COASTAL RECREATIONAL FISHING LICENSE
FINAL PERFORMANCE REPORT

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SECTION 1
DEVELOPMENT OF A FOOD HABITS SAMPLING PROGRAM FOR THE PAMLICO SOUND REGION

Sample Collection and Processing

Twenty-five predators (Table 1) were sampled from North Carolina Division of Marine Fisheries (NCDMF) programs 195, 915, 462, and 365 for food habits. From P195, five predators per 50 mm size bin, per station were sampled for food habits. For rare predator species (*i.e.* low collection numbers or limited spatial range) 10 predator samples per size bin were sampled at each station. From P915, all gulf flounder, inshore lizardfish, pinfish, northern and southern kingfish, Spanish mackerel, spotted seatrout, striped bass, summer flounder, and weakfish sampled for age and growth were also sampled for food habits. For the remaining species in P915, a maximum number per day, from each area (e.g. Neuse River, Pamlico River) were sampled based on predator length (Table 2). All striped bass collected in P462 were sampled for food habits. Only red drum collected in 2013 from P365 were sampled for food habits.

For all surveys, predators were stored on ice and brought back to the lab where length (TL or FL; mm), weight (0.1 kg), and sex were recorded. Predator stomachs were removed and frozen until they were ready to be processed. Frozen stomachs were thawed and the stomach contents were identified to the lowest possible taxa. The majority of fish prey were too degraded to identify using coloration and markings. We used otolith morphology, gizzard shape, and scale shape to identify degraded fish. Individual prey items were weighed (0.01 g) separately and digestion state (fresh, partially digested, or well digested) was recorded. Based on the condition of the prey, we also measured notochord length (mm), eye diameter (mm), caudal peduncle depth (mm) for fish, carapace width (mm) for crabs, post-orbital length (mm) for shrimp, and mantle length (mm) for squid.

This sampling of food habits has been designated as P850.

Data Entry

All P850 data were coded on NCDMF data sheets. We used NCDMF data sheet SS197 for predators and sheet SS208 for prey. NODC codes were used for predators (Table 1) and ITIS codes were assigned to the prey (Appendix A). We collaborated with George Joyner to enter P850 data into the NCDMF biological database. A description of the biological database fields used in P850 is provided in Appendix B.

Each predator was assigned a unique P850 Predator ID which allowed the food habits data to be linked to age, growth, and reproductive information collected in P930. This P850 Predator ID was also used to link the prey data to the corresponding predator. The Predator ID is a 23 digit code consisting of the P850 Control1 (Sequence) number + replicate number + predator NODC code + line number. We had to modify the Predator ID when analyzing our data in R. The default in R is to convert a number of that length (23 digits) to scientific notation, rendering the Predator ID useless. Turning off the scientific notation feature did not solve the problem, we are unsure of the algorithm that R was using, but it would alter the back half of the Predator ID code. Prior to any data analyses in R, we shortened the Predator ID by replacing the 10 digit NODC code with a 3 digit code we created (Table 1) and this resolved all of our issues with the Predator ID field in R.

Tables

Table 1: List of predators collected from Programs 195, 915, 462, and 365 and measurement type for each species. Only striped bass were sampled from P462 and only red drum were sampled from P365.

Common name	Scientific name	NODC	R Code	Length type	915	195
Atlantic croaker	*Micropogonias undulatus*	8835440701	900	TL	X	X
Black drum	*Pogonias cromis*	8835440801	901	FL	X	X
Bluefish	*Pomatomus saltatrix*	8835250101	902	FL	X	X
Gulf flounder	*Paralichthys albigutta*	8857030302	903	TL	X	
Hickory shad	*Alosa mediocris*	8747010103	904	FL	X	
Inshore lizardfish	*Synodus foetens*	8762020101	905	FL	X	X
Leopard searobin	*Prionotus scitulus*	8826020103	906	FL		X
Longnose gar	*Lepisosteus osseus*	8732010101	907	TL	X	
Northern kingfish	*Menticirrhus saxatilis*	8835440603	908	TL	X	X
Northern searobin	*Prionotus carolinus*	8826020101	909	FL		X
Pigfish	*Orthopristis chrysoptera*	8835400201	910	FL		X
Pinfish	*Lagodon rhomboides*	8835430201	911	FL	X	X
Red drum	*Sciaenops ocellatus*	8835440901	912	FL	X	
Silver perch	*Bairdiella chrysoura*	8835440301	913	TL		X
Southern flounder	*Paralichthys lethostigma*	8857030304	914	TL	X	X
Southern kingfish	*Menticirrhus americanus*	8835440601	915	TL	X	X
Spanish mackerel	*Scomberomorus maculatus*	8850030502	916	FL	X	X
Spot	*Leiostomus xanthurus*	8835440401	917	FL	X	X
Spotted hake	*Urophycis regia*	8791031002	918	TL		X
Spotted seatrout	*Cynoscion nebulosus*	8835440102	919	FL	X	
Striped bass	*Morone saxatilis*	8835020102	920	FL	X	
Striped searobin	*Prionotus evolans*	8826020102	921	FL		X
Summer flounder	*Paralichthys dentatus*	8857030301	922	TL	X	X
Weakfish	*Cynoscion regalis*	8835440104	923	FL	X	X
White perch	*Morone americana*	8835020101	924	FL	X	

Table 2: Daily maximum number of predators sampled for food habits based on length (mm) from each P915 sampling area/crew.

Species	Daily maximum requested per length bin (mm)											
Atlantic croaker	100-150	151-175	176-200	201-225	226-250	251-275	276-300	301-325	326-350	351-375	376-400	401+
	15	15	15	15	15	15	15	15	15	15	15	15
Black drum	-300	301-375	376-450	451-525	526-600	601-700	701-800	801-900	901-1000	1001+		
	10	10	10	10	10	10	10	10	10	10		
Bluefish	-200	201-300	301-400	401-500	501-600	601-700	701-800	801+				
	15	15	15	15	15	15	15	15				
Hickory shad	-250	251-280	281-310	311-340	341-370	371-400	401-430	431+				
	10	10	10	10	10	10	10	10				
Longnose gar	-200	201-300	301-400	401-500	501-600	601-700	701-800	801-900	901-1000	1000+		
	10	10	10	10	10	10	10	10	10	10		
Red drum	-300	301-375	376-450	451-525	526-600	601-700	701-800	801-900	901-1000	1001+		
	10	10	10	10	10	10	10	10	10	10		
Southern flounder	100-250	251-300	301-350	351-400	401-500	501-550	551-600	601-650	651+			
	15	15	15	15	15	15	15	15	15			
Spot	-140	140-160	161-180	181-200	201-220	220-240	241-260	260+				
	10	10	10	10	10	10	10					
White perch	-200	201-230	231-260	261-290	291-320	321+						
	10	10	10	10	10	10						

SECTION 2

FOOD HABITS OF PREDATORS IN PAMLICO SOUND, NORTH CAROLINA

Abstract

We conducted the first multi-year, multispecies food habits study in Pamlico Sound, North Carolina sampling the stomach contents of 16,979 predators from 25 species. Predators were sampled from fisheries-independent trawl and gill net surveys. We used agglomerative hierarchical cluster analyses and similarity profiles to identify significant trophic guilds in Pamlico Sound. The diets of predators sampled from the trawl survey were significantly different than predators sampled from the gill net survey. Mysids and anchovies were more important to trawl-caught predators with the majority of these predators belonging to non-piscivorous guilds. Half of gill net survey predators were piscivorous and relied more heavily on Atlantic menhaden and sciaenids. Differences in levels of piscivory between the surveys is most likely a result of larger predators being sampled in gill nets relative to trawls. Our work shows the effect of gear size selection on predator diets and the need to use a variety of gears that sample a wide-range of predator sizes.

Introduction

Fisheries management is increasingly moving from single-species approaches towards more holistic multispecies and ecosystem-based approaches (Hollowed et al. 2000; Latour et al. 2003; Pikitch et al. 2004; Link 2010). Trophic interactions are important to ecosystem regulation (Schmitz 2007) through predator-prey interactions (Buckel et al. 1999; Hallfredsson and Pederson 2009) and competition and niche partitioning (Wuenschel et al. 2013; Teffer et al. 2015). Thus, food habits data are critical for ecosystem-based modeling approaches. In ecosystem and multispecies models, it is not possible to model all of the species individually and guilds are a useful way to reduce model complexity based on biological characteristics of the species (Hawkins and MacMahon 1989).

Guilds are species that exploit the same group of environmental resources in similar ways (Root 1967). Food, habitat, and time are the resources typically partitioned by species (Pianka 1969) and for fishes, food is the most important resource driving the separation of guilds (Ross 1986). One advantage of using guilds, is the ability to group species together based on niche requirements and not taxonomic relationships (Root 1967). Trophic guilds have been used to aggregate similar predators into a single functional group (Garrison and Link 200) and synthesize food habits data on both local (Luczkovich et al. 2002; Buchheister and Latour 2015) and regional scales (Marancik and Hare 2007).

Pamlico Sound is the second largest estuary in the U.S. It is a shallow, wind-driven, lagoonal system with mean water depth of 5 m. Pamlico Sound is separated from the Atlantic Ocean by a chain of barrier islands, the Outer Banks, and water between Pamlico Sound and the Atlantic Ocean is exchanged through three permanent inlets: Oregon, Hatteras, and Ocracoke (Wells and Kim 1989; Clunies et al. 2017). In general, salinities range from 15 – 20 ppt and follow an East-West gradient with salinities increasing towards the inlets. The Tar-Pamlico (hereafter referred to as Pamlico) and Neuse Rivers provide the majority (78.9%) of freshwater input into Pamlico Sound, with precipitation and runoff accounting for the remaining input (Wells and Kim 1989). Pamlico Sound serves as critical nursery habitat for numerous species (NCDEQ 2016) and supports several recreational and commercial fisheries (NCDMF 2016) that are economically important.

Food habits in Pamlico Sound are poorly described. Previous work has been primarily short-term and focused on a single predator. While there are recent studies describing the food habits of Red drum (*Sciaenops ocellatus*; Paramore 2011; Peacock 2014) and cownose ray (*Rhinoptera bonasus*; Bade et al 2014), the majority of studies are older (Powell and Schwartz

1979; Lewis and Peters 1994; Kamermans et al. 1995; Fitzhugh et al. 1996) and may not reflect current predator-prey dynamics in Pamlico Sound. Studies in North Carolina estuaries including Albemarle Sound (Manooch 1973; Cooper et al. 1998; Creed 1985; Rudershausen et al. 2005; Riley 2012) and Cape Fear River (Hodson et al. 1981; Facendola and Scharf 2012) also have limitations with food habits studies not being recent, focused on a single predator, and/or representing a short time period. Two recent multispecies food habits in North Carolina estuaries have been conducted. The overlap of diets between striped bass (*Morone saxatilis*) and hybrid striped bass (*M. saxatilis x M. americana*) were described in a multi-year study in the Caper Fear River (Patrick and Moser 2001) and Hart (2008) conducted a short-term food habits study of eight predator species (pinfish *Lagodon rhomboides*, pigfish *Orthopristis chrysoptera*, Atlantic menhaden (*Brevoortia tyrannus*), smooth dogfish *Mustelus canis*, bluefish *Pomatomus saltatrix*, spot *Leiostomus xanthurus*, Atlantic croaker *Micropogonias undulatus*, and cownose ray) to support the development of Ecopath models for Core Sound (Deehr et al. 2014). There is a deficit of multispecies, multi-year food habits data for North Carolina, especially Pamlico Sound. This is surprising given the size of Pamlico Sound and importance as nursery and fishing habitat.

We describe the food habits data for 25 fish species in Pamlico Sound, North Carolina collected during trawl and gill-net surveys and identified trophic guilds for fish caught from both gear types. We discuss how sampling bias from survey gear choice can influence results of trophic guild analyses.

Methods

Food Habits Sampling

Twenty-five predators (Table 1) were sampled from North Carolina Division of Marine Fisheries (NCDMF) programs 195, 915, 462, and 365 for food habits. Predators were sampled

from the Pamlico and Neuse Rivers and Pamlico Sound (Fig. 1). P195 is a trawl survey and we sampled five predators per 50 mm size bin, per station for food habits. For rare predator species (*i.e.* low collection numbers or limited spatial range) 10 predator samples per size bin were sampled at each station. P915 and P462 are both gill net surveys. From P915, all gulf flounder, inshore lizardfish, pinfish, northern and southern kingfish, Spanish mackerel, spotted seatrout, striped bass, summer flounder, and weakfish sampled for age and growth were also sampled for food habits. For the remaining species in P915, a maximum number per day, from each area (e.g. Neuse River, Pamlico River) were sampled based on predator length (Table 2). All striped bass collected in P462 were sampled for food habits and were combined with striped bass from P915 for food habit analyses. Only red drum collected in 2013 from P365 were sampled for food habits. We provide a brief synopsis of P365 longline survey predator data but do not include these predators in our analyses.

Spatial Kernel Density Estimation

We used spatial kernel density estimation (SKDE) to account for non-independence for fish collected from both a single site and from nearby sites when estimating the diet composition of a predator (Binion-Rock et al. 2018). SKDE estimates a kernel (*i.e.* a 2-dimensional probability density with dimensions x = longitude and y = latitude) for each sampling location by interpolating the diet composition for a series of grid (i.e. knots) locations (s) overlaid on the area where the diet is being estimated. To compute s we overlaid a 100 * 100 grid across the spatial domain (*i.e.* Pamlico Sound). This resulted in grids spaced 0.2 decimal degrees (DD) apart in the North-South direction and 0.1 DD apart in the East-West direction. The SKDE of the composition at a location is a locally-weighted average of the n observed compositions. Let y_{ij} be the proportion prey j contributes to the diet of the predators in sample i, and s_i be the spatial location of sample i. The estimated proportion for prey j at location s is

$$\hat{y}_j(s) = \frac{1}{W}\sum_{i=1}^{n} w(s - s_i)y_{ij}$$

where *w* is the kernel function that decreases with the distance *(d)* between the prediction location *s* and the observation location s_i and $W = \sum_{i=1}^{n} w(s - s_i)$ is the normalizing constant to make the weights sum to one.

We used the Gaussian kernel function $w(d) = e^{-(d_x/h_x)^2 - (d_y/h_y)^2}$ where $d = (d_x, d_y)$. The bandwidths $h_x, h_y > 0$ are the widths of the kernel and determine the amount of spatial smoothing. If the bandwidths are close to zero then strong spatial patterns for prey are present and only the few nearest neighbors affect the estimate, whereas many points affect the estimate if the bandwidths are large and there is less spatial clustering of prey (Silverman 1986; Brunsdon and Comber 2015). The most common scenario (isotropy) is to have the same bandwidth in both directions (*i.e.* $h_x = h_y$). We allow for a different bandwidths (anisotropy) in the East-West (h_x) and North-South (h_y) directions (Brundson and Comber 2015) to account for environmental covariates such as salinity, which have an East-West gradient in our system (increasing salinity from west to east). We incorporated a tuning parameter "stretch" to allow h_x and h_y to vary. We parameterize the bandwidth as $h_x = h$ and $h_y = h$ * stretch. Stretch determines the degree of anisotropy with stretch = 1 giving the isotropic model with bandwidth $h_x = h_y = h$. We considered values of stretch ranging from 0.5 – 2 (increasing in increments of 0.25).

We used leave-one-out cross validation to select the bandwidths h_x and h_y. For each observation, we predicted its composition using the other *n-1* observations and compared the predicted $(\hat{y}_j)$ and observed (y_{ij}) values using mean square error,

$$MSE = \frac{1}{n}\sum_{j}\sum_{i=1}^{n}\left(\hat{y}_j(s_i) - y_{ij}\right)^2.$$

We repeated this for all possible combinations of *h* ranging from 0.1 – 1.0 DD (by 0.1 increments) and *stretch* ranging from 0.5 – 2 (by 0.25 increments) and selected the combination that minimized MSE. To produce the final diet estimate, we used the selected bandwidths to compute the estimate on a grid of locations covering the spatial domain. The final mean proportional contribution of prey *j* to the predator diet (M_j) is the average of the predictions $\hat{y}_j(s)$ and is calculated as

$$M_j = \frac{1}{l}\sum_{k=1}^{l}\hat{y}_j\,(s_k)$$

where *k* are the individual prediction points in *s* and *l* is the total number of points in *s*.

Statistical Analyses of Diets

Analyses comparing the diets of predators were based on Bray-Curtis dissimilarity distances. Predator diets were compared using non-metric multidimensional scaling (MDS) and analysis of similarity (ANOSIM). MDS is an ordination technique based on ranked similarities and was used to visually represent the similarity among predators. Predators located closer on the MDS plot have more similar diets than predators located further away.

We used ANOSIM to test whether diets varied by either sampling year or survey. ANOSIM is analogous to a one-way analysis of variance (ANOVA), but unlike traditional ANOVAs which assume the data are from a normal distribution, there are no distribution assumptions with ANOSIM (Clarke 1993). ANOSIM uses the test statistic *R* as a measure of the level of similarity between the groups. *R* ranges from 0 to 1 with values close to 1 indicating little similarity between groups.

Since predator diets differed between surveys (see below), predators from trawl (P915) and gill net (P915 and P462) surveys were analyzed separately using cluster analysis to identify trophic guilds. We used agglomerative hierarchical clustering with average linkage on Bray-Curtis dissimilarities and similarity profile analysis (SIMPROF) to identify significant trophic guilds. We used average linkage because it is a space-conserving method that helps to avoid distortion in the resulting clusters and is also a compatible linkage method for Bray-Curtis dissimilarity (McCune and Grace 2002). SIMPROF is a permutation test with the null hypothesis of no underlying multivariate structure among the predator diets (Clarke et al. 2008). We generated two sets of profiles (T = 1000, S = 999, where T and S represent the number of permutations in sets 1 and 2, respectively) and used $p < 0.05$ as our threshold for a cluster being significant. We used MDS to visualize inter- and intra-guild predator relationships.

We used similarity percentages (SIMPER) to identify the discriminating prey (*i.e.* prey consistently important to a guild's diet) most responsible for the observed differences in the trawl versus gill net predator comparisons and for delineating guild membership. For prey i to be considered a discriminating prey for between-guild comparisons it had to have an average dissimilarity $(\bar{\delta}_i) > 0.01$ and a ratio $\frac{\bar{\delta}_i}{SD(\delta_i)} > 1$. The value of $\bar{\delta}_i$ describes how much prey i contributes to the overall dissimilarity $(\bar{\delta})$ between the two group and $\frac{\bar{\delta}_i}{SD(\delta_i)}$ is a measure of how consistently a species contributes to $\bar{\delta}_i$ (Clarke 1993). For singleton guilds, $SD(\delta_i)$ cannot be calculated, so only $(\bar{\delta}_i) > 0.01$ was used to identify discriminating prey for those guilds. For a prey to be considered a discriminating prey at the guild-level, a prey had to meet these criteria for all inter-guild comparisons and be an important component to mean-guild predator diet relative to other guilds.

For all analyses, the predator diets are expressed as the proportional contribution by weight of a prey to a predator's diet (*W*). We made the assumption that unidentifiable prey had the same proportional composition as our identifiable prey. While other metrics, such as frequency of occurrence, are less influenced by differential digestion (Baker et al. 2014; Buckland et al. 2017), we used *W* as our diet metric because the diet data required by multispecies and ecosystem models is based on bulk not occurrence. Rare prey that did not contribute at least 1% to any predator's diet were excluded from these analyses.

All analyses were conducted in R (R Core Team 2016). MDS, ANOSIM, and SIMPER analyses were performed using the *vegan* package (Oksanen et al. 2016) and SIMPROF was performed using the *clustsig* package (Whitacker and Christman 2014).

Results

Description of Predator Diets

We sampled 16,979 predators (n_p) in 1,418 individual net collections (n_s) from four NCDMF surveys (Table 1). Both mean size and the size distribution of predators sampled differed among the surveys (Fig. 2). Pooled across species, predators from the P195 trawl survey were smaller (165.13 ± 45.96 mm) than predators from P915 (μ ± SD; 399.9 ± 193.7 mm) and P462 (567.8 ± 53.5 mm) gill net surveys. Red drum from the P365 longline survey (1029.74 ± 92.7 mm) were the largest predators sampled. The difference in size between gear types was observed for all species with the exception of silver perch and pinfish. The widest range of predator sizes was sampled from the gill net surveys. The size ranges of striped bass from the two gill net surveys overlapped but mean sizes were slightly larger in P462 relative P915 (490.3 ± 92.2 mm).

A large number of sampled predators (n_p = 5,307) had empty stomachs. Identifiable prey were found in approximately half (n_p = 8,322) of the examined stomachs. A total of 79 prey

types were identified. Almost all prey types were detected in predator samples from the P915 and P462 gill net surveys (n = 71). Fewer prey types (n = 53) were detected in predator samples from the P195 trawl survey and only 16 were detected in the P365 longline survey.

Predator diets were not significantly different (ANOSIM: R = -0.029, p = 0.950) between 2012 and 2013 but did significantly differ (ANOSIM: R = 0.312, p = 0.001) between the trawl and gill net surveys. Diet data were pooled for both years for analyses. Predators from the gill net survey were more piscivorous than predators from the trawl survey. Overall, fish prey contributed 49.9%, by weight, to the diet of gill net predators versus 31.4% for trawl predators. The most common prey for trawl net predators were mysids (Mysida; 25.0%), anchovies (*Anchoa mitchilli* and *A. hepsetus*; 15.2%) and polychaetes (Polychaeta; 13.9%; Table 2). Atlantic menhaden (14.2%), mollusks (Gastropoda and Bivalvia; 13.3%), and polychaetes (12.8%) were top prey for gill net predators (Table 2). Atlantic menhaden and mysids were discriminating prey for trawl versus gill net predator comparisons using SIMPER (Table 2). Full descriptions of predator diets from each survey can be found in Appendix C.

Trophic guilds

Four trophic guilds (PISC A, PISC B, CRUST, and BENTHIC) were identified in the P195 trawl survey using cluster analysis and SIMPROF (Fig. 3A). PISC A was a piscivorous guild composed of four predators, weakfish (*Cynoscion regalis*), southern Flounder (*Paralichthys lethostigma*), bluefish, and inshore lizardfish. Predators in this guild consumed a variety of fish; anchovies, Atlantic croaker, and spot were the discriminating prey and important (contributed > 5% by weight) to the diets of all PISC A predators (Table 3, Figs. 4A&B). There was high variability in the diet composition within this guild. Anchovies were the top prey for southern flounder, bluefish, and inshore lizardfish, but for weakfish, anchovies and mysids were the top prey contributing 21.5% and 23.0% respectively. Mysids were also a large proportion of

southern flounder diet. Inshore lizardfish consumed higher proportions of pinfish, silver perch, weakfish, and southern kingfish (*Menticirrhus americanus*) compared to other PISC A predators.

PISC B was a singleton guild containing the piscivore Spanish mackerel (*Scomberomorus maculatus*). Unlike PISC A where the predators consumed a variety of fish, anchovies contributed over 80% to the diet for PISC B (Table 3, Fig. 4A). Both anchovies and Atlantic menhaden were discriminating prey. Anchovies and Atlantic menhaden contributed higher proportions to the diet of Spanish mackerel than to the predators in PISC A, but they were important prey for both guilds (Figs. 4A & B).

Predators in the remaining guilds, CRUST and BENTHIC, had diets that relied more heavily on invertebrate prey (Table 3). CRUST consisted of Summer flounder (*Paralichthys dentatus*), striped searobin (*Prionotus evolans*), spotted hake (*Urophycis regia*), silver perch, northern searobin (*Prionotus carolinus*), gulf flounder (*Paralichthys albigutta*), and leopard searobin (*Prionotus scitulus*). Mysids and Amphipods (primarily Gammaridae, < 1% Corophidae and Caprellidae) were the discriminating prey for this guild. Mysids were major prey for all CRUST predators and had a mean contribution of 44.7% to CRUST predator diets. Amphipods contributed 13.5% to the mean guild diet, but were only a major prey item for gulf flounder, leopard searobin, and northern searobin and only contributed 3-6% to the diets of the other predators (Table 3, Fig. 4A). The amount of fish prey for this guild is reduced compared to PISC A and PISC B, but fish were important for half of CRUST predators. Anchovies were an important part of the diet for summer flounder, spotted hake, and silver perch while spot were an important contributor to both gulf and southern flounder diets. There was high within guild variability for CRUST predators (Fig. 4B) due to the varying importance of discriminating prey and fish prey to each predator.

Pinfish, Atlantic croaker, spot, pigfish, and southern kingfish made up the BENTHIC guild. These predators consumed predominately invertebrate prey and polychaetes and mollusks were the discriminating prey (Table 3). Fish prey contributed little to the diets or predators in this guild (Table 3, Figs. 4A & B). BENTHIC had the lowest within guild variability of the trawl survey guilds exhibited by the relatively tight cluster on the MDS plot (Fig. 4B). Southern kingfish and pigfish diets were the most dissimilar for this guild. Pigfish diets were the most homogenous and 76% of their diets were comprised of polychaetes while southern kingfish diets were the most variable (Fig. 4A).

From the P915 gill net survey, five trophic guilds (BENTHIC, PISC A, GEN, PISC B, and PISC C) were identified (Fig. 3B). BENTHIC consisted of pinfish, black drum (*Pogonias cromis*), spot, Atlantic croaker, hickory shad (*Alosa mediocris*), and white perch (*Morone americana*). Predators in this guild primarily consumed invertebrate prey and the discriminating prey were mollusks and polychaetes (Table 4; Fig. 5A). Within guild variability was high for BENTHIC (Fig. 5B). Spot and Atlantic croaker diets were the most similar for predators in this guild and polychaetes contributed ~ 50% to their diets. Pinfish and black drum both relied heavily on mollusks, but the importance of other prey varied between the two. White perch and hickory shad diets were the least similar to other BENTHIC predators with diets dominated by amphipods (51.4% and 12.0%, respectively; Fig. 5A). Additionally, fish prey (larval and early juvenile) were more important to hickory shad diet than for other BENTHIC predator diets (Fig. 5A).

PISC A had the largest number of gill net predators and included spotted seatrout (*Cynoscion nebulosus*), bluefish, longnose gar (*Lepisosteus osseus*), southern flounder, weakfish, summer flounder, and striped bass. Predators in this guild were piscivorous with fish prey

contributing > 70% to each predator's diet (Fig. 5A). Atlantic croaker, Atlantic menhaden, pinfish, and spot were the discriminating prey for this guild (Table 4) but a variety of fish were consumed. Within-guild variability was smaller for PISC A than BENTHIC (Fig. 5B). The cumulative contribution of discriminating prey was > 39% to the diets of all the PISC A predators. Atlantic croaker, Atlantic menhaden, and spot were important prey to each predator's diet, except for striped bass which consumed minimal amounts of Atlantic croaker. Pinfish were only important to the diets of bluefish, southern flounder, and spotted seatrout. Atlantic menhaden contributed the most to bluefish, longnose gar, spotted seatrout, and striped bass diets while spot were the most important prey for southern flounder (Fig. 5A). Anchovies were not a discriminating prey for this guild, but they were the largest contributor to summer flounder and weakfish diets. Silver perch were also an important prey for bluefish, southern flounder, and weakfish.

Only two predators, southern kingfish and red drum were in GEN. Predators in this guild had the most diverse diets of any predators in the gill net survey. Invertebrates accounted for the majority (68.5%) of prey for this guild and the discriminating prey are polychaetes, portunid crabs (Portunidae), and mud crabs (Panopidae; Table 4). The diets between the two predators were fairly similar and portunid crabs were the largest component of their diets (Fig. 5A & B). Red drum consumed higher proportions of Atlantic menhaden, amphipods, big-clawed snapping shrimp (*Alpheus heterochaelis*), and spot while southern kingfish consumed higher amounts of mollusks and polychaetes (Fig. 5A).

PISC B and PISC C were both piscivorous singleton guilds, comprised of gulf flounder and Spanish mackerel, respectively. Over 60% of the diet for gulf flounder was comprised of fish, but both fish (pigfish, pinfish, silver perch, and spot) and invertebrates (snapping shrimp

and mantis shrimp (*Squilla empusa and Nannosquilla grayi*)) were discriminating prey (Table 4). The invertebrate discriminating prey were less important to PISC B diet than the fish discriminating prey. Spot and pinfish were the biggest contributors to PISC B diet, accounting for 21.7% and 28.8%, respectively (Table 4; Fig. 5A). Spanish mackerel was piscivorous and the discriminating prey for PISC C were anchovy, Atlantic menhaden, and silversides (*Menidia menidia*, *M. beryllina*, and *Membras martinica*), which contributed > 50% to Spanish mackerel diet (Table 4, Fig. 5A).

Discussion

Predator diet and size differed between surveys

We found differences in predator diets and sizes between the gill net and trawl surveys. Predators from the gill net surveys were larger than trawl-collected predators. This is not surprising as trawls have been shown to select for smaller fish relative to other gear types (Lucena and O'Brien 2001; Morley et al. 2013). Predators caught in trawls relied more heavily on invertebrate prey and gill net predators consumed higher proportions of fish prey. Since predator size can have a large influence on diet (e.g. ontogenetic diet shifts; Overton et al. 2009; Buchheister and Latour 2015), a likely explanation for differences in predator diets between trawl and gill net surveys is predator size but temporal and spatial differences in the surveys may also contribute.

Predator guild assignment often differed between surveys. Southern kingfish switched from the BENTHIC guild in the P195 trawl survey to the GEN guild in the P915 gill net survey. Gulf and summer flounder switched from the CRUST guild in the P195 trawl survey to piscivorous guilds in the P915 gill net survey. Differences in diets were also observed for predators belonging to piscivorous guilds in both surveys. Bluefish, Spanish mackerel, southern flounder, and weakfish were classified as piscivores in both surveys; however, there was

generally a decrease in the importance of anchovies and an increase in the contribution of Atlantic menhaden and sciaenids to predator diets from the P915 gill net survey compared to the P195 trawl survey. Mysids were important to the diets of southern flounder and weakfish in the P195 trawl survey, but not in the P915 gill net survey. Similar ontogenetic shifts, with increased emphasis on fish prey or a switch from anchovies to larger fish, have also been observed for these predators in other systems (Hartman and Brandt 1995; Overton et al. 2009; Bowman et al. 2000; Smylie et al. 2015; Buchheister and Latour 2015). When constructing multispecies models based on trophic interactions, it is important to sample diets from a wide range of predator sizes, so these ontogenetic shifts are not overlooked. For Pamlico Sound, if only food habits data from the trawl survey were used to construct a multispecies model, the amount of fish prey would be greatly underestimated and the importance of invertebrates would be overstated. Size selection by gear type has important implications for stock assessment (Colombo et al. 2008; Jurvelius et al. 2011) and it should also be considered more often in food habits studies.

In addition to sampling different predator sizes, spatial and temporal differences in the survey or differences in protocol have the potential to influence diet. The trawl and gill net surveys sample different habitats within Pamlico Sound and tributaries (away from shore versus nearshore; see Figure 1). However, there are no dramatic differences in fish and invertebrate communities between these two habitat types that could explain the large differences in diet (authors pers. obs.). The trawl survey occurs in June and September only while the gill net samples from February to December; when limited to these two months, the gill net survey is still dominated by fish prey relative to the trawl survey. P915 gill net surveys had long soak times compared to the tow duration for the P195 trawl survey and this could lead to lower abilities to detect prey. Soft-bodied invertebrate prey (e.g. mysids, polychaetes, amphipods)

often digest more quickly than fish or invertebrates with hard body parts such as claws or shells (Hyslop 1980; Berens and Murie 2008; Sheffield and Grebmeier 2009). In our study, soft-bodied invertebrate prey have the potential to be digested or too degraded for identification before the predators are sampled from the gill net survey. However, based on the different variety and larger sizes of hard-bodied prey in samples from the gill net survey versus the trawl survey, we feel the observed differences in diet reflect true ontogenetic shifts and are not the result of differences in time in the net.

Estuarine trophic guilds

The trophic guilds in Pamlico Sound are similar to those described in other estuaries (Luczkovich et al. 2002; Franco et al. 2008; Buchheister and Latour 2015). For example, the trophic guilds we found in Pamlico Sound are similar to those described in St. Marks National Wildlife Refuge (Luczkovich et al. 2002) and Chesapeake Bay (Buchheister and Latour 2015). However, there were a few exceptions. Red drum and gulf Flounder (> 80 mm) were identified by Luczkovich et al (2002) as a 'fish and shrimp' guild. In our study, larger gulf glounder were also in a guild with high amounts of piscivory and shrimp feeding (PISC B) but red drum were in the GEN guild and crabs were more important than shrimp to their diet. Hickory shad were in the BENTHIC guild for our study but were classified as piscivores by Buchheister and Latour (2015). Fish prey were also important prey to hickory shad in our study, but polychaetes were the dominant prey item. Our sample size for hickory shad is much larger (n_p = 792 vs 29, respectively) than the sample size for Buchheister and Latour (2015) and may have contributed to differences in diet composition between the two studies.

Our study found four of the seven trophic guilds described for estuaries by Elliot et al. (2007). These were piscivore, zooplanktivore, zoobenthivore, and miscellaneous/opportunist. We did not identify predators that represented the detritivore, herbivore, or omnivore guilds.

Piscivorous and zoobenthivore (BENTHIC) guilds were identified in both the trawl and gill net surveys. The zooplanktivore (CRUST) guild was only described for the trawl survey where several predators relied heavily on mysids as prey. The miscellaneous/opportunist guild is used for predators that consume a wide variety of prey types and is equivalent to our GEN guild from the gill net survey.

