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Feeding Ecology of Highly Migratory Epipelagic Offshore Predators in the Western North Atlantic Ocean

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FEEDING ECOLOGY OF HIGHLY MIGRATORY EPIPELAGIC OFFSHORE PREDATORS IN THE WESTERN NORTH ATLANTIC OCEAN

By

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Abstract
Describing trophic ecology of top predators in marine ecosystems is key to understanding the dynamics of these environments. Feeding ecologies of large predatory fishes were assessed using a combination of stomach content and stable isotope analysis. The target species for this study inhabit the epipelagic ecosystem of the U.S. South Atlantic Bight in the western North Atlantic Ocean. The studied species included five tuna species, five billfish species, Common Dolphinfish, and Wahoo. The goal of this study was to describe and compare the trophic dynamics of each species. From these data, the trophic complex of the offshore pelagic ecosystem was then compared to that of the previously described nearshore pelagic trophic complex. Stomach content analysis found that teleost and cephalopods were the dominant or most common prey type for the studied species. Schoener's Diet Overlap Indices found a high diet overlap amongst all five tuna species, Wahoo, Common Dolphinfish, Sailfish and Swordfish. Stable isotope analysis found that there are two trophic levels present. Bluefin Tuna are occupying a unique isotopic niche, feeding at the highest trophic position. Stable isotope results also displayed that Bigeye Tuna, Yellowfin Tuna, and Swordfish are feeding on similar depleted carbon sources, potentially due to their unique vertical migrations. The results of this study indicate that the trophic interactions occurring offshore reflect previous findings based on the nearshore trophic complexes. The data from this study contributes to the feeding ecology and trophic understanding of these pelagic species and can be used in ecosystem-based fishery management efforts.

Keywords: Marine Ecology, Tunas, Billfish, commercial fisheries, stable isotope analysis, stomach content analysis, South Atlantic Bight

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Table of Contents

List of Figures

List of Tables

Introduction

Large pelagic fishes such as tunas and billfishes act as upper-level predators on the food web and therefore play a key role in keeping trophic structure balanced (Heithaus *et al*. 2008). These upper-level predators are often species that are targeted or occur as bycatch in offshore commercial fisheries. The importance of these fish species to commercial fisheries makes them potentially vulnerable to overfishing (Gilman 2011). Removal of upper-level predators can result in trophic cascades within a marine food web (Sala *et al.* 1998). Thus, an understanding of the trophic ecologies of these upper-level predators can provide important information necessary to manage these species. Recently, ecosystem-based fisheries management has been incorporated into fishery management strategies to move towards more sustainable fisheries (Reynolds 2008).

The present study analyzed the trophic dynamics of marine predatory fishes within the epipelagic ecosystem of the U.S. western North Atlantic Ocean. Trophic dynamics were assessed using a combination of stomach content and stable isotope analyses. Biological samples (whole stomachs and muscle tissue) were collected via commercial pelagic longline fishing vessels. From stable isotope and stomach content analysis, feeding ecologies within a species and across the trophic complex were determined.

The objectives were as follows: describe the diets of each species, analyze the dietary overlaps between species, estimate the trophic position and niche width of each species, and lastly compare the results from the newly described offshore pelagic trophic structure to that of the better understood, biologically productive, nearshore trophic complex. The present study establishes a baseline of the trophic dynamics of this offshore-pelagic environment for future ecosystem studies.

Species Review

The targeted species for this study are commercially or recreationally valued species as well as upper-level predators within the epipelagic ecosystem. All the target species are in the order Perciformes and the families Scombridae, Coryphaenidae, Istiophoridae, and Xiphiidae. Six species are in the family Scombridae: Yellowfin Tuna *Thunnus albacares*, Albacore Tuna *Thunnus alalunga*, Bigeye Tuna *Thunnus obesus*, Skipjack Tuna *Katsuwonus pelamis*, Bluefin Tuna *Thunnus thynnus*, and Wahoo *Acanthocybium solandri*; four species are in the family

Istiophoridae: White Marlin *Kajikia albida*, Blue Marlin *Makaira nigricans*, Roundscale Spearfish *Tetrapturus georgii*, and Sailfish *Istiophorus albicans*; and one species is in the family Xiphiidae, Swordfish *Xiphias gladius*. The istiophorid billfishes are known for their spear-like modified maxilla and premaxilla bones (Habegger 2014), while Swordfish have a similar structure called a rostrum (McGowan 1988). The final species is Common Dolphinfish *Coryphaena hippurus* in the Coryphaenidae family. More information on average size, lifespan, and diet of each species is represented in Table 1.

All the target species for this study are considered 'epipelagic' since these species are known to inhabit the upper 200 m of the water column beyond the continental shelf (offshore) (Habtes *et al.* 2014). They are known to migrate large horizontal distances throughout the Atlantic Ocean (Weld 1989). Since these species are vagile and migrate great distances, they are commonly referred to as highly migratory species (HMS) (Molony 2008). HMS dominate the upper trophic levels of the epipelagic ecosystem, with common prey items including small to medium size fishes, cephalopods, and pelagic crustaceans (Logan, Toppin et al. 2013). Some species in this study display diel vertical migrations, defined as repeated differences in vertical position in the water column on a 24-hour cycle (Han and Straškraba 1998). Swordfish display reverse diel vertical migrations, migrating into the epipelagic from lower depths at night (Lerner *et al.* 2013). During the day, Bigeye Tuna inhabits depths below 200 m, and come into the epipelagic zone at night (Brill *et al.* 2005). The Istiophoridae and other Scombridae species perform short duration movements to depth, potentially in search of prey (Andrzejaczek *et al.* 2019; Braun *et al.* 2015). Due to this diel vertical movement pattern, there is often an overlap and continuity of trophic relations between the epipelagic and mesopelagic environments.

Stomach Content Analysis

Stomach content analysis has traditionally been used in fish diet studies to describe trophic relationships, behavior, feeding patterns, etc. (Hynes 1950; Hyslop 1980; Buckland *et al.* 2017). Stomach content analysis provides a short-term insight as to what an individual was feeding on during a point in time close to capture, providing a 'snapshot' of the diet (Renones *et al.* 2002). Fish are ideal for stomach content analysis for multiple reasons: they typically swallow their prey whole, have well-defined stomachs, play important trophic roles, and can be sampled in large numbers (Amundsen and Sánchez-Hernández 2019).

However, stomach content analysis has many challenges. Digestion rates may introduce over- or under-estimation of some prey items. Quickly digested prey items that remain in the stomach for brief periods could be underestimated (Amundsen and Sánchez-Hernández 2019; Baker *et al.* 2014). Conversely, indigestible hard body parts such as teleost bones, otoliths, or cephalopod beaks may be overestimated due to remaining in the stomach for longer periods of time (Amundsen and Sánchez-Hernández 2019; dos Santos and Jobling 1991). Identification of stomach contents to lower taxonomic levels can often be difficult, depending on the digestion and decomposition of individual prey items (Amundsen and Sánchez-Hernández 2019; Buckland *et al.* 2017). Stomach content analysis also may not consider spatial or temporal variation within the diets (Kadye and Booth 2012). Despite these issues, stomach content analyses can still provide information on diet composition and prey selectivity of a species and provide crucial information about fish species' trophic ecologies (Amundsen and Sánchez-Hernández 2019).

Stomach contents can be described in several ways. Percentage composition by number (%N) represents the number of particular prey items to the total number of all prey items. Percentage composition by weight (%W) is the weight of a specific prey type to the overall weight of all stomach contents (Tirasin and Terje 1999). Frequency of occurrence (%O) is the number of stomachs in which a specific prey item is represented, describing the frequency of prey items in stomachs (Amundsen and Sánchez-Hernández 2019). Finally, the index of relative importance (IRI) and percentage index of relative importance (%IRI) combines %O, %N, and %W to describe the relative contribution of prey types (Cortés 1998, Liao *et al*. 2001, Pinkas 1971).

Cumulative prey curve analyses are used to determine sample size sufficiency within stomach contents for each species (Morris and Akins 2009). As sample size increases, the variation of prey items starts to decrease and with this rate decrease an asymptote occurs. Cumulative prey curves are created by plotting the number of each prey type against the number of stomachs analyzed (Ferry 1996). The asymptote of each curve, which represents a 1% increase for each new prey family, was used to assess whether the minimum sample size required to accurately describe a diet for each species had been achieved (Ferry 1996; Heemsoth *et al*. 2020; Weidner *et al.* 2017).

It is useful to know adequate sample sizes needed to accurately describe the diet of a species. Previous studies have used prey accumulation curves to determine accurate sample size for a species. Da Silva *et al.* (2019) reached the asymptote with a sample size of 195 stomachs for Bigeye Tuna and 212 stomachs for Yellowfin Tuna. For Albacore Tuna, Consoli *et al.* 2008 found that 189 stomachs was a sufficient sample size. Pleizier *et al*. (2012) reached the asymptote sample size for Bluefin Tuna at 31 stomachs. Sample sizes of 238 stomachs for Common Dolphinfish and 290 stomachs for Sailfish was sufficient in the study by Varghese *et al.* (2014). Heemsoth *et al.* (2020) found only 31 stomachs reached the asymptote for Swordfish. Rudershausen *et al.* (2010) reached a asymptote for Blue Marlin with 70 stomachs sampled and for Wahoo with 101 stomachs.

Stable Isotope Analysis

In contrast with stomach content analysis, which only provides a "snapshot" of recently ingested prey, stable isotope analysis reflects what has been not only ingested by the predator but assimilated into its tissues. Because of the time needed for this biological assimilation, stable isotope analyses give a broader insight of diets through longer-duration feeding patterns (Kadye and Booth 2012; Vizzini *et al.* 2002). When compared to stomach content analysis, stable isotope analysis is independent of digestion rates of prey items and thus is less time sensitive.

All elements have isotope species that vary in atomic weight due to differences in the number of neutrons present in the nucleus (Fry 2006). A stable isotope does not decay over time (Michener and Lajtha 2008). From an ecosystem perspective, the relative percentage of these isotopic elements change as elements are cycled through the biosphere (Peterson and Fry 1987). Isotopic composition changes can be used to examine many different biological factors, such as trophic positions and carbon source.

Stable isotope ratios are the ratio of heavier to lighter isotopes within a single sample. For the most common carbon stable isotope (^{13}C or carbon-13), the isotope ratio is $^{13}C/^{12}C$ which is represented by $\delta^{13}C$. For the nitrogen stable isotope (^{15}N or nitrogen-15) the isotope ratio is $^{15}N/^{14}N$ which is represented by $\delta^{15}N$. Isotope ratios are measured by per mil or parts per thousand which is represented by ‰. If an isotope is heavier, it is more enriched or more positive and if the isotope is lighter, it is more depleted or more negative. Isotopic discrimination or fractionation refers to the changes in the δ values between a substrate and a product. For this study, trophic fractionation of nitrogen-15 and carbon-13 are used (Bond and Hobson 2012; Fry 2006).

Stable isotopes are commonly used when reconstructing diets and observing trophic relationships by quantifying energy flow (Boecklen *et al.* 2011; Garvey and Chipps 2012). In aquatic food webs, the most commonly used stable isotopes are carbon-13 (^{13}C) and nitrogen-15 (^{15}N). The trophic fractionation for nitrogen-15 is 3-5‰ from the prey to the predator and is used to identify the trophic position of an individual. The more enriched the $\delta^{15}N$ value, the higher trophic level that individual occupies. Carbon-13 trophic fractionation is 0.5-1‰ from prey to predator and is used to identify the base (original carbon source via primary productivity) of the food chain (DeNiro and Epstein 1978,1981). In the pelagic system, the carbon source is primary production of phytoplankton and thus acts as the base of the food web (Reynolds 2008).

The standards used for stable isotope analysis are usually atmospheric nitrogen for ^{15}N and Pee Dee belemnite limestone for ^{13}C (Garvey and Chipps 2012; Peterson and Fry 1987; Post 2002). The ratio of heavier to lighter isotope, represented as $\delta^{13}C$ and $\delta^{15}N$, can be calculated using the following formula where R represents $\delta^{13}C$ or $\delta^{15}N$ of the sample and the standard (Fry 2006):

$$\delta^{13}C \text{ (or } \delta^{15}N) = [(R_{sample}/R_{standard}) - 1] \times 1000$$

When tissue growth and catabolic turnover occurs within a tissue, isotopic turnover occurs (Vander Zanden *et al.* 2015). Isotopic turnover times vary by tissue type; therefore, isotopic turnover rate of a sample is taken into consideration when evaluating feeding (Heady and Moore 2013). Skeletal muscle tissue turnover rate in fish is 3-4 months and is lower compared to that of other tissue samples like liver that has turnover rates of 1-2 weeks (Fry 2006). This makes fish muscle tissue ideal for more long-term feeding studies, since the longer turnover time provides a longer feeding history (Garvey and Chipps 2012).

When examining stable isotope values, it is useful to reference stbale isotope values from previous studies. Nitrogen and carbon stable isotope values from previous studies were found for each predator species included in this study (Table 2). Stable isotope values for common Prey items of the predators examined in this study were also found (Table 3).

Stable Isotope and Stomach Content Analysis Combination

The combined use of stomach content and stable isotope analyses gives this study an advantage over those that use just one method. As mentioned previously, stomach content analysis gives a short-term feeding history whereas stable isotopes give a longer-term feeding history. The combination of both methodologies provides a complementary understanding of trophic relationships (Davis *et al*. 2012). By combining stable isotope and stomach contents analyses, diet composition and trophic positions can be linked and provide additional insight into the trophodynamics of a community (Polo-Silva *et al.* 2013).

Keller *et al*. (2016) used the combination of stomach content and stable isotope analysis to gain knowledge of mesopelagic fishes' feeding ecologies in the North Atlantic Ocean. By using this combination, this analysis was able to determine the differences in ecosystem use between species. The evidence suggested that an ontogenetic shift occurs within the Oilfish *Ruvettus pretiosus,* a mesopelagic gemplyid species. Pasquaud *et al.* (2008) analyzed the fish food web in the Gironde Estuary (France) using the combination of stomach content and stable isotopes and highlighted the benefits of using this combination. By using the stomach content analysis, their study found that there was a sharing of resources between species and that a 'wasp-waist' control was occurring within the estuarine ecosystem. With stable isotope analysis, their study was able to further develop the structural knowledge of the estuarine food web by determining each species position within the food web using the nitrogen stable isotope. Polo-Silver *et al.* (2013) analyzed a trophic shift in the diet of the Pelagic Thresher Shark *Alopias pelagicus* in Ecuadorian waters using both stable isotope and stomach content analysis. This previous study stated how the two methodologies provided them with a better understanding of the relationship between predator and prey species and found that these predators are acting as a secondary-tertiary carnivore with a mixed diet.

Study Site

Samples for this study were collected from the South Atlantic Bight located in the Western Atlantic Ocean within the epipelagic ecosystem. Sample collection occurred onboard longline commercial fishing vessels. Figure 1 displays the starting location of each vessel on the first set for each sampling trip. All vessel locations ranged from 137 nautical miles to 446 nautical miles offshore. The minimum depth range of the vessels was 1,000m and the maximum depth range was 5,000m. This area is located offshore and is subject to seasonal temperature variations, with temperature fluctuations from cool water flowing south from New England and warm water flowing north from the Gulf Stream (Stevenson 2004). Wind driven circulation occurs within this region, driving the formation of the subtropical gyre (Hernández-Guerra, Talley *et al*. 2019). Sampling for this study occurred during the hurricane season of 2020, which was an extremely active season (Klotzbach et al. 2022). Hurricane activity can increase turbulent mixing of nutrients in the water column (Havens et al. 2011). This activity may have caused these waters to be more productive than usual during the summer and fall sampling periods. For the purpose of this study, a nearshore individual was defined as caught along the coast or on the continental shelf, while an offshore individual was defined as caught beyond the continental shelf.

The epipelagic ecosystem extends over the upper 200 meters (m) of the water column, offshore, beyond the continental shelf (Allen and Cross 2006; Hudson 1998). This environment consists of the surface layer of the ocean, where there is light penetration, and allows this ecosystem to be euphotic. The productivity of this ecosystem varies throughout the year and at times comes from oceanographic processes such as upwelling and Ekman transport which fuel phytoplankton blooms. These blooms act as the base of the trophic system on which large epipelagic predator fishes depend (Allen and Cross 2006; Childress *et al.* 1980).

The ecosystem directly below the epipelagic is the mesopelagic, which is located at 200-800 m (Allen and Cross 2006). The mesopelagic zone has diminished light, increases in hydrostatic pressure and has less nutrient productivity (Robinson *et al*. 2010). Larger epipelagic fishes, like the ones in this study, occasionally move between the epipelagic and mesopelagic zones in search of prey, connecting the two ecosystems (Brill *et al.* 2002; Vaske *et al.* 2012).

