	12/20/2016	B22	WINTER	Moderate	1093	6	0.1	0.0
B31-D2	12/20/2016	B31	WINTER	Moderate	65	5	1.1	0.7
B42-D2	12/20/2016	B42	WINTER	Moderate	19	3	1.0	1.0
B01-JAN	1/31/2017	B01	WINTER	High	241	9	0.8	0.4
B10-JAN	1/31/2017	B10	WINTER	High	37	6	1.5	0.9
B22-JAN	1/31/2017	B22	WINTER	High	11	2	0.3	0.4
B31-JAN	1/31/2017	B31	WINTER	High	2	1	0.0	0.0

SAMPLE	DATE	SITE	SEASON	FLOW TIER	TOTAL CPUE	TOTAL TAXA	DIVERSITY (H')	PIELOU'S (J)
B42-JAN	1/31/2017	B42	WINTER	High	5	5	1.6	1.0
B01-MR	3/15/2017	B01	SPRING	Moderate	383	9	1.1	0.5
B10-MR	3/15/2017	B10	SPRING	Moderate	42	6	1.5	0.8
B22-MR	3/15/2017	B22	SPRING	Moderate	4	2	0.6	0.8
B31-MR	3/15/2017	B31	SPRING	Moderate	23	2	0.3	0.4
B42-MR	3/15/2017	B42	SPRING	Moderate	5	1	0.0	0.0
B01-MA1	5/1/2017	B01	SPRING	High	68	9	1.5	0.7
B10-MA1	5/1/2017	B10	SPRING	High	16	6	1.7	0.9
B22-MA1	5/1/2017	B22	SPRING	High	76	3	0.8	0.7
B31-MA1	5/1/2017	B31	SPRING	High	76	4	0.4	0.3
B42-MA1	5/1/2017	B42	SPRING	High	5	2	0.5	0.7
B01-MA2	5/24/2017	B01	SPRING	Low	986	14	0.5	0.2
B10-MA2	5/24/2017	B10	SPRING	Low	661	13	1.1	0.4
B22-MA2	5/24/2017	B22	SPRING	Low	7	2	0.7	1.0
B31-MA2	5/24/2017	B31	SPRING	Low	216	6	0.5	0.3
B42-MA2	5/24/2017	B42	SPRING	Low	75	3	0.4	0.4

SAMPLE	DATE	SITE	SEASON	FLOW TIER	TOTAL CPUE	TOTAL TAXA	DIVERSITY (H')	PIELOU'S (J)
B01-JUN	6/27/2017	B01	SPRING	High	408	10	1.1	0.5
B10-JUN	6/27/2017	B10	SPRING	High	163	10	0.9	0.4
B22-JUN	6/27/2017	B22	SPRING	High	336	6	0.4	0.2
B31-JUN	6/27/2017	B31	SPRING	High	58	3	0.8	0.7
B42-JUN	6/27/2017	B42	SPRING	High	12	2	0.6	0.9
B01-JUL	7/31/2017	B01	SUMMER	Low	1011	11	0.7	0.3
B10-JUL	7/31/2017	B10	SUMMER	Low	18	6	1.4	0.8
B22-JUL	7/31/2017	B22	SUMMER	Low	91	7	1.5	0.8
B31-JUL	7/31/2017	B31	SUMMER	Low	327	12	1.7	0.7
B42-JUL	7/31/2017	B42	SUMMER	Low	52	5	1.1	0.7
B01-SEP	9/20/2017	B01	SUMMER	Moderate	175	7	1.0	0.5
B10-SEP	9/20/2017	B10	SUMMER	Moderate	61	6	1.3	0.7
B22-SEP	9/20/2017	B22	SUMMER	Moderate	22	2	0.3	0.4
B31-SEP	9/20/2017	B31	SUMMER	Moderate	163	3	0.2	0.1
B42-SEP	9/20/2017	B42	SUMMER	Moderate	8	1	0.0	0.0
B01-OCT	10/18/2017	B01	SUMMER	Low	74	10	0.9	0.4

SAMPLE	DATE	SITE	SEASON	FLOW TIER	TOTAL CPUE	TOTAL TAXA	DIVERSITY (H')	PIELOU'S (J)
B10-OCT	10/18/2017	B10	SUMMER	Low	269	11	1.2	0.5
B22-OCT	10/18/2017	B22	SUMMER	Low	6	2	0.7	1.0
B31-OCT	10/18/2017	B31	SUMMER	Low	256	6	0.4	0.2
B42-OCT	10/18/2017	B42	SUMMER	Low	10	3	0.8	0.7

Table 1-2. Beam trawl nekton and zooplankton summary statistics. Cumulative values for each collection are listed.

Sample	Date	Site	Season	Flow Tier	Total CPUE	Total Taxa	Diversity (H')	Pielou's (J)
B01-D	12/1/2016	B01	Winter	Low	5	3	0.9	0.8
B10-D	12/1/2016	B10	Winter	Low	3	1	0.0	0.0
B22-D	12/1/2016	B22	Winter	Low	7	3	0.9	0.9
B31-D	12/1/2016	B31	Winter	Low	2	2	0.7	1.0
B42-D	12/1/2016	B42	Winter	Low	4	4	1.4	1.0
B01-D2	12/20/2016	B01	Winter	Moderate	6	2	0.7	1.0
B10-D2	12/20/2016	B10	Winter	Moderate	4	3	0.9	0.9
B22-D2	12/20/2016	B22	Winter	Moderate	0	0	0.0	0.0

Sample	Date	Site	Season	Flow Tier	Total CPUE	Total Taxa	Diversity (H')	Pielou's (J)
B31-D2	12/20/2016	B31	Winter	Moderate	1	1	0.0	0.0
B42-D2	12/20/2016	B42	Winter	Moderate	6	3	1.1	1.0
B01-JAN	1/31/2017	B01	Winter	High	8	3	1.0	0.9
B10-JAN	1/31/2017	B10	Winter	High	12	8	1.9	0.9
B22-JAN	1/31/2017	B22	Winter	High	1	2	0.7	1.0
B31-JAN	1/31/2017	B31	Winter	High	5	5	1.5	1.0
B42-JAN	1/31/2017	B42	Winter	High	9	4	1.2	0.9
B01-MR	3/15/2017	B01	Spring	Moderate	2	2	0.6	0.9
B10-MR	3/15/2017	B10	Spring	Moderate	4	2	0.5	0.7
B22-MR	3/15/2017	B22	Spring	Moderate	6	4	1.0	0.7
B31-MR	3/15/2017	B31	Spring	Moderate	4	2	0.7	1.0
B42-MR	3/15/2017	B42	Spring	Moderate	7	4	1.3	0.9
B01-MA1	5/1/2017	B01	Spring	High	1	1	0.0	0.0
B10-MA1	5/1/2017	B10	Spring	High	3	4	1.4	1.0
B22-MA1	5/1/2017	B22	Spring	High	3	3	1.0	0.9

Sample	Date	Site	Season	Flow Tier	Total CPUE	Total Taxa	Diversity (H')	Pielou's (J)
B31-MA1	5/1/2017	B31	Spring	High	4	4	1.3	0.9
B42-MA1	5/1/2017	B42	Spring	High	4	3	1.0	0.9
B01-MA2	5/24/2017	B01	Spring	Low	1	1	0.0	0.0
B10-MA2	5/24/2017	B10	Spring	Low	3	2	0.7	1.0
B22-MA2	5/24/2017	B22	Spring	Low	3	3	1.1	1.0
B31-MA2	5/24/2017	B31	Spring	Low	2	3	1.1	1.0
B42-MA2	5/24/2017	B42	Spring	Low	4	4	1.4	1.0
B01-JUN	6/27/2017	B01	Spring	High	1	1	0.0	0.0
B10-JUN	6/27/2017	B10	Spring	High	1	1	0.0	0.0
B22-JUN	6/27/2017	B22	Spring	High	2	1	0.0	0.0
B31-JUN	6/27/2017	B31	Spring	High	1	1	0.0	0.0
B42-JUN	6/27/2017	B42	Spring	High	7	4	1.2	0.9
B01-JUL	7/31/2017	B01	Summer	Low	0	0	0.0	0.0
B10-JUL	7/31/2017	B10	Summer	Low	0	0	0.0	0.0
B22-JUL	7/31/2017	B22	Summer	Low	0	0	0.0	0.0

Sample	Date	Site	Season	Flow Tier	Total CPUE	Total Taxa	Diversity (H')	Pielou's (J)
B31-JUL	7/31/2017	B31	Summer	Low	0	0	0.0	0.0
B42-JUL	7/31/2017	B42	Summer	Low	1	1	0.0	0.0
B01-SEP	9/20/2017	B01	Summer	Moderate	0	0	0.0	0.0
B10-SEP	9/20/2017	B10	Summer	Moderate	2	2	0.7	1.0
B22-SEP	9/20/2017	B22	Summer	Moderate	1	1	0.0	0.0
B31-SEP	9/20/2017	B31	Summer	Moderate	4	3	1.0	0.9
B42-SEP	9/20/2017	B42	Summer	Moderate	7	4	1.2	0.9
B01-OCT	10/18/2017	B01	Summer	Low	1	1	0.0	0.0
B10-OCT	10/18/2017	B10	Summer	Low	0	0	0.0	0.0
B22-OCT	10/18/2017	B22	Summer	Low	2	2	0.7	1.0
B31-OCT	10/18/2017	B31	Summer	Low	2	1	0.0	0.0
B42-OCT	10/18/2017	B42	Summer	Low	3	3	1.1	1.0

Table 1-3. Otter Trawl nekton species summary statistics.

Species	Total Catch	% Total Catch	Non-zero catch collections	% Non-zero catch collections
Atlantic Croaker	4883	41.17	27	54
Star Drum	2099	17.70	19	38
Blue Catfish	1142	9.63	26	52
Brown Shrimp	1009	8.51	11	22
Macrobranchium Spp.	693	5.84	21	42
Bay Anchovy	647	5.45	17	34
Blue Crab	396	3.34	21	42
White Shrimp	310	2.61	23	46
Sand Trout	241	2.03	20	40
Hardhead Catfish	112	0.94	16	32
Silver Perch	71	0.60	11	22
Gulf Menhaden	56	0.47	9	18
Gafftopsail Catfish	53	0.45	13	26
Black Drum	21	0.18	4	8

Species	Total Catch	% Total Catch	Non-zero catch collections	% Non-zero catch collections
Hogchoker	20	0.17	7	14
Daggerblade Grass Shrimp	18	0.15	7	14
Gizzard Shad	12	0.10	4	8
Threadfin Shad	11	0.09	5	10
Sheepshead	10	0.08	4	8
Spot	7	0.06	5	10
Channel Catfish	7	0.06	3	6
Striped Mullet	6	0.05	3	6
Ribbonfish	6	0.05	2	4
Cyprinidae	4	0.03	1	2
Violet Goby	3	0.03	3	6
Spotfin Mojarra	3	0.03	2	4
Darter Goby	2	0.02	2	4
Brief Squid	2	0.02	1	2
Spadefish	2	0.02	1	2

Species	Total Catch	% Total Catch	Non-zero catch collections	% Non-zero catch collections
Atlantic Bumper	1	0.01	1	2
Atlantic Threadfin	1	0.01	1	2
Bay Whiff	1	0.01	1	2
Crevalle Jack	1	0.01	1	2
Flathead Catfish	1	0.01	1	2
Freshwater Drum	1	0.01	1	2
Marsh Grass Shrimp	1	0.01	1	2
Naked Goby	1	0.01	1	2
Paralichthyidae	1	0.01	1	2
Pink Shrimp	1	0.01	1	2
Red Drum	1	0.01	1	2
Sciaenid	1	0.01	1	2
Shoal Chub	1	0.01	1	2
Southern Flounder	1	0.01	1	2
Southern Puffer	1	0.01	1	2

Species	Total Catch	% Total Catch	Non-zero catch collections	% Non-zero catch collections
Southern Stingray	1	0.01	1	2
Total	11862	100.00		

Table 1-4. Beam trawl nekton and zooplankton species summary statistics

Species	Total Catch	%Total Catch	Non-zero catch collections	% Non-zero catch collections
Atlantic Croaker	184	25.24	9	18
Macrobranchium Spp.	131	17.97	10	20
Daggerblade Grass Shrimp	92	12.62	18	36
Striped Mullet	86	11.80	5	10
White Shrimp	58	7.96	7	14
Gulf Menhaden	48	6.58	5	10
Bay Anchovy	40	5.49	11	22
Ribbon Shiner	22	3.02	7	14
Blue crab	14	1.92	9	18
Western Mosquitofish	8	1.10	2	4
Blue Catfish	6	0.82	3	6
Shoal Chub	6	0.82	3	6
Naked Goby	6	0.82	2	4
Clupeidae	5	0.69	1	2
Brown Shrimp	4	0.55	3	6
Darter Goby	4	0.55	3	6
Inland Silverside	3	0.41	3	6
Bay Whiff	2	0.27	2	4
Paralichthyidae	2	0.27	1	2
Armored Catfish	1	0.14	1	2
Bullhead Minnow	1	0.14	1	2

Species	Total Catch	%Total Catch	Non-zero catch collections	% Non-zero catch collections
Channel Catfish	1	0.14	1	2
Crevalle Jack	1	0.14	1	2
Cyprinidae	1	0.14	1	2
Lepomis spp.	1	0.14	1	2
Notropis sp.	1	0.14	1	2
Spotfin Mojarra	1	0.14	1	2
Total	729	100.00		

Table 1-5. Otter Trawl collected Atlantic Croaker stable isotope measurements.