There are detritivorous and herbivorous fishes present in Pamlico Sound but we did not sample those fishes for food habits. Gizzard shad (*Dorosoma cepedianum*) and striped Mullet (*Mugil cephalus*) are both found in Pamlico Sound and rely heavily on detritus (Eggold and Motta 1992; Yako et al. 1996) and their diets fit the description of detritivores. Herbivores feed predominately on either macroalgae or phytoplankton (Elliot et al. 2007). Atlantic menhaden are a numerically dominant species in Pamlico Sound and are traditionally considered herbivores that feed heavily on phytoplankton (Palomeres and Pauly 1998). Omnivores are described as consuming predominately filamentous algae, macrophytes, and periphyton with epifauna and infauna contributing small amounts to their diet. Typically, these types of fish are rare in estuaries (Elliot et al 2007) and it is unclear if food habits sampling of additional species would have led to the identification of an omnivore guild. Overall, there was good agreement between our guilds and those found Elliott et al. (2007) given our focus on higher level predators.

A trophic guild analysis by Marancik and Hare (2007) combined food habits data from 17 studies describing the diets of 26 estuarine predators in the southeastern U.S. The review represented multiple size classes for some predators but not others. Eight trophic guilds were identified in their review of estuarine studies but there were no piscivorous guilds. Summer and southern flounders were classified as benthic carnivores (consuming a mixture of crustaceans and fish) in the Marancik and Hare (2007) guild analysis but were classified as piscivores in our

study. We identified summer flounder as piscivorous in the P915 gill net survey and southern flounder as piscivores in both the P195 trawl and P915 gill net surveys. The studies Marancik and Hare (2007) used to describe summer (Poole 1964; Powell and Schwartz 1979) and southern flounder (Powell and Schwartz 1979) diets used trawls to collect predators. Only southern flounder < 300 mm were included in the trophic guild analyses by Marancik and Hare (2007) and the majority of the southern flounder (90.7%) were < 200 mm. Larger summer flounder up to 700 mm (Poole 1964) were included in the diet composition, but the majority of the samples were comprised of smaller age-1 summer flounder. The selection of smaller flounders in trawls likely underestimated the importance of fish prey in these studies. This again highlights the need to sample a wide range of predator sizes when conducting food habits studies.

Use of predator stomachs as samplers

The stomach contents of predators sampled in P850 can be used as biosamplers of the environment. Non-commercial invertebrates are not routinely sampled in Pamlico Sound and many of the predators sampled rely heavily on invertebrates as prey and their stomach contents could be used to establish invertebrate species richness. This has been done in other systems. For example, Frid and Hall (1999) and Link (2004) used predator stomachs to infer long-term changes to the benthic community. Similarly, spatial and seasonal movements of small crustaceans (*e.g.* mysids, euphausiids) that are often elusive and hard to sample were identified by using stomach contents of goosefish (*Lophius americanus*; Lasley-Rasher et al. 2015).

The green porcelain crab (*Petrolisthes armatus*) has invaded oyster reefs in Georgia and South Carolina in high densities (Hollebone and Hay 2007). Porcelain crabs were commonly found in several predators sampled from P195 (*e.g.* leopard searobin, silver perch) but were not identified beyond the family level. In future P850 food habits sampling, porcelain crabs should be identified to species level, if possible, to document whether green porcelain crabs have

invaded Pamlico Sound. If P850 is continued into the future, relative abundance indices for prey that are commonly consumed, such as Atlantic menhaden, anchovy, and spot, could be created and compared to other directed surveys. Juveniles of important resource species, such as striped bass and spotted seatrout, were rarely detected in our predator diets despite the large sample size; it does not appear that development of relative abundance indices from predator stomachs is possible for these species.

Conclusions and Implications

Our trophic guild analyses identified multiple guilds in Pamlico Sound and identified differences in diet between trawl- and gill net-collected predators. The guilds were similar to those found in prior estuarine studies (e.g. Buchheister and Latour 2015) and include the invertebrate to fish gradient as well as the benthic to pelagic gradient described in Marancik and Hare (2007). The differences in diets between trawl and gill-net collected predators has implications for interpretation of diet studies. Many diet surveys are conducted only using trawl-caught fish (Powell and Schwartz 1979; Bowman et al. 2000; Buchheister and Latour 2015). These studies used larger trawls that collect larger sized fish than the trawl used in this study; however, the potential remains that the sizes of sampled predators represents a truncated size distribution and favored smaller-sized individuals. The size selectivity of trawls may lead to biased diet estimates; for example, prior work may have concluded lower piscivory when, if the entire predator size range was examined, higher piscivory may be the reality. This issue can become magnified as a food habits study sampling only small predators is repeatedly used to parameterize the diet of predators in multispecies and ecosystem models.

This is the first large-scale multispecies food habits study conducted in Pamlico Sound, NC. To date, it is the largest food habits study conducted in North Carolina and is one of the

largest studies in the mid-Atlantic region. Additionally, it is the first time the diets of several of these predators have been described in North Carolina. These data will be useful for future studies on top down and bottom up impacts as well as the construction of larger scale ecosystem models. For example, the results of this study were critical in the parameterization of an Ecopath model used to examine total predator demand in Pamlico Sound (Section 3).

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Tables

Table 1: Sample sizes for the number of predators (n_p) sampled for food habits from the P195 trawl and P915 gill net surveys where n_s indicates the number of survey collections from which the predator was sampled. Predators with an X were excluded from analyses because of low sample size. Predators samples with an * were combined and analyzed with samples from the survey where the majority of the predators were sampled. Striped bass from the P462 gill net survey (n_s = 69, n_p = 150) were combined with the P915 gill net survey. Red drum from P365 (n_s = 34, n_p = 65) were not included in our trophic guild analyses.

Common Name	Scientific Name	P195		P915	
		n_s	n_p	n_s	n_p
Atlantic croaker	*Micropogonias undulatus*	190	792	225	561
Black drum	*Pogonias cromis*	0	0	165	312
Bluefish	*Pomatomus saltatrix*	87	266	320	1315
Gulf flounder	*Paralichthys albigutta*	11	35	65	156
Hickory shad	*Alosa mediocris*	0	0	189	792
Inshore lizardfish	*Synodus foetens*	83	574	2	2*
Leopard searobin	*Prionotus scitulus*	34	146	0	0
Longnose gar	*Lepisosteus osseus*	0	0	208	1430
Northern kingfish	*Menticirrhus saxatilis*	1	1x	9	11x
Northern searobin	*Prionotus carolinus*	14	26	0	0
Pigfish	*Orthopristis chrysoptera*	80	293	0	0
Pinfish	*Lagodon rhomboides*	137	389	102	149
Red drum	*Sciaenops ocellatus*	1	1	236	837
Silver perch	*Bairdiella chrysoura*	132	611	8	13*
Southern flounder	*Paralichthys lethostigma*	110	478	620	1878
Southern kingfish	*Menticirrhus americanus*	150	733	152	244
Spanish mackerel	*Scomberomorus maculatus*	10	23	16	32
Spot	*Leiostomus xanthurus*	197	720	211	413
Spotted hake	*Urophycis regia*	38	86	0	0
Spotted seatrout	*Cynoscion nebulosus*	4	5x	327	615
Striped bass	*Morone saxatilis*	0	0	121	262
Striped searobin	*Prionotus evolans*	90	264	0	0
Summer flounder	*Paralichthys dentatus*	170	755	39	45
Weakfish	*Cynoscion regalis*	134	753	205	484
White perch	*Morone americana*	0	0	89	261

Table 2: Results of SIMPER analyses comparing food habits of predators sampled in the P195 trawl versus P915 gill net surveys. Prey marked with an * are discriminating prey for the trawl and gill net surveys.

Prey	$\bar{\delta}_i$	$SD(\delta_i)$	$\frac{\bar{\delta}_i}{SD(\delta_i)}$	Mean Proportional Contribution (W)	
				P195	P915
Mysids*	0.123	0.120	1.023	0.250	0.009
Polychaete	0.097	0.108	0.901	0.139	0.128
Mollusks	0.079	0.105	0.759	0.067	0.133
Anchovy	0.076	0.079	0.956	0.152	0.044
Atlantic menhaden*	0.072	0.098	0.728	0.018	0.142
Spot	0.056	0.056	1.004	0.050	0.107
Amphipod	0.044	0.062	0.719	0.061	0.063
Portunid crab	0.034	0.053	0.632	0.023	0.057
Seagrass	0.032	0.036	0.908	0.009	0.068
Atlantic croaker	0.030	0.035	0.843	0.044	0.034
Porcelain crab	0.026	0.037	0.707	0.053	0.000
Penaeid shrimp	0.023	0.043	0.533	0.031	0.027
Pinfish	0.022	0.040	0.555	0.004	0.043
Mud crab	0.011	0.020	0.528	0.008	0.016
Silver perch	0.010	0.017	0.619	0.003	0.019

Table 3: Results of SIMPER analyses comparing significant trophic guilds identified through SIMPROF, in the trawl survey. Prey with an * are a discriminating prey for that guild.

Prey	Mean Proportional Diet (*W*)			
	PISC A	PISC B	CRUST	BENTHIC
Amphipod	0.011	0.000	0.135*	0.057
Anchovy	0.277*	0.823*	0.120	0.011
Atlantic croaker	0.162*	0.000	0.011	0.001
Atlantic menhaden	0.032	0.177*	0.000	0.007
Mollusks	0.006	0.000	0.028	0.216*
Mysids	0.105	0.000	0.447*	0.064
Polychaete	0.008	0.000	0.012	0.430*
Spot	0.137*	0.000	0.043	0.002

Table 4: Results of SIMPER analyses comparing significant trophic guilds, identified through SIMPROF, in the P915 gill net survey. Prey with an * are a discriminating prey for that guild.

Prey	Mean Proportional Diet (*W*)				
	BENTHIC	PISC A	GEN	PISC B	PISC C
Anchovy	0.037	0.111	0.011	0.002	0.224*
Atlantic croaker	0.000	0.076*	0.020	0.000	0.000
Atlantic menhaden	0.006	0.285*	0.110	0.000	0.148*
Big-clawed snapping shrimp	0.001	0.002	0.023	0.031*	0.000
Mantis shrimp	0.000	0.002	0.000	0.025*	0.000
Mollusks	0.325*	0.005	0.047	0.000	0.000
Mud crab	0.003	0.026	0.055*	0.000	0.000
Penaeid shrimp	0.020	0.015	0.027	0.043*	0.000
Pigfish	0.000	0.007	0.003	0.109*	0.000
Pinfish	0.001	0.044*	0.020	0.288	0.000
Polychaete	0.287*	0.018	0.090*	0.000	0.000
Portunid crab	0.021	0.030	0.303*	0.000	0.000
Silver perch	0.000	0.030	0.010	0.072*	0.000
Silversides	0.000	0.024	0.005	0.000	0.519*
Spot	0.007	0.197*	0.053	0.217*	0.000

Figures

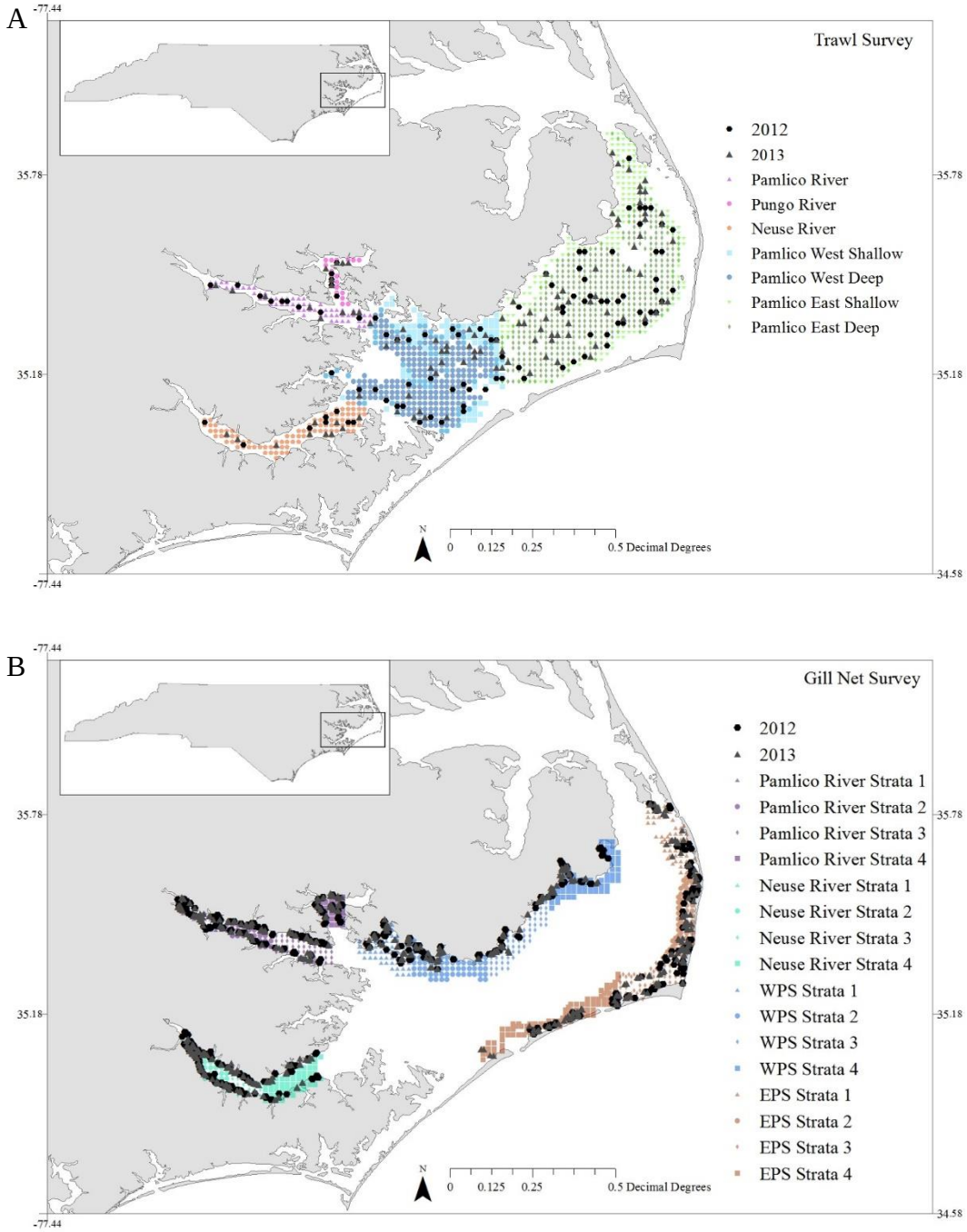

Fig. 1: Strata and sampling locations for predators collected from North Carolina Division of Marine Fisheries (A) P195 trawl and (B) P915 gill net surveys in Pamlico Sound, North Carolina. Striped bass from the P462 gill net survey were sampled from a subset of the multispecies gill net survey strata: Pamlico River Strata 2, Pamlico River Strata 3, Neuse River Strata 2, and Neuse River Strata 3.

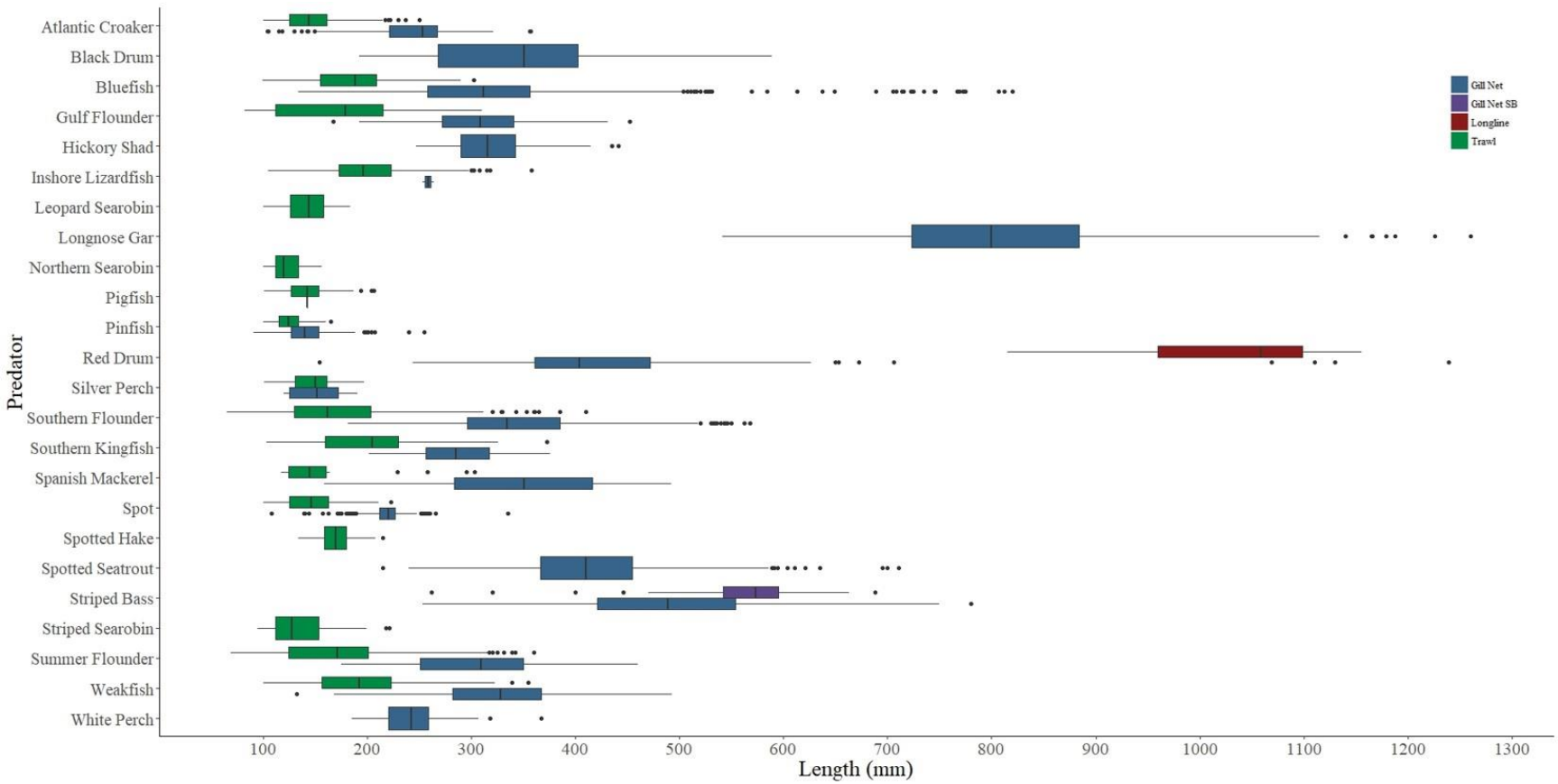

Fig. 2: Length distribution for predators sampled for food habits in Pamlico Sound, NC.

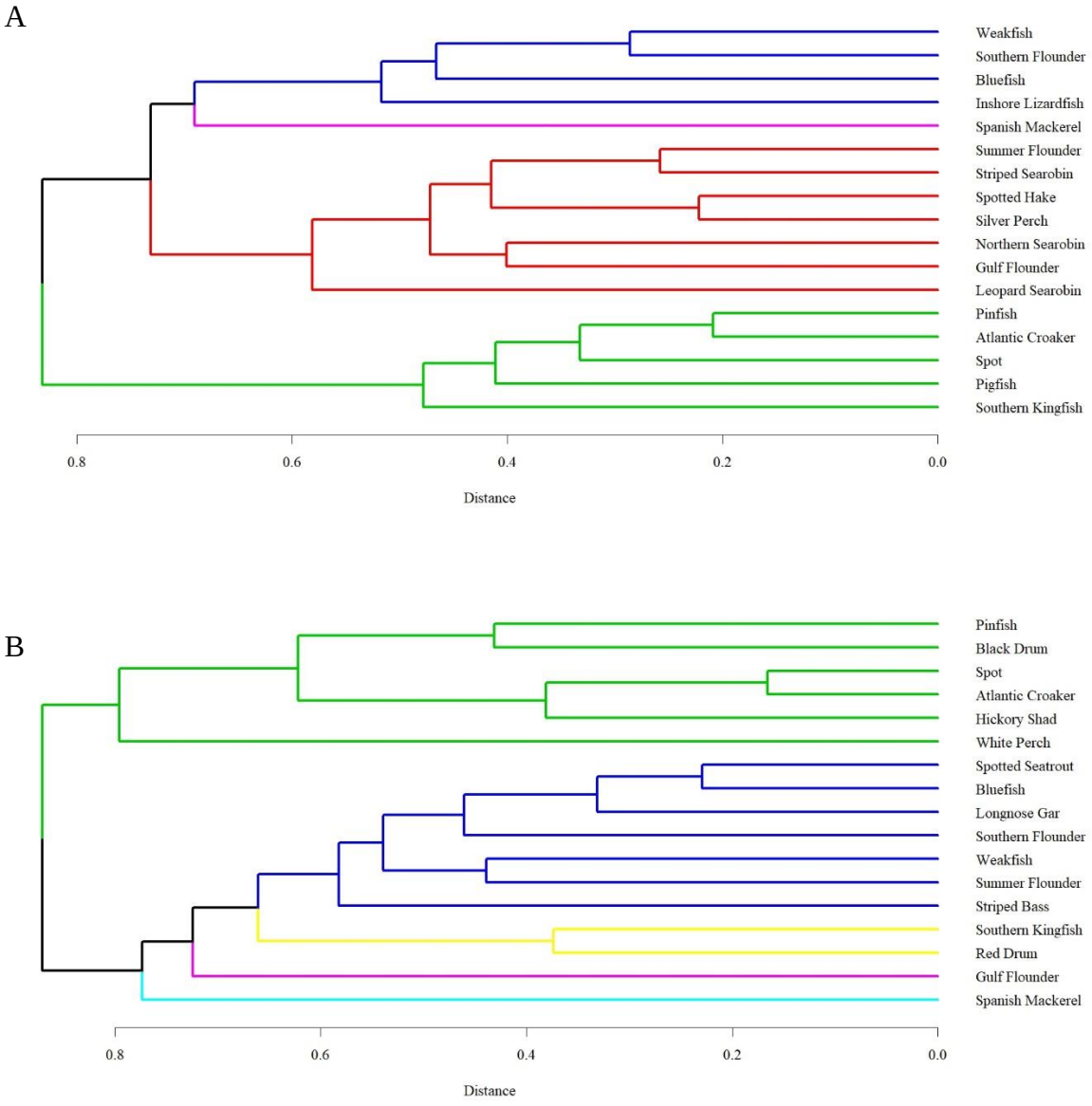

Fig. 3: Significant trophic guilds identified using agglomerative hierarchical clustering and SIMPROF analyses for predators sampled in (A) P195 trawl and (B) P915 gill net surveys. Significant trophic guilds are color coded with blue = PISC A, pink = PISC B, red = CRUST, green = BENTHIC, yellow = GEN, and aqua = PISC C.

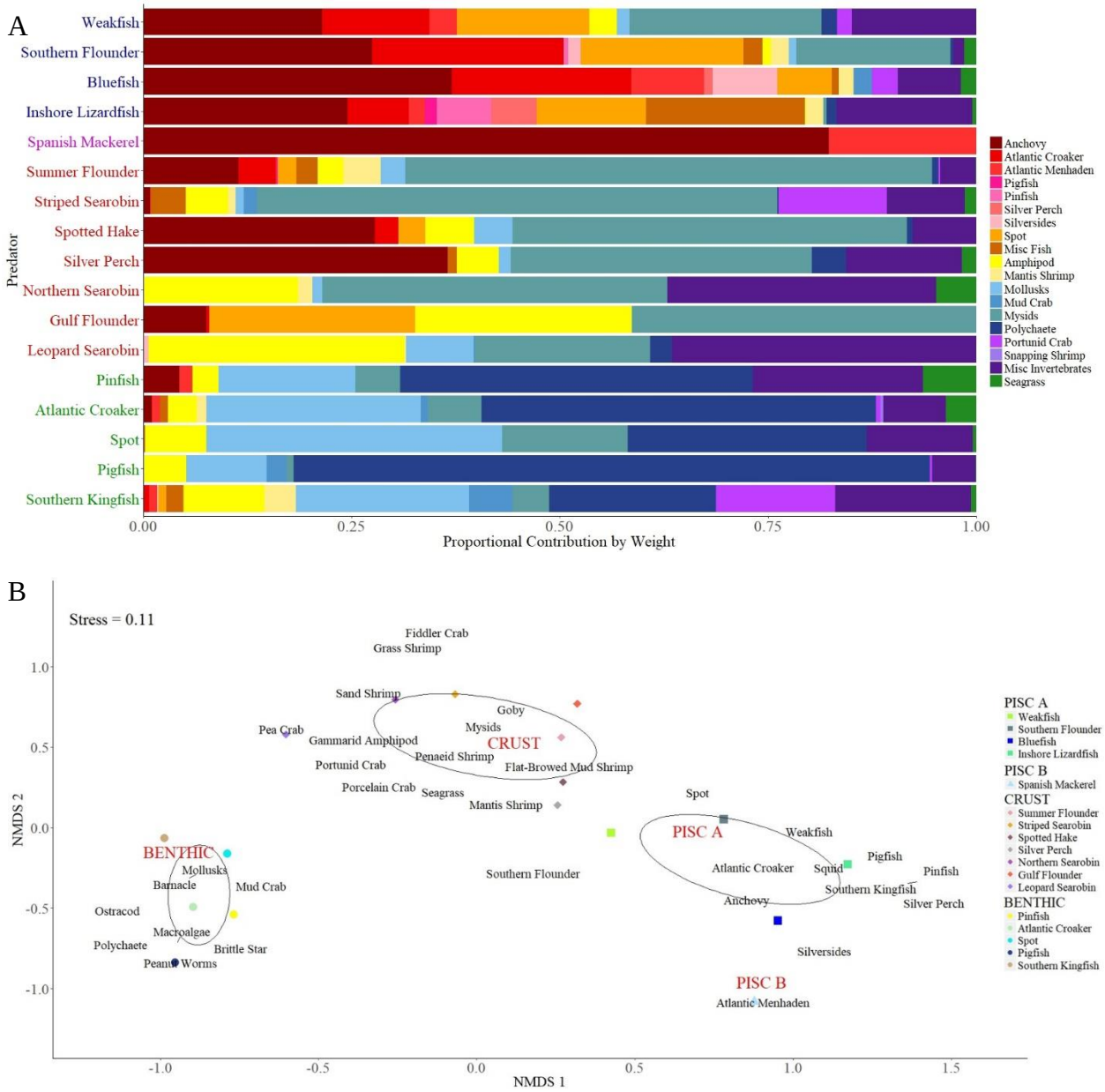

Fig. 4: (A) P195 trawl net survey predator diets based on proportional contribution, by weight, of a prey and (B) non-metric multidimensional scaling plot highlighting the trophic guilds identified using SIMPROF. For (A) predator names are color coded to correspond to trophic guild with blue = PISC A, pink = PISC B, red = CRUST, and green = BENTHIC.

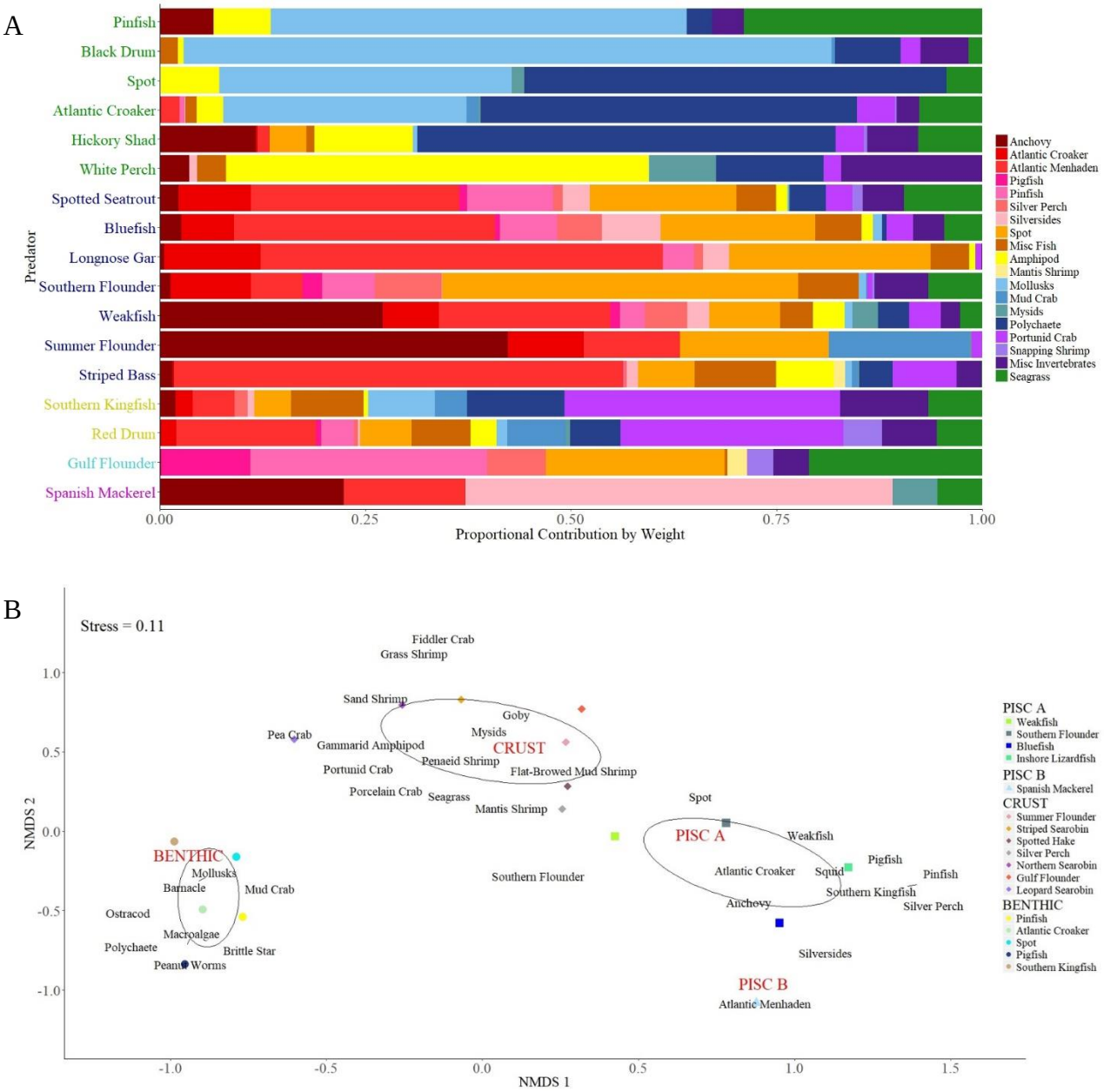

Fig. 5: (A) P 915 gill net survey predator diets based on proportional contribution, by weight, of a prey and (B) non-metric multidimensional scaling plot highlighting the trophic guilds identified using SIMPROF. For (A) predator names are color coded to correspond to trophic guild with green = BENTHIC, blue = PISC A, yellow = GEN, aqua = PISC B, and pink = PISC C.

SECTION 3

DEVELOPMENT OF AN ECOPATH MODEL FOR PAMLICO SOUND

Abstract

We developed an Ecopath we Ecosim model for Pamlico Sound and its tributaries representing 2012-13. The model contained 43 compartments and had a focus on piscivores and their prey. We identified forage fish for Pamlico Sound and estimated total predator demand to explore the degree of piscivory exhibited by predators. Changes in the trophic structure of Pamlico Sound from 1994-2017 were evaluated using mean trophic level of catch as a trophic indicator. Atlantic menhaden and anchovy were identified as forage fish as well as spot and Atlantic croaker, two species that are not traditionally considered forage fish. Dolphin and inshore lizardfish were apex predators in our model while bluefish and inshore lizardfish exhibited the highest levels of total predator demand for fish prey. When blue crabs and penaeid shrimp were included in our mean trophic level of catch analyses, there was a general increase in the mean trophic level of catch. When only fish were evaluated, there was a decrease in the mean trophic level of catch in the first half of the time series but an increase in the latter half. These trends were driven by blue crab, southern flounder, and menhaden landings. Our Ecopath model will provide the foundation for fisheries managers to move towards ecosystem-based fisheries management in Pamlico Sound.

Introduction

Fisheries management is increasingly moving from single-species approaches towards more holistic multispecies and ecosystem-based approaches (Hollowed et al. 2000; Latour et al. 2003; Pikitch et al. 2004; Link 2010). There is a lack of multispecies modeling in Pamlico Sound. Baird et al. (2004) developed a series of Ecopath models to explore the impacts of hypoxia on energy flows in the Neuse River. These models were then used by Johnson (2006) to evaluate the impacts of shrimp trawl discards on ecosystem functioning and trophic structure.

These models focused predominately on the energy flows between lower trophic levels and the fish compartments are highly aggregated. There is a need for a fish-focused multispecies model for Pamlico Sound to help aid the consideration of multispecies and ecosystem-based fisheries management alternatives to single-species approaches.

Ecopath with Ecosim (EwE) is an ecosystem model that describes the trophic flows in an ecosystem. Ecopath provides a static, mass-balanced view of the system while Ecosim uses for time-dynamic simulation modeling to predict ecosystem response to various scenarios (Christensen et al. 2008). The current iteration of EwE updates the initial energy budgeting approach of Povlina (1984a, 1984b) by removing the assumption of a steady state and combines it with the network analysis theory of Ulanowicz (1986) for analyzing energy flow between compartments (Christensen et al. 2008). EwE has been used to understand the impacts of fishing on the ecosystem (Johnson 2006; Coll et al. 2007; Deehr et al. 2014; Heymans and Tomczak 2015), explore policy options (Heymans et al. 2009; Wang et al. 2012, Chagaris et al. 2015), predict impacts of species invasions (Chagaris et al. 2017; Bumbeer et al. 2018), evaluate impacts of hypoxia (Baird et al. 2004; de Mutsert et al. 2016), and simulate ecosystem response to climate change (Ainsworth et al. 2011). Globally, EwE has been utilized in over 100 ecosystems and is increasingly being used to facilitate ecosystem-based fisheries management (Colléter et al. 2015).