Previous Research

Previous research has examined the trophic dynamics of many of the targeted species for this study. However, previous studies varied in location, species analyzed, and methods used. Rudershausen *et al.* (2011) described the feeding ecologies of Blue Marlin, Yellowfin Tuna, Wahoo, and Dolphinfish in the North Atlantic Ocean. While Rudershausen *et al.* (2011) analyzed some of the same species as this study, four additional tuna species and four additional billfish species were added for this study. Another difference is that Rudershausen *et al*. (2011) used samples from coastal species caught in recreational fishing tournaments whereas samples for this study were caught in the offshore pelagic environment by commercial pelagic longline fishing vessels. Rudershausen *et al.* (2011) also only used stomach content analysis where this study used a combination of stomach content and stable isotope analysis. Finally, Rudershausen *et al*. (2011) found that the diets of these predators were largely very similar with only minor differences between species. In contrast, Logan and Lutcavage (2013) analyzed the diets of Albacore Tuna, Bigeye Tuna, Blue Marlin, White Marlin, Swordfish, Dolphinfish, and Yellowfin Tuna, but only used stable isotope analysis. Their study also found that the diets were very similar across species and that the Swordfish occupied the highest trophic level. Other studies have used a combination of stable isotope and stomach content analysis to examine diets, but on a single species (e.g., Weidner *et al.* (2017) for pelagic stingray). Descriptive diet studies are especially lacking for billfish species because of the difficulty in obtaining dead specimens. (Retention of all billfishes is prohibited in U.S. commercial fisheries and many recreational fisheries for billfishes are transitioning to catch-and-release.) There is no study to date that uses the combination of stable isotope and stomach content analysis across all 12 of the targeted species as this study.

Previous research has also begun to examine the structure of trophic networks between nearshore and offshore environments. Kopp *et al.* (2015) found that an inshore-offshore gradient occurred within upper-level consumers of the trophic structure in the eastern English Channel. Another study found greater diversity of feeding ecologies in offshore populations of southern bluefin tuna (Young *et al.* 1997). The authors compared prior feeding ecology studies of nearshore pelagic fish species to the newly described feeding ecologies of offshore pelagic fishes to determine the differences or similarities of the upper-level predator feeding complexes between the two environments.

Materials and Methods:

Specimen Collection

All specimens for this study were collected by an NSU-based scientific observer aboard two U.S.-flagged pelagic longline fishery vessels that target tunas and swordfish in the western North Atlantic Ocean. When a sampled specimen was brought aboard, the length, boarding status (dead/alive), and sex were recorded, and each individual was assigned a tag code which acted as the individual identification. Stomachs were removed and placed into an individual plastic bag. A muscle tissue sample was taken from the dorsal side of each fish and placed inside a small plastic bag and stored in the larger plastic bag containing the stomach. Each specimen was stored separately to ensure no cross contamination of the muscle tissue occurred for stable isotope analysis.

Stomachs and tissue samples were kept on ice initially during the gear retrieval (*ca.* 1-12 hours), then transferred to the boat freezer at -20° C for the remainder of the trip (*ca.* 2-4 weeks). After the vessel was offloaded, stomach and tissue samples were transported to the NSU Fisheries and Avian Ecology Laboratory at the Oceanographic Center campus while frozen, where they were transferred to standard -20° C freezers until final processing.

Stomach Content Analysis

For stomach content analysis, fixation of the stomachs occurred first. Stomachs were removed from the freezers and transferred into 100% cotton, cloth parts bags (8”x12” or 12”x16”, ULINE), labeled, and fully submerged into a 10% neutral buffered formalin solution in a 5-gallon bucket. After the samples fixed in the 10% formalin solution for *ca.* two weeks, they were transferred to another 5-gallon bucket with 70% ethanol solution and soaked for another *ca.* two weeks to remove the residual formalin prior to examination (Bowen 1996).

Full stomach weights were recorded to the nearest 0.1 g, and a stomach fullness rating was recorded on a qualitative scale of four (completely full) to zero (completely empty). The stomach was then opened, and all contents removed, including parasites and non-prey items (e.g., macroplastics or bait). The empty stomach was weighed to the nearest 0.1 g. Prey items were sorted, weighed to the nearest 0.1 g, and measured to the nearest mm (total length). Each prey item was given a digestion rate on a scale of one (completely intact) to four (unidentifiable) and identified to the lowest possible taxonomic group with the use of identification keys (Rypel 2013; Hynes 1950; Hyslop 1980; Hollingworth 2005).

Stable Isotope Analysis

Frozen muscle tissue samples were removed from their original packaging on the vessel, rinsed with DI water, and placed into labeled centrifuge tubes and frozen again at -20° C until they could be processed. Muscle tissue samples were removed from the freezer and transferred from the centrifuge tubes to aluminum trays. The samples were placed in a drying oven at 60° C for a minimum of 72 hours to dry. Once dried, samples were homogenized into powder using a Wig-L-Bug amalgamator (Crescent Dental Mfg. Co., Lyons, IL, USA). After the samples were homogenized, they were weighed between 0.6 and 0.8 mg and then placed into tin capsules and sealed. Isotope ratio analysis was performed with a continuous flow mass spectrometer using standards of atmospheric N_2 for nitrogen and Pee Dee belemite for carbon (Thermo Delta V Advantage mass spectrometer in continuous flow mode coupled to a Costech 4010 Elemental Analyzer via a Thermo Conflo IV (Thermo Fisher Scientific, Waltham, MA, USA)).

Data Analysis

A species accumulation curve (SAC) was generated for each species to determine if a sufficient number of stomach samples had been collected to describe prey diversity. RStudio library vegan (PBC-2021.09.2) was used to generate species accumulation curves (accumcomp curve). The mean number of prey items for each species was plotted against the number of stomachs sampled for that species. Heemsoth *et al.* (2020) grouped prey items by genus since identification down to the species level can be difficult due to the digestion of prey items. For this study, prey items were also grouped by genus for the cumulative prey curves.

Other data analysis was performed using Microsoft Excel (Version 16.58). The following calculations were used to analyze stomach content: frequency of occurrence, percent composition by number, percent composition by weight, the index of relative importance, percent index of relative importance, and diet overlap indices between species.

Frequency of occurrence (%O) is the proportion of stomachs that contained one or more of a given prey item. %O is calculated by dividing the total number of stomachs with a specific prey type (N_i) by the total number individuals with items in their stomach (N_t). (Bowen 1996; Buckland *et al.* 2017; Hynes 1950; Hyslop 1980).

$$\%O = \frac{N_i}{N_t}(100)$$

Percent composition by number (%N) is the proportion of a particular prey type out of all prey items counted. %N is calculated by dividing the total number of a specific prey type (N_i) by the total number of all prey items found (N_t) (Bowen 1996; Hynes 1950; Hyslop 1980; Morris and Akins 2009).

$$\%N = \frac{N_i}{N_t}(100)$$

Percent composition by weight (%W) is the proportion of the weight of a particular prey item to the overall weight of stomach content. %W is calculated by dividing the total weight of a prey type (W_i) by the total weight of the stomach contents (W_t) (Bowen 1996; Hynes 1950; Hyslop 1980).

$$\%W = \frac{W_i}{W_t}(100)$$

Index of relative importance (IRI) combines frequency of occurrence, percentage by number, and percentage by volume to be more representative of each prey item (Bowen 1996; George and Hadley 1979; Hyslop 1980).

$$IRI = (\%N+\%W)*\%F$$

A standardized index of IRI known as percent index of relative importance (%IRI) is also calculated to better evaluate the importance of each prey taxa (Liao *et al.* 2001, Pinkas 1971).

$$\%IRI_i = 100 * IRI_i \sum_{i=1}^{n} IRI_i$$

Diet overlap indices is the similarities of diets between fish species. Diet overlap, also known as Schoener's Index, is represented by C_{xy} and is calculated by subtracting the proportion of a prey type in one species (p_{xi}) from the proportion of the same prey type for a different species (p_{yi}) (Bowen 1996; Glassic *et al*. 2021; Schoener 1971).

$$C_{xy} = 1 - 0.5(\sum |p_{xi} - p_{yi}|)$$

Using the species association analysis (spaa) package in R Studio using the values for percent frequency of occurrence (%O), Schoener's diet overlap indices were created to examine which species had dietary overlaps. These overlaps are made between two species and have values that run from zero to one. The minimum taxonomic resolution for this analysis was species. Paired relationships that have a value >0.6 indicate significant dietary overlaps between those two species (Guzzo-Haffner *et al.* 2013).

Trophic position estimates were made using stable isotope analysis data and the equation below (Richards *et al.* 2020). $\Delta^{15}N_i$ represents the mean nitrogen signature of each species, $\delta^{15}N_{base}$ represents the nitrogen signature of the primary consumer. Following Cherel *et al.* (2008), the salp *Salpa thompsoni* was chosen as the base consumer with a value of 3.4‰ and assumed a trophic level of 2.0. This salp species filter feeds on phytoplankton and other small prey items and are often used as the primary consumer to estimate trophic levels. Trophic enrichment factor (TEF) represents the enrichment of ^{15}N with every increase in trophic level. Using the number from Sweeting *et al.* (2007), this value is 3.2‰.

$$TP_{SIA} = \frac{\delta^{15}N_i - \delta^{15}N_{base}}{TEF} + 1$$

The Stable Isotope Analysis package for R-statistical environment software was used for statistical analysis of the stable isotope data. SIBER (Stable Isotope Bayesian Ellipses in R) originated from the stable isotope mixing model called Stable Isotope Analysis in R (SIAR). SIBER built off SIAR to incorporate Bayesian modeling to include additional analysis of the isotopic niche width (Jackson *et al.* 2011). SIBER was used to reconstruct ellipse areas (Wißing *et al.* 2019). These ellipses areas represent the isotopic niches for each species. Isotopic niches incorporate the stable carbon and nitrogen isotope values to display if the isotopic niche of a species is wide or narrow. A wide isotopic niche could indicate a species is displaying more generalist feeding behavior, consuming prey with varying isotopic values. A narrow isotopic niche could indicate a species is feeding more specialist, consuming on the same or similar prey with similar isotopic values (Flaherty and Ben-David 2010).

Lipids contain more negative $\delta^{13}C$ values in comparison to other biochemical compounds, which can cause variability and thus bias in the $\delta^{13}C$ values of the tissue samples. A sample with a high lipid content (fatty tissue) will cause the $\delta^{13}C$ value to be more depleted than the actual value of the sample, due to the presence of lipids (Mintenbeck *et al.* 2008). This bias can be improved with so-called lipid corrections. Lipid correction for stable isotope analyses is done by normalizing the ^{13}C:^{12}C ratios to a constant lipid content across all samples. Lipid correction of the $\delta^{13}C$ samples was performed using the following equation (McConnaughey and McRoy 1979).

$$\Delta` = \delta + D\left[\frac{\theta + 3.90}{\left(1 + \frac{287}{L}\right)}\right]$$

If C:N values are higher than 10, an algorithmic correction provided by Logan *et al*. (2008) may be needed using the following equation.

$$\delta' = \delta + D\left(\theta + \frac{3.90}{1 + \left(\frac{287}{L}\right)}\right)$$

Results

Stomach Content Analysis

In total, 455 stomachs were examined from 12 predatory fish species: Albacore Tuna (n=106), Yellowfin Tuna (n=100), Bigeye Tuna (n=86), Dolphinfish (n=67), Swordfish (n=39), Wahoo (n=28), White Marlin (n=13), Skipjack Tuna (n=7), Bluefin Tuna (n=6), Roundscale Spearfish (n=2), Blue Marlin (n=1), Sailfish (n=1). Several items that were found within the stomach were assumed to be non-prey items rather than actively consumed prey, and therefore were excluded from subsequent analyses. These non-prey items included: parasites (*Hirudinella ventricose*, parasitic nematodes, unidentifiable parasites), macroalgae (*Sargassum* sp., Zosteraceae), bait items, and mesoplastics.

Species accumulation curves were generated, but an asymptote was not reached for any of the studied species (Figure 2). This indicates that for each species, more sampling should occur to describe the diet more accurately. A species accumulation curve was not generated for Sailfish and Blue Marlin since there was no identifiable prey items from the one stomach sampled for both species.

For each species, every prey item (excluding, non-prey items such as bait, parasites, cartilaginous parts, feathers) found within the stomach was identified to the family or species level. Percent by occurrence, by weight, by number, index of relative importance and percent index of relative importance were calculated for each prey species and/or prey family identified within each predator species. These numbers can be found in tables 4-15.

For the family Scombridae (Albacore Tuna, Bigeye Tuna, Bluefin Tuna, Skipjack Tuna, Yellowfin Tuna, and Wahoo), teleost fishes had the greatest contribution to the diets of each species, followed by mollusca and crustacea. These contributions were determined by the percent by occurrence values (Figure 3, A-F). Percent by occurrence, by weight, and by number, index of relative importance, and percent index of relative importance for teleost, mollusca, and crustacea for each species was calculated (Table 16). Albacore Tuna had one juvenile loggerhead sea turtle found within a stomach, giving reptilia values of %O=1.3, %N=0.15, %W=0.75, IRI=1.17, and %IRI=0.01. No other stomach or species contained a reptile species. Bigeye Tuna had two cartilaginous parts found in two stomachs but were unidentifiable and not included in further analyses. Bluefin Tuna had one stomach containing one cartilaginous part, but it was also unidentifiable and not included in further analyses. Yellowfin Tuna had one stomach containing three bird parts (Aves; mostly feathers, that couldn't be identified), contributing a small portion to the diet by %O=1.15, %N=0.3, %W=0.41, IRI=0.82, and %IRI=0.01.

For the family Coryphaenidae (Common Dolphinfish), teleost had the greatest contribution to the diet with mollusca as the second greatest contribution and crustacea as the third greatest contribution. These contributions were determined by the percent by occurrence values (Figure 3, G). Percent by occurrence, by number, by weight index of relative importance, and percent index of relative importance were calculated (Table 17).

For the family Istiophoridae (Blue Marlin, Roundscale Spearfish, White Marlin, and Sailfish), Roundscale Spearfish had teleost as the greatest contribution to the diet followed by crustacea. White Marlin also had teleost as the greatest contribution to the diet but followed by mollusca as the second greatest contribution and crustacea as the third greatest contribution. Sailfish and Blue Marlin had an equal contribution of teleost and mollusca. These contributions were determined by the percent by occurrence values (Figure 3, H-K). Percent by occurrence, by number, by weight, index of relative importance, and percent index of relative importance for teleost, mollusca, and crustacea for each species was calculated (Table 18).

For the family Xiphiidae (Swordfish), mollusca (Cephalopoda) had the greatest contribution to the diet, teleost with the second greatest contribution and crustacea with the third greatest contribution. This was determined by the percent by occurrence values (Figure 3, L). Percent by occurrence, by number, by weight, index of relative importance, and percent index of relative importance for teleost, mollusca and crustacea were calculated (Table 19). One cartilaginous part was found but was unidentifiable and not included in analysis.

66.6% of the predator species had both mesopelagic and epipelagic prey items present in the stomachs: Albacore tuna=7 mesopelagic families, 11 epipelagic families, Bigeye Tuna= 6 mesopelagic families, 5 epipelagic families, Bluefin Tuna= 3 mesopelagic families, 3 epipelagic families, Yellowfin Tuna= 7 mesopelagic families, 13 epipelagic families, Wahoo= 8 mesopelagic families, 4 epipelagic families, Dolphinfish= 2 mesopelagic families, 13 epipelagic families, White Marlin = 1 mesopelagic family, 5 epipelagic families, and Swordfish= 4 mesopelagic families, 2 epipelagic families. Skipjack Tuna and Roundscale Spearfish both had just one family from the epipelagic and none from the mesopelagic.

Schoener's diet overlap indices identified significant dietary overlap across species, defined as a relationship with an overlap index value of 0.6 or greater, with a maximum value of 1.0 (complete overlap). The index values for each paired relationship can be found in Table 20 and Figure 4. All relationships between tuna species had overlap index values of 0.721 or greater. Wahoo and Dolphinfish had an overlap index value of 0.969. The relationships between all tuna species, Wahoo, Dolphinfish, Sailfish and Swordfish had overlap index values of 0.658 or greater. Blue Marlin had no overlaps with any other species besides White Marlin with an index value of 0.648. Roundscale Spearfish had overlaps with only Bluefin Tuna, Dolphinfish and Wahoo with index values of 0.6 or greater. White Marlin had overlap index values of 0.6 or greater with Albacore Tuna, Skipjack Tuna, Yellowfin Tuna, and Blue Marlin. It appears that the high overlaps occur strongly amongst the Scombridae, Coryphaenidae, and Xiphiidae families. The lack of overlap occurs within the Istiophoridae family. Only one species (Sailfish) of the Istiophoridae family overlapped with all Scombridae, Coryphaenidae, and Xiphiidae species. Blue Marlin, Roundscale Spearfish, and White Marlin did not overlap with more than 3 species from the Scombridae, Coryphaenidae, and Xiphiidae families.