Sample Identifier 2	$\delta^{15}N$ vs. Air	$\delta^{13}C$ vs. VPDB	$\delta^{34}S$ vs. VCDT	Date	Site
1	15.19	-26.75	6.14	12/1/2016	B22
2	16.60	-25.40	6.61	12/1/2016	B31
3	15.95	-23.54	9.26	12/1/2016	B10
4	14.99	-19.14	15.18	12/1/2016	B01
5	14.26	-27.45	4.17	12/1/2016	B22
6	13.28	-25.51	7.92	12/1/2016	B22
7	17.86	-18.07	16.50	12/1/2016	B01
8	15.17	-21.78	12.19	12/1/2016	B10
10	16.87	-19.40	16.87	12/20/2016	B22
11	16.65	-23.74	10.74	12/20/2016	B10
12	14.74	-20.59	14.52	12/20/2016	B01
13	16.17	-18.49	18.45	12/20/2016	B01
14	16.03	-21.81		12/20/2016	B01
15	15.83	-22.98		12/20/2016	B01
16	11.57	-16.67	11.57	12/20/2016	B10
17	14.61	-23.11	14.61	12/20/2016	B10
18	16.70	-25.24	16.70	1/31/2017	B31
22	15.67	-18.46	15.22	1/31/2017	B10
26	16.98	-20.33		1/31/2017	B10
28	15.31	-19.22	17.69	1/31/2017	B01

Sample Identifier 2	$\delta^{15}N$ vs. Air	$\delta^{13}C$ vs. VPDB	$\delta^{34}S$ vs. VCDT	Date	Site
29	13.22	-19.40	16.17	1/31/2017	B01
30	13.60	-20.20		1/31/2017	B01
31	16.81	-18.87		1/31/2017	B01
32	15.95	-19.05	17.09	1/31/2017	B01
33	14.21	-23.46	12.91	1/31/2017	B10
34	16.03	-20.09		1/31/2017	B10
35	16.89	-19.45		1/31/2017	B10
36	15.23	-23.10		1/31/2017	B10
37	17.70	-21.66		1/31/2017	B10
38	13.26	-20.90		1/31/2017	B01
39	15.62	-20.50		1/31/2017	B01
40	15.78	-25.30	6.85	1/31/2017	B22
47	14.43	-18.50	15.47	3/15/2017	B01
53	15.12	-17.95		3/15/2017	B01
54	16.39	-18.65		3/15/2017	B01
55	16.29	-20.31		3/15/2017	B01
56	14.58	-23.20		3/15/2017	B01
57	15.94	-20.62		3/15/2017	B01
58	16.02	-19.96	14.68	3/15/2017	B10
59	15.02	-23.29	14.86	3/15/2017	B10
60	16.45	-24.00		3/15/2017	B10
61	16.00	-18.61		3/15/2017	B10

Sample Identifier 2	δ^{15}N vs. Air	δ^{13}C vs. VPDB	δ^{34}S vs. VCDT	Date	Site
62	15.84	-18.85		3/15/2017	B10
64	15.52	-21.29	13.38	5/1/20017	B01
65	15.07	-21.36		5/1/20017	B01
71	14.33	-20.71		5/1/20017	B01
73	15.23	-17.93		5/1/20017	B01
74	15.84	-22.40		5/1/20017	B01
75	8.65	-17.65		5/1/20017	B01
79	13.58	-24.36	8.95	5/1/20017	B10
80	15.14	-21.10		5/1/20017	B10
86	14.80	-20.27		5/24/2017	B01
89	15.28	-19.80		5/24/2017	B01
93	14.96	-20.96		5/24/2017	B10
94	15.52	-20.60		5/24/2017	B10
98	15.24	-23.54		5/24/2017	B10
99	15.71	-21.62	11.34	5/24/2017	B31
100	15.79	-20.75	14.39	5/24/2017	B31
109	14.96	-21.24	16.43	7/31/2017	B01
110	15.97	-17.60		7/31/2017	B01
111	16.44	-21.12		7/31/2017	B01
118	13.59	-22.00	13.15	7/31/2017	B10
119	15.69	-22.15		7/31/2017	B10
122	15.65	-17.79		7/31/2017	B10

Sample Identifier 2	$\delta^{15}N$ vs. Air	$\delta^{13}C$ vs. VPDB	$\delta^{34}S$ vs. VCDT	Date	Site
123	14.56	-23.17	13.96	7/31/2017	B22
124	14.84	-22.01	11.33	7/31/2017	B22
129	15.18	-24.34	8.84	7/31/2017	B22
144	15.57	-25.17	6.49	7/31/2017	B31
148	13.69	-21.17	14.64	9/20/2017	B01
149	15.57	-19.21	16.22	9/20/2017	B01
158	17.79	-20.49		9/20/2017	B10
158	16.55	-19.46	17.25	9/20/2017	B10
159	16.43	-19.11		9/20/2017	B10
160	15.87	-18.33		9/20/2017	B10
171	16.25	-24.33	9.03	12/1/2016	B22
172	16.38	-23.27	10.04	12/1/2016	B22
173	16.09	-24.04	9.18	12/1/2016	B22
175	17.50	-26.87	5.06	12/1/2016	B31
176	16.60	-22.42		12/1/2016	B10
177	16.80	-24.31		12/1/2016	B10
178	16.03	-18.92		12/1/2016	B01
179	15.98	-19.16		12/1/2016	B01
180	15.50	-19.39		12/1/2016	B01
181	15.68	-19.40		12/1/2016	B01
182	16.38	-20.51	15.43	12/20/2016	B22
183	16.65	-19.62	16.74	12/20/2016	B22

Sample Identifier 2	$\delta^{15}N$ vs. Air	$\delta^{13}C$ vs. VPDB	$\delta^{34}S$ vs. VCDT	Date	Site
184	16.04	-24.49	9.08	12/20/2016	B22
185	16.98	-20.11	15.35	12/20/2016	B22
186	16.99	-20.40		12/20/2016	B10
187	16.67	-24.34		12/20/2016	B10
188	16.94	-21.19		12/20/2016	B10
189	16.76	-19.92		12/20/2016	B10
190	16.70	-20.30		12/20/2016	B01
191	15.65	-19.07		12/20/2016	B01
192	16.48	-20.35		12/20/2016	B01

Table 1-6. Particulate organic matter (POM) isotope measures.

Sample Identifier 1	Sample Identifier 2	$\delta^{15}N$ vs. Air	$\delta^{13}C$ vs. VPDB	C:N Ratio	$\delta^{34}S$ vs. VCDT	Date	Site
POM	1	6.50	-22.92	7.93	11.21	12/1/2016	B01
POM	2	7.68	-25.92	3.65	11.95	12/1/2016	B10
POM	3	11.41	-20.59	4.77	1.37	12/1/2016	B22
POM	4	7.46	-24.50	6.81	2.79	12/1/2016	B31
POM	5	9.32	-21.17	6.29	2.28	12/1/2016	B42
POM	6	6.84	-23.98	3.52	9.12	12/20/2016	B01
POM	7	7.06	-23.01	5.39	5.36	12/20/2016	B10
POM	8	5.60	-24.07	5.90	3.63	12/20/2016	B22
POM	9	6.37	-23.40	9.06	-1.29	12/20/2016	B31
POM	10	6.80	-23.22	8.83	0.13	12/20/2016	B42
POM	11	6.88	-22.03	8.29	8.20	1/31/2017	B01
POM	12	7.57	-22.13	5.97	7.88	1/31/2017	B10
POM	13	3.17	-21.35	5.21	2.62	1/31/2017	B22
POM	14	6.07	-22.30	5.79	2.18	1/31/2017	B31
POM	15	6.85	-22.42	5.23	4.22	1/31/2017	B42
POM	16	7.07	-24.89	5.87	7.89	3/15/2017	B01
POM	17	6.39	-24.79	4.94	6.49	3/15/2017	B10
POM	18	5.08	-24.64	5.05	4.10	3/15/2017	B22
POM	19	6.55	-25.46	5.99	5.47	3/15/2017	B31
POM	20	6.39	-24.89	6.86	0.89	3/15/2017	B42
POM	21	8.98	-26.33	4.22	9.60	5/1/2017	B01

Sample Identifier 1	Sample Identifier 2	$\delta^{15}N$ vs. Air	$\delta^{13}C$ vs. VPDB	C:N Ratio	$\delta^{34}S$ vs. VCDT	Date	Site
POM	22	6.30	-22.92	7.41	6.92	5/1/2017	B10
POM	23	9.65	-22.51	15.44	8.43	5/1/2017	B22
POM	24	3.66	-21.46	13.60	2.83	5/1/2017	B31
POM	25	7.69	-19.11	7.67	5.55	5/1/2017	B42
POM	26	5.14	-27.79	5.36	12.42	5/24/2017	B01
POM	27	7.13	-29.00	5.17	11.00	5/24/2017	B10
POM	28	10.84	-27.87	6.03	7.90	5/24/2017	B22
POM	29	10.79	-28.06	5.13	4.99	5/24/2017	B31
POM	30	9.31	-30.68	4.33	12.12	5/24/2017	B42
POM	31	10.39	-28.78	5.13	11.18	7/31/2017	B01
POM	32	10.72	-29.22	4.81	13.88	7/31/2017	B10
POM	33	10.39	-27.56	5.25	8.16	7/31/2017	B22
POM	34	10.79	-28.10	4.96	9.46	7/31/2017	B31
POM	35	12.72	-27.97	7.73	7.88	7/31/2017	B42
POM	36	7.72	-28.14	4.94	10.34	9/20/2017	B01
POM	37	8.47	-29.04	4.47	9.13	9/20/2017	B10
POM	38	8.69	-28.87	4.38	8.72	9/20/2017	B22
POM	39	8.27	-25.03	6.79	5.11	9/20/2017	B31
POM	40	8.05	-22.87	6.02	5.54	9/20/2017	B42

APPENDIX II. OTTER TRAWL NEKTON NONPARAMETRIC ANALYSES

Table 2-1. Results of RELATE analysis of otter trawl taxa resemblance matrix versus water quality resemblance matrix.

RELATE
Testing matched resemblance matrices

Resemblance worksheet
Name: Spp2LogXResem
Data type: Similarity
Selection: All

Secondary data: Resemblance/model matrix

Resemblance worksheet
Name: Bott4noRkm2Resem
Data type: Distance
Selection: All

Parameters
Correlation method: Spearman rank

Sample statistic (Rho): 0.335
Significance level of sample statistic: 0.1 %
Number of permutations: 999
Number of permuted statistics greater than or equal to Rho: 0

Table 2-2. Results of BEST analysis of otter trawl taxa resemblance matrix versus water quality resemblance matrix.