Forage species are traditionally described as small, schooling pelagic fish that serve as important links between lower trophic levels (e.g. plankton) and upper trophic level predators (Smith et al. 2011; Pikitch et al. 2012; Rountos 2016). Many forage species are not only important ecologically, but are also important economically and support commercial fisheries (Pikitch et al. 2012). Clupeids, engraulids, and atherinids are classically defined as forage

species, but there is an increasing awareness the forage base is comprised of a wide variety of fish and invertebrates that do not fit classic forage species criteria (Houde et al. 2014; Ihde et al 2015; Rountos 2016). It is critical that forage species are identified because a forage species may not be experiencing overfishing from a single-species perspective, but ecosystem overfishing could occur resulting in an insufficient forage base (Murawski 2000; Pikitch et al. 2004).

Trophic indicators are used to evaluate if fishing has caused a shift in the structure and functioning of an ecosystem (Cury et al. 2005; Hornborg et al. 2013; Bourdard et al. 2015). Fisheries have exerted pressure on fish communities and overfishing of larger long-lived species has often resulted in a "fishing down of marine food webs" with catches being replaced by shorter-lived, lower trophic level species (Pauly et al. 1998). There are numerous trophic indicators, but annual changes in the mean trophic level of catch is one of the most commonly used trophic indicators to explore if "fishing down the food web is occurring" (Cury et al. 2005; Bourdard et al. 2005).

We developed an EwE model for Pamlico Sound and its tributaries with a focus on the fish community. We used estimates of total consumption from Ecopath to identify both the forage fish and top piscivores in our system. Changes in the composition of commercial catch in Pamlico Sound were evaluated using the trophic indicator, mean trophic level of catch.

Methods

Model Parameterization

We developed an EwE model for Pamlico Sound and its tributaries (hereafter referred to as Pamlico Sound; Fig 1). The model area encompasses 5,641 km^2 and represents the 2012-13 time period. The Pamlico Sound EwE model has 43 compartments with 1 group each for seabirds, dolphins, sea turtles, sharks, and stingrays, 25 fish compartments, 10 invertebrate

compartments, 2 primary productivity compartments, and 1 detrital compartment (Table 1). These compartments represent the bulk of biomass and energy flow in Pamlico Sound with a focus on piscivores and their prey.

There are two master equations in Ecopath. The first equation describes production and mass balance between groups as

$$P_i = Y_i + B_i M2_i + E_i + BA_i + M0_i$$

where for compartment *i*, *P* is the total production rate, *Y* is the total fishery catch rate, *M2* is the total predation rate, *B* is biomass, *E* is the net migration rate, *BA* is the biomass accumulation rate, and *M0* the rate for "other" mortality. The second equation describes consumption and conservation of energy within a group as

Consumption = Production + Respiration + Unassimilated food.

Mass balance in Ecopath occurs for compartment *i* over a time period so that

$$B_i * \left({}^{P}/_{B}\right)_i * EE_i = Y_i + \sum_j B_j * \left({}^{Q}/_{B}\right)_i * DC_{ij}$$

where *j* is a predator of compartment *i*, *P/B* is the production/biomass ratio, *EE* is ecotrophic efficiency, *Q/B* is the consumption/biomass ratio, DC_{ij} is the contribution of prey *i* to the diet of predator *j* (Pauly et al. 2000; Christensen and Walters 2004; Christensen et al. 2008).

B, *P/B*, *Q/B*, and *EE* are considered the basic parameters required for an Ecopath model. *B* represents an annual mean with units t/km^2. *P/B* is an instantaneous annual rate of turnover and is typically approximated as being equivalent to total mortality (*Z*). *EE* ranges from 0-1 and describes the amount of production that is used in the system through predation or harvest. For each compartment, the master equations are solved for either *B*, *P/B*, *Q/B*, or *EE* (Christensen et al. 2008) and for the majority of our compartments we allowed Ecopath to estimate EE. (Table

1). Briefly, we estimated *B* from survey data or assuming catch is proportional to biomass and dividing catch by *F*. For *P/B* we used estimates of secondary production from the literature or assumed *Z* and *P/B* are equivalent. *Q/B* was estimated using the empirical equation developed by Palomares and Pauly (1998) which relates consumption to aspect ratio, water temperature, and broad feeding guild (e.g. carnivore, detritivore), scaled up estimates of daily ration, or estimated *Q/B* in Ecopath by assigning a value for gross food conversion efficiency (*P/Q*). The amount of production used within a system through predation or fishing is described by *EE*. Values for EE range between 0-1 with values closer to 1 indicating high levels of predation and/or fishing mortality (Christensen and Walters 2004; Christensen et al. 2008).

Information on diet and fisheries catch are also required for an EwE model. The diet matrix was parameterized using food habits from P850 and primary literature. We included five fishing fleets in the Pamlico Sound EwE model. Four of the fleets represent commercial fisheries (gill net, trawl, crab pot, and pound net) and the last fleet represents recreational harvest. Landings data were provided by North Carolina Division of Marine Fisheries (NCDMF). Discard estimates based on NCDMF sampling were included for the gill net, trawl, and recreational fishing fleets. In EwE, discards can have either be exported from the system or go to detritus (Christensen et al. 2008) and for the Pamlico Sound EwE model we assumed all discards go to detritus.

Prior to final model balancing, we completed a series of diagnostics (PREBAL) developed by Link (2010) which help identify issues with model structure or data quality. PREBAL diagnostics examine biomass trends across taxa and trophic levels, biomass ratios, vital rates trends across taxa and trophic levels, vital rate ratios, and total production and removals.

These diagnostics were developed for large-scale marine ecosystems, but overall these diagnostics are suitable for smaller ecosystems, such as estuaries (Link 2010).

A detailed description of how we parameterized the Pamlico Sound Ecopath model and our PREBAL are provided in Appendix D. Final parameter estimates from the balanced Ecopath model are available in Table 1.

Annual Consumption

We scaled annual consumption estimates (t/km2) to total consumption estimates (t) to explore trophic dynamics in Pamlico Sound. We identified which fish are important forage species in Pamlico Sound. While invertebrates are often important forage species (Rountos 2016) and are important to the diets of several P850 predators, we focused only on forage fish because of the high level of species aggregation for the invertebrate compartments. We also explored the degree of piscivory exhibited by each compartment and identified the top piscivores in terms of both effective trophic level (TL) and total predator demand.

Mean Trophic Level of Catch as a Trophic Indicator

We used mean TL of commercial catch as a trophic indicator for Pamlico Sound. We used catch data from the North Carolina Trip Ticket Program (NCTTP) which provides a complete census for commercial landings in North Carolina and began in 1994 (Bianchi 1994). Annual mean TL of catch was calculated using a weighted mean where TL for each compartment was weighted by their landings. We examined trends in mean TL from 1994-2017 and compared how these trends changed when invertebrates were excluded from our analyses.

Results

Total Predator Demand

Annually, over 62,000 t of fish are consumed in Pamlico Sound. Atlantic menhaden, anchovy, spot, and croaker are the top forage fish and represent over 80% of the fish consumed

(Fig. 2). All remaining fish species contributed less than 5% each to the total amount of fish consumed.

The top piscivore predators in Pamlico Sound differed depending on the criteria used to define top predator. Apex predators, based on effective trophic level are lizardfish (TL = 4.54) and dolphins (TL = 4.32; Fig 3). Top piscivore predators in terms of amount of fish consumed are bluefish and gar (Fig 2).

Both pinfish and Atlantic croaker are lower trophic level (TL = 3.19 and 3.20, respectively) predators that rely predominately on non-fish prey sources (Fig. 4). However, they are large biomass compartments and their total fish consumption is significant. Pinfish consumed more fish than both striped bass and dolphins, which are generally considered top piscivores and both pinfish and Atlantic croaker consumed more fish than lizardfish, which is the apex predator for Pamlico Sound.

Trends in Mean Trophic Level of Catch

Mean TL of catch showed a general increase from 1994-2017 (Fig. 5). This was primarily driven by the drastic decline in blue crab landings resulting in reduced contribution to total landings (Fig 6). In 1994, blue crab (TL = 3.054) accounted for 78.5% of Pamlico Sound landings, but only 30.7% in 2017. Total penaeid shrimp (TL = 3.58) landings have doubled and their proportional contribution to total landings has increased from 10.4% in 1994 to over half the landings (51.2%) in 2017 while the cumulative contribution of fish landings increased from 11.1% to 18.1%.

When only including fish in mean TL analyses, the mean TL of catch decreases from 1994-2005 and then has an increasing trend thereafter (Fig 5). Generally, the amount of inter-annual variability observed for each species is low, however, landings for southern flounder, striped mullet, and Atlantic menhaden were quite variable (Fig. 7A). Southern flounder (TL =

4.417) landings have declined by 60% since 1994 and their decreased proportional contribution to total fish landings (Fig 7B) is the main driver behind the decrease in mean TL of fish catch from 1994 to 2005. Spikes in the proportional contribution of Atlantic menhaden (TL = 2.053) in 2003 and 2005 and striped mullet (TL = 2.078) in 2012 correspond to major declines in the mean TL of fish catch. Recent increases in TL of fish landings are driven by depressed menhaden landings and increases in bluefish and Spanish mackerel.

Discussion

Atlantic menhaden, anchovy, spot, and Atlantic croaker were the top forage fish in Pamlico Sound and comprised over 80% of the total amount of fish consumed. Atlantic menhaden and anchovy are traditionally considered forage fish and their life history characteristics meet the qualitative criteria (Pikitch et al. 2012; Houde et al. 2014) typically used to define forage fish. Life history characteristics of spot and Atlantic croaker do not fit the qualitative criteria used to describe forage fish, however, they have been documented as important prey to predators in multiple ecosystems in the mid-Atlantic and southeastern U.S. (Table 2). In Chesapeake Bay, Atlantic Croaker were recently identified as a forage fish based on having a contribution > 5%, by wet weight, to the diet of at least one of five (striped bass, summer flounder, Atlantic croaker, white perch, and clearnose skate *Raja eglanteria*) predator diets used for analysis (Ihde et al. 2015). If the goal of identifying forage species is to prevent ecosystem overfishing (Pikitch et al. 2004) then predatory impacts on spot and Atlantic croaker should be more thoroughly evaluated.

Bluefish and longnose gar had the highest total predator demand for fish and this was driven primarily by their higher biomasses (compared to other piscivores) and not by higher consumption rates or higher contributions of fish to their diet. As populations fluctuate, other predators, such as southern flounder or weakfish could replace bluefish and longnose gar as the

top fish predators in Pamlico Sound. Overall, piscivores relied primarily on Atlantic menhaden, anchovy, spot, and Atlantic croaker as their main fish prey, so most changes in piscivore biomass should not result in changes to which species are considered forage fish. The exception to this would be increases in predators (*e.g.* gulf flounder, spotted seatrout) that consumed higher proportions of pinfish. Currently, pinfish contribute 4.9% to the amount of fish consumed in Pamlico Sound and increases in the biomass of their predators could significantly increase their importance as prey.

Longnose gar and inshore lizardfish are two of the top predators in Pamlico Sound. Neither support any local fishery and they are not economically important. Longnose gar are one of the only predators in Pamlico Sound whose diet relied exclusively on fish and they were one of the top piscivore predators in terms of total predator demand while inshore lizardfish were an apex predator. Longnose gar and inshore lizardfish are ecologically important but are relatively poorly studied. There have only been a limited number of food habits (Goodyear 1967; Echelle; Henzler 2011; McGrath et al. 2013; Smylie et al. 2015) and life history (McGrath 2010; Henzler 2011; Smylie et al. 2016) studies for longnose gar and even fewer studies for inshore lizardfish (Cruz-Escalona et al. 2005; Jeffers 2007). Multispecies models, such as Ecopath, require an enormous amount of information including, food habits, age, biomass, and mortality (Christensen et al. 2008) which are often poorly understood and/or borrowed from other systems. There is a fundamental need to study all components of the ecosystem, not just the economically important components.

Changes in the mean trophic level of catch represent large declines in southern flounder and blue crab landings and not “fishing down the food web”. Since 1994, landings for southern flounder and blue crabs have decreased by over 50%. Penaeid shrimp landings have doubled

while most other fish species have more moderate changing in landings. To fully evaluate changes in trophic structure resulting from fisheries, mean trophic level of catch analyses should be repeated using time series extending back earlier than 1994, preferably to at least the 1950s.

Despite the lack of multispecies modeling in Pamlico Sound there was a substantial amount of data available for the parameterization of this Ecopath model. Data were available from a variety of sources (Appendix D) although data from NCDMF surveys were our primary data source for several compartments. While we were very fortunate to have access to so much data, there were still compartments, primarily invertebrates, where there was a lack of data. We have the following list of recommendations for future data collection/priorities to support multispecies modeling and ecosystem based fisheries management in Pamlico Sound. In all NCDMF surveys, all catches should be at least enumerated or weighed. Some species, such as silversides in P120 are neither weighed nor counted and we had to rely on Ecopath to estimate the biomass for that compartment. One of the largest data needs for Pamlico Sound is a study for estimating biomasses for a wide array of invertebrates. Food habits for crabs and shrimp are also poorly understood in Pamlico Sound and a food habits study targeting invertebrates would strengthen our understanding of trophic interactions at lower trophic levels.

We developed the first multispecies model for Pamlico Sound and its tributaries. Our Ecopath model will serve as the foundation for EBFM in Pamlico Sound. It can be used to explore the effects of changes in harvest, explore policy options, and understand species interactions. This base model can easily be updated in the future to reflect any changes in the composition or biomass of species in Pamlico Sound.

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Tables

Table 1: Final parameter estimates for B, *P/B*, *Q/B*, P/Q, and EE after model balancing and PREBAL diagnostics. *Italicized* parameters were estimated by Ecopath.

Compartment Number and Name		B (t/km^2)	*P/B* (yr^{-1})	*Q/B* (yr^{-1})	P/Q (yr^{-1})	EE
1	Seabirds	0.0168	0.193	100.63	*0.002*	*0.682*
2	Dolphins	0.0191	0.040	14.170	*0.043*	*0*
3	Sea turtles	0.0138	0.153	3.500	*0.04*	*0*
4	Sharks	0.0320	0.312	2.931	*0.11*	*0.324*
5	Rays	2.4017	0.311	*2.073*	0.15	*0.027*
6	Lizardfish	0.0160	0.655	6.226	*0.11*	*0.588*
7	Bluefish	0.7780	0.702	3.875	*0.18*	*0.132*
8	Longnose gar	0.6541	0.257	3.551	*0.07*	*0.002*
9	Weakfish	0.2661	0.675	3.664	*0.18*	*0.935*
10	Spotted seatrout	0.1586	1.055	3.664	*0.29*	*0.501*
11	Red drum	1.2334	0.822	2.762	*0.30*	*0.032*
12	Kingfish	0.0896	1.024	5.500	*0.19*	*0.602*
13	Striped Bass	0.1674	1.397	3.792	*0.37*	*0.237*
14	Hickory Shad	0.1114	0.824	5.822	*0.14*	*0.043*
15	Southern flounder	0.3616	1.408	3.463	*0.41*	*0.280*
16	Summer flounder	0.0482	0.752	3.890	*0.19*	*0.155*
17	Gulf flounder	0.0253	0.949	4.389	*0.22*	*0.034*
18	Spanish mackerel	0.0739	0.863	5.339	*0.16*	*0.482*
19	Black drum	0.0852	0.866	3.704	*0.23*	*0.093*
20	Croaker	2.5322	0.630	5.617	*0.11*	*0.992*
21	Spot	2.4567	1.149	5.996	*0.19*	*0.868*
22	Silver perch	0.3006	1.376	8.556	*0.16*	*0.783*
23	White perch	0.0386	0.486	4.644	*0.10*	*0.927*
24	Pigfish	0.1030	1.376	5.573	*0.25*	*0.369*
25	Pinfish	1.9413	0.729	5.021	*0.15*	*0.412*
26	Striped mullet	0.4525	0.874	15.342	*0.06*	*0.735*
27	Gizzard shad	0.2965	0.594	11.839	*0.05*	*0.040*
28	Atlantic menhaden	3.8624	1.104	15.999	*0.07*	*0.747*
29	Anchovy	2.0425	1.791	15.673	*0.11*	*0.666*
30	Silversides	*0.2722*	2.596	13.029	*0.2*	0.5
31	Penaeid shrimp	1.0770	3.92	*19.00*	0.2	*0.530*
32	Blue crabs	1.3939	4	*20.00*	0.2	*0.827*
33	Other crabs and shrimp	*4.5779*	5.15	*25.75*	0.2	0.9
34	Polychaetes	8.1728	3.76	*18.80*	0.2	*0.825*
35	Squid	0.0140	5.92	*19.73*	0.3	*0.735*
36	Mollusks	*5.2399*	9.95	*49.75*	0.2	0.9
37	Meiofauna	*24.4615*	9.79	*48.95*	0.2	0.9
38	Mysids	*9.2616*	5.39	*26.95*	0.2	0.9
39	Ichthyoplankton	0.0265	48.50	176.091	*0.28*	*0.918*
40	Zooplankton	11.6535	142.809	*357.023*	0.4	*0.291*
41	Phytoplankton	22.2141	214.621	NA	NA	*0.918*

Compartment Number and Name		B (t/km^2)	*P/B* (yr^{-1})	*Q/B* (yr $^{-1}$)	P/Q (yr^{-1})	EE
42	SAV	99.1649	9.849	NA	NA	*0.499*
43	Detritus	1342	NA	NA	NA	*0.185*

Table 2: Summary of studies where Sciaenids were found to be a major prey item. The threshold to delineate major prey was if the Sciaenid contributed >5% to the predator's diet by %W, %F, or %N (after Ihde et al. 2015). Predators were identified through FishBase (www.fishbase.org) and literature searches on Web of Science.

Prey	Predator	Location	Source
Atlantic croaker	Alligator gar (*Atractosteus spatula*)	Biloxi Bay and Mississippi Sound	Goodyear 1967
	Bluefish	Chesapeake Bay	Hartman and Brandt 1995
		Pamlico Sound, NC	This study
	Inshore lizardfish	Pamlico Sound, NC	This study
	Longnose gar	Pamlico Sound, NC	This study
	Red drum	SE Louisiana (Hopedale)	Boothby and Avault, Jr. 1971
	Silver seatrout (*Cynoscion nothus*)	Mississippi Sound	Overstreet and Heard 1982
	Southern flounder	Charleston Harbor, SC	Wenner et al. 1990
		Pamlico Sound, NC	This study
	Spotted seatrout	Pamlico Sound, NC	This study
	Striped bass	Chesapeake Bay	Walter and Austin 2003
	Summer flounder	Chesapeake Bay	Buccheister and Latour 2011
		Pamlico Sound, NC	This study
	Weakfish	Pamlico Sound, NC	This study
	Red drum	Sapelo Island, GA	Overstreet and Heard 1978
Spot	Alligator gar	Biloxi Bay and Mississippi Sound, MS	Goodyear 1967
	Bluefish	Chesapeake Bay	Hartman and Brandt 1995; Buchheister and Latour 2015
		Pamlico Sound, NC	This study
	Gulf flounder	Pamlico Sound, NC	This study
	Hardhead catfish (*Ariopsis felis*)	St. Marks National Wildlife Refuge, FL	Luczkovich et al. 2002
	Inshore lizardfish	Pamlico Sound, NC	This study
	Longnose gar	Pamlico Sound, NC	This study
		Winyah Bay and Charleston Harbor, SC	Smylie et al. 2015

Prey	Predator	Location	Source
	Red drum	Charleston Harbor, SC	Wenner et al. 1990
		Jefferson Parish, LA	Bass and Avault, Jr. 1975
		Pamlico Sound, NC	This study
		Sapelo Island, GA	Overstreet and Heard 1978
	Southern flounder	Charleston Harbor, SC	Wenner et al 1990
		Pamlico Sound, NC	This study
	Spotted seatrout	Charleston Harbor, SC	Wenner et al. 1990
		Pamlico Sound, NC	This study
	Striped bass	Cape Fear River Estuary, NC	Patrick and Moser 2001
		Chesapeake Bay	Hartman and Brandt 1995; Walter and Austin 2003; Overton et al. 2009
		Pamlico Sound, NC	This study
	Summer flounder	Chesapeake Bay	Buccheister and Latour 2011; Bucchesiter and Latour 2015
		Pamlico Sound, NC	This study
	Tidewater silverside (*Menidia peninsulae*)	St. Marks National Wildlife Refuge, FL	Luczkovich et al. 2002
	Weakfish	Chesapeake Bay	Hartman and Brandt 1995; Buchheister and Latour 2015
		Pamlico Sound, NC	This study

Figures

Fig. 1: Map of Pamlico Sound and its tribuaties.

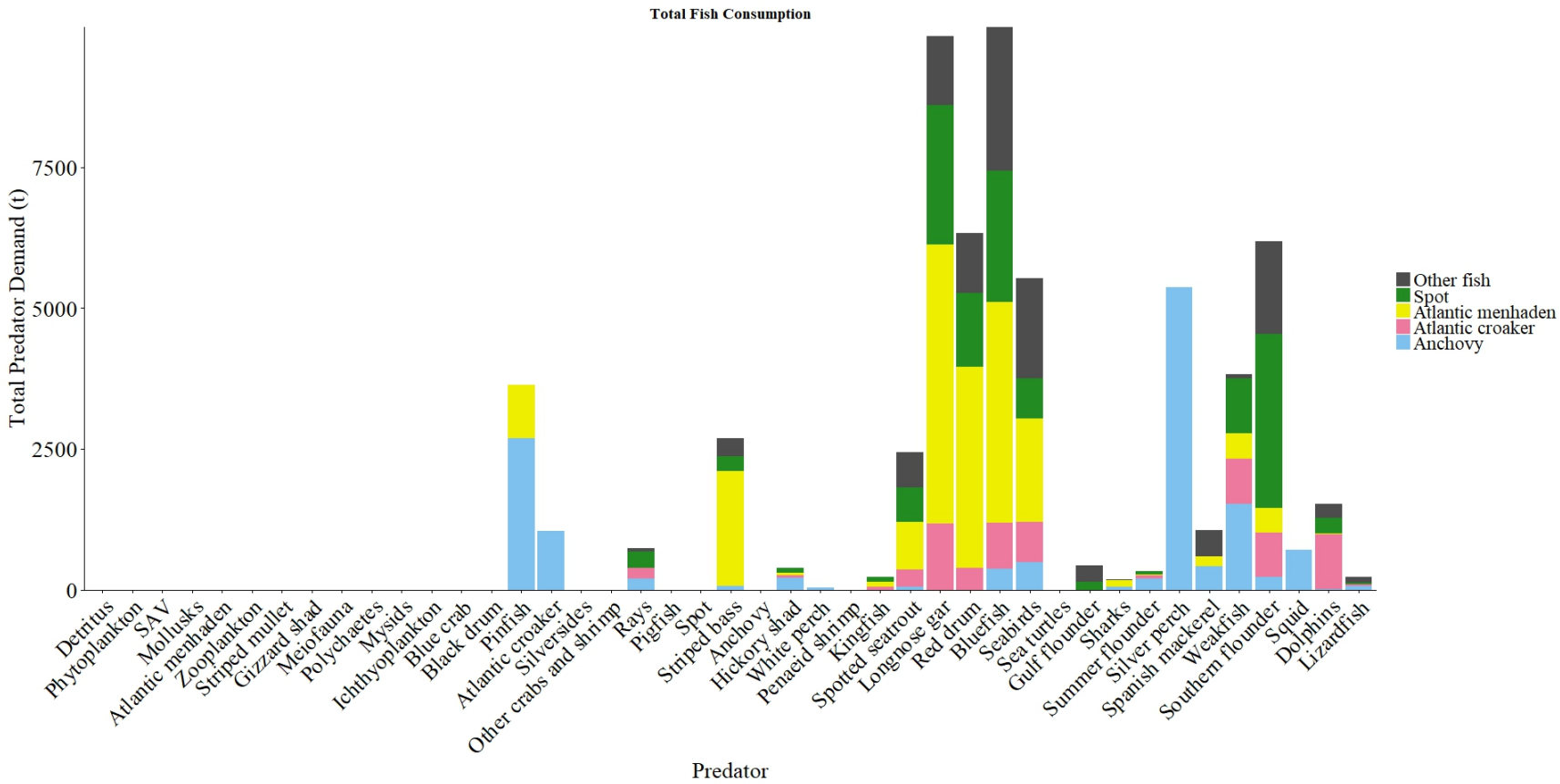


Fig. 2: Total predator demand (t) for anchovy, Atlantic croaker, Atlantic menhaden, spot, and other fish in Pamlico Sound, North Carolina.

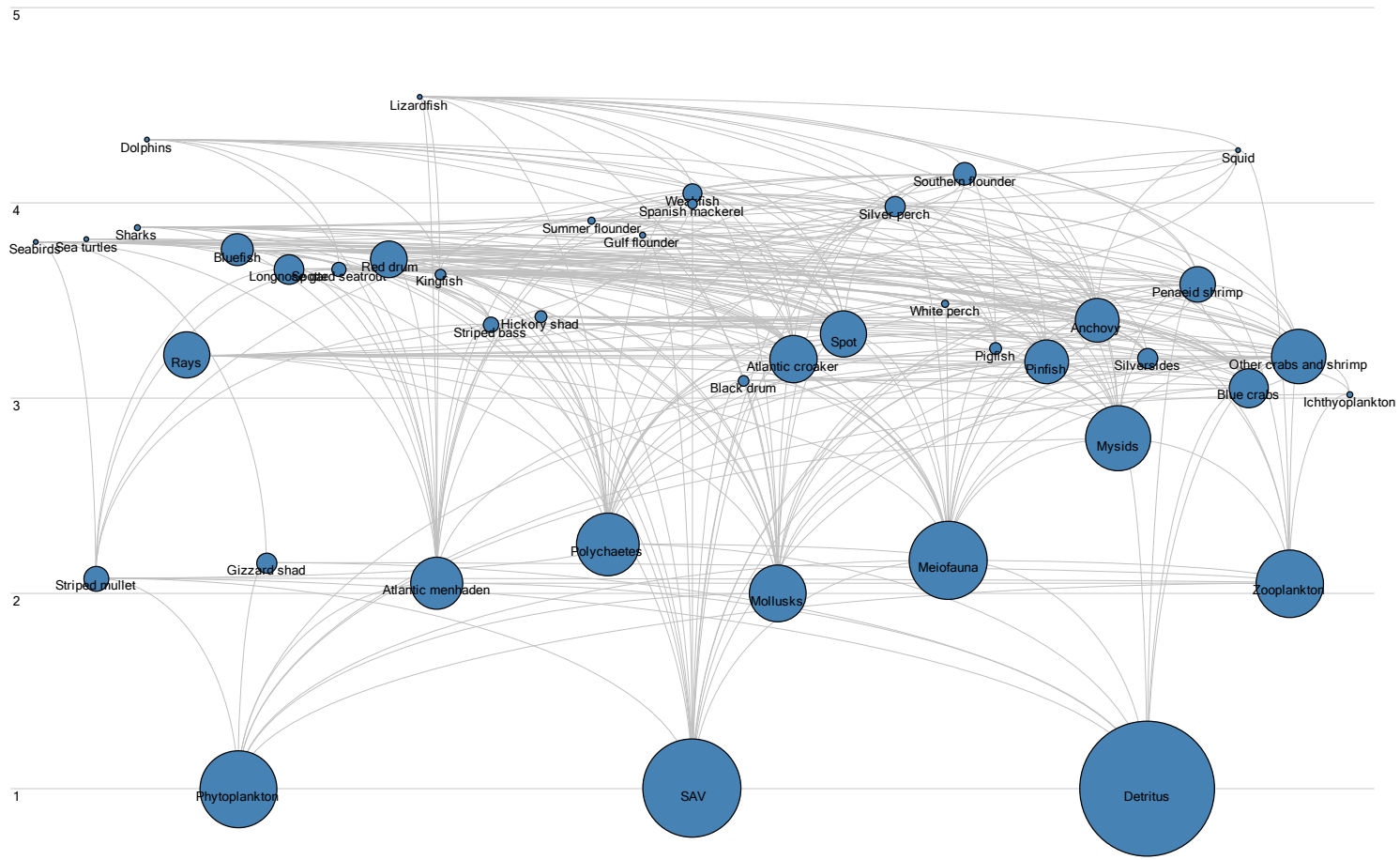


Fig. 3: Flow diagram for Pamlico Sound, North Carolina. Compartments are represented by nodes and the size is proportional to biomass and the lines represent flows between the compartments.

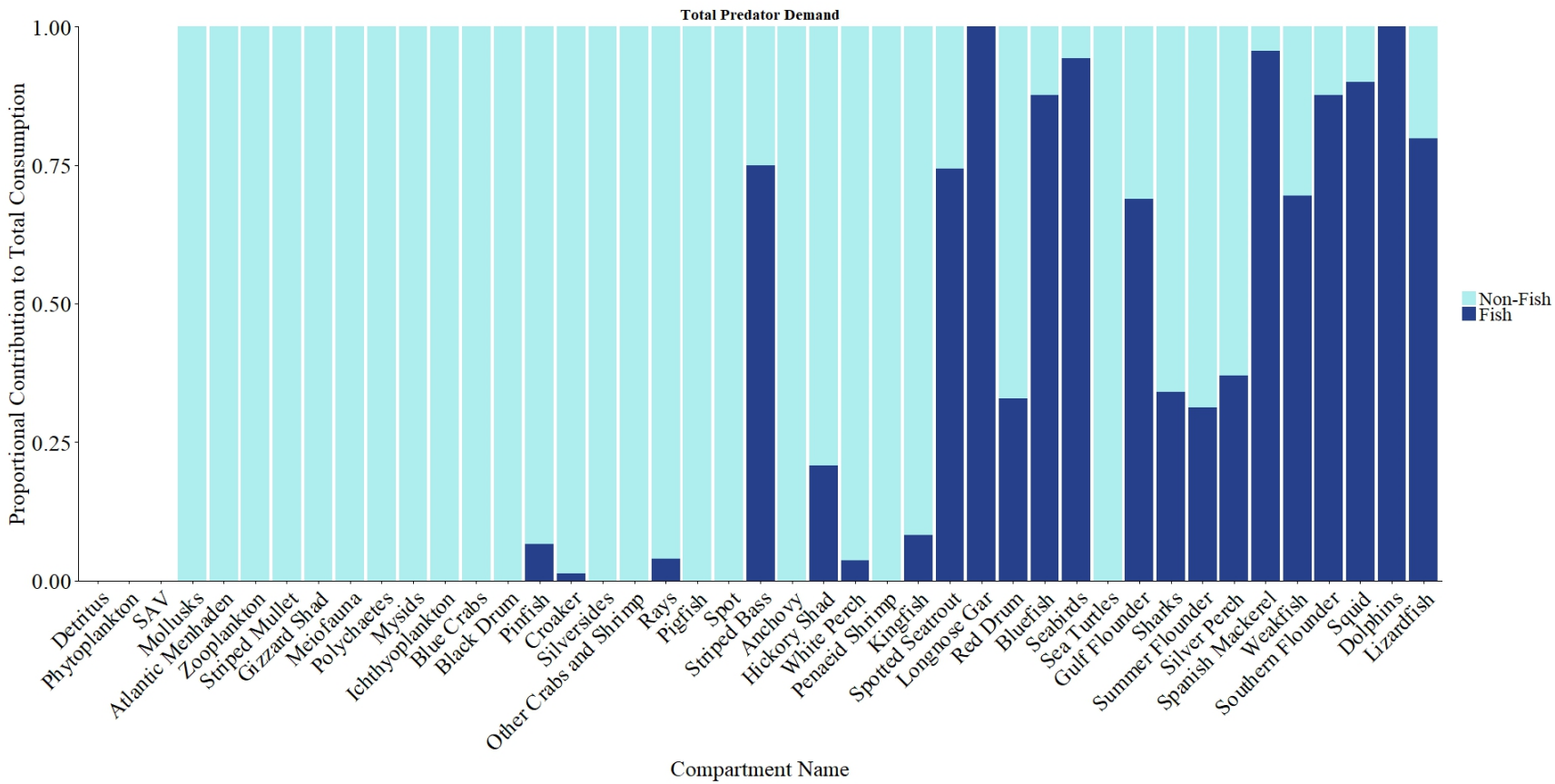


Fig. 4: Proportional contribution of fish and non-fish prey sources to the diet for each compartment.

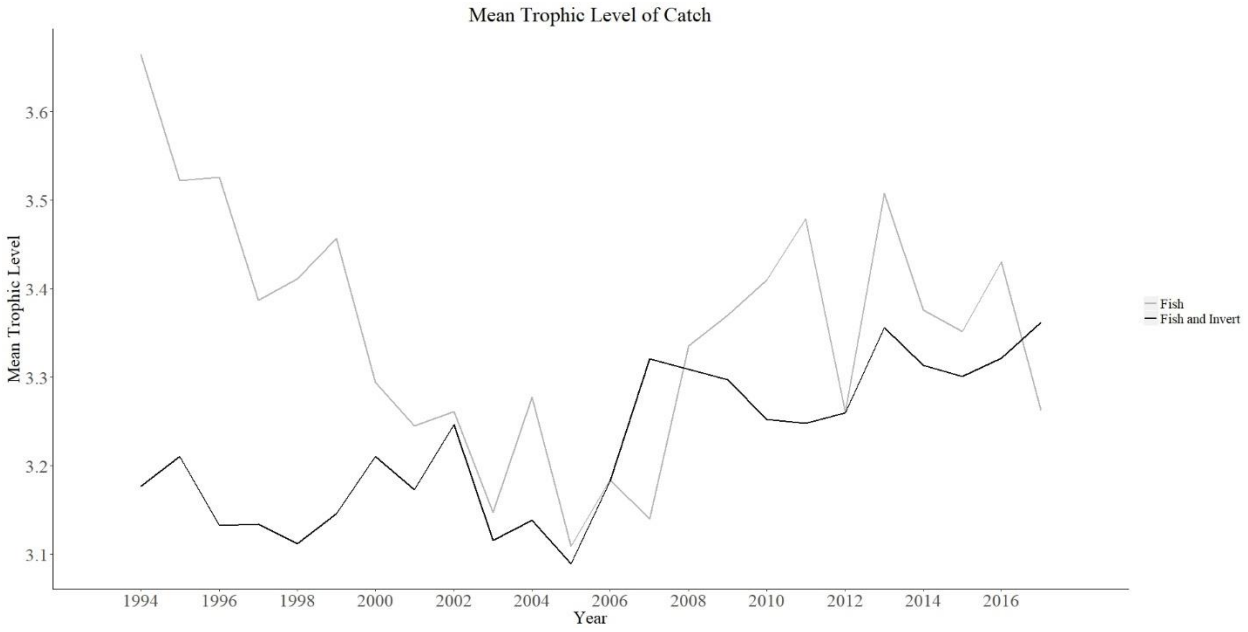


Fig. 5: Annual mean trophic level of catch in Pamlico Sound during 1994-2017.