Stable Isotope Analysis

In total, 63 stable isotope samples were analyzed from 12 predatory fish species: Yellowfin Tuna (n=10), Bigeye Tuna (n=9), Swordfish (n=9), Skipjack Tuna (n=6), Albacore Tuna (n=5), Spearfish (n=5), White Marlin (n=5), Dolphinfish (n=4), Wahoo (n=4), Bluefin Tuna (n=3), Blue Marlin (n=2), and Sailfish (n=1). Some species C:N values were greater than 4.4-6.1‰, indicating lipid corrections were needed for the $\delta^{13}C$ values. All C:N values did not warrant a further algorithmic correction using the equation by Logan *et al*. (2008). These lipid corrections are represented by $\delta^{13}C$\` and were the carbon isotope values used for all stable isotope analyses for this study. The mean and standard deviation for $\delta^{13}C$, $\delta^{13}C$' and $\delta^{15}N$ as well as trophic estimation were calculated and can be found in table 21. $\delta^{13}C$' versus $\delta^{15}N$ for each individual fish sampled can be found in figure 5. The greater $\delta^{15}N$ value, the higher trophic level where that individual fish was feeding. The $\delta^{13}C$\` represents the corrected base carbon source for each individual fish; the more negative the carbon value, the more depleted in carbon that source is. Figure 6 displays mean $\delta^{15}N$ and $\delta^{13}C$` with standard deviation values for each species. For all species, there is greater deviation within $\delta^{15}N$ values than in $\delta^{13}C$` values.

SIBER analysis was ran on the $\delta^{13}C$` and $\delta^{15}N$ values for all 12 species (Figure 7). Bluefin Tuna are the only species that has no ellipse overlaps, occupies the highest $\delta^{15}N$ values but the has the lowest $\delta^{13}C$` values. The remaining 11 species have high overlap within their ellipses. Albacore, Skipjack Tuna, Wahoo, Dolphinfish, Blue Marlin, Roundscale Spearfish, Sailfish and White Marlin ellipses all have a very small $\delta^{13}C$` (0.5-1‰) range and slightly larger $\delta^{15}N$ range (2‰). Bigeye Tuna, and Yellowfin Tuna both have larger $\delta^{13}C$` ranges (~3‰) as well as larger $\delta^{15}N$ ranges (~3-4‰). Swordfish has an ellipse that is similar to Bluefin Tuna for both $\delta^{13}C$` and $\delta^{15}N$; with a $\delta^{13}C$` range of (~3.5‰) and $\delta^{15}N$ range of (~3.5‰).

From this analysis it can be observed that Albacore Tuna, Bigeye Tuna, Skipjack Tuna, Yellowfin Tuna, Wahoo, Dolphinfish, Blue Marlin, Roundscale Spearfish, Sailfish, White Marlin, and Swordfish are all feeding at similar trophic positions. Whereas Bluefin Tuna are feeding on a separate and higher trophic position. For $\delta^{13}C$` there is a greater spread in carbon values for Bigeye Tuna, Bluefin Tuna, Yellowfin Tuna, and Swordfish. Bluefin Tuna is occupying the most depleted carbon source values as well as the highest trophic position. However, Bigeye Tuna, Yellowfin Tuna and Swordfish, all which occupy similar trophic positioning to the other eight species but are also occupying more depleted carbon source values.

The season in which samples were caught was plotted against $\delta^{13}C$` to determine if the time of year that samples were collected influenced the $\delta^{13}C$` values (Figure 8). Length was plotted against $\delta^{13}C$` to determine if size of the individual influenced the $\delta^{13}C$` values (Figure 9). From both of these figures, there appears to be no clear grouping or influence by neither season or length on $\delta^{13}C$` values. Distance from shore was grouped into two: ~140m offshore and ~450m offshore. A graph with the $\delta^{13}C$' versus $\delta^{15}N$ values was organized by these groupings and color coded based on the distance offshore they were caught (Figure 10). This was to determine if distance from shore influenced $\delta^{13}C$` or $\delta^{15}N$ values. There also appeared to be no clear groupings, indicating distance from shore did not influence $\delta^{13}C$` values.

The results of this study were compared to the literature of prior feeding studies of the same species in the western North Atlantic but from individuals that were captured in a coastal, nearshore environments (Table 22). The results of the literature comparison showed that the species feeding nearshore and those feeding offshore had teleost and mollusca as the primary prey groups. However, the specific prey species of mollusca and teleost fed on by the studied species varied between the offshore and nearshore species. This is expanded on in the discussion.

Discussion

Comparison to nearshore environment

Based on the findings of this offshore study, compared to previous studies on nearshore species, it appears that there is similar feeding occurring between nearshore and offshore environments. These previous studies defined nearshore in slightly different ways, Rudershausen *et al.* (2011) defined nearshore as a region of the U.S Atlantic Coast off North Carolina, Butler *et al.* (2010) defined nearshore to be on the continental shelf, off North Carolina, and Stillwell and Kohler (1985) defined nearshore to be on the continental shelf and slope between the North Carolina Coast and the Tail of the Grand Banks. Both nearshore and offshore predator species are feeding prominently on teleost and mollusca prey species. However, the predator species feeding offshore is feeding on teleost and mollusca prey types that are different than the prey types fed on by nearshore predator species. The difference in specific teleost and mollusca prey types is likely due to what prey availability is like nearshore versus offshore. For the purpose of this study, 'dominant prey type' was defined as the prey types with the greatest contribution to the diet. Bluefin Tuna, Yellowfin Tuna, Dolphinfish, Wahoo, and Blue Marlin all have teleost as the dominant prey type in both the nearshore and offshore environments. Swordfish had mollusca as the dominant prey type in both environments as well. However, within the dominant families of teleost, there were some differences. For Bluefin Tuna, Yellowfin Tuna, Blue Marlin, and Swordfish, this study had different dominant teleost families compared to the nearshore studies. However, Dolphinfish and Wahoo had very similar dominant teleost families between the nearshore and offshore environments. There was no comparable studies from the nearshore environment in the western Atlantic for Albacore Tuna, Bigeye Tuna, Skipjack Tuna, Roundscale Spearfish, and White Marlin.

Bluefin Tuna had teleost as the dominant prey item, followed by mollusca and then crustacea for this offshore study. This is similar to Butler *et al.* (2010), who found coastal bluefin tuna to have teleost (mostly menhaden) to have the greatest contribution, with mollusca and crustacea to have lesser importance to the diet. While menhaden were the dominant teleost for Butler *et al.* (2010), this study found Gonostomatidae and Balistidae as the dominant teleost groups.

Rudershausen *et al.* (2011) found that coastal Yellowfin Tunas had teleost and cephalopods as the dominant prey type. Their study stated that the dominant teleost families were Exocoetidae and Scombridae. Alternatively, this offshore study found small amounts of Exocoetidae and Scombridae, while Balistidae, Tetraodontidae, and Gonostomatidae were the dominant teleost families present.

For this offshore study, Dolphinfish diets consisted of species that are associated with floating structures which indicates feeding at or near the water's surface. Prey items that are commonly associated with surface feeding are: Tetraodontidae, Monacanthidae, Exocoetidae, and large amounts of *Sargassum sp*. Rudershausen *et al.* (2011) stated that, nearshore Dolphinfish also fed mostly on species associated with floating structures, Balistidae, Diodontidae, Syngnathidae, Monacanthidae, and large amounts of *Sargassum* sp. This indicates that Dolphinfish are surface feeding in both nearshore and offshore environments.

In this offshore study, teleost that inhabit deeper waters (mesopelagic zone) were found within the stomachs of Wahoo. The second most dominant teleost group was Alepisauridae, and the dominant mollusca groups were Pterotracheidae, Argonautidae, and Ommastrephiae, all which inhabit the mesopelagic. Rudershausen *et al.* (2011) and the present study both found that Wahoo had Scombridae and Cephalopoda that occurred in deeper waters, to be dominant prey types. These findings indicate that individual Wahoo are feeding in the mesopelagic environments both offshore and nearshore.

Rudershausen *et al.* (2011) found nearshore Blue Marlin to have teuthids, Scombridae and Alepisauridae as dominant prey types. However, this offshore study found teleost and crustacea to be the dominant prey types, with no Alepisauridae present, although, there is little comparable data being only one stomach was analyzed.

Stillwell and Kohler (1985) and the present study found nearshore Swordfish species had similar diets to this offshore study's findings. Both studies found that Swordfish diets had mollusca as the dominant prey type followed closely by teleost. However, Stillwell and Kohler

(1985) found Gadidae, Scombridae, Stromateidae, Pomatomidae and Ammodytidae to be the dominant teleosti while this offshore study had the dominant teleost to be Alepisauridae**.**

The species of the present study display diets that could potentially indicate an opportunistic generalist feeding behavior is occurring. Opportunistic or generalist predation is defined as a diet with great diversity of prey species and may change easily in response to changes in availability of prey items (Ménard *et al.* 2006). It has previously been observed that tunas, billfish, Dolphinfish, and Wahoo are considered opportunistic predators (Teffer *et al*. 2015). All the study species herein displayed a wide variety of prey items and showed no signs that one individual species played a crucial role within their diet. By these species not being dependent on one or two prey species, they can adapt their feeding to what prey items are available in the ecosystem they inhabit at that point in time. The findings of this study also reflect the findings by previous nearshore studies stating that these predators' diets are consistent between species, with only minor differences in specific prey items.

There is also evidence showing that these predators connect the epipelagic and mesopelagic environments. The studied species stomachs contained prey items that indicate surface feeding occurred (Tetraodontidae, Balistidae, Exocoetidae, and Sargassum patches). 83.3% of predator species had sargassum present in the stomach. The only species with no sargassum present was Sailfish and Roundscale Spearfish. Several stomachs also contained prey items that indicated feeding in the mesopelagic was occurring as well (Alepisauridae, Gonostomatidae). Feeding in both the mesopelagic and epipelagic indicates the potential that these fish act as a connection between the two environments. Previous nearshore studies also found mesopelagic prey items within the stomach contents of epipelagic predators. Stillwell and Kohler (1985) found several mesopelagic prey items such as: Lancetfish, Lanternfish, Duckbill Barracudina, Snipe Eels, and Red Fish. Rudershausen *et al.* (2010) found that Blue Marlin and Wahoo both had prey items that inhabit the mesopelagic, prey such as: Lancetfish and teuthids that occupy deep waters. Our offshore study appeared to have more mesopelagic prey items present across more predator groups.

Size ranges for our study compared to previous coastal studies varied. For Rudershausen *et al.* (2010), Dolphinfish samples had a range of 68-169cm total length (TL) our study had a range of 60-180cm (TL), for Wahoo their study had a size range of 100-187cm (TL), our study had a range of 100-190cm (TL), for Blue Marlin their study had a range of 282-421cm (TL) however, for our study, there was only one length measurement taken for blue marlin and that was 198cm (TL), for Yellowfin Tuna, their study had a range of 83-163cm (TL) and our study had a range of 78-181cm (TL). Butler *et al.* (2010), had a range for Bluefin Tuna of 185.4-205.7 cm (FL) whereas for our study we had a range of 240-280 cm (TL). Stillwell and Kohler did not list length for their Swordfish samples. Size of the predator may play big role in both stomach content and stable isotope results. The larger the predator is, potentially, the wider size range of prey the predator can eat. The ability to eat larger prey items also means the predator can potentially feed on new prey items, that they couldn't feed on when they were smaller. This could cause the stomach contents of the larger predators to be different from the content of smaller predators. It could also cause the nitrogen stable isotope values to be higher since they are feeding on larger prey and potentially at a higher trophic level (Cohen *et al.* 1993).

The studied species have displayed generalist opportunistic feeding behavior in both the nearshore environment, the offshore epipelagic and mesopelagic. Indicating their feeding shifts to what prey is easily and readily available within the ecosystem they occupy at a specific moment in time. This demonstrates that the prey types consumed changes depending on a predator's vertical and horizonal location within the water column.

58.3% of predator species had empty stomachs: Albacore had 37% of stomachs empty, Bigeye Tuna had 32% of stomachs empty, Skipjack Tuna had 14% of stomachs empty, Yellowfin Tuna had 13% of stomachs empty, Wahoo had 3% of stomachs empty, Dolphinfish had 25% of stomachs empty and Swordfish had 17% of stomachs empty. Pilling et al. 2001 discussed the link between fish caught on longlines and increase percentage of empty stomachs. The authors stated that the presence of empty stomachs is likely due to regurgitation induced by the stress of being captured on longlines. This stress-linked regurgitation by longlines increased the number of samples lost while sampling occurred.

Diet Overlap

The relationships amongst all five tuna species had indices displaying significant dietary overlap. This indicates that all the tuna species are feeding relatively similar to each other. Between Wahoo and Dolphinfish, there was the highest diet overlap indices, indicating a very strong dietary overlap is occurring. Dolphinfish and Wahoo also had a strong diet overlap with all tuna species. This indicates that the tuna species, Dolphinfish and Wahoo are all feeding relatively similar to each other. Swordfish and Sailfish showed high diet overlaps with all tuna species, Dolphinfish, and Wahoo. However, Swordfish and Sailfish both had no other dietary overlaps with any other species. This indicates that Swordfish and Sailfish are feeding more similarly to tunas, Dolphinfish, and Wahoo than they are to the other closely related billfish species. Blue Marlin had one singular overlap with White Marlin. White Marlin had overlaps with Albacore Tuna, Skipjack Tuna, Yellowfin Tuna and Blue Marlin. Spearfish had overlaps with Bluefin Tuna, Dolphinfish, and Wahoo. The overlap data indicates that the other three billfish species (Blue Marlin, White Marlin, Spearfish) are feeding more uniquely from each other. However, Sailfish and Blue Marlin had small sample size and may not fully represent actual diets.

Stable Isotopes

Stable isotope data displayed that there are two trophic levels present in this trophic structure. The ellipses generated in SIBER analysis display the niches of each species based on carbon and nitrogen stable isotope data. There is high isotopic overlap between Albacore Tuna, Skipjack Tuna, Wahoo, Dolphinfish, Blue Marlin, Sailfish, Roundscale Spearfish, and White Marlin. This indicates that these species are feeding on similar, more enriched carbon sources and occupying similar trophic roles.

Bigeye Tuna, Yellowfin Tuna, and Swordfish have similar isotopic niches, and their ellipses overlap. These three species occupy similar trophic positions as Albacore Tuna, Skipjack Tuna, Wahoo, Dolphinfish, Blue Marlin, Sailfish, Roundscale Spearfish, and White Marlin. However, Bigeye Tuna, Yellowfin Tuna, and Swordfish ellipses have more depleted carbon values. Therefore, Bigeye Tuna, Yellowfin Tuna, and Swordfish have a wider range of carbon source values compared to Albacore Tuna, Skipjack Tuna, Wahoo, Dolphinfish, Blue Marlin, Sailfish, Roundscale Spearfish, and White Marlin. Swordfish ellipses have slightly more depleted carbon source than Bigeye Tuna and Yellowfin Tuna. The Bluefin Tuna ellipse is occupying the highest trophic positioning with the most depleted carbon source values. There is also no overlap between the Bluefin Tuna ellipse and any other species ellipse. This lack of overlap indicates Bluefin Tuna is occupying its own individual isotopic niche.

Bigeye Tuna, Yellowfin Tuna, Swordfish and Bluefin Tuna all have depleted carbon source values. These depleted values may be explained by the vertical migration patterns often displayed by these species. These four species are known to make vertical migrations into the mesopelagic environment. Schaefer *et al.* (2009) used archival tagging data to observe Bigeye Tuna diving to depths as deep as 1695m and Yellowfin Tuna to depths as deep as 1022m. Wilson *et al.* (2005) observed Bluefin Tuna diving to depths as deep as 672m in the Gulf of Maine. Fromentin and Powers (2005) observed the depth range for Bluefin Tuna to be 500-1000m. Loefer *et al.* (2007) observed a depth range of 350-770m for Swordfish. Lerner *et al.* (2013) recorded one of the deepest dives performed by Swordfish, 1,448m. If feeding is occurring during these dives, it may be a cause for the varying range of carbon source values. This could explain why although Albacore Tuna, Bigeye Tuna, Skipjack Tuna, Yellowfin Tuna, Wahoo, Dolphinfish, Blue Marlin, Roundscale Spearfish, Sailfish, White Marlin, and Swordfish are all feeding on similar trophic levels, the deep divers, Bigeye Tuna, Yellowfin Tuna, and Swordfish, have more depleted carbon source values in their range of carbon values.