BEST
Biota and/or Environment matching

Resemblance worksheet
Name: Spp2LogXResem
Data type: Similarity
Selection: All

Data worksheet
Name: Data7Bott4noRkm2

Data type: Environmental
Sample selection: All

Variable selection: All

Parameters
Correlation method: Spearman rank
Method: BIOENV
Maximum number of variables: 7
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

VARIABLES

fl	flowcfs	Trial
De	DepthM	Trial
BotTe	BotTempC	Trial
bots	botsalpsu	Trial
BotTu	BotTurb	Trial
BottD	BottDOppm	Trial
Bottp	BottpH	Trial

Best result for each number of variables

No.Vars	Corr.	Selections
1	0.693	bots
2	0.614	bots,BottD
3	0.547	bots,BotTu,Bottp
4	0.502	bots,BotTu,BottD,Bottp
5	0.425	BotTe,bots,BotTu,BottD,Bottp
6	0.373	fl,BotTe,bots,BotTu,BottD,Bottp
7	0.335	fl,De,BotTe,bots,BotTu,BottD,Bottp

Global Test
Sample statistic (Rho): 0.693
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample)
Number of permuted statistics greater than or equal to Rho: 0

Best results

No.Vars	Corr.	Selections
1	0.693	bots
2	0.614	bots,BottD
2	0.612	bots,Bottp
2	0.572	bots,BotTu
3	0.547	bots,BotTu,Bottp
3	0.545	bots,BottD,Bottp
3	0.541	bots,BotTu,BottD

Table 2-3. Results of SIMPER analysis of otter trawl taxa resemblance matrix versus collection site.

SIMPER
Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: Spp2LogXData
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray-Curtis similarity
Cut off for low contributions: 70.00%

Factor Groups

Sample	Site
B01-D	B01
B01-D2	B01
B01-JAN	B01
B01-MR	B01
B01-MA1	B01
B01-MA2	B01
B01-JUN	B01
B01-JUL	B01
B01-SEP	B01
B01-OCT	B01
B10-D	B10
B10-D2	B10
B10-JAN	B10
B10-MR	B10
B10-MA1	B10
B10-MA2	B10
B10-JUN	B10
B10-JUL	B10
B10-SEP	B10
B10-OCT	B10
B22-D	B22
B22-D2	B22

B22-JAN	B22
B22-MR	B22
B22-MA1	B22
B22-MA2	B22
B22-JUN	B22
B22-JUL	B22
B22-SEP	B22
B22-OCT	B22
B31-D	B31
B31-D2	B31
B31-JAN	B31
B31-MR	B31
B31-MA1	B31
B31-MA2	B31
B31-JUN	B31
B31-JUL	B31
B31-SEP	B31
B31-OCT	B31
B42-D	B42
B42-D2	B42
B42-JAN	B42
B42-MR	B42
B42-MA1	B42
B42-MA2	B42
B42-JUN	B42
B42-JUL	B42
B42-SEP	B42
B42-OCT	B42

Group B01
Average similarity: 55.75

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Star Drum	4.34	16.32	2.17	29.27	29.27
Atlantic Croaker	3.60	11.79	2.61	21.14	50.41
White Shrimp	2.06	6.81	2.13	12.21	62.61
Blue Crab	1.99	4.98	1.54	8.93	71.55

Group B10
Average similarity: 40.73

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Atlantic Croaker	3.04	15.50	3.85	38.04	38.04
Star Drum	2.17	6.46	0.80	15.86	53.90

White Shrimp	1.69	4.28	0.83	10.52	64.42
Hardhead Catfish	1.06	3.60	0.73	8.84	73.26

Group B22
Average similarity: 17.80

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Blue Catfish	1.69	9.00	0.57	50.59	50.59
Atlantic Croaker	1.77	3.25	0.38	18.27	68.86
White Shrimp	0.84	2.23	0.47	12.53	81.39

Group B31
Average similarity: 45.39

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Macrobranchium Spp.	3.07	22.78	1.83	50.19	50.19
Blue Catfish	3.32	20.24	1.47	44.59	94.78

Group B42
Average similarity: 46.29

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Blue Catfish	1.83	24.63	1.35	53.21	53.21
Macrobranchium Spp.	1.80	21.01	1.14	45.39	98.60

Groups B01 & B10
Average dissimilarity = 53.73

	Group B01	Group B10				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Star Drum	4.34	2.17	7.74	1.42	14.40	14.40
Brown Shrimp	1.75	0.71	4.78	0.98	8.89	23.29
Atlantic Croaker	3.60	3.04	4.62	1.18	8.61	31.90
Blue Crab	1.99	0.46	4.44	1.22	8.27	40.17
White Shrimp	2.06	1.69	4.25	1.45	7.92	48.09
Bay Anchovy	0.69	1.71	4.19	1.13	7.81	55.89
Silver Perch	1.44	0.41	3.53	1.27	6.56	62.46
Hardhead Catfish	1.43	1.06	3.30	1.29	6.14	68.60
Sand Trout	1.08	1.20	2.80	1.28	5.21	73.81

Groups B01 & B22
Average dissimilarity = 80.05

Group B01 Group B22

Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Star Drum	4.34	0.51	14.39	1.97	17.98	17.98
Atlantic Croaker	3.60	1.77	11.43	1.71	14.28	32.26
Blue Crab	1.99	0.52	6.29	1.34	7.86	40.11
Brown Shrimp	1.75	0.00	5.99	0.87	7.49	47.60
Blue Catfish	0.07	1.69	5.99	0.94	7.48	55.08
White Shrimp	2.06	0.84	5.91	1.51	7.38	62.46
Hardhead Catfish	1.43	0.19	4.95	1.34	6.18	68.64
Silver Perch	1.44	0.00	4.82	1.35	6.02	74.66

Groups B10 & B22
Average dissimilarity = 80.25

Species	Group B10 Av.Abund	Group B22 Av.Abund	Av.Diss	Contrib%	Cum.%
Atlantic Croaker	3.04	1.77	13.14	16.37	16.37
Star Drum	2.17	0.51	9.52	11.87	28.24
Blue Catfish	0.11	1.69	7.86	9.80	38.03
White Shrimp	1.69	0.84	6.69	8.34	46.37
Bay Anchovy	1.71	0.28	6.49	8.09	54.46
Hardhead Catfish	1.06	0.19	5.44	6.78	61.24
Sand Trout	1.20	0.60	5.31	6.61	67.85
Gafftopsail Catfish	0.79	0.16	3.66	4.56	72.41

Groups B01 & B31
Average dissimilarity = 93.87

Species	Group B01 Av.Abund	Group B31 Av.Abund	Av.Diss	Contrib%	Cum.%
Star Drum	4.34	0.00	14.26	15.19	15.19
Atlantic Croaker	3.60	0.14	11.23	11.97	27.16
Blue Catfish	0.07	3.32	10.16	10.82	37.98
Macrobranchium Spp.	0.00	3.07	10.01	10.66	48.64
White Shrimp	2.06	0.32	6.53	6.95	55.59
Brown Shrimp	1.75	0.00	5.50	5.86	61.45
Blue Crab	1.99	0.41	5.49	5.85	67.30
Hardhead Catfish	1.43	0.00	4.62	4.92	72.23

Groups B10 & B31
Average dissimilarity = 93.59

Species	Group B10 Av.Abund	Group B31 Av.Abund	Av.Diss	Contrib%	Cum.%
Macrobranchium Spp.	0.00	3.07	12.77	13.64	13.64

Blue Catfish	0.11	3.32	12.57	13.43	27.07
Atlantic Croaker	3.04	0.14	11.93	12.75	39.82
Star Drum	2.17	0.00	8.77	9.37	49.19
White Shrimp	1.69	0.32	6.19	6.62	55.81
Bay Anchovy	1.71	0.64	5.99	6.40	62.21
Sand Trout	1.20	0.54	4.99	5.33	67.54
Hardhead Catfish	1.06	0.00	4.84	5.17	72.71

Groups B22 & B31
Average dissimilarity = 78.15

	Group B22	Group B31			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Macrobranchium Spp.	0.44	3.07	18.52	23.70	23.70
Blue Catfish	1.69	3.32	16.04	20.53	44.23
Atlantic Croaker	1.77	0.14	8.50	10.88	55.11
White Shrimp	0.84	0.32	5.00	6.40	61.51
Sand Trout	0.60	0.54	4.57	5.85	67.37
Bay Anchovy	0.28	0.64	4.29	5.49	72.85

Groups B01 & B42
Average dissimilarity = 97.70

	Group B01	Group B42			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Star Drum	4.34	0.00	17.03	17.43	17.43
Atlantic Croaker	3.60	0.00	13.79	14.12	31.55
White Shrimp	2.06	0.00	7.96	8.15	39.70
Macrobranchium Spp.	0.00	1.80	7.06	7.22	46.92
Blue Catfish	0.07	1.83	6.84	7.00	53.92
Blue Crab	1.99	0.29	6.69	6.84	60.76
Brown Shrimp	1.75	0.00	6.52	6.67	67.44
Hardhead Catfish	1.43	0.00	5.49	5.62	73.06

Groups B10 & B42
Average dissimilarity = 97.49

	Group B10	Group B42			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Atlantic Croaker	3.04	0.00	15.41	15.80	15.80
Star Drum	2.17	0.00	10.87	11.15	26.95
Macrobranchium Spp.	0.00	1.80	9.50	9.74	36.70
Blue Catfish	0.11	1.83	9.03	9.26	45.96
White Shrimp	1.69	0.00	7.43	7.62	53.58

Bay Anchovy	1.71	0.00	6.55	6.72	60.30
Hardhead Catfish	1.06	0.00	6.12	6.28	66.58
Sand Trout	1.20	0.00	5.56	5.71	72.29

Groups B22 & B42
Average dissimilarity = 79.13

	Group B22	Group B42			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Macrobranchium Spp.	0.44	1.80	16.68	21.08	21.08
Blue Catfish	1.69	1.83	15.85	20.03	41.11
Atlantic Croaker	1.77	0.00	10.73	13.56	54.67
White Shrimp	0.84	0.00	5.96	7.53	62.20
Blue Crab	0.52	0.29	4.57	5.78	67.98
Sand Trout	0.60	0.00	4.56	5.77	73.75

Groups B31 & B42
Average dissimilarity = 57.53

	Group B31	Group B42			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Blue Catfish	3.32	1.83	16.14	28.05	28.05
Macrobranchium Spp.	3.07	1.80	15.06	26.18	54.24
Blue Crab	0.41	0.29	3.46	6.01	60.25
Daggerblade Grass Shrimp	0.44	0.11	3.09	5.37	65.62
Bay Anchovy	0.64	0.00	2.57	4.47	70.09

Table 2-4. Results of SIMPER analysis of otter trawl taxa resemblance matrix versus collection flow severity.

SIMPER
Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: Spp2LogXData
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray-Curtis similarity

Cut off for low contributions: 70.00%

Factor Groups

Sample	Flow Tier
B01-D	Low
B10-D	Low
B22-D	Low
B31-D	Low
B42-D	Low
B01-MA2	Low
B10-MA2	Low
B22-MA2	Low
B31-MA2	Low
B42-MA2	Low
B01-JUL	Low
B10-JUL	Low
B22-JUL	Low
B31-JUL	Low
B42-JUL	Low
B01-OCT	Low
B10-OCT	Low
B22-OCT	Low
B31-OCT	Low
B42-OCT	Low
B01-D2	Moderate
B10-D2	Moderate
B22-D2	Moderate
B31-D2	Moderate
B42-D2	Moderate
B01-MR	Moderate
B10-MR	Moderate
B22-MR	Moderate
B31-MR	Moderate
B42-MR	Moderate
B01-SEP	Moderate
B10-SEP	Moderate
B22-SEP	Moderate
B31-SEP	Moderate
B42-SEP	Moderate
B01-JAN	High
B10-JAN	High
B22-JAN	High
B31-JAN	High
B42-JAN	High

B01-MA1	High
B10-MA1	High
B22-MA1	High
B31-MA1	High
B42-MA1	High
B01-JUN	High
B10-JUN	High
B22-JUN	High
B31-JUN	High
B42-JUN	High

Group Low
Average similarity: 24.64

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Blue Catfish	1.42	3.72	0.40	15.09	15.09
Atlantic Croaker	1.77	3.56	0.59	14.44	29.54
White Shrimp	1.47	3.36	0.65	13.63	43.17
Star Drum	1.72	2.84	0.46	11.53	54.70
Macrobranchium Spp.	1.27	2.72	0.32	11.04	65.73
Sand Trout	1.23	2.69	0.70	10.92	76.65

Group Moderate
Average similarity: 20.52

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Blue Catfish	1.26	7.31	0.51	35.65	35.65
Atlantic Croaker	2.13	3.60	0.46	17.56	53.21
Macrobranchium Spp.	0.80	3.24	0.31	15.80	69.01
Star Drum	1.46	2.02	0.36	9.87	78.88