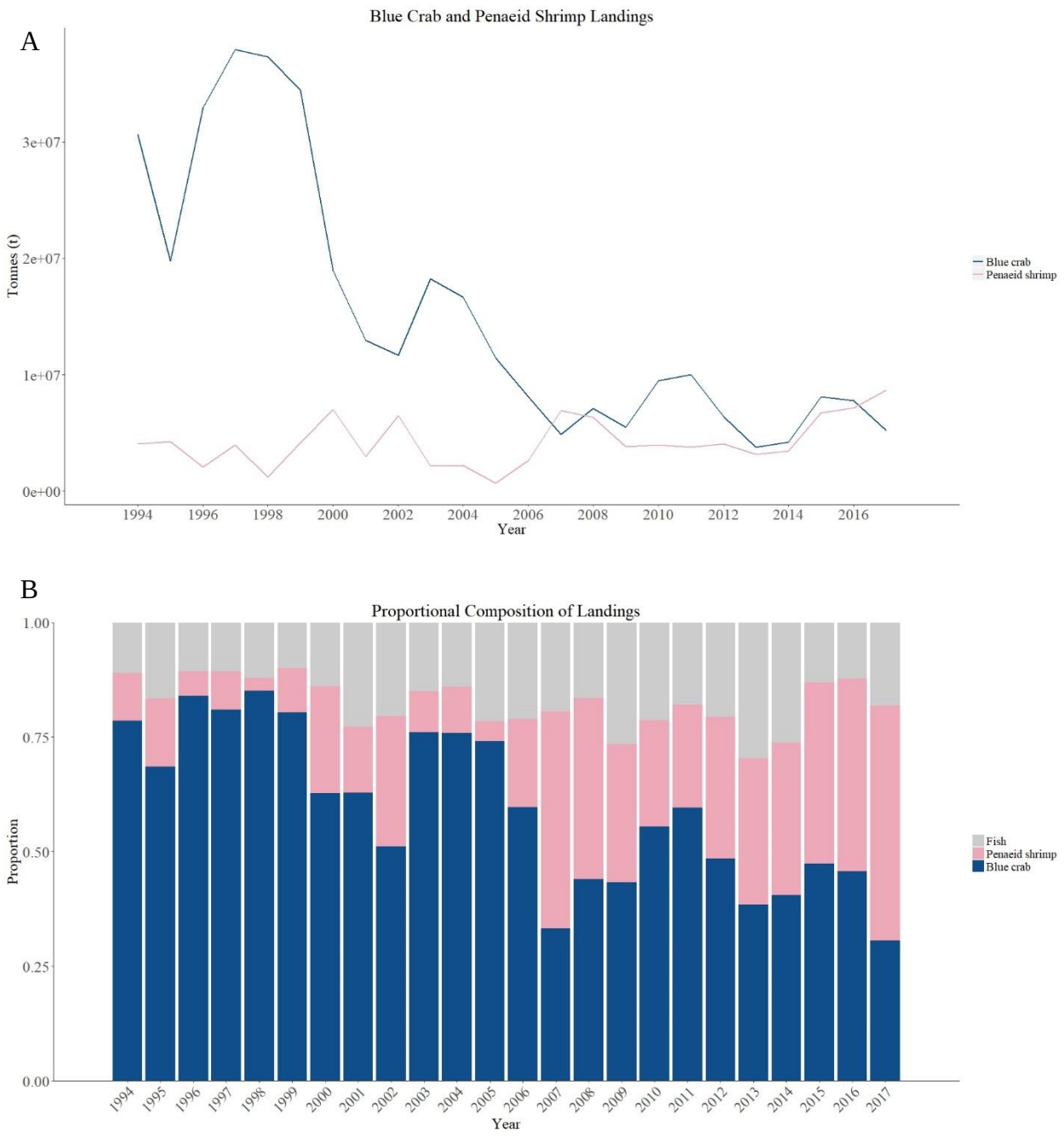


Fig. 6: (A) Landings (t) and (B) proportional contribution of blue crab and penaeid shrimp to total landings in Pamlico Sound during 1994-2017.

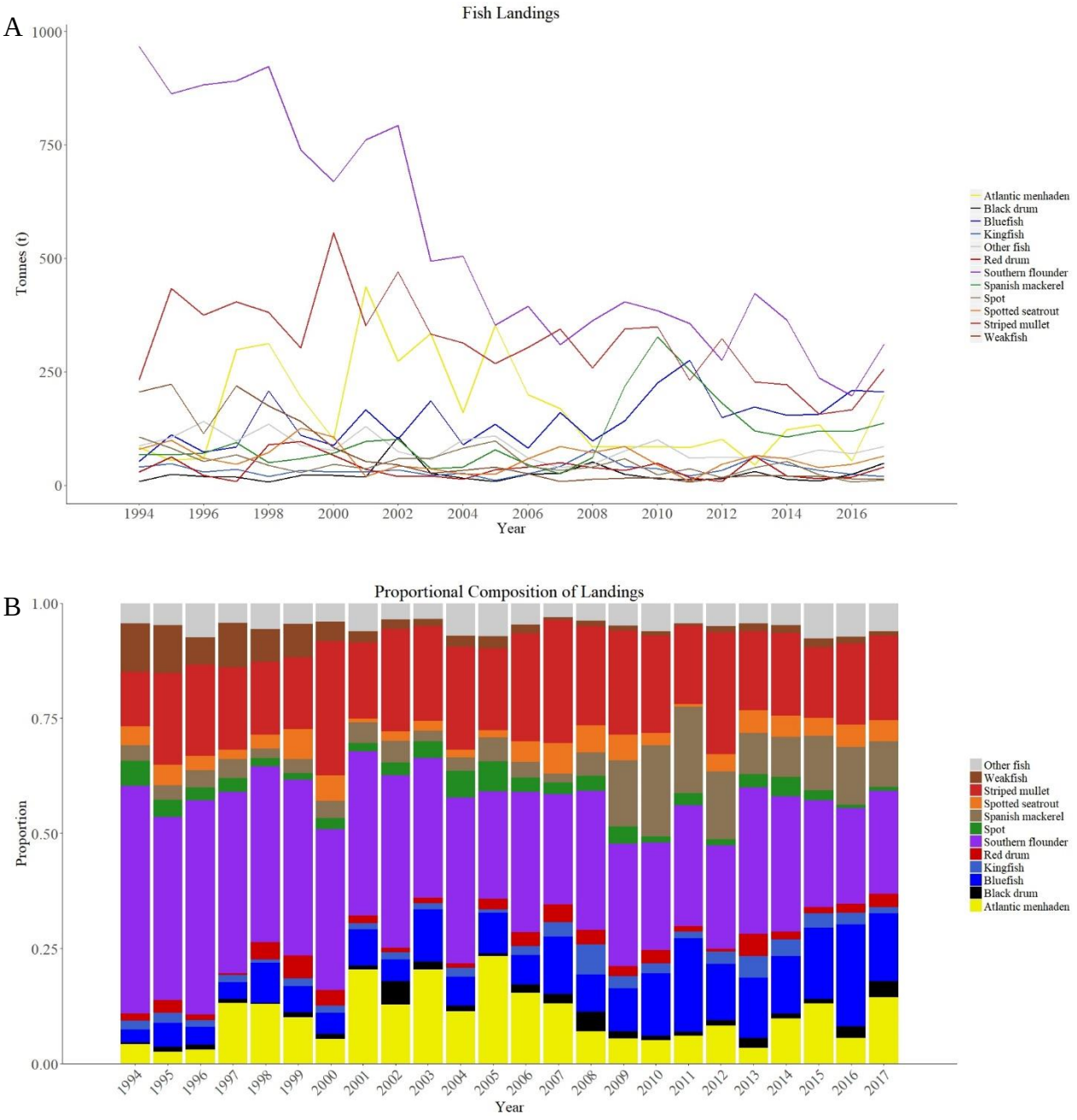


Fig. 7: (A) Landings (t) and (B) proportional contribution of each fish to total fish landings in Pamlico Sound during 1994-2017.

APPENDIX A

Prey Codes for Program 850

Table A1: List of prey codes used for P850. Non-ITIS prey codes are **bolded**.

Common Name	Scientific Name	Program 850 Code
Fish		
Unidentified Fish	Teleostei	161105XXXX
Subclass Elasmobranchii		
Unidentified Shark	Elasmobranchii	159786XXXX
Family Rajidae		
Unidentified Skate	Rajidae	160845XXXX
Family Dasyatidae		
Unidentified Stingray	Dasyatidae	160946XXXX
Family Lepisosteidae		
Longnose Gar	*Lepisosteus osseus*	161094XXXX
Order Anguilliformes		
Unidentified Eel	Anguilliformes	161123XXXX
Family Anguillidae		
American Eel	*Anguilla rostrata*	161127XXXX
Family Ophichtidae		
Speckled Worm Eel	*Myrophis punctatus*	161453XXXX
Family Ophidiidae		
Cusk Eel	Ophidiidae	164807XXXX
Family Trichiuridae		
Atlantic Cutlassfish	*Trichiurus lepturus*	172385XXXX
Family Engraulidae		
Unidentified Anchovy	*Anchoa spp.*	553173XXXX
Bay Anchovy	*Anchoa mitchilli*	161839XXXX
Striped Anchovy	*Anchoa hepsetus*	161838XXXX
Family Clupeidae		
Unidentified Shad and Herring	Clupeidae	161700XXXX
River Herring	*Alosa spp.*	161701XXXX

Common Name	Scientific Name	Program 850 Code
Alewife	*Alosa pseudoharengus*	161706XXXX
Blueback Herring	*Alosa aestivalis*	161703XXXX
Hickory Shad	*Alosa mediocris*	161704XXXX
American Shad	*Alosa sapidissima*	161702XXXX
Atlantic Thread Herring	*Opisthonema oglinum*	161748XXXX
Gizzard Shad	*Dorosoma cepedianum*	161737XXXX
Atlantic Menhaden	*Brevoortia tyrannus*	161732XXXX
Family Synodontidae		
Inshore Lizardfish	*Synodus foetens*	162376XXXX
Family Gadidae		
Spotted Hake	*Urophycis regia*	164731XXXX
Family Batrachoididae		
Oyster Toadfish	*Opsanus tau*	164423XXXX
Family Atherinopsidae		
Unidentified Silverside	*Atherniopsidae*	630579XXXX
Atlantic Silverside	*Menidia*	165994XXXX
Inland Silverside	*Menidia beryllina*	165993XXXX
Rough Silverside	*Membras martinica*	165989XXXX
Family Belonidae		
Unidentified Needlefish	Belonidae	165546XXXX
Atlantic Needlefish	*Strongylura marina*	165551XXXX
Redfin Needlefish	*Strongylura notata*	165553XXXX
Family Hemiramphidae		
Ballyhoo	*Hemiramphus brasiliensis*	165460XXXX
Family Fundulidae		
Unknown Minnow	Fundulidae	553174XXXX
Striped Killifish	*Fundulus majalis*	165649XXXX
Mummichog	*Fundulus heteroclitus*	165647XXXX
Banded Killifish	*Fundulus diaphanus*	165646XXXX
Sheepshead Minnow	*Cyprinodon variegatus*	165631XXXX
Rainwater Killifish	*Lucania parva*	165679XXXX
Mosquitofish	*Gambusia affinis*	165878XXXX
Family Syngnathidae		
Unidentified Pipefish or Seahorse	Syngnathidae	166443XXXX

Common Name	Scientific Name	Program 850 Code
Pipefish	*Syngnathus* spp.	166444XXXX
Northern Pipefish	*Syngnathus fuscus*	166451XXXX
Dusky Pipefish	*Syngnathus floridae*	166446XXXX
Chain Pipefish	*Syngnathus louisianae*	166452XXXX
Unidentified Seahorse	*Hippocampus spp.*	166487XXXX
Lined Seahorse	*Hippocampus erectus*	166488XXXX
Dwarf Seahorse	*Hippocampus zosterae*	166493XXXX
Family Gobeisocidae		
Skilletfish	*Gobiesox strumosus*	164460XXXX
Family Pomatomidae		
Bluefish	*Pomatomus saltatrix*	168559XXXX
Family Carangidae		
Unidentified Jack	Carangidae	168584XXXX
Atlantic Moonfish	*Selene setapinnis*	168684XXXX
Lookdown	*Selene vomer*	168680XXXX
Leatherjacket	*Oligoplites saurus*	168673XXXX
Family Ephippidae		
Atlantic Spadefish	*Chaetodipterus faber*	169539XXXX
Family Gerreidae		
Unidentified Mojarra	*Eucinostomus spp.*	169014XXXX
Spotfin Mojarra	*Eucinostomus argenteus*	169015XXXX
Silver Jenny	*Eucinostomus gula*	169016XXXX
Family Gobiidae		
Unidentified Goby	Gobiidae	171746XXXX
Naked Goby	*Gobiosoma bosc*	171789XXXX
Green Goby	*Microgobius thalassinus*	171809XXXX
Family Haemulidae		
Pigfish	*Orthopristis chrysoptera*	169077XXXX
Family Mugilidae		
Unidentified Mullet	*Mugil spp.*	170334XXXX
White Mullet	*Mugil curema*	170336XXXX
Striped Mullet	*Mugil cephalus*	170335XXXX
Family Sphyraenidae		

Common Name	Scientific Name	Program 850 Code
Northern Sennet	*Sphyraena borealis*	170427XXXX
Family Blenniidae		
Unidentified Blenni	Blenniidae	171124XXXX
Family Moronidae		
Unidentified Bass	*Morone spp.*	167676XXXX
Striped Bass	*Morone saxatilis*	167680XXXX
White Perch	*Morone americana*	167678XXXX
Family Sciaenidae		
Unidentified Drum	Sciaenidae	169237XXXX
Atlantic Croaker	*Micropogonias undulatus*	169283XXXX
Spot	*Leiostomus xanthurus*	169267XXXX
Silver Perch	*Bairdiella chrysoura*	169259XXXX
Unidentified Seatrout	*Cynoscion spp.*	169238XXXX
Weakfish	*Cynoscion regalis*	169241XXXX
Spotted Seatrout	*Cynoscion nebulosus*	169239XXXX
Unidentified Kingfish	*Menticirrhus spp.*	169273XXXX
Northern Kingfish	*Menticirrhus saxatilis*	169276XXXX
Southern Kingfish	*Menticirrhus americanus*	169274XXXX
Black Drum	*Pogonias cromis*	169288XXXX
Red Drum	*Sciaenops ocellatus*	169290XXXX
Family Sparidae		
Pinfish	*Lagodon rhomboides*	169187XXXX
Family Stromateidae		
Butterfish	*Peprilus triacanthus*	172567XXXX
Harvestfish	*Peprilus alepidotus*	172570XXXX
Family Scombridae		
Spanish Mackerel	*Scomberomorus maculatus*	172436XXXX
Family Paralichthyidae		
Unknown Flounder	*Paralichthys spp.*	172734XXXX
Summer Flounder	*Paralichthys dentatus*	172735XXXX
Gulf Flounder	*Paralichthys albigutta*	172736XXXX
Southern Flounder	*Paralichthys lethostigma*	172738XXXX
Family Achiridae		
Hogchoker	*Trinectes maculatus*	172982XXXX

Common Name	Scientific Name	Program 850 Code
Family Cynoglossidae		
Blackcheek Tonguefish	*Symphurus plagiusa*	173062XXXX
Invertebrates		
Phylum Mollusca		
Unidentified Mollusk	Mollusca	69458XXXXX
Snail	Gastropoda	69459XXXXX
Bivalve	Bivalvia	79118XXXXX
Unidentified Squid	Loliginidae	82369XXXXX
Longfin Inshore Squid	*Loligo pealeii*	82372XXXXX
Atlantic Brief Squid	*Lolliguncula brevis*	82379XXXXX
Phylum Sipuncula		
Peanut Worm	Sipuncula	154520XXXX
Phylum Annelida		
Unidentified Oligochaete	Oligochaeta	68422XXXXX
Unidentified Polychaete	Polychaeta	64358XXXXX
Clam Worms	*Nereis spp.*	65902XXXXX
Blood Worms	*Glycera spp.*	66102XXXXX
Trumpet Worms	*Pectinaria gouldi*	67709XXXXX
Lugworm	*Arenicola spp.*	67507XXXXX
Phylum Platyhelminthes		
Trematode	Trematoda	54556XXXXX
Stomachicola magnus	*Stomachicola magnus*	**9999916999**
Phylum Nematoda		
Nematode	Nematoda	59490XXXXX
Phylum Arthropoda		
Insects		
Unidentified Insect	Insecta	99208XXXXX
Beetle	Coleoptera	109216XXXX
Wasps/Bees/Ants	Hymenoptera	152741XXXX
Crickets and Grasshoppers	Orthoptera	102160XXXX
Caddisflies	Trichoptera	115095XXXX
Mayflies	Ephemeroptera	100502XXXX
Crustaceans		
Unidentified Crustacean	Crustacea	83677XXXXX

Common Name	Scientific Name	Program 850 Code
Unidentified Decapod	Decapoda	95599XXXXX
Parasites and Isopods		
Unidentified Parasite		**9999920999**
Parasitic Isopod	Isopoda	92120XXXXX
Seagrass Isopod	*Erichsonella attenuata*	92618XXXXX
Anchor Worm Parasite	*Lernaeenicus radiatus*	89269XXXXX
Mantis Shrimp		
Unidentified mantis shrimp	Stomatopoda	99140XXXXX
Squilla empusa	*Squilla empusa*	99143XXXXX
Nannosquilla grayi	*Nannosquilla grayi*	99156XXXXX
Amphipods		
Unidentified Amphipod	Amphipoda	93294XXXXX
Gammarid Amphipod	Gammaridae	93745XXXXX
Corophid Amphipod	*Corophium spp.*	93589XXXXX
Skeleton Shrimp	*Caprella spp.*	95392XXXXX
Mysids		
Mysid	Mysida	89856XXXXX
Ostracods		
Ostracod	Ostracoda	84195XXXXX
Barnacles		
Sessile Barnacle	Cirripedia	89433XXXXX
Crayfish		
Unidentified Crayfish	Cambaridae	97336XXXXX
Shrimp		
Unidentified Shrimp	Decapoda (Shrimp)	**9999901999**
Sand Shrimp	*Crangon spp.*	97107XXXXX
Unidentified Grass Shrimp	*Palaemonetes spp.*	96383XXXXX
Common Grass Shrimp	*Palaemonetes vulgaris*	96391XXXXX
Brackish Grass Shrimp	*Palaemonetes intermedius*	96384XXXXX
Daggerblade Grass Shrimp	*Palaemonetes pugio*	96390XXXXX
Acetes spp.	*Acetes spp.*	95888XXXXX
Estuarine Long-Eyed Shrimp	*Ogyrides alphaerotis*	96737XXXXX
Lucifer spp.	*Lucifer spp.*	95915XXXXX
Arrow Shrimp	*Tozeuma* spp.	96911XXXXX

Common Name	Scientific Name	Program 850 Code
Flat-Browed Mud Shrimp	*Upogebia affinis*	98209XXXXX
Big-Clawed Snapping Shrimp	*Alpheus heterochaelis*	96602XXXXX
Unidentified Penaeid Shrimp	Penaeidae	95602XXXXX
White Shrimp	*Litopenaeus setiferus*	551680XXXX
Pink Shrimp	*Farfantepenaeus duorarum*	551574XXXX
Brown Shrimp	*Farfantepenaeus aztecus*	551570XXXX
Crabs		
Unidentified Crab	Decapoda (Crab)	**9999902999**
Hermit Crab	*Pagurus spp.*	97775XXXXX
Unidentified Swimming Crab	Portunidae	98689XXXXX
Blue Crab	*Callinectes sapidus*	98696XXXXX
Lesser Blue Crab	*Callinectes similis*	98697XXXXX
Lady Crab	*Ovalipes ocellatus*	98714XXXXX
Pea Crab	*Pinnixa spp.*	98993XXXXX
Mole Crab	*Emerita spp.*	98132XXXXX
Mud Crab	Panopeidae	621504XXXX
Purse Crab	Leucosiidae	98361XXXXX
Porcelain Crab	Porcellanidae	98058XXXXX
Spider Crab	*Libinia emarginata*	98455XXXXX
Fiddler Crab	Ocypodidae	99080XXXXX
Phylum Echinodermata		
Unidentified Echinoderm	Echinodermata	156857XXXX
Sea Star	Asteriidae	157212XXXX
Sand Dollar	Clypeasteroida	157984XXXX
Sea Urchin	Cidaroida	157823XXXX
Sea Cucumber	Holothuroidea	158140XXXX
Brittle Star	Ophiuroidea	157325XXXX
Phylum Chordata		
Tunicate	Ascidiacea	158854XXXX
Lancelet	*Branchiostoma* spp.	159681XXXX
Miscellaneous Materials		
Animal Matter		
Unidentified Animal	Animalia	202423XXXX
Cut Bait		**9999917999**
Feather		**9999918999**
Frog	Anura	173423XXXX

Common Name	Scientific Name	Program 850 Code
Plant Matter		
Detritus		**9999915999**
Wood		**9999909999**
Vegetation		**9999910999**
Plant Seed		**9999911999**
Seagrass	Hydrocharitaceae	38935XXXXX
Macroalgae	Chlorphyta	846493XXXX
Mineral Matter		
Mud		**9999904999**
Sand		**9999903999**
Rock		**9999913999**
Nonorganic Matter		
Unidentified Material		**9999912999**
Plastic		**9999900999**
Styrofoam		**9999905999**
Fishing Line		**9999914999**
Artificial Bait and Hook		**9999906999**
Hook Only		**9999907999**
Artificial Bait Only		**9999908999**
Metal Wires/Shards		**9999919999**

APPENDIX B

Description of NC Biological Database for Program 850

Appendix B: NC Biological Database Description for Program 850.

Record type	Column number	Field name	Units	Limits	Mandatory (M) vs Desired (D)	Comments
I	2-8	Sequence number (Control1)	N/A	N/A	M	Sequence number for P850
	39-48	Samp Location	N/A	N/A	M	Water body codes found in Appendix B of Biological Coding Manual
	25-27	Program	N/A	850	M	850
	28-29	Year	N/A	N/A	M	Collection year
	30-31	Month	N/A	N/A	M	Collection month
	32-33	Day	N/A	N/A	M	Collection day
	62-64	Gear1	N/A	246,414, 539	M	246=Division gill net (P915 and P462) 414=Bottom longline (P365) 539=Mongoose trawl (P195)

Record type	Column number	Field name	Units	Limits	Mandatory (M) vs Desired (D)	Comments
	113-116	Variable #2 (Var2)	N/A	195, 365, 462, 915	D	Program number that collected predators
I	126-127	NbrRep	N/A	N/A	M	The number of replicates in record type II
II	9-10	Replicate (Rep)	N/A	N/A	M	Pgm 195: Only Rep01 Pgm 365: Rep01=Set 1 Rep02=Set 2 Pgm 462: Rep00-03. Rep00=No Set info provided Rep01=Set 1 Rep02=Set 2 Rep03=Set 3 Pgm 915: Rep01=Shallows Rep02=Deeps
	25-30	Collection Size (ColSze)	N/A	9's	M	Always = 999999
	31-36	Sample Size (SamSze)	N/A	9's	M	Always = 999999

Record type	Column number	Field name	Units	Limits	Mandatory (M) vs Desired (D)	Comments
	37-38	No. of Rec III (NbrRec3)	N/A	N/A	M	Total number of record type 3's (predator and prey) for each replicate
	60-66	SourceID	N/A	N/A	M	BDB Sequence number from collection program associated with predator initial capture
III Pred Only	2-21	Control3	N/A	N/A	M	Control2 plus the NODC species code and the species status (0)
	9-10	Replicate (Rep)	N/A	N/A	M	Same replicate number as assigned in Rec II
	11-20	Species Code (Species)	N/A	N/A	M	NODC code
	21	Status (SpStatus)	N/A	0,Z	M	**0=Predator**
III Pred Only	25-29	Collection number (ColNum)	N/A	9's	M	Always = 999999

Record type	Column number	Field name	Units	Limits	Mandatory (M) vs Desired (D)	Comments
	30-35	Collection weight (ColWgt)	N/A	9's	M	Always = 999999
	36-40	Sample number (SamNum)	N/A	9's	M	Always = 999999
	41-46	Sample weight (SamWgt)	N/A	9's	M	Always = 999999
	47-51	Subsample number (SubNum)	N/A	9's	M	Number of predators contained in replicate
	52-57	Subsample weight (SubWgt)	N/A	NA	M	Always = 999999
	58	Form of Rec Type IV (Form4)	4	N/A	M	Same replicate number assigned in Rec II
III Prey Only	2-21	Control3	N/A	N/A	M	Control2 plus the ITIS prey species code and the species status (z)
	9-10	Replicate (Rep)	N/A	N/A	M	Same replicate number as assigned in Rec II

Record type	Column number	Field name	Units	Limits	Mandatory (M) vs Desired (D)	Comments
	11-20	Species Code (Species)	N/A	N/A	M	ITIS code. Left justified with "X" as fill character
	21	Status (SpStatus)	N/A	0,Z	M	**Z=Prey**
	25-29	Collection number (ColNum)	N/A	9's	M	Always = 999999
	30-35	Collection weight (ColWgt)	N/A	9's	M	Always = 999999
	36-40	Sample number (SamNum)	N/A	9's	M	Always = 999999
	41-46	Sample weight (SamWgt)	N/A	9's	M	Always = 999999
III Prey Only	47-51	Subsample number (SubNum)	N/A	9's	M	Equals the sum of the record type 4 frequency for that prey.
	52-57	Subsample weight (SubWgt)	N/A	9's	M	Always = 999999

Record type	Column number	Field name	Units	Limits	Mandatory (M) vs Desired (D)	Comments
	58	Form of Rec Type IV (Form4)	4	N/A	M	Always = 4
IV Pred Only	22-24	Line number (Linenum)	N/A	N/A	M	Individual predator number
	25-27	Frequency (Frequenc)	1	N/A	M	
	28-31	Length	mm	N/A	D	Individual predator total or fork length
	32-36	Weight	kg	N/A	D	Individual predator weight
	37	Sex	N/A	1,2,3	D	Predator sex: 1 = Male 2 = Female 3 = Juvenile or Unidentifiable
	38	Maturity	N/A	1,2	D	Predator maturity: 1 = Gravid 2 = Not Gravid
	39-42	Parameter A (Parm_A)	mm	N/A	D	Standard length

Record type	Column number	Field name	Units	Limits	Mandatory (M) vs Desired (D)	Comments
	43-46	Parameter B (Parm_B)	N/A	N/A	D	Blank = prey 1 = empty 2 = Unable to process (i.e. spoiled or not saved) 3 = Not processed
	47-50	Parameter C (Parm_C)	mm	N/A	D	Total length
	51-54	Parameter D (Parm D)	N/A	N/A	D	Parasite Scars: Blank = none 1 = present
IV Prey Only	22-24	Line number (Linenum)	N/A	N/A	M	Individual prey number

Record type	Column number	Field name	Units	Limits	Mandatory (M) vs Desired (D)	Comments
IV Prey Only	25-27	Frequency (Frequenc)	N/A	N/A	M	The number of individuals included in the weight category. Always 1 if measuring individual prey lengths. 000=Aggregate weight when individuals are not able to be counted (*i.e* too digested). If individuals are counted and aggregate weight taken, the number of individuals in aggregate weight is recorded.
	28-31	Length	mm	N/A	D	Individual prey total or fork length
	32-36	Weight	grams	N/A	D	Prey weight
	39-42	Parameter A (Parm_A)	mm	N/A	D	Standard length
	43-46	Parameter B (Parm_B)	mm	N/A	D	Prey body depth

Record type	Column number	Field name	Units	Limits	Mandatory (M) vs Desired (D)	Comments
IV Prey Only	47-50	Parameter C (Parm_C)	mm	N/A	D	Eyeball diameter of prey
	51-54	Parameter D (Parm_D)	mm	N/A	D	Caudal peduncle depth of prey
	55	Egg/Larval Stage (Egg_Stg)	N/A	1,2,3	D	Digestion index, 1 = Fresh 2 = Partial 3= Well
	56	Status (TagStat)	N/A	1,2,3	D	Prey life stage, 1 = larvae 2 = juvenile 3 = adult
	70-75	Parm_E	N/A	1 thru 11	D	Prey body description, 1 = Whole 2 = Head 3 = Tail 4 = Partial body/ body parts 5 = Mush 6 = Scales 7 = Otoliths 8 = Gizzard 9 = Claw 10 = Other 11 = Shell

Record type	Column number	Field name	Units	Limits	Mandatory (M) vs Desired (D)	Comments
IV Prey Only	76-81	Parm_F	N/A	1	D	Blank = individual length and weight 1=Aggregate weight and no individual data weight data. This parameter is only used for animal prey items.
	98-121	Parm_G- Parm_ (Fish_ID)	N/A	N/A	M	Individual 23 digit predator ID which is composed of 850 sequence number + replicate code + NODC predator species code + predator species status + predator line number. This number corresponds to the predator stomach this prey was found in. (Same record 2 replicate)

APPENDIX C

Diet composition of predators sampled in Program 850

Table C1: Diet composition of Atlantic Croaker (*Micropogonias undulatus*) from trawl (n_s = 190, n_p = 792) and gill net (n_s = 225, n_p = 561) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had mean (μ ± SD) sizes of 146 ± 28 mm from the trawl survey and 244 ± 38 mm from the gill net survey.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Fish			
F. Engraulidae			
Anchovy	*A. mitchilli*, *A. hepsetus*	0.011 (0.012)	0.001 (0.005)
F. Clupeidae			
Atlantic Menhaden	*Brevoortia tyrannus*	0.009 (0.012)	0.023 (0.032)
F. Atherinopsidae			
Silversides	*Menidia menidia*, *Menidia beryllina*, *Membras martinica*		< 0.001 (0.000)
F. Fundulidae			
Fundulids	*Fundulus heteroclitus*, *Cyprinodon variegatus*		< 0.001 (0.000)
F. Mugilidae			
Mullet	*Mugil curema*, *Mugil cephalus*		0.004 (0.009)
F. Sciaenidae			
Spot	*Leiostomus xanthurus*	< 0.001 (0.000)	
Southern Kingfish	*Menticirrhus saxatilis*		0.008 (0.032)
F. Sparidae			
Pinfish	*Lagodon rhomboides*		0.006 (0.015)
Invertebrates			
P. Mollusca			
Mollusks	Gastropoda, Bivalvia	0.258 (0.062)	0.296 (0.166)
Squid	*Loligo pealeii*, *Lolliguncula brevis*	0.002 (0.001)	
P. Sipuncula			
Peanut Worms	Sipuncula		0.022 (0.040)
P. Annelida			
Polychaete	Polychaeta	0.473 (0.084)	0.459 (0.191)
P. Arthropoda			
Insects	Coleoptera, Orthoptera,	0.004 (0.005)	

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
	Trichoptera, Ephemeroptera		
Seagrass Isopod	*Erichsonella attenuata*	0.001 (0.001)	
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	0.012 (0.007)	
Amphipod	Gammaridae, *Corophium spp.*	0.034 (0.021)	0.033 (0.060)
Skeleton Shrimp	*Caprella spp.*		< 0.001 (0.003)
Mysids	Mysida	0.065 (0.011)	0.003 (0.023)
Barnacle	Cirripedia	0.003 (0.003)	
Sand Shrimp	*Crangon spp.*	0.004 (0.002)	
Big-Clawed Snapping Shrimp	*Alpheus heterochaelis*	0.003 (0.003)	0.002 (0.008)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.004 (0.002)	< 0.001 (0.001)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.021 (0.004)	0.046 (0.061)
Pea Crab	*Pinnixa spp.*	0.016 (0.011)	
Mud Crab	Panopeidae	0.008 (0.005)	0.014 (0.036)
Purse Crab	Leucosiidae		0.002 (0.005)
Spider Crab	*Libinia emarginata*		0.002 (0.017)
P. Echinodermata			
Brittle Star	Ophiuroidea	0.009 (0.004)	0.001 (0.002)
P. Chordata			
Tunicate	Ascidiacea	0.010 (0.007)	
Lancelet	*Branchiostoma spp.*	0.008 (0.007)	
Miscellaneous			
Macroalgae		0.021 (0.009)	0.011 (0.074)
Seagrass		0.015 (0.012)	0.065 (0.110)

Table C2: Diet composition of Black Drum (*Pogonias cromis*) from a gill net (n_s = 165, n_p = 312) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 342 ± 81 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Fish		
F. Fundulidae		
Fundulids	*Fundulus heteroclitus*, *Cyprinodon variegatus*	0.017 (0.032)
F. Gobiidae		
Goby	*Gobiosoma bosc*, *Microgobius thalassinus*	0.001 (0.005)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.792 (0.101)
P. Sipuncula		
Peanut Worms	Sipuncula	0.012 (0.016)
P. Annelida		
Polychaete	Polychaeta	0.079 (0.067)
P. Arthropoda		
Amphipod	Gammaridae, *Corophium spp.*	0.007 (0.014)
Skeleton Shrimp	*Caprella spp.*	< 0.001 (0.000)
Barnacle	Cirripedia	0.008 (0.024)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.010 (0.020)
Hermit Crab	*Pagurus spp.*	0.014 (0.022)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.024 (0.057)
Mud Crab	Panopeidae	0.005 (0.011)
Purse Crab	Luecosiidae	0.001 (0.001)
Spider Crab	*Libinia emarginata*	0.013 (0.020)
Miscellaneous		
Macroalgae		0.001 (0.005)
Seagrass		0.015 (0.021)