Caveats and Implications

One major caveat of stomach content analysis is that potential error could exist within the identification process. Identification of prey items that have been digested creates potential issues. One being the identification of hard parts, specifically for this study squid beaks and teleost bones. Squid beaks and teleost bones take much longer to breakdown and digest compared to the softer parts of the body. Over- or under estimation could occur when counting these hard parts. Some specimens were far too digested to be properly identify due to a lack of physical structures that allow for proper identification. There was also potential for misidentification of bait items. Bait items used were usually medium sized squids and fish. At times, bait items were digested and difficult to determine if it was bait or a naturally predated prey item. Efforts were made to find evident signs (hooks, hook marks/holes, knowledge of trips selected bait) that the item was bait.

Since this study relied on commercial pelagic longline fishing vessels for sample collection, data couldn't be collected in a structure that allowed evaluation of certain variables such as season. Sampling began in summer of 2020, therefore COVID-19 restrictions delayed some sampling trips and eliminated others outright. Sampling via commercial fisheries gears inherently targets larger, mature adults, which represented only the larger portions of size classes. Due to this, ontogenetic diet shifts could not be assessed due to the selectivity of the fishing gear. Both vessels set their lines at different times throughout the day and night and retrieved the lines at varying times throughout the day and night, therefore no day and night comparison within the diet could be made. Some samples were lost due to regurgitation. Some fish while they were on the longline gear, or once they were brought aboard, regurgitated stomach contents, reducing the pool of possible samples that could have been collected.

Conclusion

The findings of this offshore study's stomach content analysis reflect previous nearshore studies stating that teleost and mollusca play crucial roles within the diets of these species while crustacea plays a more minor role. An important finding from this study is that the studied species feeding offshore and the studied species feeding nearshore fed on both teleost and mollusca as the primary prey items, indicating similar diets. However, the feeding of offshore species versus the feeding of nearshore species varies with specific prey species. A strong dietary overlap was observed between the tuna species, Wahoo, Dolphinfish, Sailfish and Swordfish. Stable isotope data showed that Bluefin Tuna are occupying an individual isotopic niche, with the most depleted carbon source values and highest trophic positioning. Albacore Tuna, Bigeye Tuna, Skipjack Tuna, Yellowfin Tuna, Wahoo, Dolphinfish, Blue Marlin, Roundscale Spearfish, Sailfish, White Marlin, and Swordfish are all occupying similar trophic positionings. However, Bigeye Tuna, Yellowfin Tuna and Swordfish have a larger range in the carbon source values with more depleted carbon values. Bigeye Tuna, Bluefin Tuna, Yellowfin Tuna and Swordfish all display depleted carbon source values. These depleted values may be due to the vertical movement patterns exhibited by these four species. Feeding at a wider range of depths, causing there to be more prey items with depleted carbon source values.

Stomach content and stable isotope analysis combination gave insights to the feeding ecology of these offshore epipelagic predators. With the use of combined methodology, it was able to be determined the prey types that had the greatest contribution to diets for each species and what trophic position each species occupied. With these insights, an understanding of the trophic complex of these species was able to be formed. This information can then be added to the life history knowledge of each individual species. This knowledge can be used in ecosystem-based management as an approach create proper management of these important upper-level predators. This study adds to the overall knowledge of the ecology within the epipelagic environment.

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Table 1: Summary of fish families Scombridae, Coryphaenidae, Xiphiidae and Istiophoridae, all species included in this study, including their average size, lifespan, general diet, and references used. Average size, and lifespan obtained from NOAA's Highly Migratory Species List.

FAMILY	NAME	AVERAGE SIZE	LIFESPAN	DIET	REFERENCES
SCOMBRIDAE	Yellowfin Tuna *(Thunnus albacares)*	7 ft	7 years	Small fishes, crustaceans, cephalopods	Potier et al. 2007, Pedrosa-Gerasmio *et al.* 2012
SCOMBRIDAE	Bigeye Tuna (T*hunnus obesus)*	5-6 ft	9years	Cephalopods, small fishes, crustacean	Guelson Batista da *et al*. 2019, Vaske *et al.* 2012
SCOMBRIDAE	Albacore Tuna *(Thunnus alalunga)*	>4 ft	13 years	Cephalopods, crustaceans, small fishes	Hassani *et al*. 1997, Goni *et al*. 2011, Nikolic *et al.* 2017
SCOMBRIDAE	Skipjack Tuna *(Katsuwonus pelamis)*	>3 ft	7 years	Fishes, cephalopods and crustaceans	Dragovich 1970, Ramos *et al*. 1996
SCOMBRIDAE	Bluefin Tuna *(Thunnus thynnus)*	13 ft	20 years	Medium fishes and cephalopods	Aguado-Giménez and García-García 2005, Fromentin and Powers 2005
SCOMBRIDAE	Wahoo *(Acanthocybium solandri)*	8 ft	5-6 years	Smaller fishes and cephalopods	Satoh *et al.* 2004, Zischke 2012,
CORYPHAENIDAE	Dolphinfish *(Coryphaena hippurus)*	4-5 ft	5 years	Smaller fishes and invertebrates	Beardsley Jr 1967, Oxenford 1999, Brewton *et al*. 2016
XIPHIIDAE	Swordfish (*Xiphias gladius)*	14ft	9 Years	Fishes and cephalopods	Palko *et al*. 1981, Collette *et al*. 2011
ISTIOPHORIDAE	White Marlin *(Kajikia albida)*	9ft	18 years	Fishes and cephalopods	Nakamura 1985, Beerkircher *et al*. 2008
ISTIOPHORIDAE	Blue Marlin *(Makaira nigricans)*	11ft	15 years	Small fishes	Brock 1984, Fierstine 1997
ISTIOPHORIDAE	Roundscale Spearfish *(Istiophorus albicanas)*	5 ft	5 years	Small to medium fishes	Maksimov 1971, Jolley Jr 1977
ISTIOPHORIDAE	Sailfish (*Tetrapturus georgii)*	7-10 ft	13-15 years	Small to medium fishes	Beerkircher *et al.* 2008, Bernard *et al*. 2013

Table 2: Literature mean nitrogen and carbon stable isotope values for the predators examined in this study

Predator	Location of Study	Length (CM)	Mean δ13C Values	Mean δ15N Values	Distance from Shore	n	Reference
Albacore Tuna							
	Eastern North Atlantic Ocean		-19.3	11.4	N/A	12	Das et al. (2000)
	South West Pacific Ocean	81.01	-17.96	12.98	Inshore	180	Pethybridge et al. (2015)
	South West Pacific Ocean	92.3	-18.08	12.44	Offshore	29	Pethybridge et al. (2015)
Bluefin Tuna							
	East Atlantic Ocean- June	N/A	-19.23	10.51	Balearis Island, Spain	9	Varela et al. (2011)
	East Atlantic Ocean-Sept.	N/A	-20.89	11.11	Balearis Island, Spain	10	Varela et al. (2011)
	East Atlantic Ocean- Nov.	N/A	-20.52	11.27	Balearis Island, Spain	14	Varela et al. (2011)
Bigeye Tuna							
	Western-Central Indian Ocean	<100	-17.2	12.5	N/A	33	Sardenne et al. (2016)
	Western-Central Indian Ocean	>100	-17	13.4	N/A	26	Sardenne et al. (2016)
Yellowfin Tuna							
	Western North Atlantic	88-91	-16.8	10.3	34 to 43N	3	Logan and Lutcavage (2013)
	Western-Central Indian Ocean	<100	-17	11.7	N/A	29	Sardenne et al. (2016)
	Western-Central Indian Ocean	>100	-16.6	12.4	N/A	23	Sardenne et al. (2016)
	Western North Atlantic	116-132	-17.1	9.6	34 to 43N	36	Logan and Lutcavage (2013)
	West Atlantic (Brazil)	47-128	-17.06	10.46	Fernando de Noronha Archipelago	34	Martins et al. (2021)
Skipjack Tuna							
	Western-Central Indian Ocean	<100	-17	11.4	N/A	43	Sardenne et al. (2016)
	Western-Central Indian Ocean	>100	N/A	N/A	N/A	0	Sardenne et al. (2016)
Wahoo							
	West Atlantic (Brazil)	72-148	-16.71	11.18	Fernando de Noronha Archipelago	43	Martins et al. (2021)
Dolphinfish							
	West Atlantic (Brazil)	71-130	-17.19	10.13	Fernando de Noronha Archipelago	12	Martins et al. (2021)
	Baja California Peninsula	46-65	-17.02	15.98	30 miles from coast	7	Torres-Rojas et al. (2014)
	Baja California Peninsula	65.5-80	-17.23	15.51	30 miles from coast	7	Torres-Rojas et al. (2014)
	Baja California Peninsula	80.5-95	-17.46	14.25	30 miles from coast	11	Torres-Rojas et al. (2014)
	Baja California Peninsula	95.5-110	-17.23	14.7	30 miles from coast	16	Torres-Rojas et al. (2014)
	Baja California Peninsula	110.5-137	-16.95	13.14	30 miles from coast	7	Torres-Rojas et al. (2014)
	Western North Atlantic	95	-16.9	9.9	34 to 43N	10	Logan and Lutcavage (2013)
Blue Marlin							
	Cabo San Lucas, Pacific Ocean	216.9	-16.2	15.6	California Coast	41	Torres-Rojas et al. (2013)
	Western North Atlantic	202	-16.5	10.3	34 to 43N	2	Logan and Lutcavage (2013)
White Marlin							
	Western North Atlantic	161	-16.7	10	35 to 43N	25	Logan and Lutcavage (2014)
Swordfish							
	Western North Atlantic	<150	-16.6	10.6	36 to 43N	63	Logan and Lutcavage (2015)
	Western North Atlantic	>150	-16.5	11.1	37 to 43N	18	Logan and Lutcavage (2016)
	Eastern Australia	116.7	-19.4	13.2	Castal to 800km Offshore	30	
Sailfish							
	Eastern Taiwan waters	>181	-17.47	13.15	Coastal	31	Tsai et al. (2015)
	Eastern Taiwan waters	141-180	-17.27	11.89	Coastal	41	Tsai et al. (2015)
	Eastern Taiwan waters	<140	-18.39	10.01	Coastal	33	Tsai et al. (2015)

Table 3: Literature mean nitrogen and carbon stable isotope values of common prey of the predators examined in this study

References	Location of Prey	Distance from Shore	Prey Type	Mean Prey d13C	Mean Prey d15N	n
Logan *et al.* (2014)	Northwest Atlantic	Gulf of Maine	Sand Lance	-19.8	10.3	121
			Shortfin Squid	-19.1	11.4	9
			Atlantic Herring	-19	11.9	25
			Spiny Dogfish	-18.5	12	8
			Atlantic Mackerel	-19	12.5	11
			Silver Hake	-18.8	12.4	25
			Groundfish	-18.2	14.3	6
			Bluefish	-17.5	16.4	13
Weng *et al.* (2016)	SW Taiwan waters	Coastal	Mackerel Rastrelliger *spp.*	-17.8	8.6	2
			Bullet Tuna	-16.9	10.8	4
			Japanese Barracudina	-17.7	11.3	3
			Skinnycheek Lanternfish	-17	11	3
			Mackerel Scad	-17.1	9.2	2
			Whitetip Scad	-19	9.2	2
			Moonfish	-18.6	9.3	2
			Exocoetidae	-17.7	10.4	5
			Butterfly fishes	-20.2	10.4	2
			Pacific Pomfret	-19.6	9.3	1
			Purpleback flying squid	-18.27	8.4	4
			Octopus octopus	-17.74	8.4	1
			Mantis Shrimp	-17.87	4.8	5
			Shrimp Postiarva	-17.87	4.2	4
			Amphipoda	-19.7	7.4	5
			Crab Megalopa	-19.7	5.1	3
Torres-Rojas *et al.* (2014)	Baja California Peninsula	30 miles from coast	Argonauta cornutus	-18.09	15.6	2
			Paper nautiluses Argonauta *spp.*	-17.92	16.15	5
			Mackerels Auxiz *spp.*	-17.12	16.08	3
			Finescale Triggerfish	-18.14	15.04	3
			Jumbo Squid	-18.13	16	5
			Deepwater cornetfish	-18.02	16.46	3

Table 3: Continued

			Oceanic Puffer	-16.36	13.54	3
			Red Crab	-20.08	7.95	3
			Pacific Sardine	-17.25	15.77	5
			Bigeye Scad	-17.72	15.61	3
Biton-Porsmoguer *et al.* (2022)	Mediterranean Sea	20 m depth Catalan Sea	Deep Sea Shrimp	-19.35	7.56	3
			Deep-water rose shrimp	-18.26	7.82	5
			Angel Clubhook	-20.41	8.34	5
			Broadtail Shortfin Squid	-20.07	7.98	5
			Striped Squid	-20.02	7.71	5
			European Flying Squid	-20.03	8.62	5
			Spotted Baracudina	-19.94	8.46	4
			Anchovy	-21.37	7.61	5
			Blue Whiting	-19.09	8.87	5
			Sardine	-21.85	8.26	5
			Atlantic Horse Mackerel	-19.39	8.67	5
Tsai *et al.* (2015)	Eastern Taiwan Waters	Coastal	Auxis s*pp.*	-17.89	9.55	8
			Priacanthus macracanthus	-17.8	10.38	6
			Trichiurus lepturus	-16.91	12.8	6
			decapterus *spp.*	-17.43	9.42	8
			Mene maculate	-17.77	8.02	6
			Scomber japonicus	-17.11	10.71	5
			Katsuwonus pelamis	-17.95	10.62	4
			Exocoetidae	-17.15	8.12	2
			Belonidae	-17.37	7.31	3
			Gempylidae	-17.76	8.74	4
			Clupeidae	-17.18	6.84	2
			Tetraodontidae	-18.13	8.19	5
			Bramidae	-17.87	6.43	3
			Cephalopda	-18.25	8.71	8
Revill *et al.* (2009)	Eastern Australia	Coastal	Alepisauridae	-18.6	10.6	7
			Scombridae	-17.2	9.9	8
			Bramidae	-17.5	12.9	6
			Nomeidae	-16.7	11	3
			Myctophidae	-19.4	10.4	31
			Exocoetidae	-17.8	9.1	3
			Gempylidae	-18.9	11	4
			Macrorhamphosidae	-20.6	9.3	8
			Paralepididae	-19.5	9.9	3
			Scomberesocidae	-17.9	10.1	3
			Trichiuridae	-19.2	11	2
			Trachichthyidae	-17	12.4	35
			Chiroteuthidae	-16.5	12.5	2
			Ommastrephidae	-16.2	12.4	1

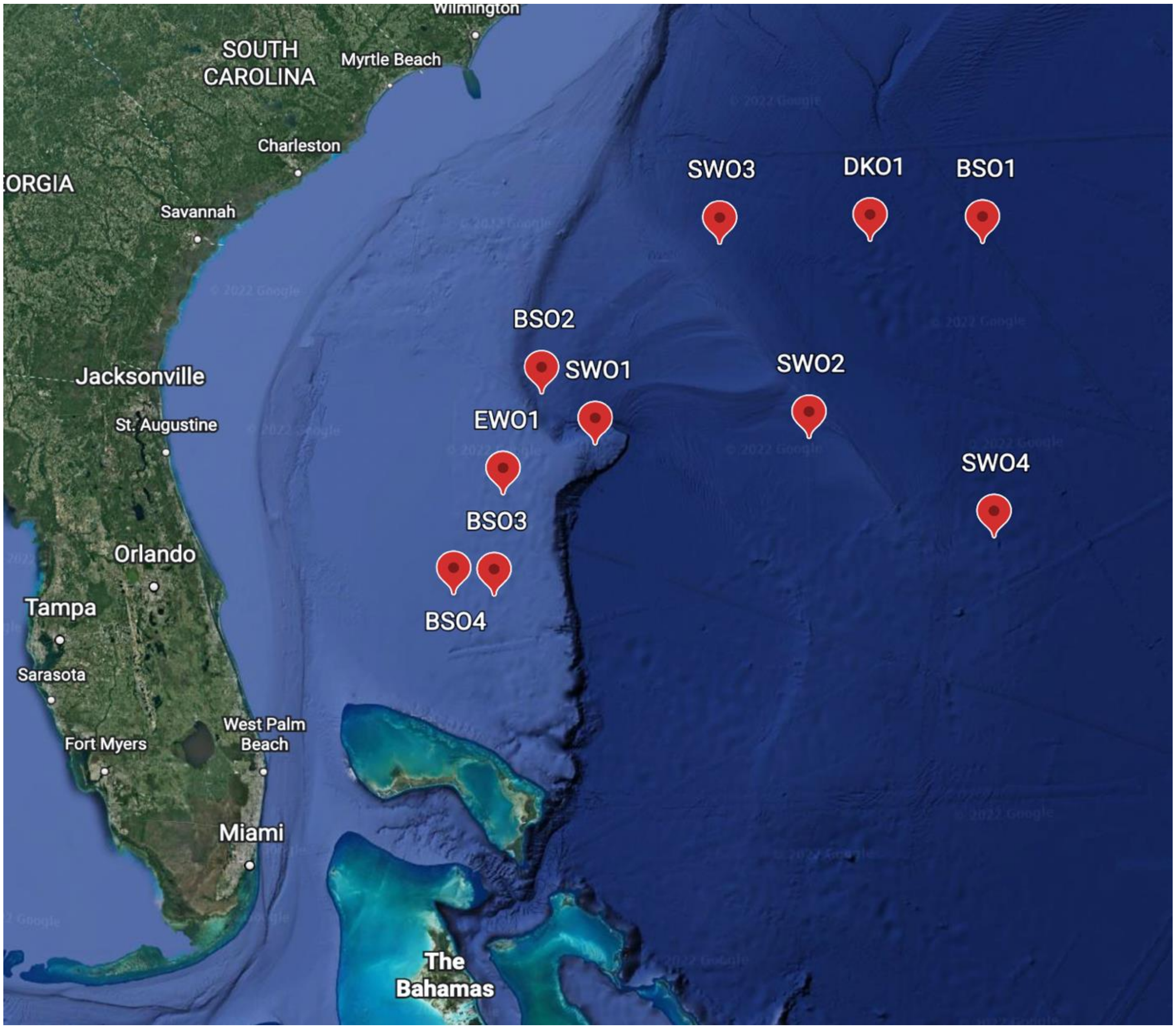

Figure 1. The longitude and latitude coordinates of each fishing vessel at the start of the first set of each sampling trip, created in Google Earth.