Group High
Average similarity: 24.30

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Blue Catfish	1.52	8.88	0.66	36.52	36.52
Macrobranchium Spp.	1.05	6.09	0.45	25.07	61.59
Blue Crab	1.13	3.05	0.62	12.57	74.16

Groups Low & Moderate
Average dissimilarity = 78.16

	Group Low	Group Moderate

Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Atlantic Croaker	1.77	2.13	9.55	12.22	12.22
Blue Catfish	1.42	1.26	9.07	11.61	23.83
Macrobranchium Spp.	1.27	0.80	8.22	10.52	34.35
Star Drum	1.72	1.46	8.05	10.30	44.65
White Shrimp	1.47	0.95	6.17	7.89	52.54
Bay Anchovy	1.24	0.19	5.02	6.42	58.96
Sand Trout	1.23	0.23	4.63	5.92	64.88
Hardhead Catfish	0.53	0.72	3.42	4.38	69.26
Blue Crab	0.71	0.37	2.93	3.75	73.02

Groups Low & High
Average dissimilarity = 76.96

	Group Low	Group High			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Blue Catfish	1.42	1.52	9.61	12.49	12.49
Macrobranchium Spp.	1.27	1.05	9.03	11.73	24.22
Atlantic Croaker	1.77	1.21	7.90	10.26	34.48
Star Drum	1.72	0.93	7.57	9.84	44.33
White Shrimp	1.47	0.37	5.71	7.41	51.74
Bay Anchovy	1.24	0.37	5.35	6.95	58.69
Blue Crab	0.71	1.13	5.02	6.52	65.21
Sand Trout	1.23	0.41	5.02	6.52	71.73

Groups Moderate & High
Average dissimilarity = 76.58

	Group Moderate	Group High			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Blue Catfish	1.26	1.52	11.26	14.70	14.70
Atlantic Croaker	2.13	1.21	10.60	13.85	28.55
Macrobranchium Spp.	0.80	1.05	9.38	12.25	40.80
Star Drum	1.46	0.93	7.50	9.79	50.59
Blue Crab	0.37	1.13	5.52	7.20	57.79
White Shrimp	0.95	0.37	4.25	5.55	63.34
Hardhead Catfish	0.72	0.36	3.83	5.00	68.34
Silver Perch	0.58	0.22	2.64	3.45	71.79

Table 2-5. Results of SIMPER analysis of otter trawl taxa resemblance matrix versus collection season.

SIMPER
Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: Spp2LogXData
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray-Curtis similarity
Cut off for low contributions: 70.00%

Factor Groups

Sample	Season
B01-D	Winter
B10-D	Winter
B22-D	Winter
B31-D	Winter
B42-D	Winter
B01-D2	Winter
B10-D2	Winter
B22-D2	Winter
B31-D2	Winter
B42-D2	Winter
B01-JAN	Winter
B10-JAN	Winter
B22-JAN	Winter
B31-JAN	Winter
B42-JAN	Winter
B01-MR	Spring
B10-MR	Spring
B22-MR	Spring
B31-MR	Spring
B42-MR	Spring
B01-MA1	Spring
B10-MA1	Spring
B22-MA1	Spring
B31-MA1	Spring

B42-MA1	Spring
B01-MA2	Spring
B10-MA2	Spring
B22-MA2	Spring
B31-MA2	Spring
B42-MA2	Spring
B01-JUN	Summer
B10-JUN	Summer
B22-JUN	Summer
B31-JUN	Summer
B42-JUN	Summer
B01-JUL	Summer
B10-JUL	Summer
B22-JUL	Summer
B31-JUL	Summer
B42-JUL	Summer
B01-SEP	Summer
B10-SEP	Summer
B22-SEP	Summer
B31-SEP	Summer
B42-SEP	Summer
B01-OCT	Summer
B10-OCT	Summer
B22-OCT	Summer
B31-OCT	Summer
B42-OCT	Summer

Group Winter
Average similarity: 22.52

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Atlantic Croaker	2.76	6.54	0.60	29.02	29.02
Blue Catfish	1.15	4.32	0.44	19.17	48.19
Macrobranchium Spp.	1.17	3.81	0.42	16.93	65.13
White Shrimp	1.16	1.71	0.41	7.59	72.71

Group Spring
Average similarity: 21.44

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Macrobranchium Spp.	1.59	8.75	0.47	40.82	40.82
Blue Catfish	1.03	5.39	0.62	25.13	65.96
Atlantic Croaker	1.24	2.17	0.44	10.12	76.08

Group Summer
Average similarity: 25.90

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Blue Catfish	1.87	8.75	0.51	33.78	33.78
Star Drum	1.91	3.75	0.46	14.47	48.24
White Shrimp	1.20	3.12	0.63	12.05	60.29
Atlantic Croaker	1.27	2.73	0.53	10.55	70.84

Groups Winter & Spring
Average dissimilarity = 78.03

	Group Winter	Group Spring			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Atlantic Croaker	2.76	1.24	11.64	14.91	14.91
Macrobranchium Spp.	1.17	1.59	10.96	14.05	28.96
Blue Catfish	1.15	1.03	8.18	10.48	39.45
Star Drum	1.35	0.79	6.01	7.71	47.15
White Shrimp	1.16	0.51	4.73	6.06	53.21
Bay Anchovy	0.67	0.69	4.06	5.21	58.42
Hardhead Catfish	0.60	0.58	3.62	4.64	63.06
Brown Shrimp	0.05	1.11	3.60	4.61	67.67
Blue Crab	0.62	0.54	3.46	4.43	72.11

Groups Winter & Summer
Average dissimilarity = 76.04

	Group Winter	Group Summer			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Atlantic Croaker	2.76	1.27	10.68	14.04	14.04
Blue Catfish	1.15	1.87	10.01	13.16	27.20
Star Drum	1.35	1.91	8.25	10.85	38.06
Macrobranchium Spp.	1.17	0.59	6.96	9.15	47.21
White Shrimp	1.16	1.20	5.99	7.88	55.09
Blue Crab	0.62	0.96	4.44	5.84	60.93
Bay Anchovy	0.67	0.63	3.74	4.92	65.85
Sand Trout	0.36	0.91	3.38	4.45	70.30

Groups Spring & Summer
Average dissimilarity = 78.49

	Group Spring	Group Summer			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Blue Catfish	1.03	1.87	11.28	14.38	14.38
Macrobranchium Spp.	1.59	0.59	9.99	12.73	27.10
Star Drum	0.79	1.91	8.31	10.59	37.70
Atlantic Croaker	1.24	1.27	6.74	8.59	46.29
White Shrimp	0.51	1.20	5.31	6.77	53.06
Sand Trout	0.70	0.91	4.76	6.07	59.12
Blue Crab	0.54	0.96	4.61	5.87	64.99
Bay Anchovy	0.69	0.63	4.36	5.55	70.54

Table 2-6. Results of ANOSIM analysis of otter trawl taxa resemblance matrix versus collection site.

ANOSIM
Analysis of Similarities

One-Way - A

Resemblance worksheet
Name: Spp2noTransformResem
Data type: Similarity
Selection: All

Factors

Place	Name	Type	Levels
A	Site	Unordered	5

Site levels
B01
B10
B22
B31
B42

Tests for differences between unordered Site groups
Global Test
Sample statistic (R): 0.531
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
B01, B10	0.099	7.2	92378	999	71
B01, B22	0.322	0.2	92378	999	1
B01, B31	0.956	0.1	92378	999	0
B01, B42	0.977	0.1	92378	999	0
B10, B22	0.257	0.6	92378	999	5
B10, B31	0.912	0.1	92378	999	0
B10, B42	0.928	0.1	92378	999	0
B22, B31	0.236	0.4	92378	999	3
B22, B42	0.284	0.3	92378	999	2
B31, B42	0.251	1.0	92378	999	9

Table 2-7. Results of ANOSIM analysis of otter trawl taxa resemblance matrix versus collection season.

ANOSIM
Analysis of Similarities

One-Way - A

Resemblance worksheet
Name: Spp2noTransformResem
Data type: Similarity
Selection: All

Factors

Place	Name	Type	Levels
A	Season	Unordered	3

Season levels
Winter
Spring
Summer

Tests for differences between unordered Season groups
Global Test
Sample statistic (R): 0.035
Significance level of sample statistic: 11.7%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to R:116

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual	Number >= Observed
Winter, Spring	0.011	33	77558760	999	329
Winter, Summer	0.032	18.6	Very large	999	185
Spring, Summer	0.056	10.3	Very large	999	102

Table 2-8. Results of ANOSIM analysis of otter trawl taxa resemblance matrix versus collection flow tier.

ANOSIM
Analysis of Similarities

One-Way - A

Resemblance worksheet
Name: Spp2noTransformResem
Data type: Similarity
Selection: All

Factors

Place	Name	Type	Levels
A	Flow Tier	Unordered	3

Flow Tier levels
Low
Moderate
High

Tests for differences between unordered Flow Tier groups
Global Test
Sample statistic (R): 0.035
Significance level of sample statistic: 14.9%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to R: 148

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Low, Moderate	0.061	9.9	Very large	999	98
Low, High	0.05	12.3	Very large	999	122
Moderate, High	-0.018	54.6	77558760	999	545

APPENDIX III. BEAM TRAWL NEKTON AND ZOOPLANKTON NON-PARAMETRIC ANALYSES

Table 3-1. Results of RELATE analysis of the beam trawl taxa resemblance matrix versus water quality variable resemblance matrix.

RELATE
Testing matched resemblance matrices

Resemblance worksheet
Name: SppBTLogXResem
Data type: Similarity
Selection: All

Secondary data: Resemblance/model matrix

Resemblance worksheet
Name: SurfNoDepConRkmResem
Data type: Distance
Selection: All

Parameters
Correlation method: Spearman rank

Sample statistic (Rho): 0.136
Significance level of sample statistic: 0.1 %
Number of permutations: 999
Number of permuted statistics greater than or equal to Rho: 0

Table 3-2. Results of BEST analysis of beam trawl taxa resemblance matrix versus water quality variable resemblance matrix.

BEST
Biota and/or Environment matching

Resemblance worksheet
Name: SppBTLogXResem
Data type: Similarity
Selection: All

Data worksheet
Name: 8DataSurfNoDepConRkm

Data type: Environmental
Sample selection: All
Variable selection: All

Parameters
Correlation method: Spearman rank
Method: BIOENV
Maximum number of variables: 6
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

VARIABLES

Fl	flow	Trial
surfte	surftemp	Trial
surfs	surfsal	Trial
surfTu	surfTurb	Trial
SurfD	SurfDO	Trial
Surfp	SurfpH	Trial

Best result for each number of variables

No.Vars	Corr.	Selections
1	0.213	surfs
2	0.238	surfte,surfs
3	0.250	surfte,surfs,SurfD
4	0.248	surfte,surfs,SurfD,Surfp
5	0.203	fl,surfte,surfs,SurfD,Surfp
6	0.136	fl,surfte,surfs,surfTu,SurfD,Surfp

Table 3-3. Results of SIMPER analysis of beam trawl taxa resemblance matrix versus collection sites.