Table C3: Diet composition of Bluefish (*Pomatomus saltatrix*) from trawl (n_s = 87, n_p = 266) and gill net (n_s = 320, n_p = 1,315) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had mean (μ ± SD) sizes of 183 ± 41 mm from the trawl survey and 319 ± 91 mm from the gill net survey.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Fish			
F. Anguillidae			
American Eel	*Anguilla rostrata*		0.002 (0.002)
Anchovy	*A. mitchilli, A. hepsetus*	0.370 (0.150)	0.026 (0.018)
F. Clupeidae			
Atlantic Thread Herring	*Opisthonema oglinum*	0.006 (0.008)	
Gizzard Shad	*Dorosoma cepedianum*		0.006 (0.009)
Atlantic Menhaden	*Brevoortia tyrannus*	0.082 (0.082)	0.317 (0.011)
F. Gadidae			
Spotted Hake	*Urophycis regia*		0.017 (0.011)
F. Atherinopsidae			
Silversides	*Menidia menidia, Menidia beryllina, Membras martinica*	0.077 (0.016)	0.071 (0.040)
F. Hemiramphidae			
Ballyhoo	*Hemiramphus brasiliensis*		< 0.001 (0.000)
F. Pomatomidae			
Bluefish	*Pomatomus saltatrix*		0.012 (0.017)
F. Haemulidae			
Pigfish	*Orthopristis chrysoptera*		0.006 (0.007)
F. Mugilidae			
Mullet	*Mugil curema, Mugil cephalus*		0.001 (0.001)
F. Moronidae			
Striped Bass	*Morone saxatilis*		< 0.001 (0.000)
F. Sciaenidae			
Atlantic Croaker	*Micropogonias undulatus*	0.215 (0.077)	0.064 (0.029)
Spot	*Leiostomus xanthurus*	0.065 (0.028)	0.187 (0.048)
Silver Perch	*Bairdiella chrysoura*	0.011 (0.013)	0.054 (0.022)
Weakfish	*Cynoscion regalis*		0.008 (0.010)
Spotted Seatrout	*Cynoscion nebulosus*		0.008 (0.009)
Southern Kingfish	*Menticirrhus saxatilis*	0.009 (0.010)	0.006 (0.005)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Red Drum	*Sciaenops ocellatus*		0.004 (0.005)
F. Sparidae			
Pinfish	*Lagodon rhomboides*		0.069 (0.039)
F. Paralichthyidae			
Gulf Flounder	*Paralichthys albigutta*		0.001 (0.002)
Southern Flounder	*Paralichthys lethostigma*		0.001 (0.002)
Invertebrates			
P. Mollusca			
Mollusks	Gastropoda, Bivalvia		0.011 (0.012)
Squid	*Loligo pealeii*, *Lolliguncula brevis*		0.009 (0.009)
Polychaete	Polychaeta		0.006 (0.009)
P. Arthropoda			
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	0.018 (0.019)	
Amphipod	Gammaridae, *Corophium spp.*		0.008 (0.011)
Sand Shrimp	*Crangon spp.*		< 0.001 (0.000)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.073 (0.056)	0.026 (0.023)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.031 (0.012)	0.032 (0.012)
Mud Crab	Panopeidae	0.022 (0.024)	
Porcelain Crab	Porcellanidae	0.003 (0.003)	
Miscellaneous			
Seagrass		0.018 (0.023)	0.046 (0.042)

Table C4: Diet composition of Gulf Flounder (*Paralichthys albigutta*) from trawl (n_s = 11, n_p = 35) and gill net (n_s = 65, n_p = 156) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had mean (μ ± SD) sizes of 173 ± 61 mm from the trawl survey and 306 ± 49 mm from the gill net survey.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Fish			
F. Engraulidae			
Anchovy	*A. mitchilli*, *A. hepsetus*	0.076 (0.152)	0.002 (0.000)
F. Fundulidae			
Fundulids	*Fundulus heteroclitus*, *Cyprinodon variegatus*		< 0.001 (0.000)
F. Sygnathidae			
Pipefish	*Syngnathus spp.*		0.003 (0.000)
F. Haemulidae			
Pigfish	*Orthopristis chrysoptera*		0.109 (0.004)
F. Sciaenidae			
Atlantic Croaker	*Micropogonias undulatus*	0.003 (0.004)	
Spot	*Leiostomus xanthurus*	0.247 (0.309)	0.217 (0.003)
Silver Perch	*Bairdiella chrysoura*		0.072 (0.003)
Spotted Seatrout	*Cynoscion nebulosus*		< 0.001 (0.000)
F. Sparidae			
Pinfish	*Lagodon rhomboides*		0.288 (0.020)
Invertebrates			
P. Mollusca			
Mollusks	Gastropoda, Bivalvia		< 0.001 (0.000)
P. Arthropoda			
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*		0.025 (0.006)
Amphipod	Gammaridae, *Corophium spp.*	0.260 (0.246)	
Mysids	Mysida	0.413 (0.276)	
Big-Clawed Snapping Shrimp	*Alpheus heterochaelis*		0.031 (0.004)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*		0.043 (0.005)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*		< 0.001 (0.000)
Miscellaneous			
Seagrass		< 0.001 (0.000)	0.211 (0.022)

Table C5: Diet composition of Hickory Shad (*Alosa mediocris*) from a gill net (n_s = 189, n_p = 792) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 318 ± 35 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Fish		
F. Anguillidae		
American Eel	*Anguilla rostrata*	< 0.001 (0.000)
F. Engraulidae		
Anchovy	*A. mitchilli*, *A. hepsetus*	0.117 (0.036)
F. Clupeidae		
Atlantic Menhaden	*Brevoortia tyrannus*	0.014 (0.020)
F. Gadidae		
Spotted Hake	*Urophycis regia*	< 0.001 (0.000)
F. Fundulidae		
Fundulids	*Fundulus heteroclitus*, *Cyprinodon variegatus*	0.005 (0.009)
F. Sciaenidae		
Atlantic Croaker	*Micropogonias undulatus*	0.002 (0.011)
Spot	*Leiostomus xanthurus*	0.045 (0.025)
F. Paralichthyidae		
Southern Flounder	*Paralichthys lethostigma*	0.004 (0.008)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.005 (0.007)
P. Annelida		
Polychaete	Polychaeta	0.509 (0.031)
P. Arthropoda		
Insects	Coleoptera, Orthoptera, Trichoptera, Ephemeroptera	0.016 (0.007)
Seagrass Isopod	*Erichsonella attenuata*	0.010 (0.015)
Amphipod	Gammaridae, *Corophium spp.*	0.120 (0.047)
Sand Shrimp	*Crangon spp.*	0.035 (0.059)
Grass Shrimp	*Palaemonetes spp.*	< 0.001 (0.000)
Arrow Shrimp	*Tozeuma spp.*	0.002 (0.000)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Big-Clawed Snapping Shrimp	*Alpheus heterochaelis*	0.004 (0.005)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	< 0.001 (0.000)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.034 (0.035)
Pea Crab	*Pinnixa spp.*	< 0.001 (0.000)
Miscellaneous		
Macroalgae		< 0.001 (0.000)
Seagrass		0.078 (0.017)

Table C6: Diet composition of Inshore Lizardfish (*Synodus foetens*) with samples combined from trawl (n_s = 83, n_p = 574) and gill net (n_s = 2, n_p = 2) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W)* with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 199 ± 40 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Trawl Survey
Fish		
F. Engraulidae		
Anchovy	*A. mitchilli, A. hepsetus*	0.245 (0.036)
F. Clupeidae		
Atlantic Menhaden	*Brevoortia tyrannus*	0.016 (0.021)
F. Synodontidae		
Inshore Lizardfish	*Synodus foetens*	0.001 (0.000)
F. Atherinopsidae		
Silversides	*Menidia menidia, Menidia beryllina, Membras martinica*	< 0.001 (0.000)
F. Ephippidae		
Atlantic Spadefish	*Chaetodipterus faber*	0.003 (0.004)
F. Gobiidae		
Goby	*Gobiosoma bosc, Microgobius thalassinus*	0.001 (0.000)
F. Haemulidae		
Pigfish	*Orthopristis chrysoptera*	0.015 (0.012)
F. Sciaenidae		
Atlantic Croaker	*Micropogonias undulatus*	0.073 (0.017)
Spot	*Leiostomus xanthurus*	0.131 (0.122)
Silver Perch	*Bairdiella chrysoura*	0.055 (0.028)
Weakfish	*Cynoscion regalis*	0.077 (0.051)
Southern Kingfish	*Menticirrhus saxatilis*	0.102 (0.041)
F. Sparidae		
Pinfish	*Lagodon rhomboides*	0.065 (0.045)
F. Paralichthyidae		
Southern Flounder	*Paralichthys lethostigma*	0.011 (0.005)
F. Cynoglossidae		
Blackcheek Tonguefish	*Symphurus plagiusa*	0.005 (0.003)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	< 0.001 (0.000)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Trawl Survey
Squid	*Loligo pealeii*, *Lolliguncula brevis*	0.131 (0.053)
P. Annelida		
Polychaete	Polychaeta	0.012 (0.008)
P. Arthropoda		
Seagrass Isopod	*Erichsonella attenuata*	< 0.001 (0.000)
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	0.021 (0.007)
Amphipod	Gammaridae, *Corophium spp.*	0.002 (0.002)
Mysids	Mysida	0.004 (0.004)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.026 (0.005)
Miscellaneous		
Macroalgae		0.002 (0.001)
Seagrass		0.003 (0.002)

Table C7: Diet composition of Leopard Searobin (*Prionotus scitulus*) from a trawl net (n_s = 34, n_p = 146) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 143 ± 20.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Trawl Survey
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.081 (0.060)
Squid	*Loligo pealeii*, *Lolliguncula brevis*	< 0.001 (0.000)
P. Annelida		
Polychaete	Polychaeta	0.026 (0.022)
P. Arthropoda		
Insects	Coleoptera, Orthoptera, Trichoptera, Ephemeroptera	0.002 (0.004)
Seagrass Isopod	*Erichsonella attenuata*	< 0.001 (0.000)
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	0.001 (0.001)
Amphipod	Gammaridae, *Corophium spp.*	0.308 (0.137)
Skeleton Shrimp	*Caprella spp.*	0.006 (0.003)
Mysids	Mysida	0.211 (0.168)
Grass Shrimp	*Palaemonetes spp.*	0.001 (0.001)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.045 (0.047)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	< 0.001 (0.000)
Pea Crab	*Pinnixa spp.*	0.087 (0.028)
Mud Crab	Panopeidae	0.001 (0.001)
Purse Crab	Leucosiidae	0.007 (0.011)
Porcelain Crab	Porcellanidae	0.222 (0.102)
P. Echinodermata		
Brittle Star	Ophiuroidea	< 0.001 (0.001)
Miscellaneous		
Seagrass		< 0.001 (0.000)

Table C8: Diet composition of Longnose Gar (*Lepisosteus osseus*) from a gill net (n_s = 208, n_p = 1,430) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 809 ± 108 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Fish		
F. Anguillidae		0.004 (0.003)
American Eel	*Anguilla rostrata*	
F. Engraulidae		
Anchovy	*A. mitchilli, A. hepsetus*	0.006 (0.005)
F. Clupeidae		
Hickory Shad	*Alosa mediocris*	< 0.001 (0.001)
Gizzard Shad	*Dorosoma cepedianum*	0.007 (0.006)
Atlantic Menhaden	*Brevoortia tyrannus*	0.489 (0.163)
F. Atherinopsidae		
Silversides	*Menidia menidia, Menidia beryllina, Membras martinica*	0.031 (0.040)
F. Belonidae		
Needlefish	*Strongylura spp.*	< 0.001 (0.000)
F. Fundulidae		
Fundulids	*Fundulus heteroclitus, Cyprinodon variegatus*	0.001 (0.000)
F. Pomatomidae		
Bluefish	*Pomatomus saltatrix*	0.001 (0.001)
F. Mugilidae		
Mullet	*Mugil curema, Mugil cephalus*	0.005 (0.002)
F. Moronidae		
Striped Bass	*Morone saxatilis*	0.019 (0.032)
F. Sciaenidae		
Atlantic Croaker	*Micropogonias undulatus*	0.117 (0.022)
Spot	*Leiostomus xanthurus*	0.244 (0.082)
Silver Perch	*Bairdiella chrysoura*	0.011 (0.006)
Weakfish	*Cynoscion regalis*	0.012 (0.010)
Spotted Seatrout	*Cynoscion nebulosus*	0.001 (0.001)
F. Sparidae		
Pinfish	*Lagodon rhomboides*	0.038 (0.015)
F. Paralichthyidae		

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Southern Flounder	*Paralichthys lethostigma*	0.004 (0.005)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	< 0.001 (0.000)
P. Arthropoda		
Amphipod	Gammaridae, *Corophium spp.*	< 0.001 (0.000)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	< 0.001 (0.000)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.008 (0.003)
Miscellaneous		
Seagrass		< 0.001 (0.000)

Table C9: Diet composition of Northern Searobin (*Prionotus carolinus*) from a trawl net (n_s = 14, n_p = 26) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 123 ± 15 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Trawl Survey
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.012 (0.012)
P. Arthropoda		
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	0.017 (0.018)
Amphipod	Gammaridae, *Corophium spp.*	0.186 (0.240)
Skeleton Shrimp	*Caprella spp.*	
Mysids	Mysida	0.414 (0.159)
Sand Shrimp	*Crangon spp.*	0.034 (0.036)
Grass Shrimp	*Palaemonetes spp.*	0.042 (0.054)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.151 (0.196)
Pea Crab	*Pinnixa spp.*	0.042 (0.037)
Porcelain Crab	Porcellanidae	0.052 (0.063)
P. Echinodermata		
Brittle Star	Ophiuroidea	0.002 (0.004)
Miscellaneous		
Seagrass		0.048 (0.073)

Table C10: Diet composition of Pigfish (*Orthopristis chrysoptera*) from a trawl net (n_s = 80, n_p = 293) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 141 ± 20 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Trawl Survey
Fish		
F. Engraulidae		
Anchovy	*A. mitchilli*, *A. hepsetus*	< 0.001 (0.000)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.096 (0.078)
P. Annelida		
Polychaete	Polychaeta	0.764 (0.148)
P. Arthropoda		
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	< 0.001 (0.001)
Amphipod	Gammaridae, *Corophium spp.*	0.052 (0.068)
Mysids	Mysida	0.008 (0.022)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.001 (0.001)
Pea Crab	*Pinnixa spp.*	0.003 (0.007)
Mud Crab	Panopeidae	0.024 (0.040)
Porcelain Crab	Porcellanidae	0.003 (0.081)
P. Echinodermata		
Brittle Star	Ophiuroidea	0.009 (0.012)
Miscellaneous		
Macroalgae		< 0.001 (0.000)
Seagrass		0.001 (0.002)

Table C11: Diet composition of Pinfish (*Lagodon rhomboids*) from trawl (n_s = 137, n_p = 389) and gill net (n_s = 102, n_p = 149) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had mean (μ ± SD) sizes of 125 ± 14 mm from the trawl survey and 143 ± 24 mm from the gill net survey.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Fish			
F. Engraulidae			
Anchovy	*A. mitchilli*, *A. hepsetus*	0.044 (0.085)	0.066 (0.007)
F. Clupeidae			
Atlantic Menhaden	*Brevoortia tyrannus*	0.015 (0.061)	
F. Sygnathidae			
Pipefish	*Syngnathus spp.*	< 0.001 (0.000)	
F. Sciaenidae			
Spot	*Leiostomus xanthurus*	< 0.001 (0.000)	
Weakfish	*Cynoscion regalis*	< 0.001 (0.000)	
Invertebrates			
P. Mollusca			
Mollusks	Gastropoda, Bivalvia	0.165 (0.113)	0.506 (0.014)
P. Sipuncula			
Peanut Worms	Sipuncula	0.010 (0.021)	
P. Annelida			
Polychaete	Polychaeta	0.423 (0.167)	0.031 (0.006)
P. Arthropoda			
Amphipod	Gammaridae, *Corophium spp.*	0.031 (0.033)	0.069 (0.004)
Mysids	Mysida	0.053 (0.054)	
Ostracod	Ostracoda	0.010 (0.019)	
Barnacle	Cirripedia	0.007 (0.011)	
Sand Shrimp	*Crangon spp.*		0.034 (0.004)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*		0.004 (0.001)
Pea Crab	*Pinnixa spp.*	0.021 (0.032)	
Porcelain Crab	Porcellanidae	0.088 (0.099)	
P. Echinodermata			
Brittle Star	Ophiuroidea	0.069 (0.089)	
P. Chordata			
Tunicate	Ascidiacea	0.001 (0.005)	
Miscellaneous			
Macroalgae		0.035 (0.029)	0.036 (0.009)

Seagrass	0.029 (0.050)	0.254 (0.022)

Table C12: Diet composition of Red Drum (*Sciaenops ocellatus*) from a gill net (n_s = 236, n_p = 837) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 422 ± 93 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Fish		
F. Anguillidae		
American Eel	*Anguilla rostrata*	0.010 (0.001)
F. Opichtidae		
Speckled Worm Eel	*Myrophis punctatus*	< 0.001 (0.000)
F. Engraulidae		
Anchovy	*A. mitchilli, A. hepsetus*	0.002 (0.001)
F. Clupeidae		
Atlantic Menhaden	*Brevoortia tyrannus*	0.170 (0.036)
F. Synodontidae		
Inshore Lizardfish	*Synodus foetens*	0.006 (0.002)
F. Gadidae		
Spotted Hake	*Urophycis regia*	< 0.001 (0.000)
F. Batrachoididae		
Oyster Toadfish	*Opsanus tau*	0.002 (0.000)
F. Atherinopsidae		
Silversides	*Menidia menidia, Menidia beryllina, Membras martinica*	0.001 (0.000)
F. Fundulidae		
Fundulids	*Fundulus heteroclitus, Cyprinodon variegatus*	0.019 (0.001)
F. Sygnathidae		
Pipefish	*Syngnathus spp.*	0.013 (0.004)
F. Pomatomidae		
Bluefish	*Pomatomus saltatrix*	0.006 (0.002)
F. Haemulidae		
Pigfish	*Orthopristis chrysoptera*	0.006 (0.001)
F. Mugilidae		
Mullet	*Mugil curema, Mugil cephalus*	0.005 (0.000)
F. Sciaenidae		
Atlantic Croaker	*Micropogonias undulatus*	0.018 (0.002)
Spot	*Leiostomus xanthurus*	0.062 (0.012)
Silver Perch	*Bairdiella chrysoura*	0.005 (0.002)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Spotted Seatrout	*Cynoscion nebulosus*	< 0.001 (0.000)
F. Sparidae		
Pinfish	*Lagodon rhomboides*	0.040 (0.003)
F. Paralichthyidae		
Summer Flounder	*Paralichthys dentatus*	0.007 (0.001)
Southern Flounder	*Paralichthys lethostigma*	0.010 (0.002)
F. Achiridae		
Hogchoker	*Trinectes maculatus*	0.006 (0.001)
F. Cynoglossidae		
Blackcheek Tonguefish	*Symphurus plagiusa*	0.001 (0.000)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.013 (0.002)
Polychaete	Polychaeta	0.061 (0.008)
P. Arthropoda		
Insects	Coleoptera, Orthoptera, Trichoptera, Ephemeroptera	0.006 (0.001)
Seagrass Isopod	*Erichsonella attenuata*	0.001 (0.000)
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	< 0.001 (0.000)
Amphipod	Gammaridae, *Corophium spp.*	0.032 (0.006)
Skeleton Shrimp	*Caprella spp.*	0.002 (0.001)
Mysids	Mysida	0.006 (0.002)
Crayfish	Cambaridae	0.004 (0.001)
Sand Shrimp	*Crangon spp.*	0.004 (0.002)
Grass Shrimp	*Palaemonetes spp.*	< 0.001 (0.000)
Big-Clawed Snapping Shrimp	*Alpheus heterochaelis*	0.047 (0.011)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.028 (0.004)
Hermit Crab	*Pagurus spp*.	0.007 (0.000)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.271 (0.022)
Mole Crab	*Emerita spp*.	0.002 (0.001)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Mud Crab	Panopeidae	0.071 (0.001)
Fiddler Crab	Ocypodidae	< 0.001 (0.000)
P. Chordata		
Tunicate	Ascidiacea	0.001 (0.001)
Miscellaneous		
Macroalgae		< 0.001 (0.000)
Seagrass		0.055 (0.006)

Table C13: Diet composition Silver Perch (*Bairdiella chrysoura*) with sampled combined from trawl (n_s = 132, n_p = 611) and the gill net (n_s = 8, n_p = 13) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 147 ± 20 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Trawl Survey
Fish		
F. Engraulidae		
Anchovy	*A. mitchilli*, *A. hepsetus*	0.366 (0.237)
F. Gobiidae		
Goby	*Gobiosoma bosc*, *Microgobius thalassinus*	0.010 (0.031)
F. Sciaenidae		
Spot	*Leiostomus xanthurus*	< 0.001 (0.000)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.014 (0.020)
P. Annelida		
Polychaete	Polychaeta	0.041 (0.066)
P. Arthropoda		
Amphipod	Gammaridae, *Corophium spp.*	0.051 (0.032)
Mysids	Mysida	0.362 (0.175)
Sand Shrimp	*Crangon spp.*	0.006 (0.009)
Grass Shrimp	*Palaemonetes spp.*	0.005 (0.018)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.010 (0.018)
Hermit Crab	*Pagurus spp*.	< 0.001 (0.001)
Purse Crab	Leucosiidae	0.008 (0.008)
Porcelain Crab	Porcellanidae	0.109 (0.126)
Miscellaneous		
Seagrass		0.017 (0.031)

Table C14: Diet composition of Southern Flounder (*Paralichthys lethostigma*) from trawl (n_s = 110, n_p = 478) and the gill net (n_s = 620, n_p = 1,878) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had mean (μ ± SD) sizes of 172 ± 62 mm from the trawl survey and 341 ± 64 mm from the gill net survey.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Fish			
F. Ophidiidae			
Cusk Eel	Ophidiidae		0.003 (0.010)
F. Engraulidae			
Anchovy	*A. mitchilli, A. hepsetus*	0.275 (0.060)	0.013 (0.027)
F. Clupeidae			
Atlantic Menhaden	*Brevoortia tyrannus*	< 0.001 (0.001)	0.063 (0.085)
F. Gadidae			
Spotted Hake	*Urophycis regia*		0.002 (0.008)
F. Atherinopsidae			
Silversides	*Menidia menidia, Menidia beryllina, Membras martinica*	0.015 (0.028)	0.001 (0.003)
F. Fundulidae			
Fundulids	*Fundulus heteroclitus, Cyprinodon variegatus*		< 0.001 (0.000)
F. Sygnathidae			
Pipefish	*Syngnathus spp.*		< 0.001 (0.000)
F. Gobiidae			
Goby	*Gobiosoma bosc, Microgobius thalassinus*	0.006 (0.008)	0.005 (0.017)
F. Haemulidae			
Pigfish	*Orthopristis chrysoptera*		0.024 (0.035)
F. Mugilidae			
Mullet	*Mugil curema, Mugil cephalus*		0.021 (0.035)
F. Sciaenidae			
Atlantic Croaker	*Micropogonias undulatus*	0.229 (0.135)	0.097 (0.103)
Spot	*Leiostomus xanthurus*	0.195 (0.113)	0.432 (0.248)
Silver Perch	*Bairdiella chrysoura*		0.081 (0.067)
Weakfish	*Cynoscion regalis*	0.017 (0.024)	0.018 (0.036)
Southern Kingfish	*Menticirrhus saxatilis*		0.028 (0.050)
Red Drum	*Sciaenops ocellatus*		< 0.001 (0.004)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
F. Sparidae			
Pinfish	*Lagodon rhomboides*	0.005 (0.011)	0.064 (0.069)
F. Paralichthyidae			
Gulf Flounder	*Paralichthys albigutta*		0.005 (0.012)
Southern Flounder	*Paralichthys lethostigma*		< 0.001 (0.004)
Invertebrates			
P. Mollusca			
Mollusks	Gastropoda, Bivalvia	0.009 (0.014)	0.009 (0.016)
Squid	*Loligo pealeii*, *Lolliguncula brevis*	0.013 (0.023)	0.023 (0.054)
P. Annelida			
Polychaete	Polychaeta	0.003 (0.006)	
P. Arthropoda			
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	0.021 (0.019)	
Amphipod	Gammaridae, *Corophium spp.*	0.010 (0.015)	
Mysids	Mysida	0.186 (0.062)	
Barnacle	Cirripedia		< 0.001 (0.001)
Sand Shrimp	*Crangon spp.*		0.010 (0.033)
Estuarine Long-Eyed Shrimp	*Ogyrides alphaerotis*	< 0.001 (0.000)	
Big-Clawed Snapping Shrimp	*Alpheus heterochaelis*		0.003 (0.010)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*		0.023 (0.037)
Hermit Crab	*Pagurus spp.*	< 0.001 (0.000)	
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*		0.006 (0.017)
Pea Crab	*Pinnixa spp.*	< 0.001 (0.000)	
Mud Crab	Panopeidae		0.002 (0.007)
Miscellaneous			
Macroalgae			0.004 (0.010)
Seagrass		0.014 (0.029)	0.061 (0.097)

Table C15: Diet composition of Southern Kingfish (*Menticirrhus americanus*) from trawl (n_s = 150, n_p = 733) and gill net (n_s = 152, n_p = 244) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had mean (μ ± SD) predator sizes of 198 ± 46 mm from the trawl survey and 341 ± 64 mm from the gill net survey.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Fish			
F. Anguillidae			
American Eel	*Anguilla rostrata*		0.031 (0.017)
F. Engraulidae			
Anchovy	*A. mitchilli, A. hepsetus*	< 0.001 (0.000)	0.020 (0.014)
F. Clupeidae			
Gizzard Shad	*Dorosoma cepedianum*		0.004 (0.004)
Atlantic Menhaden	*Brevoortia tyrannus*	0.010 (0.001)	0.051 (0.024)
F. Gadidae			
Spotted Hake	*Urophycis regia*		0.015 (0.017)
F. Batrachoididae			
Oyster Toadfish	*Opsanus tau*		0.002 (0.002)
F. Atherinopsidae			
Silversides	*Menidia menidia, Menidia beryllina, Membras martinica*		0.009 (0.010)
F. Fundulidae			
Fundulids	*Fundulus heteroclitus, Cyprinodon variegatus*		< 0.001 (0.000)
F. Sygnathidae			
Pipefish	*Syngnathus spp.*	0.001 (0.000)	0.013 (0.016)
F. Gobiidae			
Goby	*Gobiosoma bosc, Microgobius thalassinus*	< 0.001 (0.000)	0.010 (0.008)
F. Haemulidae			
Pigfish	*Orthopristis chrysoptera*		< 0.001 (0.000)
F. Mugilidae			
Mullet	*Mugil curema, Mugil cephalus*		0.020 (0.045)
F. Sciaenidae			
Atlantic Croaker	*Micropogonias undulatus*	0.007 (0.001)	0.021 (0.018)
Spot	*Leiostomus xanthurus*	0.009 (0.001)	0.044 (0.041)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Silver Perch	*Bairdiella chrysoura*		0.015 (0.009)
Spotted Seatrout	*Cynoscion nebulosus*	0.004 (0.001)	
F. Sparidae			
Pinfish	*Lagodon rhomboides*		< 0.001 (0.000)
F. Paralichthyidae			
Southern Flounder	*Paralichthys lethostigma*	0.009 (0.001)	
F. Cynoglossidae			
Blackcheek Tonguefish	*Symphurus plagiusa*	0.005 (0.001)	0.003 (0.004)
Invertebrates			
P. Mollusca			
Mollusks	Gastropoda, Bivalvia	0.208 (0.002)	0.081 (0.033)
Squid	*Loligo pealeii*, *Lolliguncula brevis*	0.010 (0.000)	0.011 (0.009)
P. Sipuncula			
Peanut Worms	Sipuncula		0.026 (0.014)
P. Annelida			
Polychaete	Polychaeta	0.200 (0.002)	0.119 (0.049)
P. Arthropoda			
Seagrass Isopod	*Erichsonella attenuata*	0.001 (0.000)	
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	0.038 (0.002)	
Amphipod	Gammaridae, *Corophium spp.*	0.097 (0.002)	0.002 (0.002)
Skeleton Shrimp	*Caprella spp.*	0.002 (0.000)	
Mysids	Mysida	0.044 (0.000)	
Ostracod	Ostracoda	0.010 (0.001)	
Barnacle	Cirripedia	0.002 (0.000)	
Sand Shrimp	*Crangon spp.*		0.001 (0.001)
Grass Shrimp	*Palaemonetes spp.*		0.005 (0.004)
Estuarine Long-Eyed Shrimp	*Ogyrides alphaerotis*	0.003 (0.000)	
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.071 (0.003)	0.026 (0.018)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.143 (0.006)	0.335 (0.049)
Pea Crab	*Pinnixa spp.*	0.034 (0.005)	
Mud Crab	Panopeidae	0.052 (0.001)	0.039 (0.035)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Porcelain Crab	Porcellanidae	0.018 (0.000)	
Spider Crab	*Libinia emarginata*		0.013 (0.012)
Fiddler Crab	Ocypodidae		0.021 (0.044)
P. Chordata			
Tunicate	Ascidiacea	0.007 (0.000)	
Lancelet	*Branchiostoma spp.*	0.009 (0.002)	
Miscellaneous			
Macroalgae		0.003 (0.000)	
Seagrass		0.004 (0.000)	0.065 (0.066)

Table C16: Diet composition of Spanish Mackerel (*Scomberomorus maculatus*) from trawl (n_s = 10, n_p = 23) and gill net (n_s = 16, n_p = 32) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had mean (μ ± SD) predator sizes of 162 ± 55 mm from the trawl survey and 352 ± 87 mm from the gill net survey.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Fish			
F. Engraulidae			
Anchovy	*A. mitchilli*, *A. hepsetus*	0.823 (0.017)	0.224 (0.025)
F. Clupeidae			
Atlantic Menhaden	*Brevoortia tyrannus*	0.177 (0.017)	0.148 (0.034)
F. Atherinopsidae			
Silversides	*Menidia menidia*, *Menidia beryllina*, *Membras martinica*		0.519 (0.007)
F. Sphyraenidae			
Northern Sennet	*Sphyraena borealis*		0.054 (0.008)
Miscellaneous			
Seagrass			0.054 (0.008)

Table C17: Diet composition of Spot (*Leiostomus xanthurus*) from trawl (n_s = 197 n_p = 720) and gill net (n_s = 211, n_p = 413) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had mean (μ ± SD) sizes of 145 ± 26 mm from the trawl survey and 219 ± 17 mm from the gill net survey.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Fish			
F. Gobiidae			
Goby	*Gobiosoma bosc*, *Microgobius thalassinus*	0.002 (0.002)	
Invertebrates			
P. Mollusca			
Mollusks	Gastropoda, Bivalvia	0.355 (0.049)	0.356 (0.035)
Squid	*Loligo pealeii*, *Lolliguncula brevis*	0.003 (0.003)	
P. Annelida			
Polychaete	Polychaeta	0.287 (0.039)	0.513 (0.103)
P. Arthropoda			
Amphipod	Gammaridae, *Corophium spp.*	0.074 (0.012)	0.072 (0.032)
Mysids	Mysida	0.150 (0.017)	0.015 (0.020)
Barnacle	Cirripedia	0.023 (0.006)	
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.004 (0.003)	
Pea Crab	*Pinnixa spp.*	0.005 (0.003)	
Purse Crab	Leucosiidae	0.008 (0.004)	
Porcelain Crab	Porcellanidae	0.082 (0.044)	
P. Echinodermata			
Brittle Star	Ophiuroidea	0.002 (0.000)	
Miscellaneous			
Macroalgae		0.004 (0.002)	0.007 (0.020)
Seagrass			0.036 (0.041)

Table C18: Diet composition of Spotted Hake (*Urophycis regia*) from a trawl net (n_s = 38, n_p = 86) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 171 ± 17 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Trawl Survey
Fish		
F. Engraulidae		
Anchovy	*A. mitchilli*, *A. hepsetus*	0.278 (0.148)
F. Sciaenidae		
Atlantic Croaker	*Micropogonias undulatus*	0.028 (0.032)
Spot	*Leiostomus xanthurus*	0.033 (0.041)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.046 (0.037)
P. Annelida		
Polychaete	Polychaeta	0.007 (0.007)
P. Arthropoda		
Seagrass Isopod	*Erichsonella attenuata*	0.001 (0.002)
Amphipod	Gammaridae, *Corophium spp.*	0.058 (0.059)
Mysids	Mysida	0.474 (0.294)
Flat-Browed Mud Shrimp	*Upogebia affinis*	0.012 (0.017)
Porcelain Crab	Porcellanidae	0.063 (0.064)