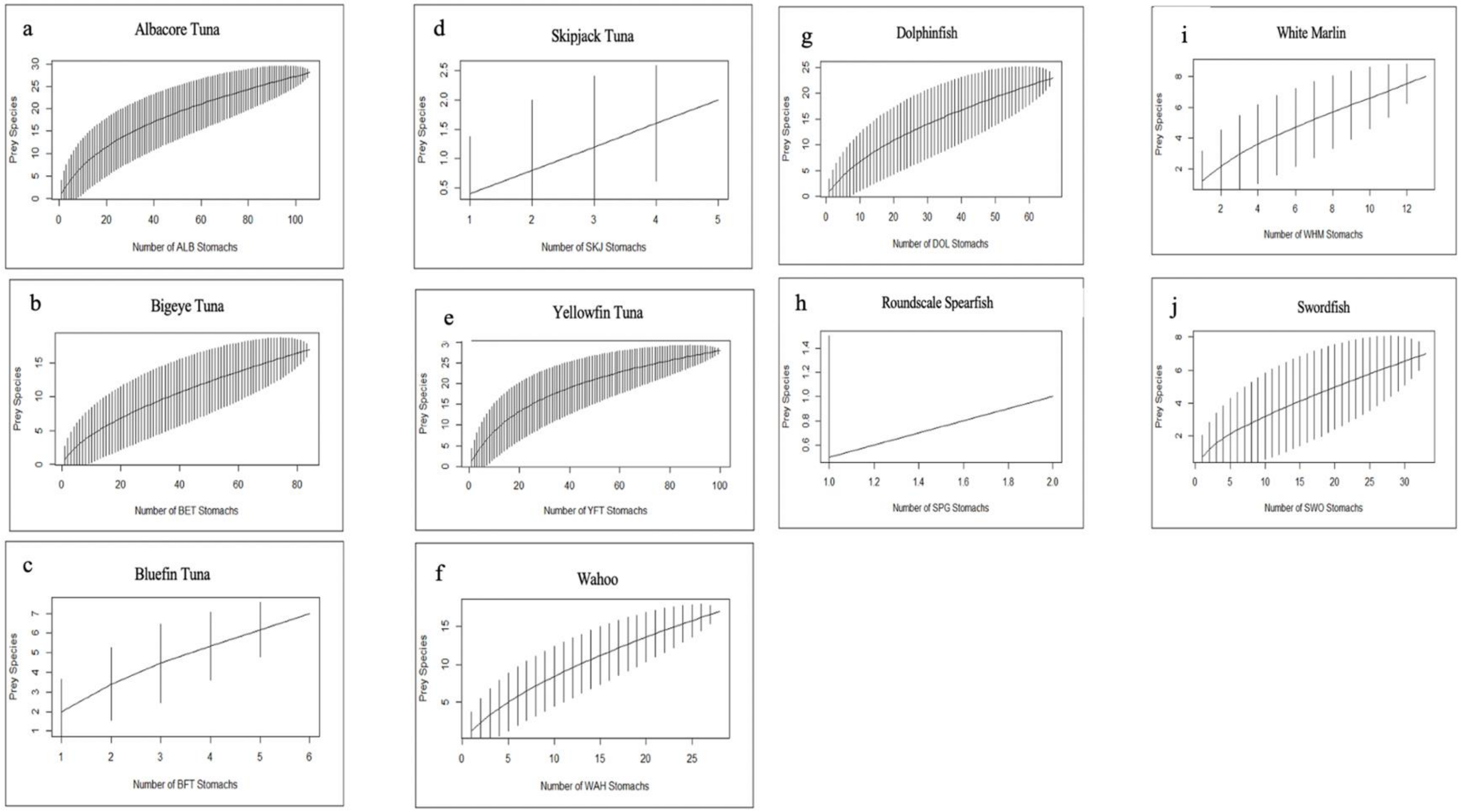

Figure 2**.** Species accumulation curves for all 11 species. There was no stomach content data for sailfish, therefore excluded from analysis. a. Albacore Tuna, b. Bigeye Tuna, c. Bluefin Tuna, d. Skipjack Tuna, e. Yellowfin Tuna, f. Wahoo, g. Dolphinfish, h. Roundscale Spearfish, i. White Marlin, and j. Swordfish.

41

Table 4: Prey items from Albacore Tuna stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Albacore Tuan (n=106)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	197	126.6	28.64	28.53	1673.62	13.22
Unidentified teleost	120	50.65	17.42	8.99	1337.67	10.56
Alepisauridae	*23*	22.08	3.34	8.41	259.44	2.05
Gonostomatidae	16	7.79	2.32	0.93	25.32	0.2
Gempylidae	7	1.3	1.02	0	1.33	0.01
Gempylus serpens	7	5.19	1.02	3	20.86	0.16
Tetraodontidae	5	6.49	0.73	0.45	7.66	0.06
Balistidae	8	1.3	1.16	5.64	8.84	0.07
Bramidae						0
Brama brama	2	22.1	0.29	0.15	9.72	0.08
Pterycombus brama	1	1.3	0.15	0.07	0.29	0
Nomeidae						0
Cubiceps caeruleus	1	1.3	0.15	0.13	0.36	0
Anoplogastridae						0
Anoploggaster cornuta	1	1.3	0.15	0.02	0.22	0
Caproidae						0
Antigoniae capros	1	1.3	0.15	0.01	0.21	0
Chaetodontidae	2	0.6	0.29	0.01	0.18	0
Belonidae	1	1.3	0.15	0.05	0.26	0
Pomacanthidae						0
Centropyge argi	1	1.3	0.15	0.01	0.21	0
Pricanthidae						0
Cookeolus boops	1	1.3	0.15	0.66	1.05	0.01
Mollusca	244	93.52	34.85	15.47	3342.64	26.4
Unidentified cephalopod	222	72.73	32.22	13.44	3320.85	26.23
Loliginidae	5	2.6	0.15	N/A	N/A	N/A
Loligo pealeii	2	1.3	0.29	N/A	N/A	N/A
Ommastrephidae	1	1.3	0.15	N/A	N/A	N/A
Illex illecebrosus	2	2.6	0.29	1.93	5.77	0.05
Onychoteuthidae	1	1.3	0.15	N/A	N/A	N/A
Onychoteuthis banksii	1	1.3	0.15	0.03	0.23	0
Pterotracheidae	10	10.39	1.45	0.07	15.79	0.12
CRUSTACEAN	131	33.76	19.02	0.84	248.9	1.97
Decapoda	7	6.49	1.02	0.07	7.07	0.06
Pleocyemata	1	1.3	0.15	N/A	N/A	N/A
Salpidae	37	5.19	5.37	0.69	31.45	0.25
Isopoda	52	19.48	7.55	0.11	149.22	1.18
Amphipoda	42	9.09	6.1	0.04	55.81	0.44
Phronimidae	7	5.19	1.02	0.01	5.35	0.04
Reptile	1	1.3	0.15	0.75	1.17	0.01
Caretta caretta	1	1.3	0.15	0.75	1.17	0.01
Parasites	38	24.67	5.52	0.01	8.02	0.06
Nematoda	31	16.88	4.5	N/A	N/A	N/A
Hirudinellidae						0
Hirudinell ventricosa	7	7.79	1.02	0.01	8.02	0.06
Macroalgae	30	29.87	4.35	0.06	131.73	1.04
Sargassum muticum	30	29.87	4.35	0.06	131.73	1.04
Bait	30	31.17	4.35	55.01	1850.25	14.61
Plastic	4	2.6	0.58	N/A	N/A	0

Table 5: Prey items from Bigeye Tuna stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Bigeye Tuna (n=86)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	143	94.75	27.444	23.71	1954.17	14.17
Unidentified teleost	108	54.39	23.48	11.55	1905.28	13.81
Alepisauridae	*14*	17.54	0.03	0.87	15.79	0.13
Gonostomatidae	5	5.26	1.09	0.06	6.05	0.05
Gempylidae						0
Nesiarchus nasutus	1	0.02	0	3.14	0.06	0
Nealotus tripes	1	1.75	0.22	0.08	0.53	0
Gempylus serpens	5	8.77	1.09	0.05	10	0.08
Tetraodontidae	4	1.75	0.87	0.02	1.56	0.01
Balistidae	2	0.02	0.004	0.09	0	0
Bramidae						0
Brama caribbea	1	1.75	0.22	0.12	0.6	0.01
Pteraclis carolinus	1	1.75	0.22	6.08	11.03	0.09
Scombridae	1	1.75	0.22	1.65	3.27	0.03
Mollusca	164	89.83	3.38	58.64	4149.73	30.08
Unidentified cephalopod	150	78.95	0.33	51.9	4123.56	29.89
Loliginidae						0
Loligo pealeii	1	1.75	0.22	4.29	7.89	0.06
Enoploteuthidae	1	1.75	0.22	2.41	4.6	0.03
Onychoteuthidae	1	1.75	0.22	0		0
Pterotracheidae	11	5.63	2.39	0.04	13.68	0.01
Crustacea	15	12.27	3.26	0.15	6.82	0.05
Shrimps	4	5.26	0.87	0.02	4.68	0.03
Isopoda	6	5.26	1.3	0		0
Salpidae	5	1.75	1.09	0.13	2.14	0.02
Macroalgae	40	42.11	8.7	0.21	375.2	2.72
Sargassum muticum	40	42.11	8.7	0.21	375.2	2.72
Parasite	82	31.58	17.82	0.02	329.01	2.39
Nematoda	72	19.3	15.65	0.01	302.24	2.19
Hirudinellidae						0
Hirudinell ventricosa	10	12.28	2.17	0.01	26.77	0.19
Cartlidge	2	0.04	0.004	0.44	0.02	0
Bait	13	14.04	0.03	11.69	164.55	1.19

Table 6: Prey items from Bluefin Tuna stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Bluefin Tuna (n=6)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	25	150.01	39.32	65.01	5269.86	30.39
Unidentified teleost	12	66.67	23.53	16.54	2671.47	15.4
Alepisauridae	*5*	50	0.1	45.72	2291	13.21
Gonostomatidae	1	16.67	1.96	0.12	34.67	0.2
Balistidae	7	16.67	13.73	2.63	272.72	1.57
Mollusca	11	83.34	2.16	34.6	2305.79	13.29
Unidentified Cephalopoda	10	66.67	0.2	33.66	2257.45	13.02
Argonautidae	1	16.67	1.96	0.94	48.34	0.28
Crustacea	2	33.34	3.92078	0.0185	65.67	0.38
Salpidae	1	16.67	1.96078	0.0135	32.91	0.19
Isopoda	1	16.67	1.96	0.005	32.76	0.19
Macroalgae	4	66.67	7.84	0.18	534.69	3.08
Sargassum muticum	4	66.67	7.84	0.18	534.69	3.08
Parasite	8	50	15.69	0.19	495.8	2.86
Hirudinellidae						0
Hirudinell ventricosa	7	33.33	13.73	0.14	462.29	2.67
Unidentified parasite	1	16.67	1.96	0.05	33.51	0.19
Cartlidge	1	16.67	0.02	N/A	N/A	2.86

Table 7: Prey items from Skipjack Tuna stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Skipjack Tuna (n=7)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	11	66.67	36.67	38.44	5007.58	24.3
Unidentified teleost	11	66.67	36.67	38.44	5007.58	24.3
Mollusca	13	50	43.33	56.16	5050.02	24.51
Unidentified cephalopod	13	50	43.33	56.16	4974.5	24.14
Pterotracheidae	6	16.67	3.33	1.2	75.52	0.37
Crustacea	13	50.01	9.99	1.8	196.53	0.95
Isopoda	1	16.67	3.33	0.6	65.51	0.32
Salpidae	6	16.67	3.33	0.9	70.51	0.34
Amphipoda	6	16.67	3.33	0.3	60.51	0.29
Macroalgae	6	16.67	3.33	0	0	0
Sargassum muticum	6	16.67	3.33	0	0	0
Plastic	6	16.67	3.33	2.4	95.52	0.46

Table 8: Prey items from yellowfin tuna stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Yellowfin Tuna (n=100)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	447	143.8	43.891	59.51	2603.99	19.45
Unidentified teleost	178	65.52	17.59	15.33	2156.92	16.11
Alepisauridae	*9*	5.75	0.89	5.25	35.31	0.26
Gonostomatidae	18	0.1	1.78	8.18	1	0.01
Nesiarchus nasutus	1	11.49	0.1	0.05	1.72	0.01
Gempylus serpens	1	1.15	0.1	1.42	1.75	0.01
Tetraodontidae	116	10.34	11.46	1.21	131.01	0.98
Didon hystrix	15	4.6	1.48	1.97	15.87	0.12
Balistidae	40	16.09	3.95	6.93	175.06	1.31
Engraulidae	1	1.15	0	0	0	0
Clupeidae	4	4.6	0.4	0.39	3.63	0.03
Brama caribbea	1	1.15	0.1	0.01	0.13	0
Pterycombus brama	25	2.3	2.47	0.39	6.58	0.05
Scombridae	7	6.9	0.69	7.63	57.41	0.43
Acanthuridae	3	1.15	0.3	0.01	0.36	0
Anoploggaster cornuta	1	1.15	0.1	0.01	0.13	0
Belonidae	2	2.3	0.2	0.47	1.54	0.01
Syngnathidae					0	0
Hippocampus	3	3.45	0.3	0.1	1.38	0.01
Pomacanthidae					0	0
Centropyge argi	3	2.3	0.3	0.01	0.71	0.01
Stomiidae	16	1.15	1.58	10.14	13.48	0.1
Exocoetidae	2	1.15	0.1	N/A		0
Echeneidae					0	0
Remora osteochir	1	0.01	0.001	0.01	0	0
Mollusca	360	87.36	35.58	19.44	3719.89	27.78
Unidentified cephalopod	321	74.71	31.72	17.74	3695.16	27.6
Loliginidae	7	2.3	0.69	0.9	3.66	0.03
Ommastrephidae					0	0
Illex illecebrosus	2	1.15	0.2	0.66	0.99	0.01
Onychoteuthidae	1	1.15	0.1	N/A		0
Octopoda	1	1.15	0.1	0.02	0.14	0
Pterotracheidae	28	6.9	2.77	0.12	19.94	0.15
Crustacea	120	34.48	11.86	0.68	131.85	0.98
Unidentified Crustacean	1	1.15	0.1	N/A		0
Decapoda					0	0
Shrimps	2	2.3	0.2	N/A		0
Isopoda	26	11.49	2.57	0.01	29.64	0.22
Amphipoda	5	3.45	0.49	0.03	1.79	0.01
Phronimidae	4	4.6	0.4	N/A		0
Salpidae	82	11.49	8.1	0.64	100.42	0.75
Aves	3	1.15	0.3	0.41	0.82	0.01
Unidentifiable bird	3	1.15	0.3	0.41	0.82	0.01
Parasite	30	9.2	2.97	0.15	9.73	0.07
Unidentified parasite	N/A	N/A	N/A	0.12	0	0
Hirudinellidae						0
Hirudinell ventricosa	9	8.05	0.89	0.02	7.33	0.05
Nematoda	21	1.15	2.08	0.01	2.4	0.02
Macroalgae	29	26.44	2.87	4.91	205.7	1.54
Sargassum Muticum	29	26.44	2.87	4.91	205.7	1.54
Bait	12	2.3	1.19	14.86	36.92	0.28
Plastic	11	6.9	1.09	0.04	7.8	0.06