SIMPER
Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: SppBTLogXData
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters

Resemblance: S17 Bray-Curtis similarity
Cut off for low contributions: 70.00%

Factor Groups

Sample	Site
B01-D	B01
B01-D2	B01
B01-JAN	B01
B01-MR	B01
B01-MA1	B01
B01-MA2	B01
B01-JUN	B01
B01-JUL	B01
B01-SEP	B01
B01-OCT	B01
B10-D	B10
B10-D2	B10
B10-JAN	B10
B10-MR	B10
B10-MA1	B10
B10-MA2	B10
B10-JUN	B10
B10-JUL	B10
B10-SEP	B10
B10-OCT	B10
B22-D	B22
B22-D2	B22
B22-JAN	B22
B22-MR	B22
B22-MA1	B22
B22-MA2	B22
B22-JUN	B22
B22-JUL	B22
B22-SEP	B22
B22-OCT	B22
B31-D	B31
B31-D2	B31
B31-JAN	B31
B31-MR	B31
B31-MA1	B31
B31-MA2	B31
B31-JUN	B31
B31-JUL	B31
B31-SEP	B31

B31-OCT	B31
B42-D	B42
B42-D2	B42
B42-JAN	B42
B42-MR	B42
B42-MA1	B42
B42-MA2	B42
B42-JUN	B42
B42-JUL	B42
B42-SEP	B42
B42-OCT	B42

Group B01
Average similarity: 13.35

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Atlantic Croaker	1.35	9.66	0.51	72.35	72.35

Group B10
Average similarity: 4.39

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
White Shrimp	0.55	1.45	0.15	33.06	33.06
Daggerblade Grass Shrimp	0.36	1.11	0.25	25.29	58.35
Blue crab	0.30	0.99	0.23	22.53	80.87

Group B22
Average similarity: 8.66

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Blue crab	0.43	5.27	0.46	60.87	60.87
Darter Goby	0.25	2.52	0.26	29.06	89.93

Group B31
Average similarity: 10.48

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Bay Anchovy	0.52	5.21	0.36	49.75	49.75
Daggerblade Grass Shrimp	0.60	2.45	0.26	23.33	73.09

Group B42
Average similarity: 31.97

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%

Daggerblade Grass Shrimp	1.34	18.24	1.39	57.06	57.06
Macrobranchium Spp.	1.22	6.67	0.63	20.85	77.91

Groups B01 & B10
Average dissimilarity = 93.23

	Group B01	Group B10			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Atlantic Croaker	1.35	0.32	22.45	24.08	24.08
White Shrimp	0.42	0.55	15.50	16.63	40.71
Gulf Menhaden	0.36	0.41	11.09	11.89	52.60
Bay Anchovy	0.14	0.18	10.63	11.40	64.00
Daggerblade Grass Shrimp	0.07	0.36	8.70	9.33	73.33

Groups B01 & B22
Average dissimilarity = 95.06

	Group B01	Group B22			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Atlantic Croaker	1.35	0.35	24.49	25.76	25.76
Bay Anchovy	0.14	0.19	13.18	13.86	39.62
Blue crab	0.00	0.43	11.01	11.58	51.20
Darter Goby	0.00	0.25	9.32	9.81	61.01
White Shrimp	0.42	0.24	8.27	8.70	69.71
Daggerblade Grass Shrimp	0.07	0.23	8.05	8.46	78.17

Groups B10 & B22
Average dissimilarity = 92.08

	Group B10	Group B22			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
White Shrimp	0.55	0.24	12.79	13.89	13.89
Blue crab	0.30	0.43	12.33	13.39	27.28
Bay Anchovy	0.18	0.19	8.69	9.44	36.72
Daggerblade Grass Shrimp	0.36	0.23	8.40	9.12	45.84
Darter Goby	0.00	0.25	8.05	8.74	54.58
Gulf Menhaden	0.41	0.07	7.78	8.45	63.03
Striped Mullet	0.25	0.43	7.64	8.30	71.33

Groups B01 & B31
Average dissimilarity = 91.63

	Group B01	Group B31			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%

Atlantic Croaker	1.35	0.18	22.58	24.64	24.64
Bay Anchovy	0.14	0.52	18.04	19.69	44.33
Daggerblade Grass Shrimp	0.07	0.60	12.36	13.49	57.82
Macrobranchium Spp.	0.00	0.39	6.69	7.30	65.12
Striped Mullet	0.00	0.30	6.57	7.17	72.28

Groups B10 & B31
Average dissimilarity = 92.72

Species	Group B10 Av.Abund	Group B31 Av.Abund	Av.Diss	Contrib%	Cum.%
Bay Anchovy	0.18	0.52	14.78	15.94	15.94
Daggerblade Grass Shrimp	0.36	0.60	12.09	13.04	28.98
White Shrimp	0.55	0.07	10.98	11.84	40.82
Striped Mullet	0.25	0.30	7.79	8.40	49.22
Gulf Menhaden	0.41	0.00	6.81	7.35	56.57
Macrobranchium Spp.	0.07	0.39	6.78	7.31	63.88
Atlantic Croaker	0.32	0.18	6.16	6.64	70.52

Groups B22 & B31
Average dissimilarity = 93.64

Species	Group B22 Av.Abund	Group B31 Av.Abund	Av.Diss	Contrib%	Cum.%
Bay Anchovy	0.19	0.52	17.05	18.20	18.20
Daggerblade Grass Shrimp	0.23	0.60	11.87	12.68	30.88
Striped Mullet	0.43	0.30	10.59	11.31	42.19
Blue crab	0.43	0.07	9.39	10.03	52.22
Atlantic Croaker	0.35	0.18	8.03	8.57	60.80
Darter Goby	0.25	0.00	7.40	7.91	68.71
Macrobranchium Spp.	0.00	0.39	6.38	6.81	75.52

Groups B01 & B42
Average dissimilarity = 95.74

Species	Group B01 Av.Abund	Group B42 Av.Abund	Av.Diss	Contrib%	Cum.%
Daggerblade Grass Shrimp	0.07	1.34	22.46	23.46	23.46
Macrobranchium Spp.	0.00	1.22	15.14	15.81	39.28
Atlantic Croaker	1.35	0.00	14.96	15.63	54.90
Ribbon Shiner	0.00	0.81	10.65	11.13	66.03
Bay Anchovy	0.14	0.34	6.92	7.22	73.25

Groups B10 & B42

Average dissimilarity = 92.63

Species	Group B10 Av.Abund	Group B42 Av.Abund	Av.Diss	Contrib%	Cum.%
Daggerblade Grass Shrimp	0.36	1.34	19.65	21.21	21.21
Macrobranchium Spp.	0.07	1.22	14.04	15.16	36.37
Ribbon Shiner	0.00	0.81	9.92	10.71	47.08
White Shrimp	0.55	0.00	7.31	7.90	54.98
Bay Anchovy	0.18	0.34	6.13	6.61	61.59
Gulf Menhaden	0.41	0.00	4.99	5.39	66.98
Blue crab	0.30	0.00	3.82	4.12	71.10

Groups B22 & B42
Average dissimilarity = 95.05

Species	Group B22 Av.Abund	Group B42 Av.Abund	Av.Diss	Contrib%	Cum.%
Daggerblade Grass Shrimp	0.23	1.34	21.36	22.47	22.47
Macrobranchium Spp.	0.00	1.22	14.61	15.37	37.84
Ribbon Shiner	0.00	0.81	10.28	10.81	48.65
Bay Anchovy	0.19	0.34	7.25	7.63	56.28
Blue crab	0.43	0.00	6.14	6.46	62.74
Darter Goby	0.25	0.00	4.48	4.71	67.44
Striped Mullet	0.43	0.00	4.00	4.21	71.65

Groups B31 & B42
Average dissimilarity = 84.56

Species	Group B31 Av.Abund	Group B42 Av.Abund	Av.Diss	Contrib%	Cum.%
Daggerblade Grass Shrimp	0.60	1.34	20.63	24.40	24.40
Macrobranchium Spp.	0.39	1.22	14.88	17.59	41.99
Bay Anchovy	0.52	0.34	10.63	12.57	54.56
Ribbon Shiner	0.07	0.81	10.07	11.91	66.47
Striped Mullet	0.30	0.00	4.10	4.85	71.32

Table 3-4. Results of SIMPER analysis of beam trawl taxa resemblance matrix versus collection flow tier.

SIMPER
Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: SppBTLogXData
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray-Curtis similarity
Cut off for low contributions: 70.00%

Factor Groups

Sample	Flow Tier
B01-D	Low
B10-D	Low
B22-D	Low
B31-D	Low
B42-D	Low
B01-MA2	Low
B10-MA2	Low
B22-MA2	Low
B31-MA2	Low
B42-MA2	Low
B01-JUL	Low
B10-JUL	Low
B22-JUL	Low
B31-JUL	Low
B42-JUL	Low
B01-OCT	Low
B10-OCT	Low
B22-OCT	Low
B31-OCT	Low
B42-OCT	Low
B01-D2	Moderate
B10-D2	Moderate
B22-D2	Moderate
B31-D2	Moderate

B42-D2	Moderate
B01-MR	Moderate
B10-MR	Moderate
B22-MR	Moderate
B31-MR	Moderate
B42-MR	Moderate
B01-SEP	Moderate
B10-SEP	Moderate
B22-SEP	Moderate
B31-SEP	Moderate
B42-SEP	Moderate
B01-JAN	High
B10-JAN	High
B22-JAN	High
B31-JAN	High
B42-JAN	High
B01-MA1	High
B10-MA1	High
B22-MA1	High
B31-MA1	High
B42-MA1	High
B01-JUN	High
B10-JUN	High
B22-JUN	High
B31-JUN	High
B42-JUN	High

Group Low
Average similarity: 6.37

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Daggerblade Grass Shrimp	0.21	1.77	0.23	27.74	27.74
Atlantic Croaker	0.45	1.41	0.17	22.18	49.92
Bay Anchovy	0.22	1.24	0.18	19.53	69.45
Blue crab	0.22	1.01	0.16	15.79	85.24

Group Moderate
Average similarity: 6.56

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Daggerblade Grass Shrimp	0.52	1.71	0.27	26.03	26.03
Macrobranchium Spp.	0.48	1.31	0.23	19.97	46.00
Gulf Menhaden	0.51	1.22	0.19	18.64	64.64
Bay Anchovy	0.33	0.79	0.17	12.04	76.68

Group High
Average similarity: 13.01

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Daggerblade Grass Shrimp	0.93	7.33	0.55	56.34	56.34
Bay Anchovy	0.30	2.21	0.19	17.01	73.35

Groups Low & Moderate
Average dissimilarity = 93.29

	Group Low	Group Moderate			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Atlantic Croaker	0.45	0.33	11.98	12.84	2.84
Daggerblade Grass Shrimp	0.21	0.52	10.95	11.74	24.58
Bay Anchovy	0.22	0.33	10.27	11.01	35.59
White Shrimp	0.34	0.19	8.52	9.13	44.72
Gulf Menhaden	0.03	0.51	8.48	9.08	53.81
Macrobranchium Spp.	0.07	0.48	7.77	8.33	62.13
Striped Mullet	0.03	0.44	7.39	7.92	70.05

Groups Low & High
Average dissimilarity = 90.28

	Group Low	Group High			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Daggerblade Grass Shrimp	0.21	0.93	17.16	19.00	19.00
Bay Anchovy	0.22	0.30	13.05	14.46	33.46
Atlantic Croaker	0.45	0.54	10.73	11.89	45.35
Macrobranchium Spp.	0.07	0.54	7.40	8.20	53.55
Blue crab	0.22	0.18	6.86	7.60	61.15
White Shrimp	0.34	0.21	6.58	7.29	68.44
Ribbon Shiner	0.09	0.18	3.47	3.85	72.28

Groups Moderate & High
Average dissimilarity = 89.96

	Group Moderate	Group High			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Daggerblade Grass Shrimp	0.52	0.93	15.16	16.85	6.85
Bay Anchovy	0.33	0.30	10.45	11.61	28.47
Macrobranchium Spp.	0.48	0.54	9.68	10.76	39.23
Atlantic Croaker	0.33	0.54	8.33	9.26	48.48
Striped Mullet	0.44	0.17	6.58	7.32	55.80

Gulf Menhaden	0.51	0.00	6.43	7.15	62.95
White Shrimp	0.19	0.21	4.91	5.46	68.41
Ribbon Shiner	0.29	0.18	4.44	4.94	73.35

Table 3-5. Results of SIMPER analysis of beam trawl taxa resemblance matrix versus collection season.