Table C19: Diet composition of Spotted Seatrout (*Cynoscion nebulosus*) from a gill net (n_s = 327, n_p = 615) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 416 ± 66 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*) Trawl Survey
Fish		
F. Engraulidae		
Anchovy	*A. mitchilli, A. hepsetus*	0.018 (0.009)
F. Clupeidae		
Alewife	*Alosa pseudoharengus*	0.006 (0.009)
Gizzard Shad	*Dorosoma cepedianum*	0.002 (0.003)
Atlantic Menhaden	*Brevoortia tyrannus*	0.253 (0.094)
F. Gadidae		
Spotted Hake	*Urophycis regia*	< 0.001 (0.000)
F. Atherinopsidae		
Silversides	*Menidia menidia, Menidia beryllina, Membras martinica*	0.033 (0.021)
F. Pomatomidae		
Bluefish	*Pomatomus saltatrix*	< 0.001 (0.000)
F. Carangidae		
Jacks	*Selene spp., Oligoplites saurus*	< 0.001 (0.000)
F. Haemulidae		
Pigfish	*Orthopristis chrysoptera*	0.009 (0.010)
F. Mugilidae		
Mullet	*Mugil curema, Mugil cephalus*	0.012 (0.010)
F. Moronidae		
Striped Bass	*Morone saxatilis*	0.024 (0.018)
F. Sciaenidae		
Atlantic Croaker	*Micropogonias undulatus*	0.088 (0.035)
Spot	*Leiostomus xanthurus*	0.178 (0.046)
Silver Perch	*Bairdiella chrysoura*	0.012 (0.006)
Weakfish	*Cynoscion regalis*	0.003 (0.003)
F. Sparidae		
Pinfish	*Lagodon rhomboides*	0.104 (0.066)
F. Paralichthyidae		
Southern Flounder	*Paralichthys lethostigma*	0.003 (0.005)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*) Trawl Survey
F. Cynoglossidae		
Blackcheek Tonguefish	*Symphurus plagiusa*	0.003 (0.002)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.001 (0.002)
P. Annelida		
Polychaete	Polychaeta	0.044 (0.029)
P. Arthropoda		
Amphipod	Gammaridae, *Corophium spp.*	0.013 (0.011)
Mysids	Mysida	0.002 (0.004)
Sand Shrimp	*Crangon spp.*	0.011 (0.012)
Grass Shrimp	*Palaemonetes spp.*	0.009 (0.008)
Arrow Shrimp	*Tozeuma spp.*	0.005 (0.006)
Flat-Browed Mud Shrimp	*Upogebia affinis*	0.004 (0.005)
Big-Clawed Snapping Shrimp	*Alpheus heterochaelis*	0.012 (0.014)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.023 (0.011)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.032 (0.011)
Pea Crab	*Pinnixa spp.*	0.001 (0.001)
Miscellaneous		
Seagrass		0.095 (0.079)

Table C20: Diet composition of Striped Bass (*Morone saxatilis*) combined from two gill net (n_s = 190, n_p = 412) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 519 ± 89 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Fish		
F. Anguillidae		
American Eel	*Anguilla rostrata*	0.006 (0.000)
F. Engraulidae		
Anchovy	*A. mitchilli*, *A. hepsetus*	0.016 (0.001)
F. Clupeidae		
Atlantic Menhaden	*Brevoortia tyrannus*	0.555 (0.008)
F. Atherinopsidae		
Silversides	*Menidia menidia*, *Menidia beryllina*, *Membras martinica*	0.013 (0.000)
F. Belonidae		
Needlefish	*Strongylura spp.*	0.001 (0.000)
F. Fundulidae		
Fundulids	*Fundulus heteroclitus*, *Cyprinodon variegatus*	0.007 (0.001)
F. Mugilidae		
Mullet	*Mugil curema*, *Mugil cephalus*	0.054 (0.003)
F. Moronidae		
White Perch	*Morone americana*	0.020 (0.003)
F. Sciaenidae		
Atlantic Croaker	*Micropogonias undulatus*	0.001 (0.000)
Spot	*Leiostomus xanthurus*	0.068 (0.001)
Red Drum	*Sciaenops ocellatus*	< 0.001 (0.000)
F. Sparidae		
Pinfish	*Lagodon rhomboides*	0.002 (0.000)
F. Paralichthyidae		
Southern Flounder	*Paralichthys lethostigma*	0.004 (0.000)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.008 (0.000)
P. Annelida		
Polychaete	Polychaeta	0.040 (0.001)
P. Arthropoda		

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Insects	Coleoptera, Orthoptera, Trichoptera, Ephemeroptera	< 0.001 (0.000)
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	0.014 (0.005)
Amphipod	Gammaridae, *Corophium spp.*	0.071 (0.002)
Skeleton Shrimp	*Caprella spp.*	0.001 (0.000)
Sand Shrimp	*Crangon spp.*	0.003 (0.000)
Grass Shrimp	*Palaemonetes spp.*	0.006 (0.000)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.021 (0.006)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.078 (0.002)
Mud Crab	Panopeidae	0.008 (0.000)
Miscellaneous		
Frog	Anura	0.001 (0.000)
Seagrass		< 0.001 (0.000)

Table C21: Diet composition of Striped Searobin (*Prionotus evolans*) from a trawl net (n_s = 90, n_p = 264) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) size of 133 ± 25 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Trawl Survey
Fish		
F. Engraulidae		
Anchovy	*A. mitchilli*, *A. hepsetus*	0.008 (0.010)
F. Clupeidae		
Atlantic Menhaden	*Brevoortia tyrannus*	0.001 (0.002)
F. Gobiidae		
Goby	*Gobiosoma bosc*, *Microgobius thalassinus*	0.026 (0.028)
F. Sciaenidae		
Spot	*Leiostomus xanthurus*	< 0.001 (0.000)
Weakfish	*Cynoscion regalis*	0.016 (0.021)
F. Cynoglossidae		
Blackcheek Tonguefish	*Symphurus plagiusa*	< 0.001 (0.000)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	0.010 (0.012)
P. Annelida		
Polychaete	Polychaeta	0.001 (0.001)
P. Arthropoda		
Insects	Coleoptera, Orthoptera, Trichoptera, Ephemeroptera	0.001 (0.003)
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	0.009 (0.011)
Amphipod	Gammaridae, *Corophium spp.*	0.051 (0.034)
Mysids	Mysida	0.625 (0.089)
Grass Shrimp	*Palaemonetes spp.*	0.001 (0.001)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.011 (0.009)
Pea Crab	*Pinnixa spp.*	0.033 (0.041)
Mud Crab	Panopeidae	0.016 (0.011)
Porcelain Crab	Porcellanidae	0.130 (0.026)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Trawl Survey
Fiddler Crab	Ocypodidae	0.020 (0.039)
Miscellaneous		
Seagrass		0.014 (0.016)

Table C22: Diet composition of Summer Flounder (*Paralichthys dentatus*) from trawl (n_s = 170, n_p = 755) and gill net (n_s = 39, n_p = 45) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had mean (μ ± SD) sizes of 168 ± 54 mm from the trawl survey and 308 ± 71 mm from the gill net survey.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Fish			
F. Engraulidae			
Anchovy	*A. mitchilli*, *A. hepsetus*	0.114 (0.092)	0.423 (0.210)
F. Clupeidae			
Atlantic Menhaden	*Brevoortia tyrannus*	0.001 (0.002)	0.117 (0.119)
F. Sygnathidae			
Seahorse	*Hippocampus spp.*	0.004 (0.012)	
F. Gobiidae			
Goby	*Gobiosoma bosc*, *Microgobius thalassinus*	0.012 (0.031)	
F. Haemulidae			
Pigfish	*Orthopristis chrysoptera*	0.002 (0.005)	
F. Sciaenidae			
Atlantic Croaker	*Micropogonias undulatus*	0.045 (0.061)	0.092 (0.032)
Spot	*Leiostomus xanthurus*	0.022 (0.031)	0.181 (0.058)
Silver Perch	*Bairdiella chrysoura*	0.001 (0.003)	
Weakfish	*Cynoscion regalis*	0.009 (0.013)	
Southern Kingfish	*Menticirrhus saxatilis*	0.005 (0.009)	
Invertebrates			
P. Mollusca			
Mollusks	Gastropoda, Bivalvia	0.029 (0.026)	
Squid	*Loligo pealeii*, *Lolliguncula brevis*	< 0.001 (0.000)	
P. Annelida			
Polychaete	Polychaeta	0.007 (0.011)	
P. Arthropoda			
Insects	Coleoptera, Orthoptera, Trichoptera, Ephemeroptera	0.001 (0.000)	
Mantis Shrimp	*Squilla empusa*, *Nannosquilla grayi*	0.045 (0.057)	
Amphipod	Gammaridae, *Corophium spp.*	0.031 (0.046)	

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Mysids	Mysida	0.633 (0.120)	0.002 (0.001)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.016 (0.035)	
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.002 (0.005)	0.013 (0.014)
Pea Crab	*Pinnixa spp.*	0.014 (0.023)	
Mud Crab	Panopeidae		0.171 (0.072)
Purse Crab	Leucosiidae	0.001 (0.002)	
Porcelain Crab	Porcellanidae	0.006 (0.016)	
Miscellaneous			
Seagrass		0.001 (0.002)	

Table C23: Diet composition of Weakfish (*Cynoscion regalis*) from trawl (n_s = 134, n_p = 753) and gill net (n_s = 205, n_p = 484) surveys in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had mean (μ ± SD) predator sizes of 193 ± 45 mm from the trawl survey and 325 ± 61 mm from the gill net survey.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Fish			
F. Engraulidae			
Anchovy	*A. mitchilli, A. hepsetus*	0.215 (0.100)	0.271 (0.036)
F. Clupeidae			
Atlantic Thread Herring	*Opisthonema oglinum*	0.002 (0.005)	
Gizzard Shad	*Dorosoma cepedianum*		0.002 (0.001)
Atlantic Menhaden	*Brevoortia tyrannus*	0.031 (0.018)	0.208 (0.070)
F. Gadidae			
Spotted Hake	*Urophycis regia*		0.011 (0.005)
F. Atherinopsidae			
Silversides	*Menidia menidia, Menidia beryllina, Membras martinica*		0.017 (0.008)
F. Fundulidae			
Fundulids	*Fundulus heteroclitus, Cyprinodon variegatus*		< 0.001 (0.000)
F. Haemulidae			
Pigfish	*Orthopristis chrysoptera*		0.012 (0.003)
F. Mugilidae			
Mullet	*Mugil curema, Mugil cephalus*		0.010 (0.004)
F. Sciaenidae			
Atlantic Croaker	*Micropogonias undulatus*	0.129 (0.013)	0.068 (0.017)
Spot	*Leiostomus xanthurus*	0.159 (0.166)	0.086 (0.033)
Silver Perch	*Bairdiella chrysoura*		0.052 (0.006)
Weakfish	*Cynoscion regalis*	< 0.001 (0.000)	0.006 (0.002)
Southern Kingfish	*Menticirrhus saxatilis*		0.014 (0.004)
F. Sparidae			
Pinfish	*Lagodon rhomboides*	< 0.001 (0.000)	0.030 (0.016)
Invertebrates			
P. Mollusca			
Mollusks	Gastropoda, Bivalvia	0.015 (0.015)	0.009 (0.004)

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)	
		Trawl Survey	Gill Net Survey
Squid	*Loligo pealeii*, *Lolliguncula brevis*	0.002 (0.001)	0.010 (0.007)
P. Annelida			
Polychaete	Polychaeta	0.018 (0.009)	0.038 (0.017)
P. Arthropoda			
Seagrass Isopod	*Erichsonella attenuata*		< 0.000 (0.000)
Amphipod	Gammaridae, *Corophium spp.*	0.033 (0.014)	0.036 (0.011)
Skeleton Shrimp	*Caprella spp.*		0.009 (0.004)
Mysids	Mysida	0.230 (0.075)	0.031 (0.005)
Sand Shrimp	*Crangon spp.*		0.006 (0.006)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*, *Farfantepenaeus aztecus*	0.001 (0.001)	0.007 (0.005)
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.018 (0.009)	0.039 (0.017)
Pea Crab	*Pinnixa spp.*	0.003 (0.002)	
Purse Crab	Leucosiidae	< 0.001 (0.000)	
Porcelain Crab	Porcellanidae	0.134 (0.099)	
P. Echinodermata			
Brittle Star	Ophiuroidea	0.009 (0.007)	
Miscellaneous			
Seagrass			0.027 (0.017)

Table C24: Diet composition of White Perch (*Morone Americana*) from a gill net (n_s = 89, n_p = 261) survey in Pamlico Sound, North Carolina. Values represent mean prey proportional contribution by weight (*W*) with standard deviation in parentheses. Sampled predators had a mean (μ ± SD) predator size of 242 ± 25 mm.

Prey Name	Scientific Name(s)	Proportional Contribution by Weight (*W*)
		Gill Net Survey
Fish		
F. Engraulidae		
Anchovy	*A. mitchilli*, *A. hepsetus*	0.036 (0.024)
F. Clupeidae		
Atlantic Menhaden	*Brevoortia tyrannus*	< 0.001 (0.000)
F. Fundulidae		
Fundulids	*Fundulus heteroclitus*, *Cyprinodon variegatus*	0.035 (0.079)
F. Sciaenidae		
Atlantic Croaker	*Micropogonias undulatus*	< 0.001 (0.000)
Invertebrates		
P. Mollusca		
Mollusks	Gastropoda, Bivalvia	< 0.001 (0.000)
P. Annelida		
Polychaete	Polychaeta	0.131 (0.045)
P. Arthropoda		
Insects	Coleoptera, Orthoptera, Trichoptera, Ephemeroptera	0.037 (0.035)
Amphipod	Gammaridae, *Corophium spp.*	0.514 (0.217)
Skeleton Shrimp	*Caprella spp.*	0.010 (0.008)
Mysids	Mysida	0.081 (0.033)
Sand Shrimp	*Crangon spp.*	0.002 (0.007)
Grass Shrimp	*Palaemonetes spp.*	0.028 (0.042)
Penaeid Shrimp	*Litopenaeus setiferus*, *Farfantepenaeus duorarum*,	0.104 (0.139)

	Farfantepenaeus aztecus	
Portunid Crab	*Callinectes sapidus*, *Callinectes similis*, *Ovalipes ocellatus*	0.021 (0.034)
Miscellaneous		
Seagrass		< 0.001 (0.000)

APPENDIX D

Model construction, balancing, and tuning for a Pamlico Sound Ecopath with Ecosim model

We developed an Ecopath with Ecosim (EwE) model for Pamlico Sound, North Carolina and its tributaries (Fig. 1) covering an area of 5,641 km for the 2012-2013 time period. The model is composed of 43 compartments, with 1 group each for seabirds, dolphins, sea turtles, sharks, and stingrays, 25 fish compartments, 10 invertebrate compartments, 2 primary productivity compartments, and 1 detrital compartment (Table 1). Our initial parameter estimates (Table 2) were based primarily on North Carolina Division of Marine Fisheries (NCDMF) survey data and were supplemented by primary literature searches and the use of empirical relationships (e.g. Palomares and Pauly 1989) to estimate model parameters.

The following sections provide detailed descriptions of how we estimated our input parameters, balanced the model, results from our PREBAL (Link 2010) diagnostics, our final parameter estimates, and a description of the time series we used to tune the Pamlico Sound model. Hereafter, we use the term Pamlico Sound to refer to both Pamlico Sound and its tributaries (Pamlico and Neuse Rivers).

Fig. 1: Map of Pamlico Sound and its tributaries.

Table 1: Description of compartments included in the Pamlico Sound Ecopath model.

Compartment Number and Name		Species or pooled taxa
1	Seabirds	*Ardea alba*, *Egretta caerulea*, *E. thula*, *E. tricolor*, *Gelochelidon nilotica*, *Haliaeetus leucocephalus*, *Hydroprogne caspia*, *Larus argentatus*, *L. marinus*, *Leucophaeus atricilla*, *Nycticorax nycticorax*, *Pandion haliaetus*, *Pelacanus occidentalis*, *Phalacrocorax auritus*, *Rynchops niger*, *Sterna forsteri*, *S. hirundo*, *Sternula antillarum*, *Thalasseus maximus*, *Thalasseus sandvicensis*
2	Dolphins	*Tursiops truncates*
3	Sea turtles	*Caretta caretta*, *Chelonia mydas*, and *Lepidochelys kempii*
4	Sharks	*Carcharhinus leucas*, *C. limbatus*, *C. plumbeus*, *Mustelus canis*, *Sphyrna tiburo*, and *Squalus acanthias*,
5	Rays	*Gymnua altavela*, *G. micrura*, *Rhinoptera bonasus*, *Hypanus americanus*, *H. sabinus*
6	Lizardfish	*Synodus foetens*
7	Bluefish	*Pomatomus saltatrix*
8	Longnose gar	*Lepisosteus osseus*
9	Weakfish	*Cynoscion regalis*
10	Spotted seatrout	*Cynosion nebulosus*
11	Red drum	*Sciaenops ocellatus*
12	Kingfish	*Menticirrhus americanus* and *M. saxatilis*
13	Striped bass	*Morone saxatilis*
14	Hickory shad	*Alosa mediocris*
15	Southern flounder	*Paralichthys lethostigma*
16	Summer flounder	*Paralichthys dentatus*
17	Gulf flounder	*Paralichthys albigutta*
18	Spanish mackerel	*Scomberomorus maculatus*
19	Black drum	*Pogonias cromis*
20	Croaker	*Micropogonias undulatus*
21	Spot	*Leiostomus xanthurus*
22	Silver perch	*Bairdiella chrysoura*
23	White perch	*Morone americana*
24	Pigfish	*Orthopristis chrysoptera*

Compartment Number and Name		Species or pooled taxa
25	Pinfish	*Lagodon rhomboides*
26	Striped mullet	*Mugil cephalus*
27	Gizzard shad	*Dorosoma cepedianum*
28	Atlantic menhaden	*Brevoortia tyrannus*
29	Anchovy	*Anchoa hepsetus* and *A. mitchilli*
30	Silversides	*Membras martinica*, *Menidia beryllina*, and *M. menidia*
31	Penaeid shrimp	*Farfantepenaeus aztecus*, *F. duorarum*, and *Litopenaeus setiferus*
32	Blue crabs	*Callinectes sapidus* and *C. similis*
33	Other crabs and shrimp	*Acetes spp*., *Alpheus heterochaelis*, Leucosiidae, *Lucifer spp*., *Nannosquilla grayi*, *Pagurus spp*., *Palaemonetes spp*., Panopeidae, Porcellanidae, Ocypodidae, *Ogyrides alphaerotis*, *Squilla empusa*, and *Upogebia affinis*,
34	Polychaetes	Ampharetidae, Capiellidae, Eunicidae, Glyceridae, Nereidae, Phyllodocidae Sphaerodoridae, and Spoinidae,
35	Squid	*Loligo pealeii* and *Lolliguncula brevis*
36	Mollusks	Acteonidae, Cerithiidae, *Gemma gemma*, Hydrobiidae, Macoma *balthica*, *M. mitchelli*, *Mulinia lateralis*, Nassariidae, *Parvalucinea multilineata*, Pyramidellidae, and *Rangia cuneata*
37	Meiofauna	Amphipoda, Isopoda, Nematoda, Oligochaeta, and Ostracoda
38	Mysids	*Bowmaniella spp*., *Mysidopsis spp*., and *Neomysis spp*.
39	Ichthyoplankton	
40	Zooplankton	*Acartia spp*., Copepod nauplii, *Oithona spp*., Polychaete larva, and Rotifers
41	Phytoplankton	Cryptophyceae, Bacillariophyceae, and Dinophyceae
42	SAV	*Codium spp*., *Enteromorpha spp*., *Gracilaria spp*., *Hydrilla verticillata*, *Holodule wrightii*, *Myriophyllum spicatum*, *Potamogeton pectinatus*, *P. perfoliatus*, *Ruppia maritima*, *Ulva spp*., and *Zostera marina*,
43	Detritus	

Table 2: Initial parameter estimates for B, P/B, Q/B, P/Q, and EE. Shaded values were estimated by Ecopath.

Compartment Number and Name		B (t/km^2)	P/B (yr^{-1})	Q/B (yr^{-1})	P/Q (yr^{-1})	EE
1	Seabirds	0.0147	0.193	100.635		
2	Dolphins	0.0191	0.040	14.170		
3	Sea turtles	0.0138	0.153	3.500		
4	Sharks	0.0105	0.312	2.931		
5	Rays	2.4017	0.311		0.3	
6	Lizardfish	0.0160	0.655	6.226		
7	Bluefish	0.7780	0.702	3.875		
8	Longnose gar	0.6541	0.257	3.551		
9	Weakfish	0.2661	0.675	3.664		
10	Spotted seatrout	0.1586	1.055	3.664		
11	Red drum	1.2334	0.822	2.762		
12	Kingfish	0.0896	1.024	5.500		
13	Striped Bass	0.1674	1.397	3.792		
14	Hickory Shad	0.1114	0.824	5.822		
15	Southern flounder	0.3616	1.408	3.463		
16	Summer flounder	0.0482	0.752	3.890		
17	Gulf flounder	0.0253	0.949	4.389		
18	Spanish mackerel	0.0739	0.863	5.339		
19	Black drum	0.0852	0.202	2.443		
20	Croaker	2.5322	0.630	5.617		
21	Spot	2.4567	1.149	5.996		
22	Silver perch	0.2061	1.376	8.556		
23	White perch	0.0144	0.386	4.644		
24	Pigfish	0.1030	1.376	5.573		
25	Pinfish	1.9413	0.729	5.021		
26	Striped mullet	0.3017	0.874	15.342		
27	Gizzard shad	0.2965	0.594	11.839		
28	Atlantic menhaden	1.5386	1.104	21.782		
29	Anchovy	2.0425	1.791	15.673		
30	Silversides		2.596	13.029		0.5
31	Penaeid shrimp	1.0770	3.92		0.2	
32	Blue crabs	1.3939	4.000		0.2	
33	Other crabs and shrimp		5.15		0.2	0.9
34	Polychaetes	8.1728	3.76		0.2	
35	Squid	0.0140	5.92		0.3	
36	Mollusks		9.95		0.2	0.9
37	Meiofauna		9.79		0.2	0.9
38	Mysids		5.39		0.2	0.9
39	Ichthyoplankton	0.0122	36.29	176.091		
40	Zooplankton	11.6535	142.809		0.17	
41	Phytoplankton	22.2141	214.621	NA	NA	

Compartment Number and Name		B (t/km^2)	P/B (yr^{-1})	Q/B (yr^{-1})	P/Q (yr^{-1})	EE
42	SAV	99.1649	9.849	NA	NA	
43	Detritus	1342	NA	NA	NA	

Compartment 43: Detritus

Detritus estimates were borrowed from a Core Sound, NC Ecopath model (Deehr 2012). We used estimates of allocthhonous total organic carbon (TOC) in the Pamlico River (Davis et al. 1978) for our estimates of detrital import. We assumed the estimates of allocthhonous TOC from Davis et al. (1978) corresponded only to the riverine portions (Pamlico and Neuse Rivers) or ~ 11% of the model area. The values in both Deehr (2012) and Davis et al. (1978) are in g C/m^2. We used the following ratios to convert g C to g wet weight. For detritus, the carbon to dry weight ratio is 1:2.22 and the dry weight to wet weight ratio is 1:5 (Jorgensen et al. 1991).

Compartment 42: Submerged Aquatic Vegetation

There are 102,791 acres of SAV in Pamlico Sound and the dominant species is eelgrass (NCDEQ 2016). We used biomass estimates (g dry weight/m^2) of leaves and roots and rhizomes measured in NC eelgrass beds (Thayer et al. 1984) to convert area SAV estimates to biomass estimates. We included an extra 10% to our final biomass estimate to account for macroalgae (NCDEQ 2016). We estimated *P/B* from productivity estimates published in Thayer et al. (1984).

We used a conversion ratio of 1:5 to convert dry weight to wet weight (Jorgensen et al. 1991).

Compartment 41: Phytoplankton

We estimated phytoplankton biomass using unpublished chl-a data from two fixed-station monitoring programs conducted by Hans Paerl at UNC-CH Institute of Marine Science in 2012-13. The first monitoring program measured chl-a values at 11 stations in the Neuse River. Samples are taken twice a month from March – October and once a month the remaining months. The second monitoring program samples nine stations monthly, but, not all months were sampled each year. For both monitoring programs, surface and bottom chl-a concentrations (µg/L) were measured using in vitro fluorometry. We used a geometric mean to estimate mean chl-a values for each program. We used a weighted average, based on surface area of the riverine and sound portions of the model area, to produce our final chl-a estimate.

Phytoplankton *P/B* was estimated using phytoplankton primary productivity data measured in the Neuse River (Christian et al. 1991; Boyer et al. 1993). We calculated production (kt C/km^{2}y) by dividing the mean total mass of carbon fixed by the area of the river segment being sampled (Boyer et al. 1993). We used chl-a (µg/L) measurements to estimate phytoplankton biomass for each river segment (Christian et al. 1993). For each river segment, we divided our phytoplankton production estimates by our biomass estimates to calculate *P/B*. We used a weighted average, based on river segment size, to get our final *P/B* estimate.

We used the following conversions to convert chl-a to phytoplankton biomass. We used a ratio of 1:44.9 for chl-a to C, 1:2.5 for C to dry weight, and 1:5 for dry weight to wet weight (Jorgensen et al. 1991). Chl-a concentrations are volumetric (l). To convert the concentrations to represent area we multiplied by the mean station depth for the Neuse River and Pamlico Sound monitoring programs and the river segment depth for our production data.

Compartment 40: Zooplankton

Zooplankton abundance and species composition were taken from a study in the Neuse River (Kimmel et al. 2015). We used the mean station depth of 4.7 m from the Neuse River phytoplankton monitoring program (H. Paerl, UNC-CH IMS) in our conversions of abundance from number/m^3 to number/m^2. We used mean weights for *Acartia hudsonica* (Durbin et al. 1992), *Oithona nana* (Williams and Muxagata 2006), copepod nauplii (Almeda et al. 2010), rotifers (Dumont et al. 1975), and polychaete larvae (Almeda et al. 2009) to convert abundance to biomass estimates. All weights were given as dry weights and we used the ratio 1:5 to convert dry weight to wet weight (Jorgensen et al. 1991).

We estimated zooplankton *P/B* using zooplankton biomass and production data in Avila et al. (2012). We estimated seasonal *P/B* based on the 90 µm zooplankton samples. We extrapolated seasonal *P/B* to yearly *P/B* and took the mean of the estimates produce our final estimate.

We allowed Ecopath to estimate *Q/B* by setting P/Q to 0.4 (Christensen et al. 2009).

Compartment 39: Ichthyoplankton

We used larval fish abundance estimates from Oregon and Ocracoke Inlets (Hettler and Barker 1993). We used mean station depth of 5 m when converting abundance from number/100 m^3 to number/100 ^{2}. To estimate biomass, we used a larval fish weight of 1455 µg from Meng (1993) and used the a ratio of 1:5 when converting dry weight to wet weight (Jorgensen et al. 1991).

We used *Z* as a proxy for *P/B*. We set *F* = 0 and used a 10-day survival rate (*S*) of 37% for larval American shad (Riley et al. 2012) to estimate *M* using

$$M = -\ln(S).$$

Our estimate of *M* was for a 10-day period and we multiplied our estimate by 36.5 to calculate an annual *M*.

We scaled up estimates of minimum daily food requirement for larval striped bass from Meng (1993) to estimate *Q/B*. Meng (1993) estimated larvae need 2.06 Joules/day to grow and support metabolism which is the equivalent of 73 copepod nauplii. Using a mean copepod nauplii weight of 6.22E-07 g (Almeda et al. 2010) we estimated a daily food consumption of 4.54E-05 g per larvae which scaled up to a *Q/B* of 176.09.

Compartment 38: Mysids

Biomass was estimated by Ecopath by setting *EE* = 0.9. Mysids are an important prey to several predators in Pamlico Sound (Binion-Rock et al. Chapter 2) and we feel a high *EE* is justified.

P/B was estimated by taking the mean of secondary production values (Table 3) measured in field-collected mysids from estuarine environments in the Netherlands (Mees et al. 1994), Portugal (Azeiteiro et al. 1999; Azeiteiro et al. 2001), Japan (Yamada et al. 2007), New Zealand (Lill et al. 2012), and Australia (Fenton 1996). Both Fenton (1996) and Yamada et al. (2007) calculated secondary production using multiple methods (e.g. size-frequency, empirical model, Petrovich method). We used the production estimates using the size-frequency method because it was the most commonly-used method in all of the studies.

Q/B was estimated by Ecopath by setting P/Q = 0.2.

We used food habits data from Lehitiemi and Nordstrom (2008), Vilas et al. (2008), Barz and Hirche (2009), and Carrasco and Perissinotto (2010) to develop our diet composition for mysids.

Table 3: Mysid secondary production values used in our estimate of *P/B*.

Species	P:B	Source
Anisomysis mixta	7.54	Fenton 1996
Mesopodopsis slabberi	2.57	Azeiteiro et al. 1999
Mesopodopsis slabberi	9.32	Azeiteiro et al. 2001
Neomysis awatschensis	5.23	Yamada et al. 2007
Neomysis czerniawskii	4.13	Yamada et al. 2007
Neomysis mirabilis	3.54	Yamada et al. 2007
Paramesopodopsis rufa	5.43	Fenton 1996
Tenagomysis tasmaniae	5.36	Fenton 1996

Compartment 37: Meiofauna

This compartment contains amphipods, ostracods, nematodes, and oligochaetes. Biomass was estimated by Ecopath by setting *EE* = 0.9.

We estimated *P/B* by taking the mean of secondary production estimates (Table 4) calculated for amphipods (Möller etal. 1985; Fredette et al. 1990; Franz and Tanacredi 1992; Cunha et al. 2000; Jeong et al. 2006; Jeong et al. 2009), isopods (Fredette et al. 1990), and ostracods (Möller et al. 1985).

We estimated *Q/B* in Ecopath by setting P/Q = 0.2.

We synthesized diet information from Thayer et al. (1978), Guerra-García and Tierno de Figueroa (2009), Douglass et al. (2011), and Jeong et al. (2012) to create the diet composition for this compartment.

Table 4: Meiofauna secondary production values used to estimate *P/B*.

Species	*P/B*	Source
Ampelisca abdita	3.53	Franz and Tanacredi 1992
Ampelisca abdita	4.16	Franz and Tanacredi 1992
Ampelisca abdita	3.72	Franz and Tanacredi 1992
Gammarus mucronatus	23.6	Fredette et al. 1990
Jassa slatteryi	5.21	Jeong et al. 2006
Gammaropsis japonicus	6.74	Jeong et al. 2009
Corophium volutator	11.3	Möller et al. 1985
Corophium multisetosum	10.14	Cunha et al. 2000
Erichsonella attenuata	18.8	Fredette et al. 1990
Edotia triloba	10.8	Fredette et al. 1990
Idotea balthica	9.5	Fredette et al. 1990
Ostracoda	10	Möller et al. 1985

Compartment 36: Mollusks

This compartment contains bivalves and gastropods. Bivalves *Macoma balthica* and *M. mitchelli* and gastropods in the family Acteonidae are some of the more common species in Pamlico Sound (Luettich et al. 2000). Mollusk biomass was estimated in Ecopath by setting *EE* = 0.9.

P/B was estimated by taking the mean of secondary production values (Table 5) from Möeller et al. (1985) and Fredette et al. (1990).

We estimated *Q/B* in Ecopath by setting P/Q = 0.2.

We aggregated the diets of oyster, clam, and predatory gastropod compartments from a Neuse River Ecopath model (Christian et al. 2003) to form the diet composition for our mollusk compartment. We used weighted averages based on the compartment biomass when combining the diets of the Neuse River model oysters, clams, and predatory gastropods.

Table 5: Bivalve and Gastropod secondary production values used to estimate Mollusk *P/B*.

Species	*P/B*	Source
Bittium varium	3.2	Fredette et al. 1990
Cardium edule	19.6	Möller et al. 1985
Gemma gemma	5.6	Fredette et al. 1990
Mya arenaria	11.4	Möller et al. 1985

Compartment 35: Squid

Our squid compartment includes Atlantic brief squid and longfin inshore squid. We used trawl survey data (P195) from NCDMF to estimate squid biomass. P195 is a stratified random trawl survey sampling 54 stations in June and September (Rock 2009) throughout the entire Pamlico Sound region. We estimated the mean squid catch (kg) per tow using a delta-generalized linear model (GLM; Lo et al. 1992) with a lognormal error distribution (Dick 2004). Delta-glm is a two part model. This first part is a binomial model which estimates the probability of a species being caught in each strata. The second part only includes positive catches and estimates the mean catch of the species in each strata. The two estimates are then multiplied together to produce the estimate of mean catch for all samples (including zeroes) in each strata. We used weighted averages, based on strata size, to calculate our final estimate of mean catch. We included bottom water temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) as covariates when estimating mean catch. We extrapolated our estimate of mean catch using the area swept method and assumed a gear efficiency of 0.1 (Walker et al. 2017).

We used *Z* as a proxy for *P/B*. Squid landings in Pamlico Sound are small (A. Bianci, NCDMF) and we assumed a low *F* of 0.2. We estimated *M* by extrapolating a weekly *M* estimate of 0.11 (NEFSC 2011) for longfin inshore squid to an annual *M*.

We estimated *Q/B* in Ecopath by setting P/Q = 0.3 (Trites 2003).

We based the diets of our squid compartment on food habits from Martins and Perez (2007).

Compartment 34: Polychaetes

Over 100 species of polychaetes have been identified in Pamlico Sound and species from the families Capitellidae and Spoinidae are among the most abundant (Luettich et al. 2000; NBID 2018). We used polychaete abundance data from Pamlico Sound that were collected as part of the Environmental Quality of Estuaries in the Carolinian Province study conducted from 1993 – 1997. Data from this study are available from the National Benthic Infaunal Database (NBID; https://nbi.noaa.gov/default.aspx). We converted abundance to biomass using mean polychaete weights from Qu et al. (2015).

To estimate *P/B*, we used the mean of secondary production estimates (Table 6) from Möller et al. (1985), Seitz and Schaffner (1995), Sardá et al. (2000), and Thompson and Schaffner (2001).

We estimated *Q/B* in Ecopath by setting P/Q = 0.2.

We borrowed diet data from the Neuse River Ecopath model (Christian et al. 2003) to develop our polychaete diet composition. We aggregated the diets of the deposit feeding polychaete and predatory polychaete compartments using weighted averages based on their compartment biomass.