Table 9: Prey items from Wahoo stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Wahoo (n=28)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	91	177.82	8.28	30.58	677.06	15.44
Unidentified teleost	67	66.67	0.23	0.23	30.67	0.7
Alepisauridae	*9*	25.93	3.15	14.62	460.78	10.51
Gonostomatidae	2	7.41	0.7	0.31	7.48	0.17
Gempylidae	2	7.41	0.7	0.23	6.89	0.16
Nealotus tripes	1	3.7	0.35	0.39	2.74	0.06
Tetraodontidae	1	0.04	0.35	0.1	0.02	0
Didon hystrix	2	7.41	0.7	0.18	6.52	0.15
Balistidae	1	3.7	0	0.11	0.41	0.01
Scombridae	3	11.11	1.05	10.89	132.65	3.03
Acanthuridae	1	37.04	0.35	0.01	13.33	0.3
Paralepididae	1	3.7	0.35	3.14	12.91	0.29
Trichiuridae	1	3.7	0.35	0.37	2.66	0.06
Mollusca	44	62.95	15.39	5.97	955.84	21.8
Unidentified cephalopod	38	51.85	13.29	4.92	944.19	21.54
Ommastrephidae					0	0
Illex illecebrosus	2	3.7	0.7	0.87	5.81	0.13
Argonautidae	1	3.7	0.35	0.14	1.81	0.04
Pterotracheidae	3	3.7	1.05	0.04	4.03	0.09
Crustacea	20	11.3	4.23	0.02	28.69	0.65
Isopoda	8	0.19	0.03	0	0.01	0
Amphipoda	11	7.41	3.85	0.02	28.68	0.65
Salpidae	1	3.7	0.35	N/A	0	0
Macroalgae	12	29.63	4.2	0.04	125.63	2.87
Sargassum muticum	12	29.63	4.2	0.04	125.63	2.87
Parasite	96	12.11	33.57	13.9	46.42	1.06
Nematoda	3	11.11	1.05	N/A	0	0
Hirudinellidae						0
Hirudinell ventricosa	93	1	32.52	13.9	46.42	1.06
Bait	19	25.93	0.31	27.02	708.67	16.17
Plastic	3	7.41	1.05	0.03	8	0.18

Table 10: Prey items from Dolphinfish stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Dolphinfish (n=67)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	155	148	32.54	38.69	1971.16	27.64
Unidentified teleost	81	52	17.23	13.07	1575.6	22.09
Alepisauridae	*1*	2	0.21	2.66	5.74	0.11
Tetraodontidae	23	20	4.89	1.24	122.6	1.72
Didon hystrix	2	4	0.43	0.11	2.16	0.03
Balistidae	4	6	0.85	0.22	6.42	0.09
Monacanthidae	7	12	1.49	4.33	69.84	0.98
Clupeidae	1	2	0.21	0.24	0.9	0.01
Bramidae					0	0
Pterycombus brama	3	2	0.21	0.11	0.64	0.01
Acanthuridae	20	8	4.26	0.32	36.64	0.51
Syngnathidae					0	0
Hippocampus	1	2	0.21	0.06	0.54	0.01
Exocoetidae	2	28	0.43	3.89	120.96	1.7
Lobotidae					0	0
Lobotes surinamensis	1	2	0.21	6.64	13.7	0.19
Ammodytidae					0	0
Ammodytes dubius	6	2	1.28	0.14	2.84	0.04
Centrolophidae					0	0
Hyperoglyphe bythites	1	2	0.21	4.68	9.78	0.14
Holocenridae	1	2	0.21	0.1	0.62	0.01
Mollusca	28	46	10.01	11.97	651.1	9.13
Unidentified cephalopod	25	36	5.32	11.78	615.6	8.63
Loliginidae	1	2	0.43	0.16	1.18	0.02
Pterotracheidae	2	8	4.26	0.03	34.32	0.48
Crustacea	33	16	7.01	1.22	75.62	1.06
Unidentified Crustacean	1	2	0.21	0.1	0.62	0.01
Decapoda					0	0
Portunus sayi	30	10	6.38	1.12	75	1.05
Isopoda	1	2	0.21	0		0
Amphipoda					0	0
Salpidae	1	2	0.21	0		0
Macroalgae	21	34	4.47	0.49	138.92	1.95
Sargassum muticum	18	32	3.83	0.47	137.6	1.93
Zosteraceae	3	2	0.64	0.02	1.32	0.02
Parasite	214	32	51.49	0.24		0
Nematoda	212	28	51.06	0.23	1436.12	0.02

Table 11: Prey items from blue marlin stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Blue Marlin (n=1)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	11	1	55	94.73	149.73	46.79
Unidentified teleost	11	1	55	94.73	149.73	46.79
Crustacea	8	1	0.4	0.01	0.41	0.13
Isopoda	8	1	0.4	0.01	0.41	0.13
Macroalgae	1	1	5	4.86	9.86	3.08
Sargassum muticum	1	1	5	4.86	9.86	3.08

Table 12: Prey items from Roundscale Spearfish stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Roundscale Spearfish (n=2)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	15	100	42.85	95.83	6934	42.09
Unidentified teleost	2	50	5.71	26.94	1632.5	9.91
Tetraodontidae	13	50	37.14	68.89	5301.5	32.18
Mollusca	12	1	34.29	1.67	35.96	0.22
Unidentified cephalopod	12	1	34.29	1.67	35.96	0.22
Crustacea	8	100	22.86	2.5	1268	7.7
Unidentified Crustacean	1	50	2.86	0.56	171	1.04
Isopoda	7	50	20	1.94	1097	6.66

Table 13: Prey items from Sailfish stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Sailfish (n=1)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	3	1	60.0	0.67	20.67	25.41
Unidentified teleost	3	1	60.0	0.67	20.67	25.41
Mollusca	1	1	20.0	0	20	24.59
Unidentified Mollusca	1	1	20.0	0	20	32.97

Table 14: Prey items from White Marlin stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

White Marlin (n=13)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	50	176.91	18.88	32.7	2542.03	17.47
Unidentified teleost	25	69.23	9.43	7.14	1147.14	7.88
Actinopterygii					0	0
Alepisauridae	*13*	46.15	4.91	21.11	1200.82	8.25
Gonostomatidae	8	30.77	3.02	2.52	170.47	1.17
Tetraodontidae	1	7.69	0.38	0.13	3.92	0.03
Bramidae					0	0
Pteraclis carolinus	1	7.69	0.38	1.67	15.76	0.11
Acanthuridae	1	7.69	0.38	0.13	3.92	0.03
Hemiramphidae	1	7.69	0.38	0	0	0
Mollusca	39	100	14.72	10.71	1807.57	12.42
Unidentified cephalopod	38	92.31	14.34	4.71	1758.51	12.09
Loliginidae	1	7.69	0.38	6	49.06	0.34
Crustacea	103	92.3	38.86	0.85	1824.56	12.42
Unidentified Crustacean	2	15.38	0.75	0.03	12	0.08
Isopoda	82	53.85	30.94	0.69	1703.28	11.71
Amphipoda	18	15.38	6.79	0.12	106.28	0.73
Penaeidae	1	7.69	0.38	0.01	3	0.02
Macroalgae	3	15.38	1.13	0	0	0
Sargassum muticum	3	15.38	1.13	0	0	0
Parasite	63	15.38	23.77	0.52	373.58	2.57
Nematoda	63	15.38	23.77	0.52	373.58	2.57
Bait	5	23.08	1.89	60.52	1440.42	9.9
Plastic	2	15.38	0.75	0.08	12.77	0.09

Table 15: Prey items from Swordfish stomachs classified as family or species name with the total, percent occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI).

Swordfish (N=39)						
Prey Item	**Total**	**%O**	**%N**	**%W**	**IRI**	**%IRI**
Teleost	39	84.4	4.63	64.45	632.58	3.95
Unidentified teleost	31	65.63	3.59	1.75	350.46	2.19
Alepisauridae	*4*	9.38	0.46	12.76	124	0.77
Balistidae					0	0
Canthidermis sufflamen	1	3.13	0.23	0.33	1.75	0.01
Scombridae					0	0
Thunnus alalunga	1	3.13	0.12	49.28	154.62	0.96
Paralepididae					0	0
Sudis hyalina	2	3.13	0.23	0.33	1.75	0.01
Mollusca	248	87.51	28.74	27.51	3662.56	22.86
Unidentified cephalopod	245	81.25	28.39	16.24	3626.19	22.63
Ommastrephidae					0	0
Illex illecebrosus	1	3.13	0.12	11.26	35.62	0.22
Pterotracheidae	2	3.13	0.23	0.01	0.75	0
Crustacea	4	12.51	0.47	0.05	3.75	0.02
Unknown Crustacean	3	9.38	0.35	0.05	3.75	0.02
Decapoda	1	3.13	0.12	0	0	0
Macroalgae	129	50	14.95	0.3	762.5	4.76
Sargassum muticum	129	50	14.95	0.3	762.5	4.76
Parasite	435	56.25	50.41	0.72	2876.06	17.95
Nematoda	435	56.25	50.41	0.72	2876.06	17.95
Cartlidge	1	3.13	0.12	0	0	0
Bait	7	18.75	0.81	7.15	149.25	0.93

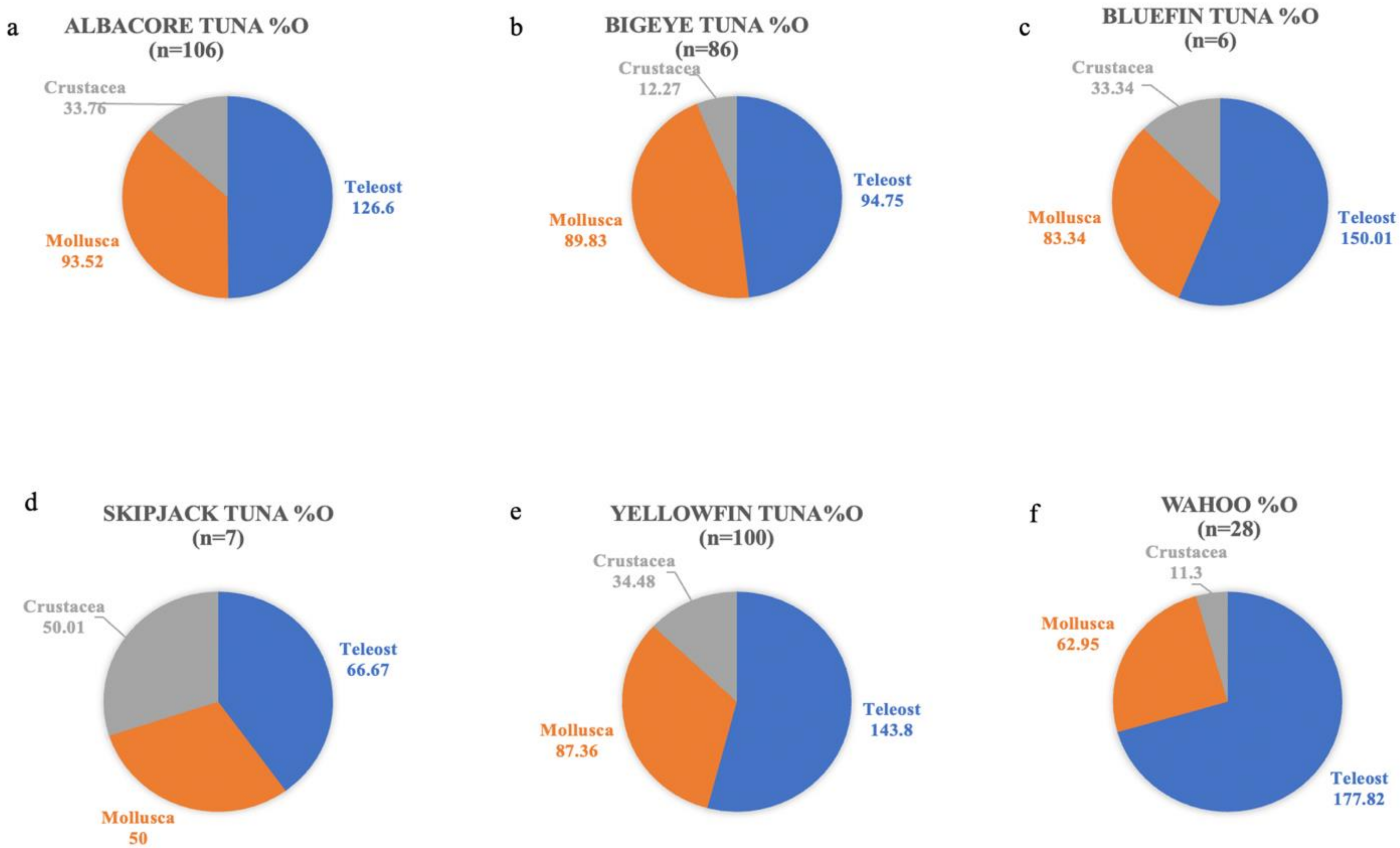

Figure 3. A graphical representation of the contribution of teleost, mollusca, and crustacea to the diet of each species. The numbers represent the percent of occurrence values for each prey type for the Scombridae family: A. Albacore Tuna, B. Bigeye Tuna, C. Bluefin Tuna, D. Skipjack Tuna, E. Yellowfin Tuna, F. Wahoo, G. Dolphinfish, H. Blue Marlin, I. Swordfish, J. Roundscale Spearfish, K. White Marlin, L. Sailfish

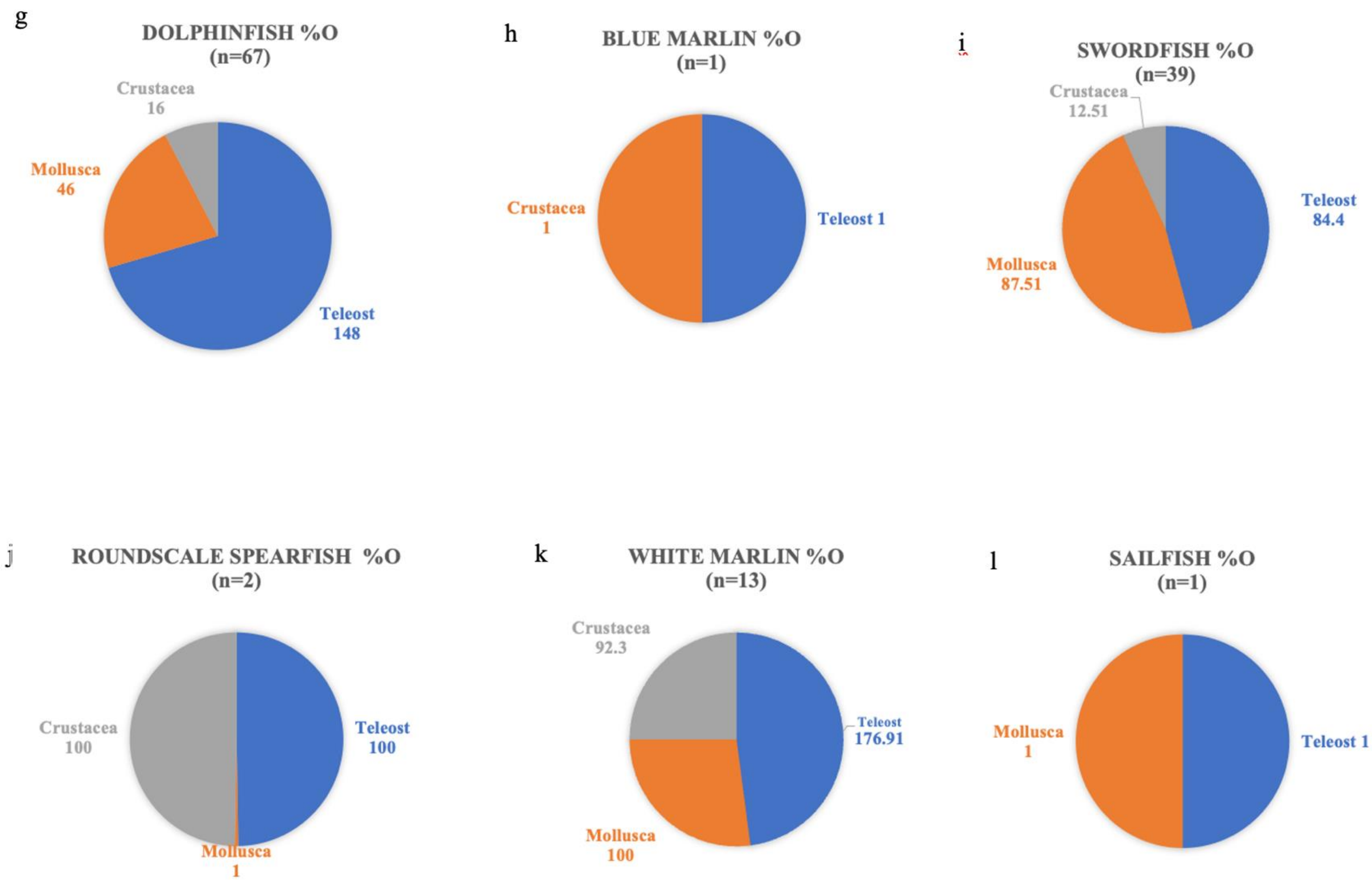

Figure 3. Continued

Table 16: Sample size (n), percentage of empty stomachs, percentage of unidentifiable material, percent of occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI) for teleost, mollusca and crustacea found within the stomachs of the six species from the Scombridae family.