SIMPER
Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: SppBTLogXData
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray-Curtis similarity
Cut off for low contributions: 70.00%

Factor Groups

Sample	Season
B01-D	Winter
B10-D	Winter
B22-D	Winter
B31-D	Winter
B42-D	Winter
B01-D2	Winter
B10-D2	Winter
B22-D2	Winter
B31-D2	Winter
B42-D2	Winter
B01-JAN	Winter
B10-JAN	Winter
B22-JAN	Winter
B31-JAN	Winter
B42-JAN	Winter
B01-MR	Spring
B10-MR	Spring
B22-MR	Spring
B31-MR	Spring

B42-MR	Spring
B01-MA1	Spring
B10-MA1	Spring
B22-MA1	Spring
B31-MA1	Spring
B42-MA1	Spring
B01-MA2	Spring
B10-MA2	Spring
B22-MA2	Spring
B31-MA2	Spring
B42-MA2	Spring
B01-JUN	Summer
B10-JUN	Summer
B22-JUN	Summer
B31-JUN	Summer
B42-JUN	Summer
B01-JUL	Summer
B10-JUL	Summer
B22-JUL	Summer
B31-JUL	Summer
B42-JUL	Summer
B01-SEP	Summer
B10-SEP	Summer
B22-SEP	Summer
B31-SEP	Summer
B42-SEP	Summer
B01-OCT	Summer
B10-OCT	Summer
B22-OCT	Summer
B31-OCT	Summer
B42-OCT	Summer

Group Winter
Average similarity: 13.73

Species	Av.Abund	Av.Sim	Contrib%	Cum.%
Atlantic Croaker	1.29	6.19	45.05	45.05
White Shrimp	0.76	3.42	24.91	69.96
Ribbon Shiner	0.38	1.17	8.48	78.44

Group Spring
Average similarity: 17.03

Species	Av.Abund	Av.Sim	Contrib%	Cum.%

Daggerblade Grass Shrimp	0.73	8.81	51.70	51.70
Macrobranchium Spp.	0.51	2.97	17.42	69.12
Striped Mullet	0.53	1.44	8.48	77.60

Group Summer
Average similarity: 7.78

Species	Av.Abund	Av.Sim	Contrib%	Cum.%
Bay Anchovy	0.55	5.78	74.33	74.33

Groups Winter & Spring
Average dissimilarity = 89.97

	Group Winter	Group Spring			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Atlantic Croaker	1.29	0.11	14.57	16.19	16.19
Daggerblade Grass Shrimp	0.43	0.73	11.88	13.20	29.39
White Shrimp	0.76	0.09	10.54	11.72	41.11
Macrobranchium Spp.	0.44	0.51	8.92	9.91	51.03
Striped Mullet	0.12	0.53	7.00	7.78	58.81
Gulf Menhaden	0.29	0.27	6.19	6.88	65.69
Ribbon Shiner	0.38	0.17	5.72	6.36	72.04

Groups Winter & Summer
Average dissimilarity = 96.68

	Group Winter	Group Summer			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Atlantic Croaker	1.29	0.05	18.39	19.02	19.02
White Shrimp	0.76	0.00	13.26	13.71	32.73
Daggerblade Grass Shrimp	0.43	0.42	10.15	10.50	43.23
Bay Anchovy	0.05	0.55	9.92	10.26	53.49
Ribbon Shiner	0.38	0.03	6.56	6.79	60.27
Macrobranchium Spp.	0.44	0.12	6.36	6.58	66.85
Blue crab	0.18	0.05	4.59	4.75	71.61

Groups Spring & Summer
Average dissimilarity = 91.70

	Group Spring	Group Summer			
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Daggerblade Grass Shrimp	0.73	0.42	19.11	20.84	20.84
Bay Anchovy	0.14	0.55	13.68	14.92	35.76
Macrobranchium Spp.	0.51	0.12	9.80	10.69	46.45

Striped Mullet	0.53	0.00	9.57	10.44	56.89
Blue crab	0.27	0.05	7.21	7.86	64.74
Gulf Menhaden	0.27	0.00	4.88	5.32	70.06

Table 3-6. Results of ANOSIM analysis of beam trawl taxa resemblance matrix versus collection sites.

ANOSIM
Analysis of Similarities

One-Way - A

Resemblance worksheet
Name: SppBTnoTransformResem
Data type: Similarity
Selection: All

Factors

Place	Name	Type	Levels
A	Site	Unordered	5

Site levels
B01
B10
B22
B31
B42

Tests for differences between unordered Site groups
Global Test
Sample statistic (R): 0.154
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
B01, B10	-0.019	56	92378	999	559
B01, B22	0.179	1	92378	999	9
B01, B31	0.043	21.3	92378	999	212
B01, B42	0.466	0.1	92378	999	0
B10, B22	-0.03	68.6	92378	999	685

B10, B31	-0.038	74	92378	999	739
B10, B42	0.247	0.3	92378	999	2
B22, B31	0.122	4.1	92378	999	40
B22, B42	0.469	0.1	92378	999	0
B31, B42	0.131	4	92378	999	39

Table 3-7. Results of ANOSIM analysis of beam trawl taxa resemblance matrix versus collection flow tier.

ANOSIM
Analysis of Similarities

One-Way - A

Resemblance worksheet
Name: SppBTnoTransformResem
Data type: Similarity
Selection: All

Factors

Place	Name	Type	Levels
A	Flow Tier	Unordered	3

Flow Tier levels
Low
Moderate
High

Tests for differences between unordered Flow Tier groups
Global Test
Sample statistic (R): -0.014
Significance level of sample statistic: 69.3%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to R: 692

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Low, Moderate	-0.011	57.9	Very large	999	578
Low, High	-0.028	77.8	Very large	999	777
Moderate, High	0.003	43.7	77558760	999	436

Table 3-8. Results of ANOSIM analysis of beam trawl taxa resemblance matrix versus collection season.

ANOSIM
Analysis of Similarities

One-Way - A

Resemblance worksheet
Name: SppBTnoTransformResem
Data type: Similarity
Selection: All

Factors

Place	Name	Type	Levels
A	Season	Unordered	3

Season levels
Winter
Spring
Summer

Tests for differences between unordered Season groups
Global Test
Sample statistic (R): 0.123
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Winter, Spring	0.153	0.5	77558760	999	4
Winter, Summer	0.147	0.3	Very large	999	2
Spring, Summer	0.079	3.8	Very large	999	37

APPENDIX IV. ANOVA TABLES.

Table 4-1. Results of Kruskal Wallis test for differences in median discharge between seasons.

Kruskal-Wallis Test: discharge (cfs) versus Season

Descriptive Statistics

Season	N	Median	Mean Rank	Z-Value
Winter	15	3428.54	26.3	0.26
Spring	20	6360.72	34.3	3.47
Summer	15	2812.91	13.0	-3.97
Overall	50		25.5	

Test

Null hypothesis	H_0: All medians are equal
Alternative hypothesis	H_1: At least one median is different

Method	DF	H-Value	P-Value
Not adjusted for ties	2	18.28	0.000
Adjusted for ties	2	18.46	0.000

Table 4-2. Results of analysis of variance and Tukey multiple comparison test for differences in mean otter trawl Log (CPUE+1) between sites.

One-way ANOVA: Log CPUE versus Site

Factor Information

Factor	Levels	Values
Site	5	B01, B10, B22, B31, B42

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	4	47.27	11.817	5.98	0.001
Error	45	88.88	1.975		
Total	49	136.15			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.40539	34.72%	28.91%	19.40%

Means

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Site	N	Mean	Grouping	
B01	10	5.835	A	
B10	10	4.561	A	B
B31	10	4.419	A	B
B22	10	3.891		B
B42	10	2.844		B

Means that do not share a letter are significantly different.

Table 4-3. Result of analysis of variance test for differences in mean otter trawl Log (CPUE+1) between seasons.

One-way ANOVA: Log CPUE versus Season

Factor Information

Factor	Levels	Values
Season	3	Spring, Summer, Winter

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Season	2	2.107	1.054	0.37	0.693
Error	47	134.042	2.852		
Total	49	136.149			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.68877	1.55%	0.00%	0.00%

Means

Season	N	Mean	StDev	95% CI
Spring	20	4.130	1.659	(3.370, 4.889)
Summer	15	4.246	1.480	(3.369, 5.123)
Winter	15	4.615	1.911	(3.738, 5.492)

Pooled StDev = 1.68877

Table 4-4. Result of analysis of variance test for differences in mean otter trawl Log (CPUE+1) between flow tiers.

One-way ANOVA: Log CPUE versus Flow Tier

Factor Information

Factor	Levels	Values
Flow Tier	3	Low, Moderate, High

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Flow Tier	2	10.27	5.135	1.92	0.158
Error	47	125.88	2.678		
Total	49	136.15			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.63655	7.54%	3.61%	0.00%

Means

Flow Tier	N	Mean	StDev	95% CI
Low	20	4.800	1.502	(4.064, 5.536)
Moderate	15	4.259	1.874	(3.409, 5.109)
High	15	3.708	1.555	(2.858, 4.558)

Pooled StDev = 1.63655

Table 4-5. Result of analysis of variance and Tukey multiple comparison test for differences in mean otter trawl taxa richness between sites.

One-way ANOVA: taxa Richness versus Site

Factor Information

Factor	Levels	Values
Site	5	B01, B10, B22, B31, B42

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	4	432.1	108.020	18.58	0.000
Error	45	261.6	5.813		
Total	49	693.7			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2.41109	62.29%	58.94%	53.44%

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Site	N	Mean	Grouping	
B01	10	10.500	A	
B10	10	8.500	A	
B31	10	4.900		B
B22	10	3.700		B
B42	10	2.800		B

Table 4-6. Result of analysis of variance test for differences in mean otter trawl taxa richness between seasons.

One-way ANOVA: taxa Richness versus Season

Factor Information

Factor	Levels	Values
Season	3	Spring, Summer, Winter

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Season	2	7.797	3.898	0.27	0.767
Error	47	685.883	14.593		
Total	49	693.680			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3.82011	1.12%	0.00%	0.00%

Means

Season	N	Mean	StDev	95% CI
Spring	20	5.650	3.951	(3.932, 7.368)
Summer	15	6.133	3.583	(4.149, 8.118)
Winter	15	6.600	3.869	(4.616, 8.584)

Pooled StDev = 3.82011

Table 4-7. Result of Analysis of Variance test for differences in mean otter trawl taxa richness between flow tiers.

One-way ANOVA: taxa Richness versus Flow Tier

Factor Information

Factor	Levels	Values
Flow Tier	3	High, Low, Moderate

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Flow Tier	2	58.08	29.04	2.15	0.128
Error	47	635.60	13.52		
Total	49	693.68			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3.67742	8.37%	4.47%	0.00%

Means

Flow Tier	N	Mean	StDev	95% CI
High	15	5.200	3.121	(3.290, 7.110)
Low	20	7.400	3.952	(5.746, 9.054)
Moderate	15	5.200	3.802	(3.290, 7.110)

Pooled StDev = 3.67742

Table 4-8. Result of analysis of variance and Tukey multiple comparison test for differences in mean otter trawl diversity between sites.

One-way ANOVA: Shannon Diversity versus Site

Factor Information

Factor	Levels	Values
Site	5	B01, B10, B22, B31, B42

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	4	3.532	0.8831	5.21	0.002
Error	45	7.635	0.1697		
Total	49	11.167			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.411899	31.63%	25.55%	15.59%

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Site	N	Mean	Grouping	
B10	10	1.2897	A	
B01	10	0.913	A	B
B42	10	0.660		B
B31	10	0.624		B
B22	10	0.575		B

Means that do not share a letter are significantly different.

Table 4-9. Result of analysis of variance test for differences in mean otter trawl diversity between seasons.

One-way ANOVA: Shannon Diversity versus Season

Factor Information

Factor	Levels	Values
Season	3	Spring, Summer, Winter

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Season	2	0.1018	0.05090	0.22	0.806
Error	47	11.0653	0.23543		
Total	49	11.1671			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.485213	0.91%	0.00%	0.00%

Means

Season	N	Mean	StDev	95% CI
Spring	20	0.7735	0.4407	(0.5552, 0.9918)
Summer	15	0.880	0.509	(0.628, 1.132)
Winter	15	0.797	0.518	(0.545, 1.049)

Pooled StDev = 0.485213

Table 4-10. Result of analysis of variance test for differences in mean otter trawl diversity between flow tiers.

One-way ANOVA: Shannon Diversity versus Flow Tier

Factor Information

Factor	Levels	Values
Flow Tier	3	High, Low, Moderate

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Flow Tier	2	0.7303	0.3651	1.64	0.204
Error	47	10.4368	0.2221		
Total	49	11.1671			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.471232	6.54%	2.56%	0.00%

Means

Flow Tier	N	Mean	StDev	95% CI
High	15	0.870	0.522	(0.625, 1.115)
Low	20	0.9064	0.4028	(0.6944, 1.1184)
Moderate	15	0.629	0.503	(0.384, 0.874)

Pooled StDev = 0.471232

Table 4-11. Result of analysis of variance test for differences in mean otter trawl evenness between sites.

One-way ANOVA: Pielous Evenness versus Site

Factor Information

Factor	Levels	Values
Site	5	B01, B10, B22, B31, B42

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	4	0.5266	0.13165	1.73	0.160
Error	45	3.4218	0.07604		
Total	49	3.9485			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.275755	13.34%	5.63%	0.00%

Means

Site	N	Mean	StDev	95% CI
B01	10	0.4009	0.1599	(0.2253, 0.5766)
B10	10	0.6459	0.2225	(0.4702, 0.8215)
B22	10	0.569	0.331	(0.394, 0.745)
B31	10	0.3923	0.2461	(0.2167, 0.5680)
B42	10	0.583	0.367	(0.407, 0.758)

Pooled StDev = 0.275755

Table 4-12. Result of analysis of variance test for differences in mean otter trawl evenness between seasons.