Table 6: Secondary production values used to estimate Polychaete *P/B*.

Species	*P/B*	Source
Chaetopterus variopedatus	2.4	Thompson and Schaffner 2001
Leitoscoloplos fragilis	7.9	Sardá et al. 2000
Leitoscoloplos fragilis	0.9	Sardá et al. 2000
Liomia medusa	3.0	Seitz and Schaffner 1995
Nereis diversicolor	4.3	Sardá et al. 2000
Nereis diversicolor	3.9	Sardá et al. 2000
Nereis spp.	2.7	Möller et al. 1985
Owenia fusiformis	6.28	Sardá et al. 2000
Owenia fusiformis	2.93	Sardá et al. 2000

Compartment 33: Other Crabs and Shrimp

This compartment is an aggregation of a variety of crabs and shrimp including mantis shrimp, grass shrimp, pea crab, porcelain crabs, mole crabs, and mud crabs that are not economically important in Pamlico Sound, but are ecologically important. We estimated the biomass for this compartment in Ecopath by setting *EE* = 0.9.

P/B was estimated by taking the mean of secondary production values (Table 7) from Möller et al. (1985) and Fredette et al. (1990).

We estimated *Q/B* in Ecopath by setting P/Q = 0.2 (Trites 2003).

The diet matrix for this compartment is based on used food habits for *Crangon spp.* (Möller et al. 1985; Antonio et al. 2011; Douglass et al. 2011), *Carcinus maenas* (Möller et al. 1985), and *Palaemonetes spp.* (Anderson 1985; Douglass et al. 2011).

Table 7: Secondary production values used to estimate *P/B* for Other Crabs and Shrimp.

Species	*P/B*	Source
Palaemontes vulgaris	3.5	Fredette et al. 1990
Crangon septemspinosa	5.0	Fredette et al. 1990
Crangon crangon	5.4	Möller et al. 1985
Carcinus maenas	6.7	Möller et al. 1985

Compartment 32: Blue Crabs

Blue crabs support one of the largest commercial fisheries in North Carolina in terms of both total landings and value (NCDMF 2018a). We used population estimates from a recently completed blue crab stock assessment (NCDMF 2018b) to estimate biomass. The population is divided into two size classes, recruits and fully-recruited. To convert abundance to biomass we assumed that 5 recruits have a biomass of 1 pound and 3 fully-recruited crabs is the equivalent of 1 pound. The stock unit for blue crabs includes all crabs in estuarine and coastal NC waters. To delineate the proportion of the stock inhabiting Pamlico Sound, we made the assumption that landings are proportional to biomass. In 2012 and 2013, 20% of NC blue crab landings were from Pamlico Sound and we assumed that 20% of the stock resided in Pamlico Sound.

We used a *P/B* value of 4.0 that was estimated by Fredette et al. (1990) using the size-frequency method on field-collected blue crabs in Chesapeake Bay.

Q/B was estimated in Ecopath by setting P/Q = 0.2 (Trites 2003).

We synthesized food habits data from Laughlin (1982), Hill et al. (1989), Hines et al. (1990); Hsueh et al. (1992), and Douglass et al. (2011) to create the diet composition for blue crabs in our model. We set a small portion of the diet (5%) as cannibalism since it has been observed multiple studies (Laughlin 1982; Hines et al. 1990; and Hsueh et al. 1992).

We estimated biomass accumulation rate by estimating the mean rate of population change (lambda) for 2012 and 2013.

Compartment 31: Penaeid Shrimp

Penaeid shrimp is one of the largest commercial fisheries in North Carolina in both landings and value (NCDMF 2018a). This compartment includes three species of penaeid shrimp: white, pink, and brown. We assumed that catch is proportional to biomass and estimated biomass as

$$B = {}^{C}/_{F}$$

where *C* is landings (A. Bianchi, NCDMF) and *F* is the instantaneous fishing mortality rate (Hart 2015).

We used *Z* as a proxy for *P/B*. We estimated an annual *M* of 3.65 by extrapolating a daily *M* estimate of 0.01 (Laney and Copeland 1981 in Mace and Rozas 2015). We used an *F* of 0.27 from Hart (2015).

We estimated *Q/B* in Ecopath by setting P/Q = 0.2 (Trites 2003).

The diet composition of our penaeid shrimp compartment was based on food habits from Muncy (1984), Hunter and Feller (1987), and Schwamborn and Criales (2000). We included a low-level of cannibalism (2%) because cannibalism was prevalent in the Muncy (1984) study, but not in Hunter and Feller (1987) and Schwamborn and Criales (2000).

Compartments 6 – 30: Fishes

We have included 25 fish compartments in our model (Table 1). The majority of these compartments are single-species compartments, however, there are three multispecies compartments: kingfish, anchovy, and silversides. Kingfish includes both northern and southern kingfish, but southern kingfish are the more dominant species in Pamlico Sound. Bay and striped anchovy are both included in the anchovy compartment, and the silversides compartment includes Atlantic, inland, and rough silversides.

Biomass was estimated using data from three NCDMF surveys (P120, P195, and P915) for all compartments except Spanish mackerel and silversides. Sixty-eight near-shore sites in Pamlico Sound are sampled in May and June with a subset of stations are also sampled in July (West et al. 2009). P120 survey data was only used for our estimates of anchovy biomass. In P120, the catch is only enumerated, not weighed, so the number of anchovies caught per tow was modeled. The mean individual weight of anchovies from P195 was used to convert P120 abundance estimates to biomass estimates. P195 is a stratified random trawl survey sampling 54 stations in June and September (Rock 2009) throughout the entire Pamlico Sound region. P915 is a stratified random gill net survey sampling the near-shore areas of Pamlico Sound. Sampling is conducted from mid-February – mid December (Paramore et al. 2009). We modeled catch weight (kg) for P195 and P915.

For each survey, we estimated the mean catch (kg) for each species using a delta-generalized linear model (Lo et al. 1992) with a lognormal error distribution (Dick 2004). Delta-glm is a two part model. This first part is a binomial model which estimates the probability of a species being caught in each strata (P195 and P915) or year (P120). The second part only includes positive catches and estimates the mean catch (kg) of the species in each strata or year.

The two estimates are then multiplied together to produce the estimate of mean catch for all samples (including zeroes) in each strata or year. For P195 and P915, we used weighted averages, based on strata size, to produce our final estimate of mean catch and used an arithmetic mean for P120. We included bottom water temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) as covariates when estimating mean catch.

We extrapolated our estimate of mean catch for P120 and P195 using the area swept method and assumed gear efficiencies between 0.1 – 0.3 (Walker et al. 2017). Since gill nets are a passive gear, it is difficult to estimate the "area fished" by a gill net. We estimated biomass from P915 mean catch estimates by scaling to biomass estimates for spotted seatrout from a single-species stock assessment (NCDMF SSPDT 2015). The stock unit for spotted seatrout consists of all fish in North Carolina and Virginia waters. Based on tagging and telemetry studies, it is believed that the proportion of the spotted seatrout stock inhabiting Pamlico Sound ranges between 50 – 75% (T. Ellis, Albemarle-Pamlico National Estuary Partnership). Pamlico Sound is responsible for 32% of the Spotted Seatrout landings, so we used the low end of the range estimate, 50%, to apportion spotted seatrout biomass to Pamlico Sound.

Both Spanish mackerel and silversides are sampled in NCDMF surveys, however, the data were not usable. Spanish mackerel are caught in P915, however, their oily flesh causes them to spoil quickly and the majority are not able to be sampled for weights. We estimated Spanish mackerel biomass using

$$B = {}^{C}/_{F}$$

which assumes catch (C) is proportional to biomass. We set F = 0.36 which the geometric mean for F from 2009 – 2011 and is the most recent F estimate available (SEDAR 2012). Large numbers of silversides are caught in P120 but they are not weighed or enumerated so we used

Ecopath to estimate the biomass for Silversides by setting *EE* = 0.5. We used a value of 0.5 because silversides are not heavily consumed in Pamlico Sound (Binion-Rock Chapter 2)

For all compartments, we used *Z* as a proxy for *P/B*. We estimated *M* using an updated Hoenig estimator (Then et al. 2015). *M* is calculated as

$$M = 4.899(t_{max})^{-0.916}$$

where t_{max} is maximum age in years. Thirteen of these compartments are sampled by NCDMF for age and growth data (P930) and we used the oldest observed age by NCDMF as t_{max}. For the remaining compartments we used values of t_{max} from Fishbase (Frose and Pauly 2018), published literature (Nelson 2002; Harris et al. 2007; Grammer et al. 2009; Then et al. 2015; Smylie et al. 2016), and theses (Jeffers 2007: Table 8). When available, *F* was taken from the most recent stock assessment for species that are harvested (Table 8). No *F* estimates are available for Kingfish and Spot, so we assumed *F* = 0.2.

Table 8. Ages and sources for t_{max}, estimates of M using the updated Hoenig estimator described in Then et al. (2015), and values and sources for F. Compartments of F with values listed as . were assumed to be 0.

Compartment Number and Name		t_{max}	t_{max} Source	M	F	F source
6	Lizardfish	9	Jeffers 2007	0.655	.	
7	Bluefish	11	NCDMF P930	0.545	0.157	Celestino et al. 2015
8	Longnose gar	25	Smylie et al. 2016	0.257	.	
9	Weakfish	15	NCDMF P930	0.410	0.265	ASMFC 2016
10	Spotted seatrout	9	NCDMF P930	0.655	0.4	NCDMF SSPDT 2015
11	Red drum	62	NCDMF P930	0.112	0.71	NCDMF RDFMPAC 2001
12	Kingfish	7	NCDMF P930	0.824	0.2	Assumed
13	Striped bass	13	NCDMF P930	0.467	0.93	NCDMF and NCWRC 2004
14	Hickory shad	7	Harris et al. 2007	0.824	.	
15	Southern flounder	9	NCDMF P930	0.655	0.753	NCDMF 2013
16	Summer flounder	18	NCDMF P930	0.347	0.405	NMFS NEFSC 2015
17	Gulf flounder	6	NCDMF P930	0.949	.	
18	Spanish mackerel	12	NCDMF P930	0.503	.	
19	Black drum	43	Frose and Pauly 2018	0.156	0.046	ASMFC 2015
20	Croaker	15	NCDMF P930	0.410	0.22	ASMFC 2010
21	Spot	6	NCDMF P930	0.949	.	
22	Silver perch	4	Grammer et al. 2009	1.376	.	
23	White perch	16	Frose and Pauly 2018	0.386	.	
24	Pigfish	4	Frose and Pauly 2018	1.376	.	
25	Pinfish	8	Nelson 2002	0.729	.	
26	Striped mullet	14	NCDMF P930	0.437	0.437	NCDMF 2015
27	Gizzard shad	10	Frose and Pauly 2018	0.594	.	
28	Atlantic menhaden	10	Then et al. 2015	0.594	0.51	Schueller et al. 2017
29	Anchovy	3	Then et al. 2015	1.791	.	
30	Silversides	2	Frose and Pauly 2018	2.596	.	

For all fish compartments, we estimated *Q/B* using the empirical relationship developed by Palomares and Pauly (1998) and defined as

$$log_{10}\left(\frac{Q}{B}\right) = 7.964 - 0.204log_{10}(W_\infty) + 1.965T + 0.083A + 0.0532h + 0.398d$$

where W_∞ is the asymptotic fish body weight in grams, T is mean annual water temperature in Kelvin (K), and A is the caudal fin aspect ratio (tail height/area)^2. Values of $h = 1$ indicates the species is an herbivore and values of $d = 1$ indicates the species is a detritivore, while values of 0 for both h and d indicates carnivorous feeding. The mean water temperature for Pamlico Sound was 3.42 K during 2012-13.

Values for W_∞ were estimated using two approaches. For species with both weight and age data available from NCDMF P930, we estimated W_∞ using the weight parameterization of the von Bertalanffy growth equation

$$W_t = \left(W_\infty\left(1 - e^{-K(t-t_0)}\right)\right)^b$$

where K is the Brody growth rate coefficient with year as units, t is age in years, t_0 is the age when the average weight is 0, and b is the allometric relation term from the length weight relationship

$$W = aL^b.$$

When we were unable to estimate W_∞ using a von Bertalanffy, we used the maximum observed weight (W_{max}) to estimate W_∞ as

$$W_{max} = W_\infty * 0.95.$$

If NCDMF surveys sampled the full size distribution of a species, we used the largest sampled fish as W_{max}. For the remaining species, W_{max} values were borrowed from the literature (Conover and Ross, 1982; Newberger and Houde 1995) and Fishbase Frose and Pauly 2018; Table 9).

When available, we used species-specific values of *A* from Fishbase (Frose and Pauly 2018; Table 9), however, for most species, this information is not available. For these species, we used default values, based on caudal fin shape (lunate = 6.55, forked = 1.9, and heterocercal = 1.63) from the life history table in Fishbase. The default values are based on 125 species records and represent the median values for each fin shape. For five caudal fin shapes (emarginate, truncate, round, pointed, and double emarginate), no information is available and we used the default *A* value of 1.32 provided by Fishbase (Frose and Pauly 2018).

Table 9: Input parameters for *Q/B* estimates. W_∞ values with an * were estimated using the weight parameterization of the von Bertalanffy growth equation and with a ^ were taken from Fishbase (Frose and Pauly 2018). All other W_∞ were estimated from W_{max}.

Compartment Number & Name		W_∞ (kg)	Source	*A*	h	d
6	Lizardfish	0.95	Frose and Pauly 2018	1.9	0	0
7	Bluefish*	17.75	NCDMF	2.547	0	0
8	Longnose Gar	8.63	NCDMF	1.32	0	0
9	Weakfish	7.40	NCDMF	1.32	0	0
10	Spotted Seatrout	7.4	NCDMF	1.32	0	0
11	Red Drum	29.58	NCDMF	1.32	0	0
12	Kingfish	1.01	NCDMF	1.32	0	0
13	Striped Bass	15.79	NCDMF	2.309	0	0
14	Hickory Shad	1.32	NCDMF	1.9	0	0
15	Southern Flounder	9.76	NCDMF	1.32	0	0
16	Summer Flounder*	5.52	NCDMF	1.32	0	0
17	Gulf Flounder	3.05	NCDMF	1.32	0	0
18	Spanish Mackerel	1.17	NCDMF	1.32	0	0
19	Black Drum	54.00	Frose and Pauly 2018	1.32	0	0
20	Atlantic Croaker*	0.91	NCDMF	1.32	0	0
21	Spot	0.71	NCDMF	1.388	0	0
22	Silver Perch	0.12	NCDMF	1.32	0	0
23	White Perch	2.32	Frose and Pauly 2018	1.32	0	0
24	Pigfish	0.95	Frose and Pauly 2018	1.32	0	0
25	Pinfish	1.58	Frose and Pauly 2018	1.32	0	0
26	Striped Mullet*	1.87	NCDMF	2.55	0	1
27	Gizzard Shad	2.11	Frose and Pauly 2018	1.32	0	1
28	Atlantic Menhaden^	1.22	Frose and Pauly 2018	2.31	1	0
29	Anchovy	0.01	Newberger and Houde 1995	1.32	0	0
30	Silversides	0.01	Connover and Ross 1982	1.32	0	0

Diet data for 20 of the fish compartments were taken from Binion-Rock (Chapter 2). This food habits study was designed to support the development of a Pamlico Sound Ecopath model and sampled predators from P915 and P195 for stomach contents. The diet compositions for each predator were estimated separately for each survey. When combining the predator diets, we weighted the diets by the proportion of the biomass estimated from each survey. Diet compositions for striped mullet, gizzard shad, Atlantic menhaden, anchovy, and silversides were borrowed from the literature (Table 10). Prey contributing < 1% to a predator's diet were not include in our diet compositions.

Table 10: Diet sources for fish compartments. Diets for compartments not listed are based on food habits data from Binion-Rock (Chapter 2).

Compartment Number and Name		Source(s)
26	Striped Mullet	Collins 1985; Eggold and Mota 1992
27	Gizzard Shad	Yako et al. 1996; Schaus et al. 2002
28	Atlantic Menhaden	Lewis and Peters 1994; Hart 2008
29	Anchovy	Hartman et al. 2004
30	Silversides	Cardigan and Fell 1985; Warkentine and Rachline 1989

Compartment 5: Rays

This compartment contains 5 species of rays: Atlantic stingray, cownose ray, smooth butterfly ray, southern stingray and spiny stingrays. Biomass was estimated using data from two NCDMF fisheries-independent surveys: P915 and P195. P915 is a stratified-random gill net survey conducted from mid-February – mid-December. P195 is a stratified-random trawl survey conducted in June and September. P915 samples the near shore areas of Pamlico Sound, while P195 samples the entire Pamlico Sound area. For both surveys, we estimated the mean catch (kg) for each species using a delta-generalized linear model (GLM; Lo et al. 1992) with a lognormal error distribution (Dick 2004). Delta-glm is a two part model. This first model is a binomial model which estimates the probability of the species being caught in each strata. The second model only includes positive catches and estimates the mean catch (kg) of the species in each strata. The two estimates are then multiplied together to produce the estimate of mean catch for all samples in each strata. We used a weighted average, based on strata size, to estimate mean catch for all of Pamlico Sound.

We used *Z* as a proxy for *P/B*. We estimated *M* using an updated Hoenig estimator (Then et al. 2015). *M* is calculated as

$$M = 4.899(t_{max})^{-0.916}$$

where t_{max} is maximum age in years (Table 6). While rays are caught as bycatch (J. Boyd, NCDMF; K. Brown, NCDMF), there is no direct harvest for rays in Pamlico Sound and used $F = 0$ for all species. We weighted the species estimates of *M* by biomass to calculate our final compartment-level *P/B*.

Q/B was estimated by Ecopath by setting P/Q to 0.3 (Trites 2003).

We used food habits data from Core Sound, NC (Hart 2008) and Chesapeake Bay (Smith and Merriner 1985; Buchheister and Latour 2015) to characterize the diet composition of rays. We excluded prey contributing < 1% to an individual species' diet. Species diets were weighted by biomass when we aggregated their diets into a single diet composition.

Compartment 4: Sharks

Six species of sharks: blacktip, bonnethead, bull, sandbar, smooth dogfish, and spiny dogfish, are included in this compartment. We made the assumption that catch (C) is proportional to biomass and estimated biomass as

$$B = {}^{C}/_{F}.$$

Shark landings for Pamlico Sound in 2012-13 were provided by A. Bianchi (NCDMF). We used *F* values of 0.102 for smooth dogfish (SEDAR 2015), 0.11 spiny dogfish (TRAC 2010), and 0.128 for all other sharks (SEDAR 2013).

We used *Z* as our proxy for *P/B*. We used *M* values of 0.232 for smooth dogfish (SEDAR 2015), 0.092 spiny dogfish (TRAC 2010), and 0.233 for all other sharks (SEDAR 2013) and the above *F* values when estimating *Z*.

We estimated *Q/B* using the approach of Palomares and Pauly (1998) where

$$log_{10}\left(\frac{Q}{B}\right) = 7.964 - 0.204log_{10}(W_\infty) + 1.965T + 0.083A + 0.0532h + 0.398d$$

and W_∞ is in grams, *T* is mean annual water temperature in Kelvin, *A* is the caudal fin aspect ratio (tail height/area)^2 values of $h = 1$ indicates the species is an herbivore, and values of $d = 1$ indicates the species is a detritivore. For all species we used values of $h = 0$, $d = 0$ for carnivorous feeding. We used values of W_{max} (Table 11) from Fishbase (Frose and Pauly 2018) to estimate values of W_∞ as

$$W_{max} = W_\infty * 0.95.$$

The mean water temperature for Pamlico Sound was 3.42 K. We used the default value of A = 1.63 for heterocercal tails from Fishbase (Frose and Pauly 2018) when estimating *Q/B*.

We used food habits data from Chesapeake Bay (Buchheister and Latour 2015) and unpublished data from North Carolina (C. Bangley, Smithsonian Environmental Research

Center) to determine the diet composition. We did not include prey species contributing < 1% to a shark species' diet when compiling the final diet composition.

Table 11: Species-specific values of W_{max} (Frose and Pauly 2018) and estimates of *Q/B*.

Common Name	W_{max} (kg)	*Q/B*
Blacktip	122.8	2.169
Bonnethead	10.8	3.561
Bull	316.5	1.788
Sandbar	117.9	2.187
Smooth Dogfish	12.2	3.474
Spiny Dogfish	9.1	3.688

Compartment 3: Sea Turtles

Our sea turtle compartment includes three species: loggerhead, green, and Kemp's ridley. Our biomass estimates are based on aerial surveys conducted by Epperly et al. (1995a) in Pamlico Sound in 1989 – 91 which produced sea turtle density estimated ranging from 0 - 13.32 turtles/100 km^2. We assumed the proportional species composition of pound net bycatch from 1988 – 1992 in Epperly et al. (1995b) was representative of the species composition of sea turtles in Pamlico Sound (Table 12) with loggerheads being the most abundant species. Loggerhead bycatch rates in pound nets has been increasing at a rate of 13% a year (Epperly et al. 2007) and we included this increase to the base density from Epperly et al. (1995a) when estimating biomass. We used mean over-the-curve carapace length (cm) from Epperly et al. (1995b) in our estimates of mean weights for each species. We converted over-the-curve-carapace lengths to straight carapace lengths (Table 12) and then used the length-weight relationship

$$W = aL^b$$

where L is straight carapace length to estimate the mean weight for each species (Wabnitz and Pauly 2008).

We used Z as a proxy for P/B. We used $F = 0$ and converted survival (S) estimates of green turtles (Bjourdal et al. 2003) to M using

$$M = -ln(S)$$

to produce our final estimate of Z.

We used a sea turtle Q/B of 3.5 from Povlina (1984).

We used food habits data from Plotkin et al. (1993), Seney and Musick (2007), and Wallace et al. (2009) for loggerhead, Shaver (1991) and Servis et al. (2015) for Kemp's ridley, and Howell et al. (2016) for green sea turtles. When combining the diets for each species, we

weighted the diets by our biomass estimates for each species to produce the final compartment diet composition.

Table 12: Summary of data used to estimate biomass of sea turtles in Pamlico Sound. The proportion of pound net bycatch and mean over-the-curve carapace lengths (CCL) are from Epperly et al. 1995b. SCL conversion is the equation used to convert CCL to straight carapace length (SCL; Wabnitz and Pauly 2008), and a and b are the parameters for the length-weight equation (Wabnitz and Pauly 2008).

Species	Proportion of Bycatch	CCL (cm)	SCL Conversion	a	b
Loggerhead	0.77	66	SCL = 0.948 * CCL – 1.442	0.000282	2.823
Green	0.13	33	SCL = 0.932 * CCL + 0.369	0.000206	2.895
Kemp's Ridley	0.10	43	SCL = 0.957 * CCL – 0.696	0.000247	2.834

Compartment 2: Dolphins

Bottlenose dolphins are the only marine mammal included in our model. Resident bottlenose dolphins in Pamlico Sound are considered a distinct stock (Northern North Carolina Estuarine System Stock; NNCESS) and the estimated population size is 950 animals (NMFS 2014). Length data from 303 stranded bottlenose dolphins from Pamlico Sound, Core Sound, and the Outer Banks in 2009 – 2017 were used to estimate a mean dolphin total length of 205.18 cm (V. Thayer, NCDMF, unpublished data). This data set included a mixture of both male and female dolphins and all age classes and we feel our estimate is representative of NNCESS. Using the length-weight relationship for bottlenose dolphins in Barco et al. (2016)

$$W = 0.004(L - 196.833)^2 + 1.373L - 168.61$$

where L is total length in cm we estimated a mean weight (W) of 113.39 kg for bottlenose dolphins in Pamlico Sound.

We used Z as a proxy for P/B. We used an estimate of $M = 0.04$ for bottlenose dolphins in Indian River Lagoon, FL (Stolen and Barlow 2003) and calculated F using

$$F = \ln(1 - H)$$

where H is the ratio harvested animals/stock size. Between 2 – 9 NNCESS bottlenose dolphins are killed via fisheries interactions each year (NMFS 2014) resulting in F estimates ranging from 0.002 – 0.010.

We estimated Q/B by extrapolating mean daily ration (R) to an annual time period for the entire population. Our mean daily ration value of 4.40 kg/day was calculated using the method presented in Trites and Heise (1996) where

$$R = 0.1W^{0.8}$$

and W is bottlenose dolphin weight.

The diet composition is based on studies by Mead and Potter (1990) and Gannon and Wapples (2004) and unpublished food habits data from stranded bottlenose dolphins from Pamlico Sound and the Outer Banks from 2011 - 2017 (V. Thayer, NCDMF).

Compartment 1: Seabirds

Pamlico Sound is home to a variety of resident and migratory seabirds (NC Audubon 2010). We did not include non-piscivorous seabirds (e.g. waterfowl) since the focus of our model is to explore piscivorous fish trophic dynamics in Pamlico Sound and the majority of the diets of non-piscivorous seabirds comes from terrestrial sources outside of Pamlico Sound. This compartment includes 20 species of seabirds, representing a variety of terns, gulls, herons, and larger predatory birds.

NC Audubon has conducted bird counts at 25 sites within Pamlico Sound that are identified as important bird areas (NC Audubon 2010). To estimate biomass for our seabird compartment, we used the counts from NC Audubon (2010) as an estimate of the minimum population size of all seabirds in Pamlico Sound except for osprey. For ospry, we used population estimates from (Henny and Noltemeier 1975). Weight ranges for each species were found on the Cornell Lab of Ornithology All About Birds (https://www.allaboutbirds.org/) website. We used the median range value for each species for our initial biomass estimates (Table 13).

We used estimates of *Z* as our proxy for *P/B*. We converted estimates of survival (*S*) to *M* using the equation

$$M = -ln(S).$$

We averaged *S* across years, age classes, and species to get mean estimates of *M* of 0.197 for double-crested cormorants (Seamans et al. 2012), 0.178 for terns (Collins and Doherty, Jr 2006; Palestis and Hines 2015), 0.141 for gulls (Kadlec 1976; Breton et al. 2008; Robertson et al. 2016), 0.256 for osprey (Monti et al. 2015), and 0.310 for egrets (Hafner et al. 1998; Koczur et al. 2017). When averaging *S* across age classes, we assumed that younger age-classes (e.g. 1, 2)

each comprised 10% of the population and used weighted averages to produce the final estimate of *S* (with *F* = 0 for all species).

We estimated *Q/B* by scaling up our estimates of species-specific mean daily food consumption (Nilsson and Nilsson 1976). Mean daily food consumption (R), in grams, is calculated as

$$ln(R) = -0.293 + 0.850 \times ln(W)$$

where W is the weight of the bird in grams. We used a weighted average (by biomass) of our species-specific *Q/B* values to estimate our final compartment-level *Q/B* (Table 13).

We synthesized food habits data from numerous studies (Table 13) to develop the diet composition of our seabird compartment. When aggregating the diets of the individual species into a single seabird compartment diet, we weighted the species' diets by their biomass to give higher influence to larger biomass species. For individual species, we did not include prey contributing < 1% to total predator diet, however, there are prey contributing < 1% to the aggregated seabird compartment diet as the result of combining multiple predator diets. We used diet import to reflect time spent feeding outside of Pamlico Sound due to either migration or feeding on terrestrial (e.g. refuse, reptiles) or oceanic food sources.

Table 13: Species-specific weight ranges (g), biomass (B, mt), mean daily ration (R, g), consumption/biomass (*Q/B*, year^{-1}), and sources of diet information for seabirds included in Ecopath model.

Common Name	Weight Range (g)	B (mt)	R (g)	*Q/B* (yr $^{-1}$)	Diet Source(s)
Bald Eagle	3,000 – 6,000	0.181	977.432	76.723	Mersmann 1989; Buehler 2000
Brown Pelican	2,000 – 5,000	10.479	767.732	80.063	Shields 2014
Double-crested Cormorant	1,200 – 2,500	27.750	446.527	88.099	Withers and Brooks 2004; Dorr et al. 2014
Osprey	1,400 – 2,000	0.411	415.560	89.223	Glass and Watts 2009; Bierregaard et al. 2016
Black Skimmer	212 – 447	0.215	103.022	114.121	Gochfeld and Burger 1994
Caspian Tern	530 – 782	0.021	184.978	102.922	Cuthbert and Wires 1999
Common Tern	93 – 200	0.081	51.727	128.875	Nisbet et al. 2017a
Forster's Tern	130 – 190	0.270	55.751	127.182	McNicholl et al. 2001
Gull-billed Tern	120 – 205	0.005	56.491	126.887	Molina et al. 2014
Least Tern	30 – 45	0.091	16.243	158.103	Thompson et al. 1997
Royal Tern	350 – 450	6.050	121.479	110.850	McGinnis and Emslie 2001; Buckley and Buckley 2002; Liechty et al. 2016
Sandwich Tern	180 – 300	0.760	78.692	119.678	McGinnis and Emslie 2001; Shealer et al. 2016; Liechty et al. 2016
Great Black-backed Gull	1,300 – 2,000	0.396	405.147	89.624	Good 1998
Herring Gull	800 – 1,250	0.705	270.313	96.258	Nisbet et al. 2017b
Laughing Gull	203 – 371	8.093	91.612	116.510	Dosch 1997; Burger 2015
Black-crowned Night Heron	727 – 1,014	0.077	235.264	98.646	Hothem et al. 2010
Great Egret	1,000	0.194	264.699	96.615	Post 2008; McCrimmon Jr. et al. 2011
Little Blue Heron	296 – 412	0.270	109.498	112.900	Niethammer and Kaiser 1983; Rodgers and Smith 2012
Snowy Egret	370	0.155	113.690	112.154	Parson and Master 2000
Tricolored Heron	415	0.330	125.341	110.240	Frederick 2013

Landings and Discards

Five fishing fleets are included in the Pamlico Sound Ecopath Model: gill net, trawl net, pound net, pots, and recreational (Table 14). For the commercial fleets (gill net, trawl net, pots, and recreational) a complete census of landings are recorded through the North Carolina Trip Ticket Program (NCTTP; Bianchi 2017). The NCTTP is mandated through a North Carolina State General Statute and all North Carolina seafood dealers are required to submit monthly trip tickets to NCDMF. We obtained NCTTP landings data for 2012-13 from A. Bianchi, NCDMF. Recreational landings are estimated from the Marine Recreational Information Program (MRIP), mail surveys, and creel surveys conducted by NCDMF (A. Cathey, NCDMF, personal communication). Recreational landings estimates for Pamlico Sound in 2012-13 were provided by A. Cathey and C. Wilson, NCDMF.

Discards from gill net, trawl net, and recreational fishing fleets are included in our model (Table 15). Gill net discards are sampled by NCDMF in Program 466 (P466). We extrapolated observed discards from P466 (J. Boyd, NCDMF) to get an estimate of total gill net discards. We assumed a 0.67 post-release survival rate for fish released alive from gill nets (Smith and Scharf 2011). We estimate trawl net discards, using the catch composition observed in NC estuarine waters in 2012-13 as part of a shrimp otter trawl fishery characterization study (Brown 2015). We assumed a trawl discard mortality rate of 89% for finfish and 20% for crabs (Johnson 2006). Discard estimates from the recreational fleet were provided by A. Cathey and C. Wilson, NCDMF. We assumed a discard mortality rate of 11% for the recreational fishery (Bartholomew and Bohnsack 2005). In Ecopath, there are two potential fates for discards. Discards can either go to detritus or by exported out of the system (Christensen et al. 2008). We had all discards go to detritus in our model.

Table 14: Landings (t/km^2) for the five fishing fleets included in the Pamlico Sound Ecopath model.

Compartment Number and Name		Gill Net	Trawl	Pots	Pound Nets	Recreational
4	Sharks	0.0016				
5	Rays					0.0001
6	Lizardfish					0.0000
7	Bluefish	0.0283			0.0003	0.0077
9	Weakfish	0.0029	0.0001		0.0004	0.0006
10	Spotted seatrout	0.0097			0.0002	0.0350
11	Red drum	0.0055			0.0008	0.0093
12	Kingfish	0.0022	0.0061			0.0007
13	Striped Bass	0.0020				0.0013
14	Hickory Shad	0.0027				
15	Southern flounder	0.0224	0.0007	0.0001	0.0386	0.0079
16	Summer flounder					0.0037
18	Spanish mackerel	0.0243			0.0023	0.0018
19	Black drum	0.0025			0.0014	0.0013
20	Croaker	0.0019			0.0003	0.0024
21	Spot	0.0041	0.0006		0.0001	0.0011
22	Silver perch					0.0001
23	White perch	0.0019				0.0003
24	Pigfish	0.0003				0.0009
25	Pinfish					0.0007
26	Striped mullet	0.0483		0.0001	0.0005	0.0032
28	Atlantic menhaden	0.0105			0.0024	0.0033
31	Penaeid shrimp		0.2908			0.0010
32	Blue crabs	0.0002	0.0025	0.4062		0.0029
35	Squid		0.0002			
36	Mollusks			0.0006		

Table 15: Discard estimates (t/km^2) for the gill net, trawl, and recreational fishing fleets in the Pamlico Sound Ecopath model.