	Albacore Tuna	Bigeye Tuna	Bluefin Tuna	Skipjack Tuna	Yellowfin Tuna	Wahoo
n	106	86	6	7	100	28
% Empty	38	32	0	14	13	4
% Unidentifiable	79	65	0	0	55	57
Teleost						
%O	126.6	94.75	150.01	66.67	143.8	177.82
%N	28.64	27.44	39.32	36.67	43.89	8.28
%W	28.53	23.71	65.01	38.44	59.51	30.58
IRI	1673.62	1954.17	5269.86	5007.58	2603.99	677.06
%IRI	13.22	14.17	30.39	24.3	19.45	15.44
Mollusca						
%O	93.52	89.83	83.34	50	87.36	62.95
%N	93.52	3.38	2.16	43.44	35.58	15.39
%W	34.85	58.64	34.6	56.16	19.44	5.97
IRI	3342.64	4149.7	2305.79	36.67	3719.89	955.84
%IRI	26.4	30.08	13.29	24.51	27.78	21.8
Crustacea						
%O	33.76	12.27	34	50.01	34.48	11.3
%N	33.76	3.26	3.92	9.99	11.86	4.23
%W	19.02	0.15	0.02	1.8	0.68	0.02
IRI	248.9	6.82	65.67	196.53	131.85	28.69
%IRI	1.97	0.05	0.38	0.95	0.98	0.65

Table 17: Sample size (n), percentage of empty stomachs, percentage of unidentifiable material, percent of occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI) for teleost, mollusca and crustacea found within the stomachs of one species from the Coryphaenidae family.

	Dolphinfish
n	67
% Empty	25
% Unidentifiable	46
Teleost	
%O	148
%N	32.54
%W	38.69
IRI	1971.16
%IRI	27.64
Mollusca	
%O	46
%N	10.01
%W	11.97
IRI	651.1
%IRI	9.13
Crustacea	
%O	16
%N	7.01
%W	1.22
IRI	75.62
%IRI	1.06

Table 18: Sample size (n), percentage of empty stomachs, percentage of unidentifiable material, percent of occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI) for teleost, mollusca and crustacea found within the stomachs of the three species from the Istiophoridae family.

	Blue Marlin	Roundscale spearfish	White Marlin	Sailfish
n	2	2	13	1
% Empty	0	0	0	0
% Unidentifiable	100	50	69	100
Teleost				
%O	1	100	176.91	1
%N	55	42.85	18.88	60.00
%W	94.73	95.83	32.7	0.67
IRI	149.73	6934	2542.03	20.67
%IRI	46.79	42.09	17.47	25.41
Mollusca				
%O	0	1	100	1
%N	0	34.29	14.72	20.00
%W	0	1.67	10.71	<0.1
IRI	0	35.97	1807.57	20.00
%IRI	0	0.22	12.42	24.59
Crustacea				
%O	1	100	92.3	0
%N	0.4	22.86	38.86	0
%W	0.01	2.5	0.85	0
IRI	0.4162	1268	1824.56	0
%IRI	0.41	7.7	12.54	0

Table 19: Sample size (n), percentage of empty stomachs, percentage of unidentifiable material, percent of occurrence (%O), percent by number (%N), percent by weight (%W), index of relative importance (IRI), and percent index of relative importance (%IRI) for teleost, mollusca and crustacea found within the stomachs one species from the Xiphiidae family.

	Swordfish
n	39
% Empty	17
% Unidentifiable	36
Teleost	
%O	84.4
%N	4.63
%W	64.45
IRI	632.58
%IRI	3.21
Mollusca	
%O	87.51
%N	28.74
%W	27.51
IRI	3662.56
%IRI	22.86
Crustacea	
%O	12.51
%N	0.47
%W	0.05
IRI	3.75
%IRI	0.02

Table 20: Schoener's diet overlap indices for each species interaction. Values in bold text represents the interactions that are >0.6 meaning there is significant dietary overlaps (Guzzo et al 2013).

	ALB	BET	BFT	SKJ	YFT	DOL	WAH	BUM	SPG	SWO	WHM
BET	**0.812**										
BFT	**0.875**	**0.856**									
SKJ	**0.921**	**0.762**	**0.825**								
YFT	**0.908**	**0.721**	**0.783**	**0.949**							
DOL	**0.774**	**0.763**	**0.858**	**0.695**	**0.705**						
WAH	**0.774**	**0.776**	**0.857**	**0.695**	**0.703**	**0.969**					
BUM	0.361	0.173	0.236	0.411	0.453	0.187	0.156				
SPG	0.562	0.553	**0.645**	0.483	0.492	**0.787**	**0.759**	0.183			
SWO	**0.796**	**0.976**	**0.838**	**0.768**	**0.726**	**0.745**	**0.752**	0.179	0.535		
WHM	**0.714**	0.526	0.589	**0.764**	**0.805**	0.54	0.508	**0.648**	0.343	0.531	
SAI	**0.750**	**0.938**	**0.812**	**0.699**	**0.658**	**0.719**	**0.750**	0.111	0.509	**0.932**	0.464

ALB= Albacore Tuna	BUM= Blue Marlin
BFT= Bluefin Tuna	SPG= Roundscale Spearfish
BET= Bigeye Tuna	SWO= Swordfish
SKJ= Skipjack Tuna	WHM= White Marlin
YFT= Yellowfin Tuna	WAH= Wahoo
DOL= Dolphinfish	SAI= Sailfish

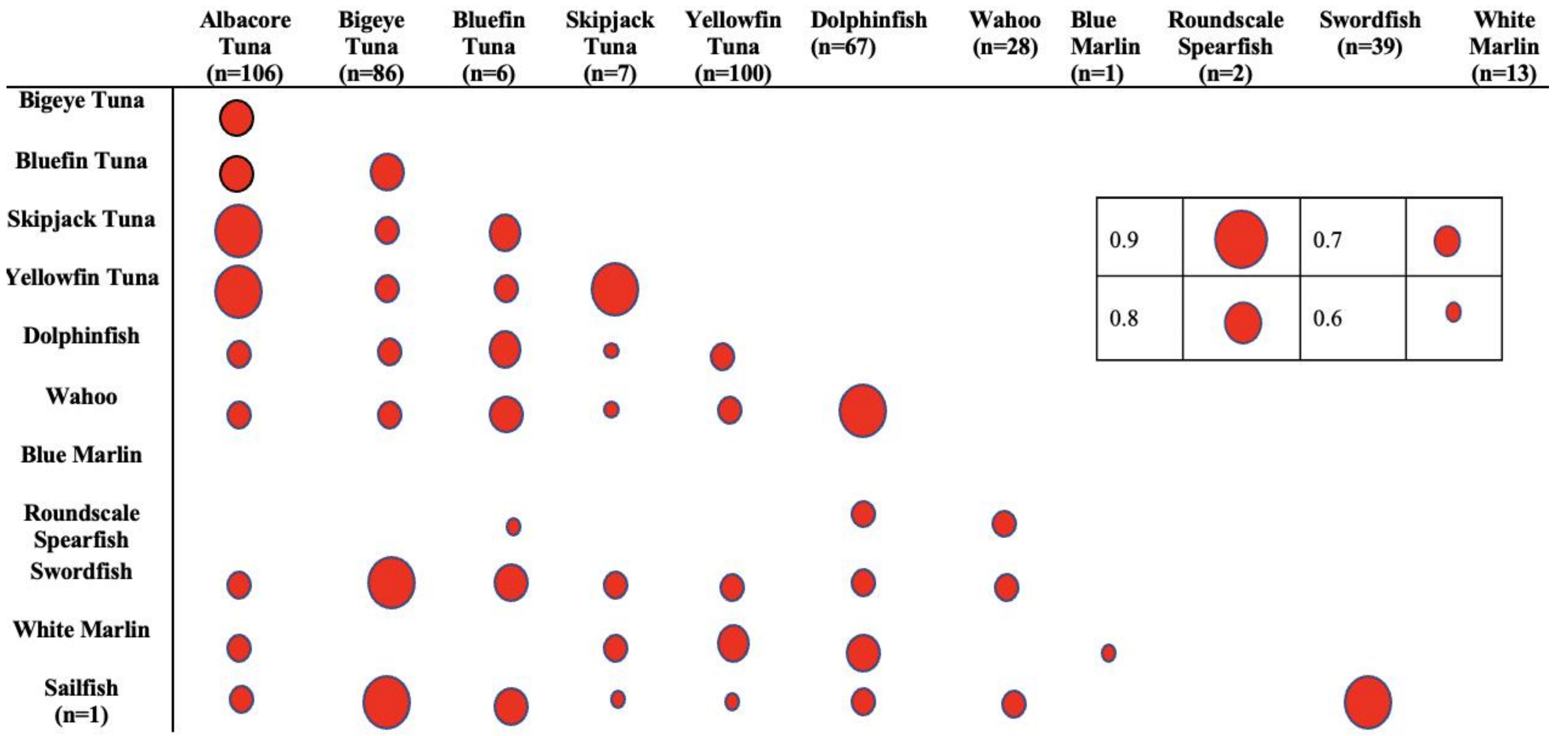

Figure 4. Visual representation of the Schoener's diet overlap index. The larger the circle, the greater the diet overlap. A circle represents a Schoener's index of >0.6. If an overlap has a value <0.6 then there is not circle present, indicating no significant overlap is occurring (Herder, Schliewen et al. 2012)

Table 21: Stable isotope data represented as: total samples collected (n), C:N ratio, $\delta^{13}C$ mean and standard deviation, $\delta^{13}C$` mean and standard deviation, $\delta^{15}N$ mean and standard deviation, and estimated trophic position (TP) for each species sampled.

Species	n	C: N	$\delta^{13}C$ mean	$\delta^{13}C$ SD	$\delta^{13}C'$ Mean	$\delta^{13}C'$ SD	$\delta^{15}N$ mean	$\delta^{15}N$ SD	Trophic Estimation
Albacore Tuna	5	3.2	-17.8	0.2	-17.8	0.2	9.8	0.4	2
Bigeye Tune	9	3.4	-17.9	0.6	-17.9	0.6	10.5	0.9	2.2
Bluefin Tuna	3	5.6	-20.8	1.3	-19.8	1	13.0	0.9	3
Skipjack Tuna	6	3.1	-17.5	0.8	-17.5	0.8	8.3	0.9	1.5
Yellowfin Tuna	10	3.4	-18.1	0.9	-18.1	0.9	9.3	0.8	1.9
Dolphinfish	4	3.1	-17.3	0.7	-17.3	0.7	9.9	1.3	2
Wahoo	4	4.4	-18.3	0.3	-17.2	0.3	10.4	0.4	2.2
Blue Marlin	2	3	-16.9	0.3	-16.9	0.3	10.9	0.7	2.3
Spearfish	5	3	-17.1	0.3	-17.1	0.3	8.5	0.8	1.6
Sailfish	1	3	-17.1	0	-17.1	0	8.4	0	1.6
Swordfish	9	6.1	-21.1	1.3	-19.3	1	11.1	0.8	2.4
White Marlin	5	3	-16.9	0.4	-16.9	0.4	9.2	0.5	1.8

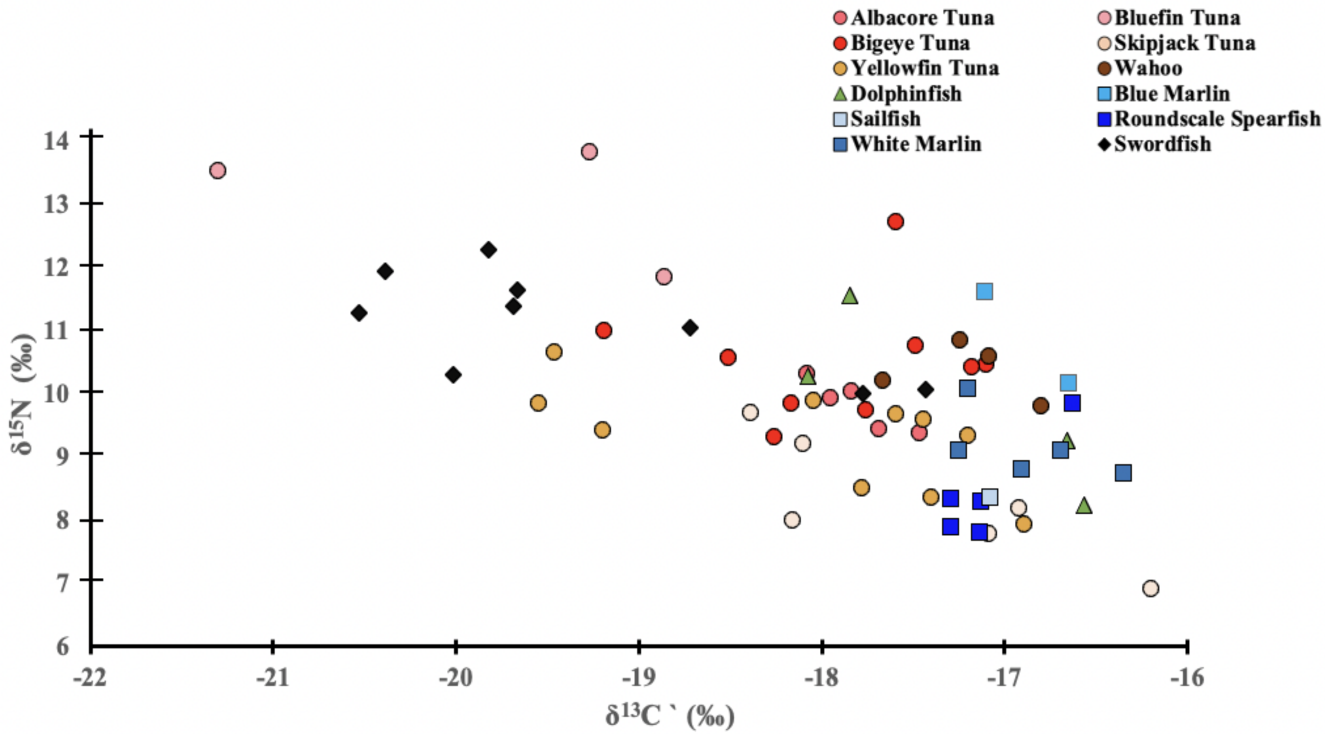

Figure 5. The δ^{13}C` and δ^{15}N values for each individual samples, organized by species