One-way ANOVA: Pielous Evenness versus Season

Factor Information

Factor	Levels	Values
Season	3	Spring, Summer, Winter

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Season	2	0.05513	0.02757	0.33	0.719
Error	47	3.89332	0.08284		
Total	49	3.94846			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.287814	1.40%	0.00%	0.00%

Means

Season	N	Mean	StDev	95% CI
Spring	20	0.5489	0.2780	(0.4194, 0.6784)
Summer	15	0.5259	0.2780	(0.3764, 0.6754)
Winter	15	0.4696	0.3098	(0.3201, 0.6191)

Pooled StDev = 0.287814

Table 4-13. Result of analysis of variance test for differences in mean otter trawl evenness between flow tiers.

One-way ANOVA: Pielous Evenness versus Flow Tier

Factor Information

Factor	Levels	Values
Flow Tier	3	High, Low, Moderate

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Flow Tier	2	0.1906	0.09528	1.19	0.313
Error	47	3.7579	0.07996		
Total	49	3.9485			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.282764	4.83%	0.78%	0.00%

Means

Flow Tier	N	Mean	StDev	95% CI
High	15	0.5865	0.2932	(0.4397, 0.7334)
Low	20	0.5330	0.2417	(0.4058, 0.6602)
Moderate	15	0.4302	0.3212	(0.2833, 0.5771)

Pooled StDev = 0.282764

Table 4-14. Result of analysis of variance test for differences in mean beam trawl Log (CPUE+1) between sites.

One-way ANOVA: Log CPUE versus Site

Factor Information

Factor	Levels	Values
Site	5	B01, B10, B22, B31, B42

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	4	6.701	1.675	0.97	0.434
Error	45	77.753	1.728		
Total	49	84.454			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.31447	7.93%	0.00%	0.00%

Means

Site	N	Mean	StDev	95% CI
B01	10	1.648	1.614	(0.811, 2.485)
B10	10	1.860	1.388	(1.023, 2.697)
B22	10	1.738	1.412	(0.901, 2.575)
B31	10	1.690	0.917	(0.853, 2.528)
B42	10	2.632	1.129	(1.795, 3.469)

Pooled StDev = 1.31447

Table 4-15. Result of analysis of variance test for differences in mean beam trawl Log (CPUE+1) between flow tiers.

One-way ANOVA: Log CPUE versus Flow Tier

Factor Information

Factor	Levels	Values
Flow Tier	3	High, Low, Moderate

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Flow Tier	2	8.016	4.008	2.46	0.096
Error	47	76.438	1.626		
Total	49	84.454			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.27528	9.49%	5.64%	0.00%

Means

Flow Tier	N	Mean	StDev	95% CI
High	15	2.241	1.354	(1.578, 2.903)
Low	20	1.423	1.152	(0.850, 1.997)
Moderate	15	2.240	1.351	(1.578, 2.903)

Pooled StDev = 1.27528

Table 4-16. Result of analysis of variance and Tukey multiple comparison test for differences in mean beam trawl Log (CPUE+1) between seasons.

One-way ANOVA: Log CPUE versus Season

Factor Information

Factor	Levels	Values
Season	3	Spring, Summer, Winter

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Season	2	19.68	9.838	7.14	0.002
Error	47	64.78	1.378		
Total	49	84.45			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.17399	23.30%	20.03%	12.91%

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Season	N	Mean	Grouping	
Winter	15	2.669	A	
Spring	20	1.989	A	B
Summer	15	1.057		B

Means that do not share a letter are significantly different.

Table 4-17. Result of Kruskal-Wallis analysis of variance test for differences in median beam trawl taxa richness between sites.

Kruskal-Wallis Test: taxa richness versus site				
Descriptive Statistics				
Site	N	Median	Mean Rank	Z-Value
B01	10	1	17.8	-1.87
B10	10	2	23.5	-0.49
B22	10	2	22.9	-0.63
B31	10	2	25.4	-0.04
B42	10	4	38.0	3.02
Overall	50		25.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	4	10.59	0.032
Adjusted for ties	4	11.02	0.026

Table 4-18. Result of Kruskal-Wallis analysis of variance test for differences in median beam trawl taxa richness between seasons.

Kruskal-Wallis Test: species richness versus Season				
Descriptive Statistics				
Season	N	Median	Mean Rank	Z-Value
Winter	15	3.0	30.7	1.64
Spring	20	2.5	28.9	1.33
Summer	15	1.0	15.9	-3.06
Overall	50		25.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	2	9.49	0.009
Adjusted for ties	2	9.87	0.007

Table 4-19. Result of Kruskal-Wallis analysis of variance test for differences in median beam trawl taxa richness between flow tiers.

Kruskal-Wallis Test: species richness versus Flow Tier

Descriptive Statistics

Flow Tier	N	Median	Mean Rank	Z-Value
Low	20	1.5	20.9	-1.83
Moderate	15	2.0	25.9	0.14
High	15	3.0	31.2	1.82
Overall	50		25.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	2	4.35	0.114
Adjusted for ties	2	4.52	0.104

Table 4-20. Result of analysis of variance and Tukey multiple comparison test for differences in mean beam trawl diversity between sites.

One-way ANOVA: Shannon Diversity (H) versus Site

Factor Information

Factor	Levels	Values
Site	5	B01, B10, B22, B31, B42

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	4	2.328	0.5820	2.78	0.038
Error	45	9.428	0.2095		
Total	49	11.756			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.457718	19.80%	12.67%	0.99%

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Site	N	Mean	Grouping	
B42	10	0.871	A	
B31	10	0.549	A	B
B10	10	0.499	A	B
B22	10	0.411	A	B
B01	10	0.2081		B

Means that do not share a letter are significantly different.

Table 4-21. Result of analysis of variance test for differences in mean beam trawl diversity between seasons.

One-way ANOVA: Shannon Diversity (H) versus Season

Factor Information

Factor	Levels	Values
Season	3	Spring, Summer, Winter

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Season	2	1.349	0.6746	3.05	0.057
Error	47	10.406	0.2214		
Total	49	11.756			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.470546	11.48%	7.71%	0.01%

Means

Season	N	Mean	StDev	95% CI
Spring	20	0.573	0.503	(0.362, 0.785)
Summer	15	0.263	0.403	(0.019, 0.508)
Winter	15	0.664	0.487	(0.420, 0.909)

Pooled StDev = 0.470546

Table 4-22. Result of analysis of variance test for differences in mean beam trawl evenness between seasons.

One-way ANOVA: Pielous Evenness (J) versus Season

Factor Information

Factor	Levels	Values
Season	3	Spring, Summer, Winter

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Season	2	0.8063	0.4032	2.51	0.092
Error	47	7.5432	0.1605		
Total	49	8.3495			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.400616	9.66%	5.81%	0.00%

Means

Season	N	Mean	StDev	95% CI
Spring	20	0.5157	0.4144	(0.3355, 0.6959)
Summer	15	0.273	0.411	(0.065, 0.481)
Winter	15	0.5810	0.3697	(0.3729, 0.7891)

Pooled StDev = 0.400616

Table 4-23. Result of analysis of variance test for differences in mean beam trawl diversity between flow tiers.

One-way ANOVA: Shannon Diversity (H) versus Flow Tier

Factor Information

Factor	Levels	Values
Flow Tier	3	High, Low, Moderate

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Flow Tier	2	0.3241	0.1620	0.67	0.518
Error	47	11.4315	0.2432		
Total	49	11.7556			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.493177	2.76%	0.00%	0.00%

Means

Flow Tier	N	Mean	StDev	95% CI
High	15	0.630	0.560	(0.374, 0.886)
Low	20	0.447	0.514	(0.225, 0.669)
Moderate	15	0.4663	0.3799	(0.2102, 0.7225)

Pooled StDev = 0.493177

Table 4-24. Result of analysis of variance test for differences in mean beam trawl evenness between flow tiers.

One-way ANOVA: Pielous Evenness (J) versus Flow Tier

Factor Information

Factor	Levels	Values
Flow Tier	3	High, Low, Moderate

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Flow Tier	2	0.03144	0.01572	0.09	0.915
Error	47	8.31810	0.17698		
Total	49	8.34953			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.420691	0.38%	0.00%	0.00%

Means

Flow Tier	N	Mean	StDev	95% CI
High	15	0.480	0.395	(0.261, 0.698)
Low	20	0.432	0.466	(0.243, 0.621)
Moderate	15	0.4859	0.3786	(0.2674, 0.7044)

Pooled StDev = 0.420691

Table 4-25. Result of analysis of variance test for differences in mean beam trawl evenness between sites.

One-way ANOVA: Pielous Evenness (J) versus Site

Factor Information

Factor	Levels	Values
Site	5	B01, B10, B22, B31, B42

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	4	0.9474	0.2368	1.44	0.236
Error	45	7.4022	0.1645		
Total	49	8.3495			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.405577	11.35%	3.47%	0.00%

Means

Site	N	Mean	StDev	95% CI
B01	10	0.252	0.360	(-0.006, 0.510)
B10	10	0.438	0.435	(0.179, 0.696)
B22	10	0.441	0.448	(0.182, 0.699)
B31	10	0.501	0.445	(0.243, 0.759)
B42	10	0.681	0.322	(0.423, 0.939)

Pooled StDev = 0.405577

Table 4-26. Result of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker Log (CPUE+1) in otter trawl collections between sites.

Kruskal-Wallis Test: CPUE versus Site

Descriptive Statistics

Site	N	Median	Mean Rank	Z-Value
B01	10	30.0	38.9	3.24
B10	10	17.5	37.3	2.85
B22	10	0.5	23.9	-0.39
B31	10	0.0	16.5	-2.18
B42	10	0.0	11.0	-3.52
Overall	50		25.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	4	28.71	0.000
Adjusted for ties	4	31.04	0.000

Table 4-27. Results of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker Log (CPUE+1) in otter trawl collections between seasons.

Kruskal-Wallis Test: CPUE versus Season				
Descriptive Statistics				
Season	N	Median	Mean Rank	Z-Value
Winter	15	35.0	32.1	2.11
Spring	20	0.5	22.1	-1.34
Summer	15	1.0	23.4	-0.68
Overall	50		25.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	2	4.50	0.105
Adjusted for ties	2	4.86	0.088

Table 4-28. Result of Kruskal-Wallis Analysis of Variance test for differences in median Atlantic Croaker Log (CPUE+1) in otter trawl collections between flow tiers.

Kruskal-Wallis Test: CPUE versus Flow Tier				
Descriptive Statistics				
Flow Tier	N	Median	Mean Rank	Z-Value
Low	20	1.5	26.9	0.57
Moderate	15	0.0	26.0	0.16
High	15	1.0	23.1	-0.77
Overall	50		25.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	2	0.63	0.729
Adjusted for ties	2	0.70	0.704

Table 4-29. Results of Kruskal-Wallis Analysis of Variance test for differences in median Atlantic Croaker length from otter trawl collections between sites.

Kruskal-Wallis Test: Length versus Site

Descriptive Statistics

Site	N	Median	Mean Rank	Z-Value
B01	114	104.5	141.9	1.74
B10	109	109.0	144.0	2.05
B22	39	18.0	70.8	-5.47
B31	2	108.0	172.8	0.75
Overall	264		132.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	3	30.23	0.000
Adjusted for ties	3	30.24	0.000

The chi-square approximation may not be accurate when some sample sizes are less than 5.

Table 4-30. Result of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker length from otter trawl collections between seasons.

Kruskal-Wallis Test: Length versus Season

Descriptive Statistics

Season	N	Median	Mean Rank	Z-Value
Winter	109	31.0	101.8	-5.48
Spring	88	71.5	138.2	0.85
Summer	67	119.0	175.0	5.28
Overall	264		132.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	2	38.90	0.000
Adjusted for ties	2	38.91	0.000

Table 4-31. Result of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker length from otter trawl collections between flow tiers.

Kruskal-Wallis Test: Length versus Flow Tier				
Descriptive Statistics				
Flow Tier	N	Median	Mean Rank	Z-Value
Low	115	116	156.3	4.46
Moderate	89	58	103.0	-4.47
High	60	68	130.5	-0.23
Overall	264		132.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	2	24.50	0.000
Adjusted for ties	2	24.50	0.000

Table 4-32. Result of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker $\delta^{13}C$ between sites.