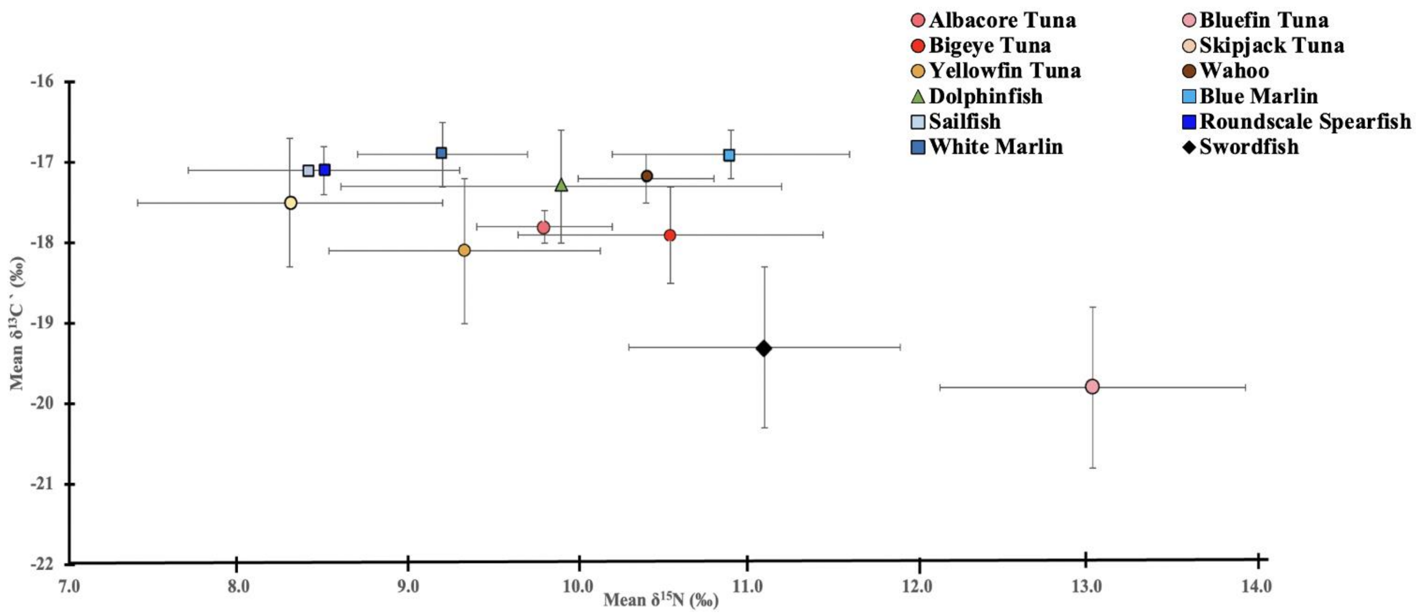

Figure 8. The mean $\delta^{13}C$` and mean $\delta^{15}N$ values for each species with standard deviation bars

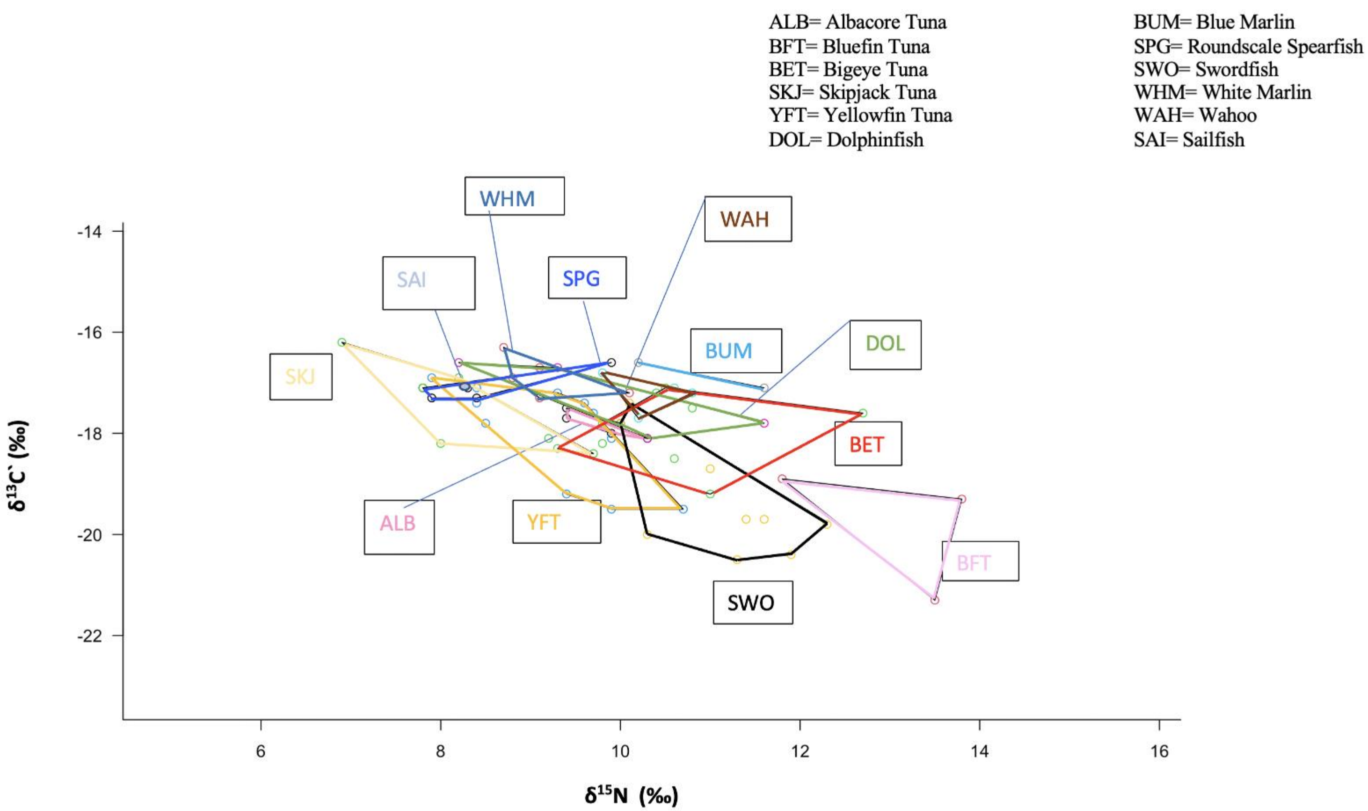

Figure 7. Stable Isotope Bayesian Ellipses in R (SIBER) for each species.

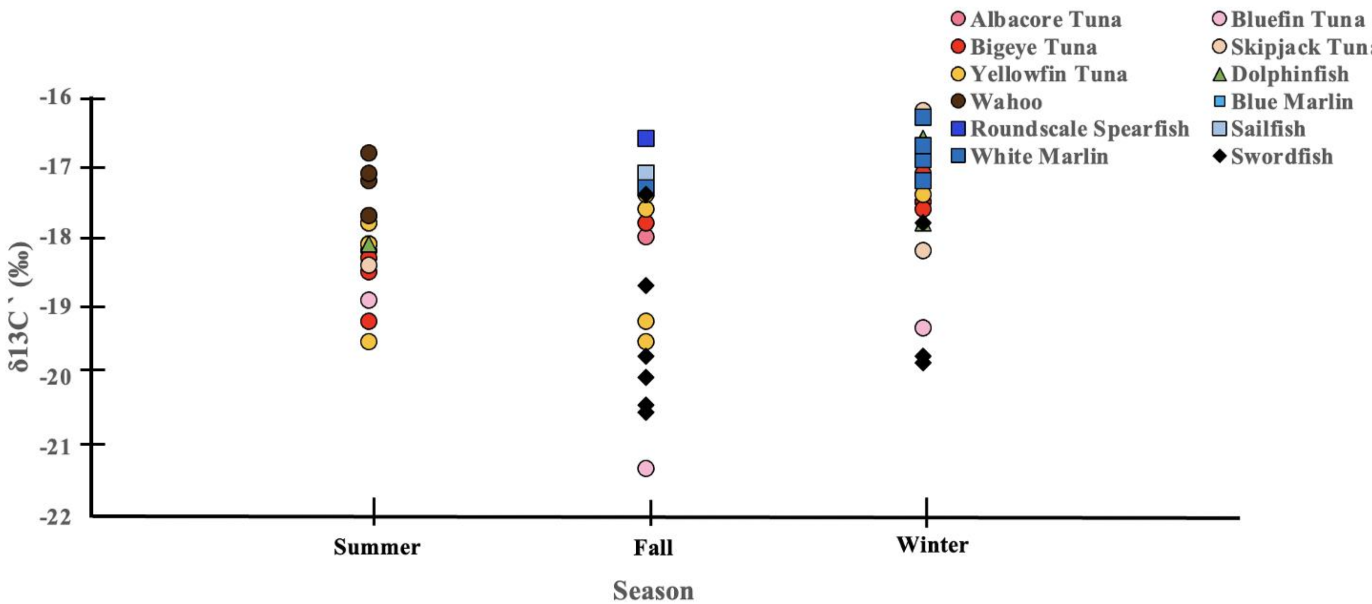

Figure 8. $\delta^{13}C$` values for each individual sampled grouped by time of year the samples were caught (Summer, Fall, Winter)

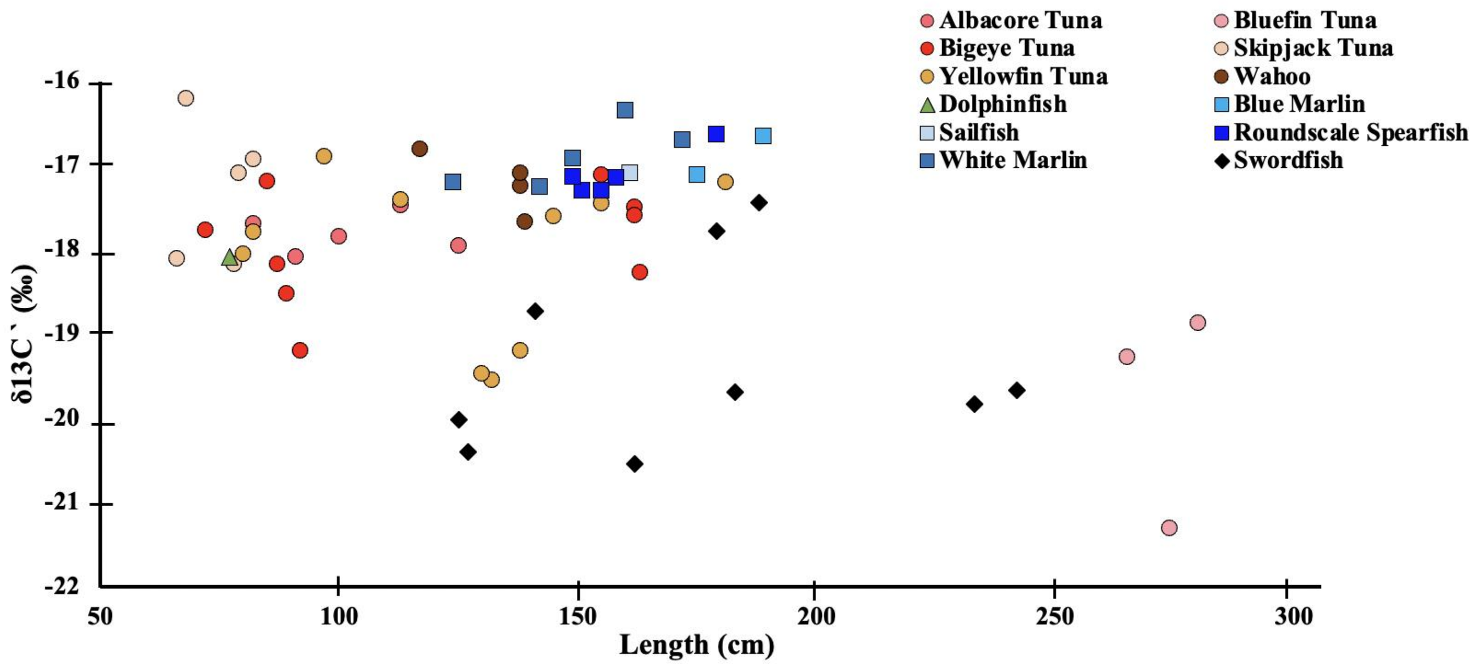

Figure 9. δ^{13}C` and length of each individual sampled, organized by species

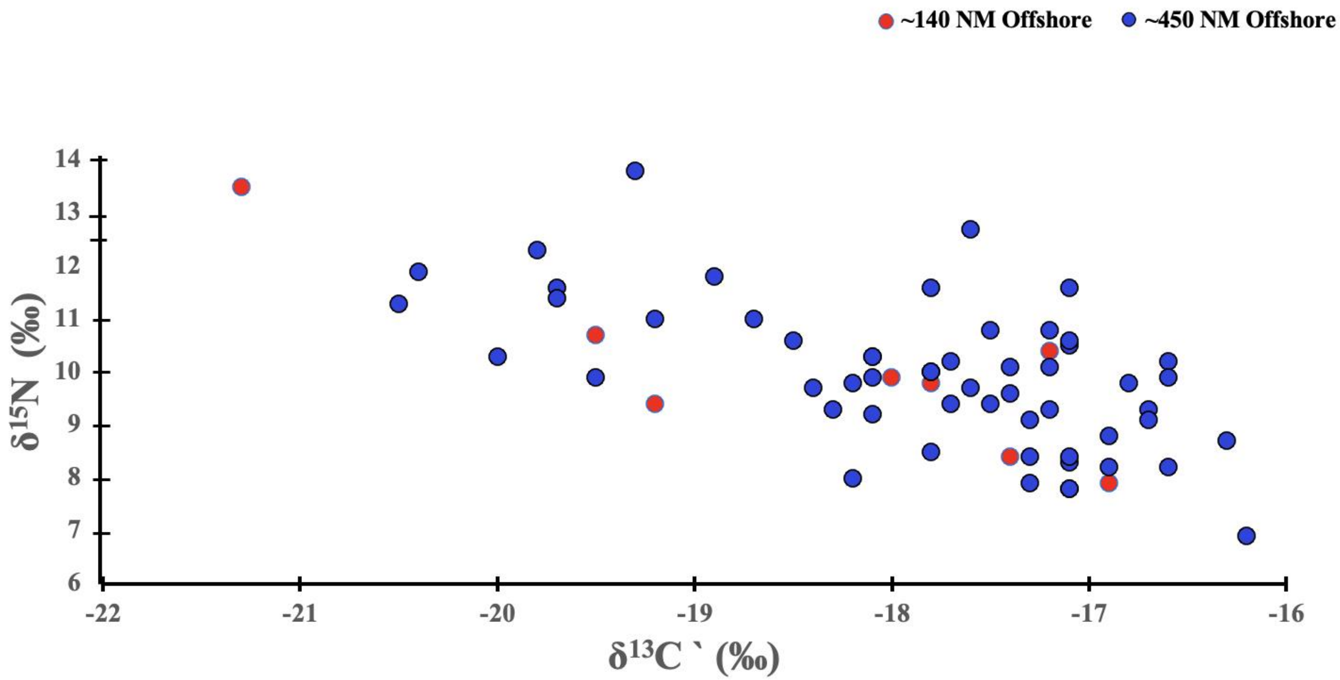

Figure 10. The $\delta^{13}C$` and $\delta^{15}N$ values for each individual sampled, color coded by the distance offshore the individual was caught. Red circles are individuals caught by vessels at ~140 nautical miles offshore and blue circle represent individuals caught ~450 nautical miles offshore

Table 22: Previous research studies on the studied species from the nearshore, coastal ecosystem. The definitions for nearshore used by each previous study, the definition of offshore used for this study, dominate prey species for the nearshore studies and for this offshore study, showing the similarities in prey items from both ecosystems.

Predator	**Nearshore Paper**	**Defintion of Nearshore**	**Nearshore Dominant Prey types**	**Definition of Offshore**	**Offshore Dominant Prey Types**
Bluefin Tuna	Butler *et al* . (2010)	On the Continential Shelf off Norrth Carolina	Teleost: menhaden	Beyond the contiential Shelf	Teleost: Gonostomatidae and Balistidae
Yellowfin Tuna	Rudershausen *et al.* (2011)	U.S Atlantic Coast off North Carolina	Teleost and cephalopods: Exocoethidae, Scombridae	Beyond the contiential Shelf	Teleost: Balistidae, Tetraodontidae, Gonostomatidae
Dolphinfish	Rudershausen *et al* . (2011)	U.S Atlantic Coast off North Carolina	Surface associated species- Teleost: Tetraodontidae, Monacanthidae, Exocoetidae, *Sargassum sp.*	Beyond the contiential Shelf	Surface associated species- Teleost: Balistidae, Diodontidae, Syngnathidae, Monacanthidae, *sargassum sp.*
Wahoo	Rudershausen *et al* . (2011)	U.S Atlantic Coast off North Carolina	Mesopelagic species- Teleost and cephalopoda	Beyond the contiential Shelf	Mesopelagic species-Mollusca and Teleost: Alepisauridae, Pterotracheidae, Argonautidae, and Ommastrephiae
Blue Marlin	Rudershausen *et al.* (2011)	U.S Atlantic Coast off North Carolina	Teleost and teuthids: Scombridae, Alepisauridae	Beyond the contiential Shelf	Teleost and Crustacea
Swordfish	Stillwell and Kohler (1985)	On the Continential Shelf and Slope between North Carolina and Tail of the Grand Banks	Mollusca: Gadidae, Scombridae, Stromateidae, Pomatomidae and Ammodytidae	Beyond the contiential Shelf	Mollusca: Alepisauridae