Kruskal-Wallis Test: $\delta^{13}C$ versus Site				
Descriptive Statistics				
Site	N	Median	Mean Rank	Z-Value
B01	39	-19.7987	63.6	4.41
B10	35	-21.1033	47.3	-0.31
B22	16	-24.0796	25.7	-3.59
B31	6	-25.2048	17.7	-2.80
Overall	96		48.5	

DF	H-Value	P-Value
3	29.66	0.000

Table 4-33. Result of Kruskal-Wallis Analysis of Variance test for differences in median Atlantic Croaker $\delta^{34}S$ between sites.

Kruskal-Wallis Test: $\delta^{34}S$ versus Site				
Descriptive Statistics				
Site	N	Median	Mean Rank	Z-Value
B22	16	9.1900	17.9	-2.30
B31	6	10.7028	17.6	-1.52
B10	12	13.0293	24.8	0.10
B01	12	16.1936	37.5	3.71
Overall	46		24.5	

DF	H-Value	P-Value
3	15.80	0.001

Table 4-34. Result of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker $\delta^{15}N$ between sites.

Kruskal-Wallis Test: $\delta^{15}N$ versus Site				
Descriptive Statistics				
Site	N	Median	Mean Rank	Z-Value
B22	16	16.0672	53.1	0.56
B31	6	15.7487	56.1	0.69
B10	35	15.9543	55.0	1.42
B01	39	15.5692	41.8	-2.19
Overall	96		49.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	3	4.88	0.181
Adjusted for ties	3	4.88	0.181

Table 4-35. Results of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker $\delta^{15}N$ between seasons.

Kruskal-Wallis Test: $\delta^{15}N$ versus Season				
Descriptive Statistics				
Season	N	Median	Mean Rank	Z-Value
Winter	54	16.0352	58.0	3.26
Spring	26	15.2586	37.0	-2.62
Summer	16	15.6115	42.2	-1.20
Overall	96		49.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	2	11.02	0.004
Adjusted for ties	2	11.02	0.004

Table 4-36. Results of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker $\delta^{13}C$ between seasons.

Kruskal-Wallis Test: $\delta^{13}C$ versus Season				
Descriptive Statistics				
Season	N	Median	Mean Rank	Z-Value
Winter	54	-20.5458	46.5	-1.15
Spring	26	-20.6666	54.3	1.01
Summer	16	-21.1435	51.4	0.32
Overall	96		49.5	

DF	H-Value	P-Value
2	1.43	0.488

Table 4-37. Results of Kruskal-Wallis Analysis of Variance test for differences in median Atlantic Croaker $\delta^{34}S$ between seasons.

Kruskal-Wallis Test: $\delta^{34}S$ versus Season				
Descriptive Statistics				
Season	N	Median	Mean Rank	Z-Value
Winter	30	12.5497	24.1	-0.28
Spring	7	14.3877	25.6	0.22
Summer	9	13.9550	25.0	0.13
Overall	46		24.5	

DF	H-Value	P-Value
2	0.08	0.959

Table 4-38. Results of Kruskal-Wallis Analysis of Variance test for differences in median Atlantic Croaker $\delta^{13}C$ between flow tiers.

Kruskal-Wallis Test: $\delta^{13}C$ versus Flow Tier				
Descriptive Statistics				
Flow Tier	N	Median	Mean Rank	Z-Value
Low	36	-22.0062	39.5	-2.76
Moderate	36	-20.3061	57.9	2.23
High	24	-20.6046	52.7	0.64
Overall	96		49.5	

DF	H-Value	P-Value
2	8.11	0.017

Table 4-39. Result of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker $\delta^{34}S$ between flow tiers.

Kruskal-Wallis Test: $\delta^{34}S$ versus Flow Tier				
Descriptive Statistics				
Flow Tier	N	Median	Mean Rank	Z-Value
Low	21	10.0380	16.7	-3.73
Moderate	16	15.1040	32.9	2.93
High	9	15.2162	29.7	1.23
Overall	46		24.5	

DF	H-Value	P-Value
2	14.18	0.001

Table 4-40. Result of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker $\delta^{15}N$ between flow tiers.

Kruskal-Wallis Test: $\delta^{15}N$ versus Flow Tier				
Descriptive Statistics				
Flow Tier	N	Median	Mean Rank	Z-Value
Low	36	15.6674	45.8	-1.02
Moderate	36	16.1042	59.0	2.52
High	24	15.4158	41.1	-1.66
Overall	96		49.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	2	6.75	0.034
Adjusted for ties	2	6.75	0.034

Table 4-41. Result of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker $\delta^{13}C$ between length bins.

Kruskal-Wallis Test: $\delta^{13}C$ versus Length Bin				
Descriptive Statistics				
Length Bin (mm)	N	Median	Mean Rank	Z-Value
10-30	35	-20.3507	48.5	-0.26
31-50	10	-19.9661	56.1	0.86
51-70	8	-20.9297	50.1	0.06
71-90	7	-21.9979	37.3	-1.18
91-110	8	-19.7601	70.1	2.14
111-130	12	-20.9236	52.6	0.40
131-150	8	-22.3639	35.4	-1.47
151-170	5	-21.1197	52.4	0.23
171-215	3	-23.1011	27.0	-1.39
Overall	96		49.5	

DF	H-Value	P-Value
8	10.24	0.249

Table 4-42. Result of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker $\delta^{34}S$ between length bins.

Kruskal-Wallis Test: $\delta^{34}S$ versus Length

Descriptive Statistics

Length Bin (mm)	N	Median	Mean Rank	Z-Value
10-30	20	12.9611	24.9	0.19
31-50	5	14.3877	25.9	0.28
51-70	2	13.2455	28.0	0.36
71-90	4	10.9945	15.0	-1.42
91-110	3	16.2160	36.7	1.55
111-130	3	12.1899	22.7	-0.23
131-150	5	12.9096	20.2	-0.73
151-170	3	14.6763	27.7	0.40
171-215	1	11.3280	18.0	-0.47
Overall	46		24.5	

DF	H-Value	P-Value
8	5.21	0.735

The chi-square approximation may not be accurate when some sample sizes are less than 5.

Table 4-43. Result of Kruskal-Wallis analysis of variance test for differences in median Atlantic Croaker $\delta^{15}N$ between length bins.

Kruskal-Wallis Test: $\delta^{15}N$ versus Length

Descriptive Statistics

Length Bin (mm)	N	Median	Mean Rank	Z-Value
10-30	35	16.4794	68.7	4.97
31-50	10	15.0225	29.2	-2.64
51-70	8	15.0523	24.9	-2.56
71-90	7	15.1793	35.0	-1.40
91-110	8	15.7562	46.8	-0.29
111-130	12	15.8364	53.5	0.52
131-150	8	15.6151	43.2	-0.66
151-170	5	15.6942	41.6	-0.64
171-215	3	15.2328	28.0	-1.33
Overall	96		49.5	

Method	DF	H-Value	P-Value
Not adjusted for ties	8	32.68	0.000
Adjusted for ties	8	32.68	0.000

The chi-square approximation may not be accurate when some sample sizes are less than 5.

Table 4-44. Result of Analysis of Variance and Tukey Multiple Comparison test for differences in mean POM $\delta^{34}S$ between sites.

One-way ANOVA: $\delta^{34}S$ versus Site

Factor Information

Factor	Levels	Values
Site	5	B01, B10, B22, B31, B42

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	4	230.4	57.591	6.34	0.001
Error	35	317.7	9.078		
Total	39	548.1			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3.01295	42.03%	35.41%	24.28%

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Site	N	Mean	Grouping		
B01	8	9.996	A		
B10	8	9.08	A	B	
B22	8	5.62		B	C
B42	8	4.83		B	C
B31	8	3.94			C

Means that do not share a letter are significantly different.

Table 4-45. Result of Kruskal-Wallis analysis of variance test for differences in median POM $\delta^{13}C$ between sites.

Kruskal-Wallis Test: $\delta^{13}C$ versus Site

Descriptive Statistics

Site	N	Median	Mean Rank	Z-Value
B01	8	-25.6115	18.1	-0.64
B10	8	-25.3568	16.8	-1.01
B22	8	-24.3565	22.5	0.54
B31	8	-24.7644	20.8	0.07
B42	8	-23.0427	24.4	1.05
Overall	40		20.5	

DF	H-Value	P-Value
4	2.27	0.686

Table 4-46. Result of Kruskal-Wallis analysis of variance test for differences in median POM $\delta^{15}N$ between sites.

Kruskal-Wallis Test: $\delta^{15}N$ versus Sites				
Descriptive Statistics				
Site	N	Median	Mean Rank	Z-Value
B01	8	6.97757	18.6	-0.51
B10	8	7.35114	19.6	-0.24
B22	8	9.17263	22.5	0.54
B31	8	7.00847	18.4	-0.57
B42	8	7.87428	23.4	0.78
Overall	40		20.5	

DF	H-Value	P-Value
4	1.23	0.873

Table 4-47. Result of Kruskal-Wallis analysis of variance test for differences in median POM $\delta^{13}C$ between seasons.

Kruskal-Wallis Test: $\delta^{13}C$ versus Season				
Descriptive Statistics				
Season	N	Median	Mean Rank	Z-Value
Winter	15	-22.9153	29.2	3.65
Spring	15	-24.8931	18.7	-0.74
Summer	10	-28.1190	10.1	-3.25
Overall	40		20.5	

DF	H-Value	P-Value
2	16.56	0.000

Table 4-48. Result of Kruskal-Wallis analysis of variance test for differences in median POM $\delta^{15}N$ between seasons.

Kruskal-Wallis Test: $\delta^{15}N$ versus Season				
Descriptive Statistics				
Season	N	Median	Mean Rank	Z-Value
Winter	15	6.84898	15.9	-1.91
Spring	15	7.07185	18.1	-0.99
Summer	10	9.54001	30.9	3.25
Overall	40		20.5	

DF	H-Value	P-Value
2	10.82	0.004

Table 4-49 Result of Kruskal-Wallis analysis of variance test for differences in median POM $\delta^{34}S$ between seasons.

Kruskal-Wallis Test: $\delta^{34}S$ versus Season				
Descriptive Statistics				
Season	N	Median	Mean Rank	Z-Value
Winter	15	3.63207	14.7	-2.44
Spring	15	6.91520	21.7	0.52
Summer	10	8.92089	27.4	2.16
Overall	40		20.5	

DF	H-Value	P-Value
2	7.39	0.025

Table 4-50. Result of analysis of variance test for differences in mean POM $\delta^{13}C$ between flow tiers.

One-way ANOVA: $\delta^{13}C$ versus Flow tier

Factor Information

Factor	Levels	Values
Flow tier	3	Low, Moderate, High

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Flow tier	2	117.5	58.727	10.13	0.000
Error	37	214.4	5.795		
Total	39	331.9			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2.40723	35.39%	31.90%	25.09%

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Flow tier	N	Mean	Grouping	
High	10	-22.256	A	
Moderate	15	-25.086		B
Low	15	-26.675		B

Means that do not share a letter are significantly different.

Table 4-51. Result of Kruskal-Wallis analysis of variance test for differences in median POM $\delta^{15}N$ between flow tiers.

Kruskal-Wallis Test: $\delta^{15}N$ versus Flow Tier

Descriptive Statistics

Flow Tier	N	Median	Mean Rank	Z-Value
Low	15	10.3865	28.6	3.39
Moderate	15	6.8407	15.9	-1.91
High	10	6.8661	15.2	-1.66
Overall	40		20.5	

DF	H-Value	P-Value
2	11.55	0.003

Table 4-52. Result of Analysis of Variance and Tukey multiple comparison test for differences in mean POM $\delta^{34}S$ between flow tiers.

One-way ANOVA: $\delta^{34}S$ versus Flow tier

Factor Information

Factor	Levels	Values
Flow tier	3	Low, Moderate, High

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Flow tier	2	86.30	43.15	3.46	0.042
Error	37	461.79	12.48		
Total	39	548.09			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3.53283	15.75%	11.19%	2.21%

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Flow tier	N	Mean	Grouping	
Low	15	8.57	A	
High	10	5.843	A	B
Moderate	15	5.375		B

Means that do not share a letter are significantly different.