Compartment Number and Name		Gill Net	Trawl	Recreational
1	Seabirds	0.0013		
4	Sharks	0.0033	0.0002	
5	Rays	0.0135	0.0031	
6	Lizardfish	0.000	0.0061	0.0000
7	Bluefish	0.0057	0.0047	0.0010
8	Longnose gar	0.0008		
9	Weakfish	0.0009	0.0265	0.0003
10	Spotted seatrout	0.0012	0.0004	0.0114
11	Red drum	0.0116		0.0102
12	Kingfish	0.0003	0.0044	
13	Striped Bass	0.0008		0.0005
14	Hickory Shad	0.0035		
15	Southern flounder	0.0204	0.0106	0.0000
16	Summer flounder	0.0003	0.0017	
17	Gulf flounder	0.0001	0.0008	
18	Spanish mackerel	0.0005	0.0021	0.0001
19	Black drum	0.0023	0.0002	0.0001
20	Croaker	0.0007	0.4597	0.0009
21	Spot	0.0002	0.1913	0.0002
22	Silver perch	0.0000	0.0025	0.0000
23	White perch	0.0002		0.0000
24	Pigfish	0.0001	0.0051	0.0003
25	Pinfish	0.0000	0.0351	0.0005
26	Striped mullet	0.0009		
27	Gizzard shad	0.0002	0.0001	
28	Atlantic menhaden	0.0007	0.0075	0.0001
29	Anchovy		0.0029	
32	Blue crabs		0.0004	
33	Other crabs and shrimp		0.0013	
35	Squid		0.0094	

Model Balancing

Prior to balancing the model, we established a set of rules to follow when balancing the model. The rules were

1. Keep changes to the diet composition to compartments based on Binion-Rock (Chapter 2) minimal.
2. Do not remove any predator/prey interactions from the diet matrix.
3. When updating biomass estimates, stay within the following limits. For data from P195, stay within the estimates using 0.1-0.3 gear efficiency. For P915, stay within biomass estimates where Pamlico Sound represents 50-75% of the spotted seatrout stock. Also, stay within 2 standard deviations of the estimate of mean catch from the delta-glm analyses.
4. For compartments where abundance estimates were converted to biomass, stay within the known size range for that species when updating biomass.

Seven compartments were considered unbalanced (*EE* > 1) upon initial model construction. The following changes were made to balance the model.

Compartment 1 – Seabirds

To balance the seabirds compartment we recalculated biomass. For our initial estimates, used the median of the size range for each species as the average weight. For our new estimates, we used the value corresponding to 75% of the maximum weight, which increased biomass to 0.017 t/km^2. We also reduced cannibalism from 0.01% to 0.001%.

Compartment 23 – White Perch

Our initial estimate for P/Q was low (0.083), so we updated our *P/B* estimate. Our initial estimate for *P/B* assumed *F* = 0. There are low levels of white perch harvest in Pamlico Sound and we updated *F* to 0.1 to reflect this harvest. We also increased white perch biomass to 0.0386 t/km^2 by recalculating biomass by increasing mean catch by one standard deviation.

Compartment 39 – Ichthyoplankton

Several changes were needed to balance the ichthyoplankton compartment. We recalculated the biomass using only abundance estimates for Oregon Inlet (185.8 fish/100 m^3) instead of the mean abundance for both Oregan and Ocracoke Inlets (154.0 fish/100 m^3; Hettler and Barker 1993). This increased biomass to 0.027 t/km^2. Predation by other crabs and shrimp was reduced to 0.01 (from 0.02). Predation by hickory shad was decreased to 0.005 from 0.01. We increased *P/B* by recalculating *M*. Our initial estimate was based on a 10-day survival estimate of 37% for larval American shad in a medium zooplankton density treatment (Riley et al. 2012). Survival was not significantly different among the treatments, so we recalculated *M* based on mean survival (*S* = 26.5%) for the starved and low zooplankton treatments, giving us an updated *P/B* value of 48.50.

Compartment 28 – Atlantic Menhaden

We increased biomass for Atlantic menhaden by increasing mean catch by one standard deviation and using the biomass value if Pamlico Sound is responsible for 75% of the spotted seatrout stock. This increased our biomass value to 3.862 t/km^2.

Compartment 4 – Sharks

For our initial estimated, we estimated shark biomass as

$$B = {}^{C}/_{F}$$

based on landings from Pamlico Sound. In North Carolina, almost all shark landings (99.5%) are in the Atlantic Ocean (A. Bianchi, NCDMF) and only 0.3% are landed in Pamlico Sound. Pamlico Sound provides habitat for multiple shark species, however, sharks are migratory and move between estuarine and near-shore habitats as well as undergoing long-distance seasonal migrations (Bangley et al. 2018). Since they are highly mobile species, we feel it is reasonable to assume are larger proportion of landed sharks inhabit Pamlico Sound and re-estimated biomass assuming 1% of the catch was from sharks inhabiting Pamlico Sound. Our updated estimate for biomass is 0.032 t/km^2.

Compartment 26 – Striped Mullet

To balance this compartment, we increased our biomass estimate for striped mullet. We scaled our mean catch for striped mullet to our spotted seatrout biomass using the assumption Pamlico Sound accounts for 75% of spotted seatrout biomass instead of 50%. Our final biomass estimate for striped mullet is 0.453 t/km^2.

Compartment 22 – Silver Perch

We updated our biomass estimate for silver perch by increasing our estimate for mean catch by 1 standard deviation. Our final biomass estimate for silver perch is 0.301 t/km^2.

Pre-balance (PREBAL) Diagnostics

A set of guidelines (PREBAL) has been developed (Link 2010) to help identify issues with model structure or data quality. PREBAL diagnostics examine biomass trends across taxa and trophic levels, biomass ratios, vital rates trends across taxa and trophic levels, vital rate ratios, and total production and removals (Link 2010). Below, we present the results of our PREBAL diagnostics and describe any changes made to our input parameters based on these diagnostics. It is important to note these diagnostics were developed for large-scale marine ecosystems but these criteria overall are suitable for smaller ecosystems, such as estuaries.

Biomass Diagnostics

Biomass PREBAL diagnostics examines how biomasses changes across taxa and trophic levels and the ratios of biomasses among compartments. Biomass should span 5-7 orders of magnitude on a $\log_{10}$-scale. The slope, when biomasses ($\log_{10}$) are plotted in order from lowest to highest trophic level should decline ~ 5-10% decline (not including detrital biomass) with only a small number of compartments deviating significantly from the trend line. The biomass ratios are used to identify marine ecosystem functioning. Typically, prey biomass should exceed predator biomass and total biomass at the trophic-level should decrease with increasing-trophic levels and have biomass ratios < 1 (Link 2010).

These diagnostics were met for our Pamlico Sound model. Our biomasses span 6 orders of magnitude and the slope decreases 9% across the trophic levels. The majority of compartments have biomasses close to the trend line and prey biomasses exceeds predator biomass (Fig. 2).

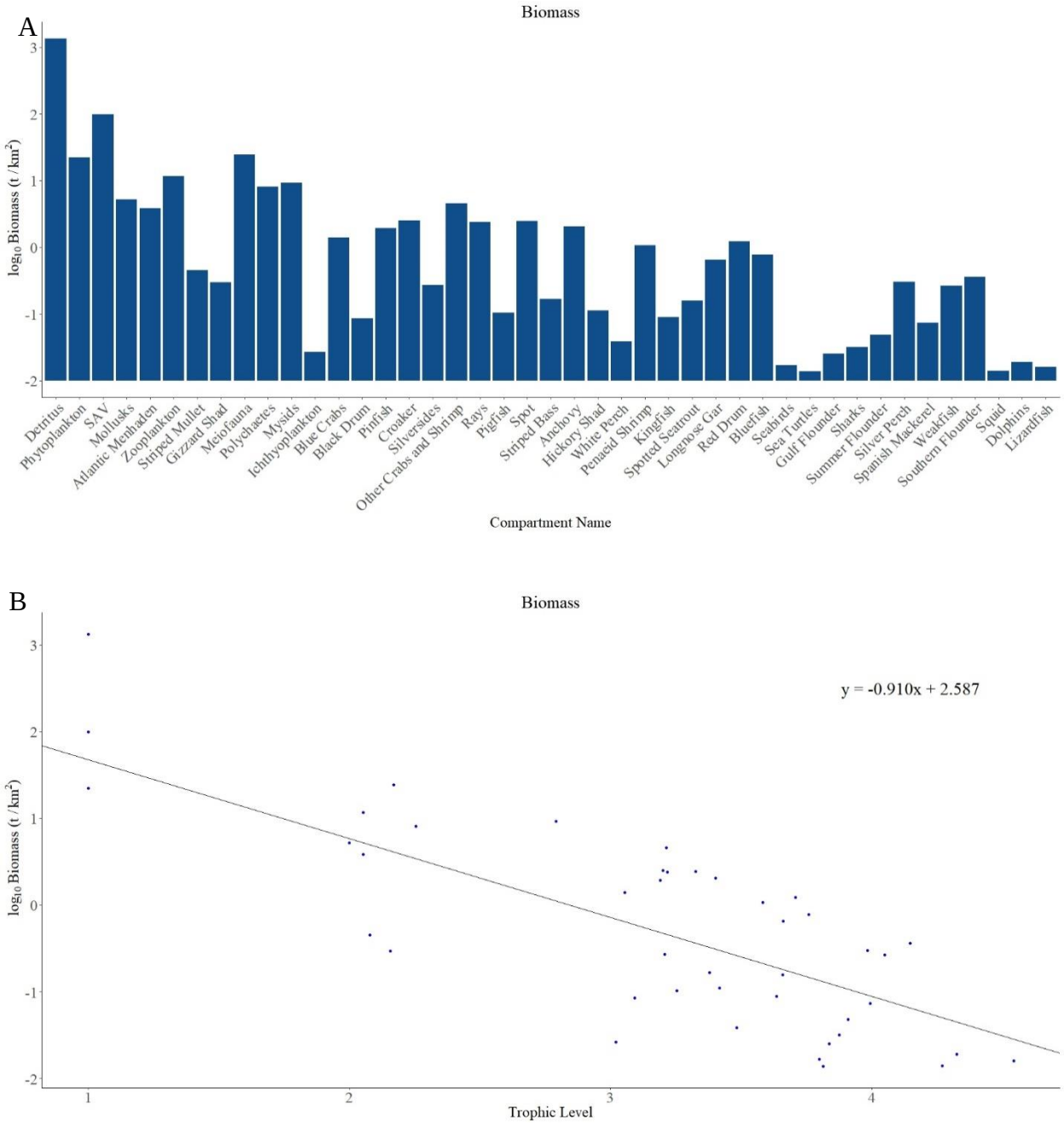


Figure 2: (A) Bar and (B) scatter plot of compartment biomasses ($\log_{10}$ scale) from Pamlico Sound Ecopath model. Compartments are arranged in order of increasing trophic level on the *x*-axis in (A).

Vital Rate Diagnostics

PREBAL vital rate diagnostics examine how vital rates change across trophic levels and also compares the ratios among compartments (Link 2010). The vital rates consumption (Q), production (P), and respiration (R) are closely related to body size and biomass. These vital rates are often presented as ratios to biomass (*Q/B*, *P/B*, and R/B) to scale the rates up to the population level. *P/B* typically follows the same patterns as biomass and declines with increasing trophic level. *Q/B* and R/B for poikilotherms also follow this general pattern while values for homeotherms are larger than those for poikilotherms at the same trophic level. When comparing vital rates among compartments, the vital rate biomass ratios of predators should be smaller than their prey. *P/B* for primary producers should exceed *P/B* for all other compartments. For each compartment, P should be less than Q resulting in a gross efficiency (P/Q) less than 1 (Link 2010).

We identified a few compartments that needed reevaluating after examining our vital rate biomass ratios. Overall, *P/B* ($\log_{10}$ scale) exhibited a general decline with increasing trophic level. Black drum *P/B* was much lower than the overall trend line. We used *Z* as a proxy for black drum *P/B* and our initial estimate of *M* was fairly low ($M = 0.156$) compared to the estimate of *M* (0.820) from the black drum stock assessment (ASMFC 2015). We updated our estimate of *P/B* using *M* from the stock assessment for a new *P/B* estimate of 0.866 which resulted in a better fit along the trend line (Fig. 3).

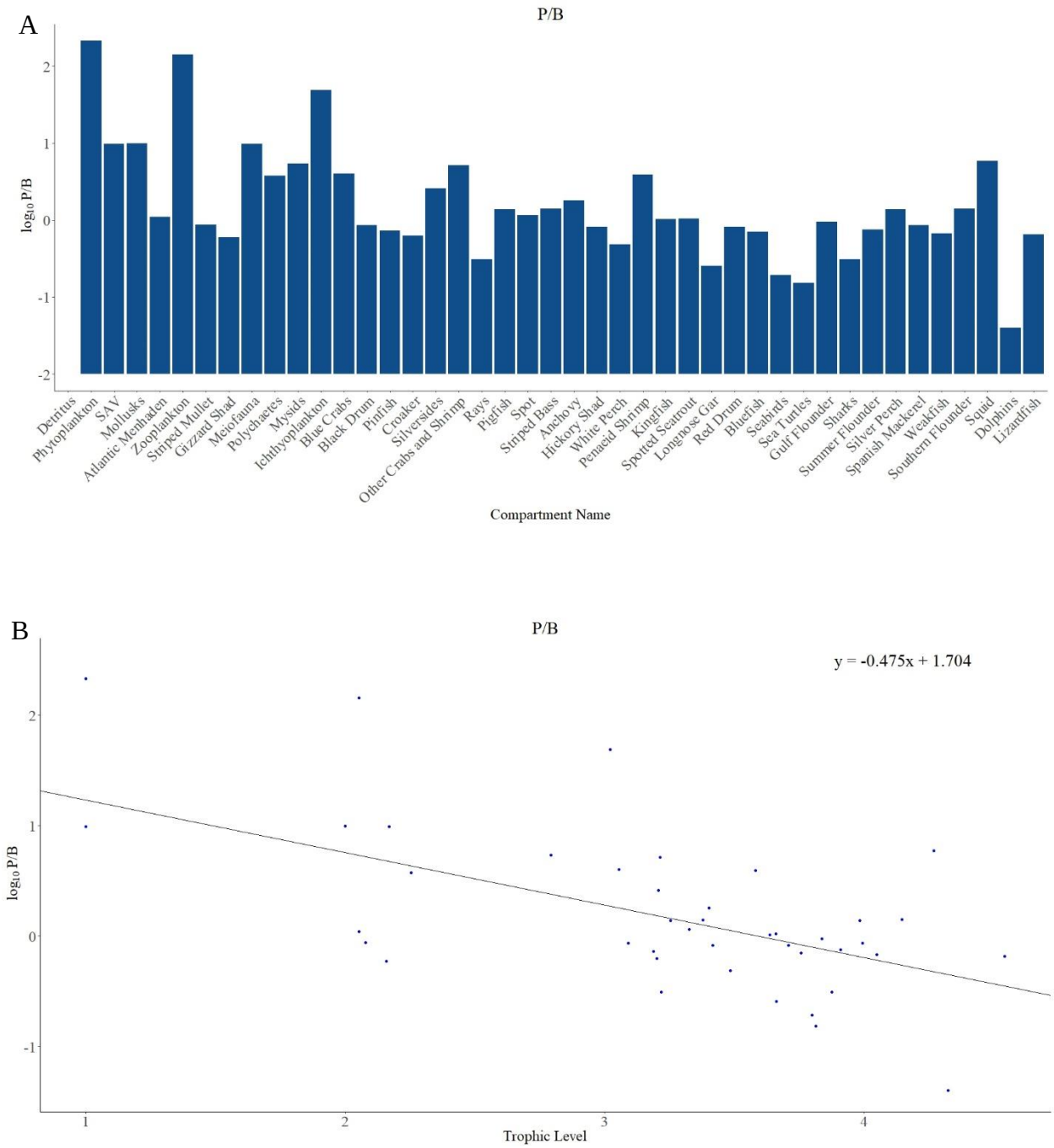


Fig. 3: (A) Bar and (B) scatter plot of $\log_{10}$ *P/B*. Compartment names on the *x*-axis are arranged in order of increasing trophic level in (A).

Our initial estimates for both rays and black drum *Q/B* were low compared to the trend line. We re-estimated ray *Q/B* by setting P/Q to 0.15 instead of our initial value of 0.3 which increased ray *Q/B* to 2.073. We recalculated black drum *Q/B* using the empirical equation of Palomeres and Pauly (1998). We used an and updated estimate of W_{max} using the maximum size observed in Blasina et al (2010) with the length converted to weight using the length-weight relationship developed by Beckman et al. (1990) and our updated value for *Q/B* is 3.666. We also recalculated *Q/B* for Atlantic menhaden. Based on Palomeres and Pauly (1998) we initially categorized Atlantic menhaden as herbivores, however, in Pamlico Sound they rely more heavily on detritus than phytoplankton (Lewis and Peters 1994) so we classified Atlantic menhaden as detritivores. Classifying Atlantic menhaden as detrivores instead of herbivores caused *Q/B* to decrease to 15.999. After making these updates, the trend line seems to fit the data well overall, however, ray *Q/B* still deviates the most of all compartments (Fig. 4).

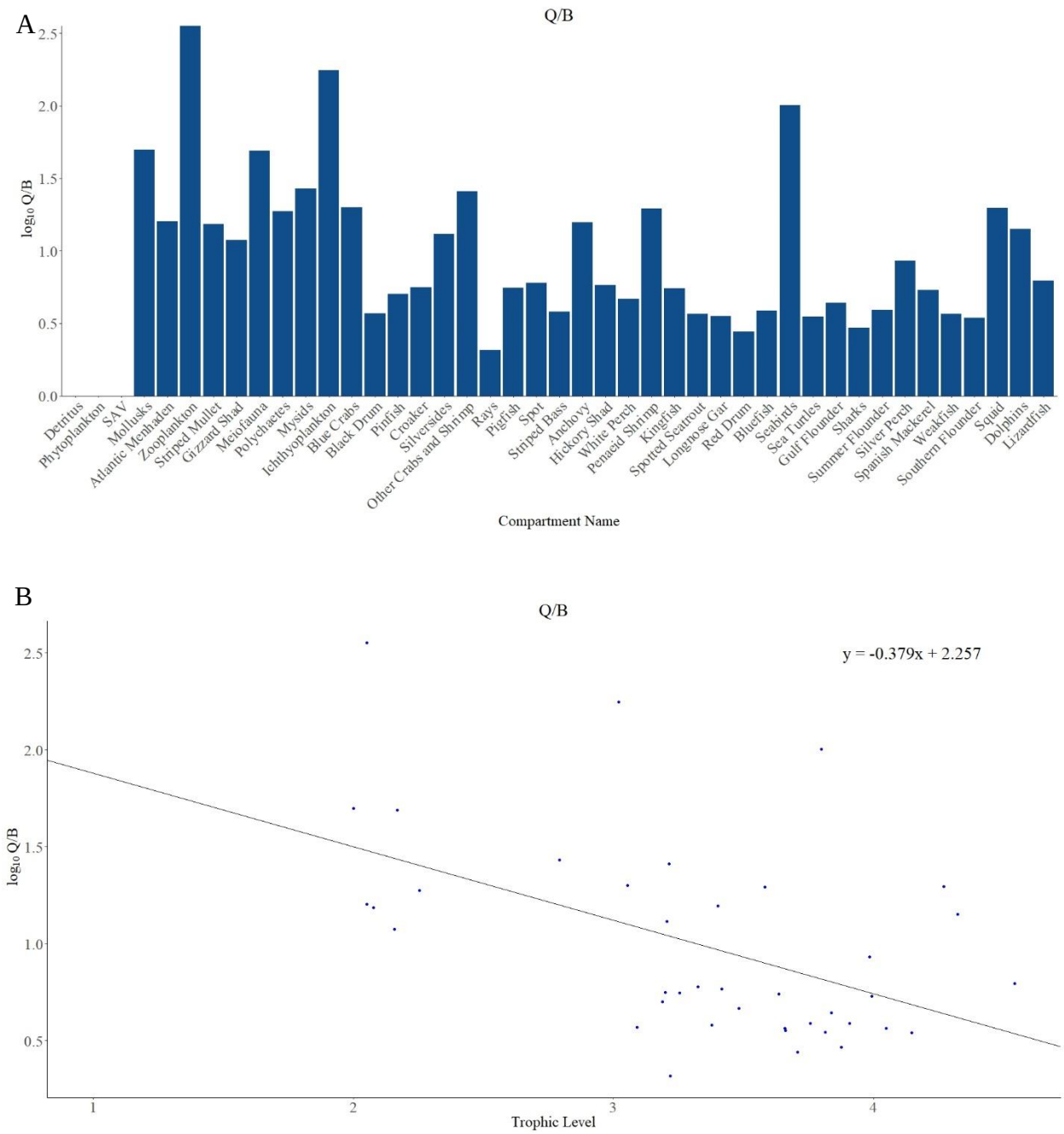


Fig. 4: (A) Bar and (B) scatter plot of $\log_{10}$ *Q/B*. Compartment names on the *x*-axis are arranged in order of increasing trophic level in (A).

Our R/B ($\log_{10}$ scale) values show a general decrease with increasing trophic level for poikilotherms. There is an uptick for squid and lizardfish and values for black drum, rays, striped bass, red drum, and southern flounder are a little low but we think the overall fit to the trend line is satisfactory (Fig. 5).

For all three vital rate to biomass ratios, the values for prey are larger than those of their predators (Figs. 3-5).

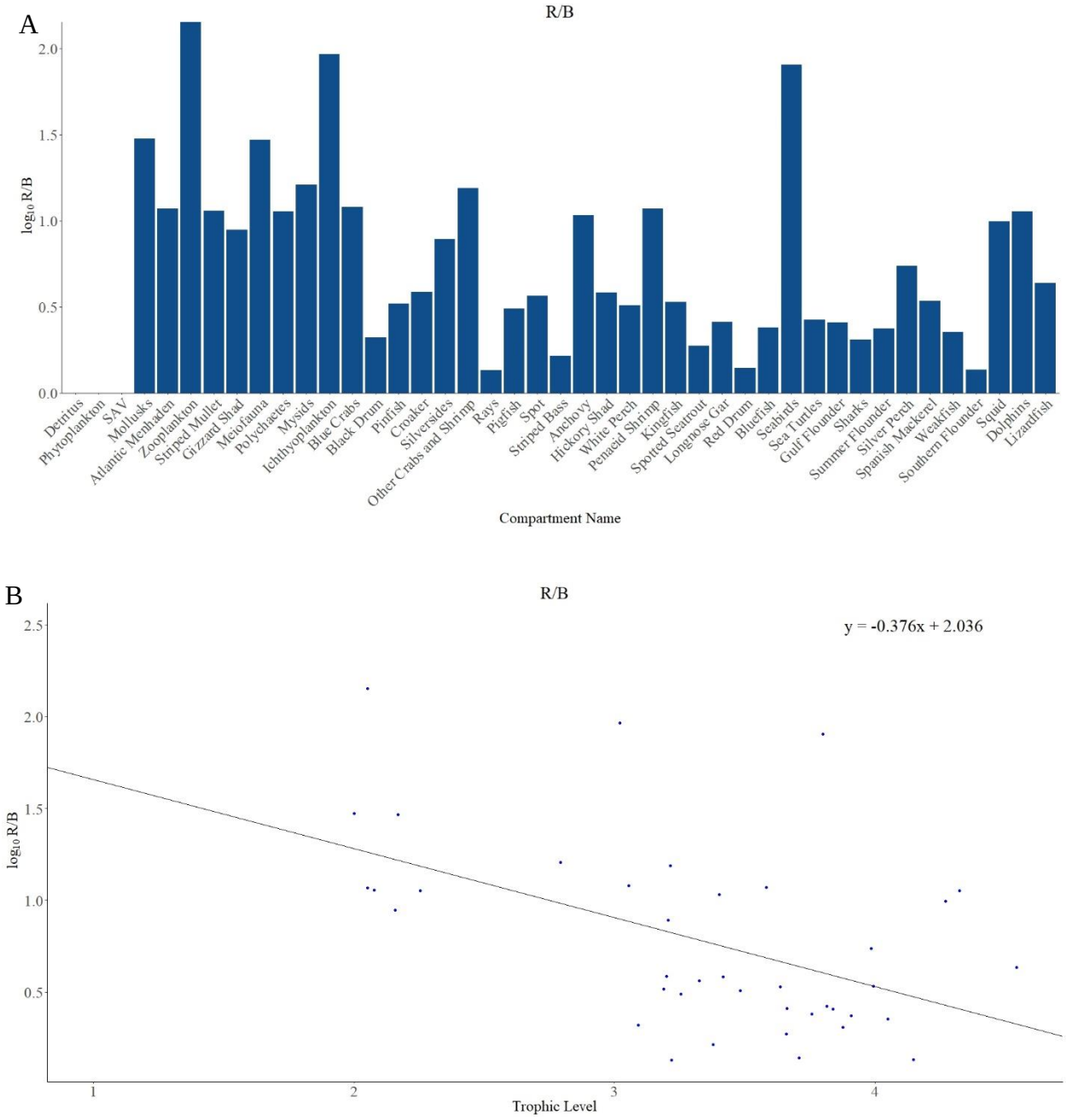


Fig. 5: (A) Bar and (B) scatter plot of $\log_{10}$ R/B. Compartment names are arranged in order of increasing trophic level in (A).

When comparing summed *P/B* for primary producers (phytoplankton and SAV) to other compartments, primary producer *P/B* is larger than all other compartments (Fig 6).

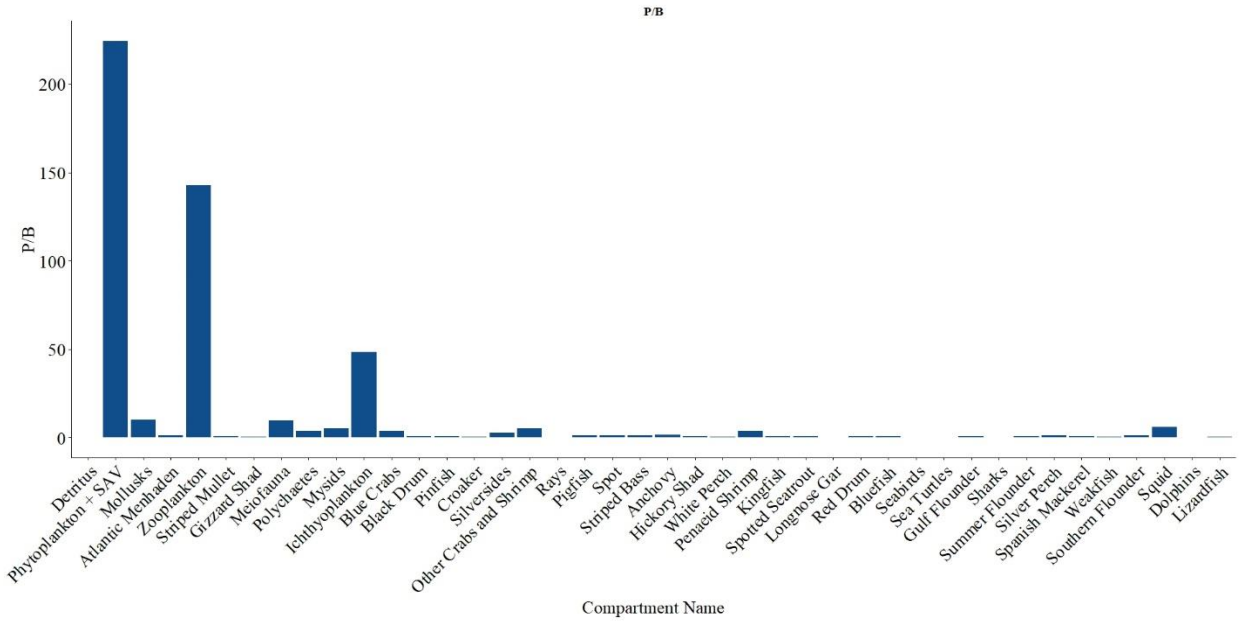


Fig. 6: *P/B* for all compartments with primary productivity (phytoplankton and SAV) *P/B* combined. On the *x*-axis, compartment names are arranged in order of increasing trophic level.

P/Q was less than 1 for all compartments (Fig. 7), which meets the diagnostics criteria in Link (2010).

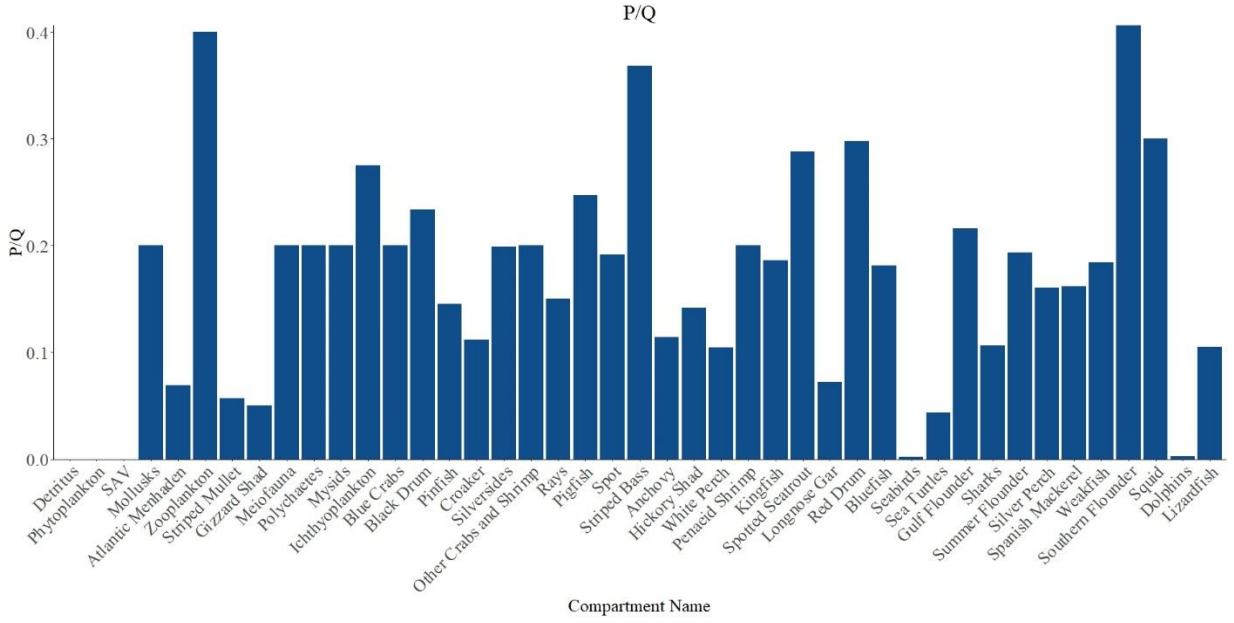


Fig. 7: Bar plot of P/Q values for compartments in the Pamlico Sound Ecopath model. On the *x*-axis, compartment name is arranged in order of increasing trophic level.

Overall, the vital rates in our Pamlico Sound Ecopath model meet the criteria for the majority of the PREBAL diagnostics (Link 2010). However, there is one PREBAL vital rate diagnostic for P/R where there is disagreement. Link (2010) states that P/R should be greater than 1. We do not agree that P/R should exceed 1. P/R is a dimensionless ratio expressing the fate of assimilated food. Mathematically, P/R can be any positive value, but normally it is less than 1 because of thermodynamic constraints (Christensen et al. 2005). For the Pamlico Sound Ecopath model, all of the compartments have P/R values near 1 or less than 1 (Fig. 8).

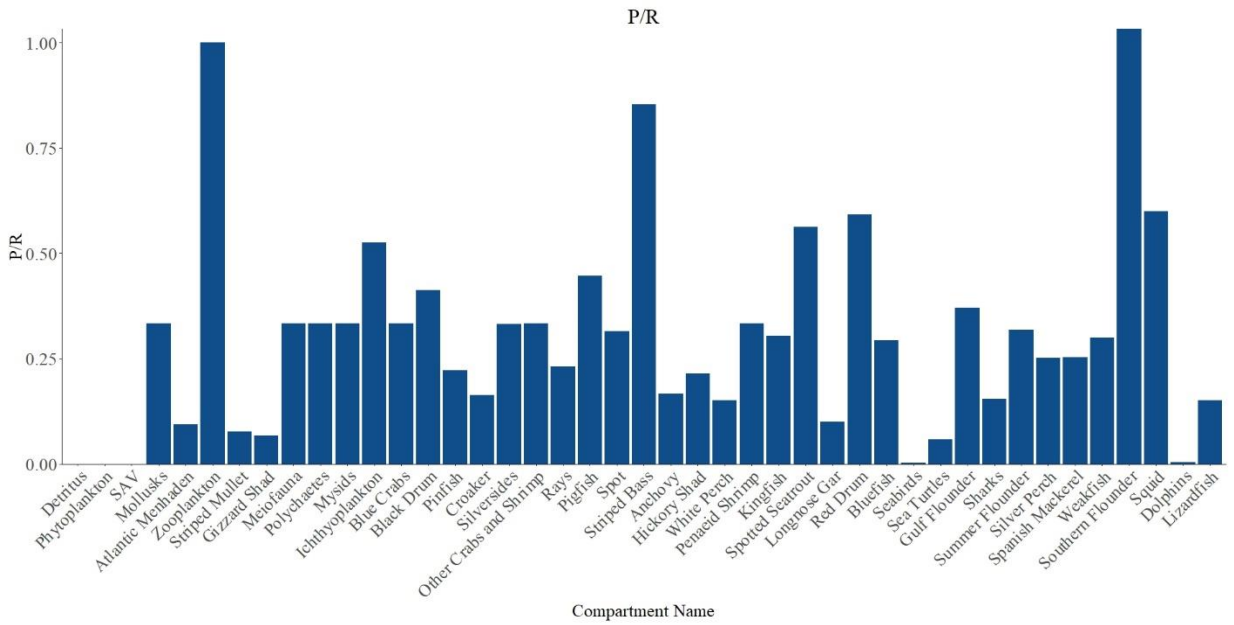


Fig. 8: Bar plot of P/R for the Pamlico Sound Ecopath model. Compartments are arranged in increasing trophic level on the *x*-axis.

Total production and removal diagnostics

The final set of PREBAL diagnostics examines production, consumption, respiration, and total human removals scaled up to the system-level. Total production, consumption, and respiration ($\log_{10}$ scale) should show a general decrease with increasing trophic level. Total consumption by a compartment should exceed total production. Finally, total production should be greater than total human removals (e.g. landings, discards).

When examining these diagnostics, all criteria were met and no potential issues were revealed. Total production, consumption, and respiration exhibited decreases with increasing trophic level, with minimal compartments deviating far from the trend line (Figs. 9-11). Total production was less than total consumption and greater than total human removals (Fig. 12).

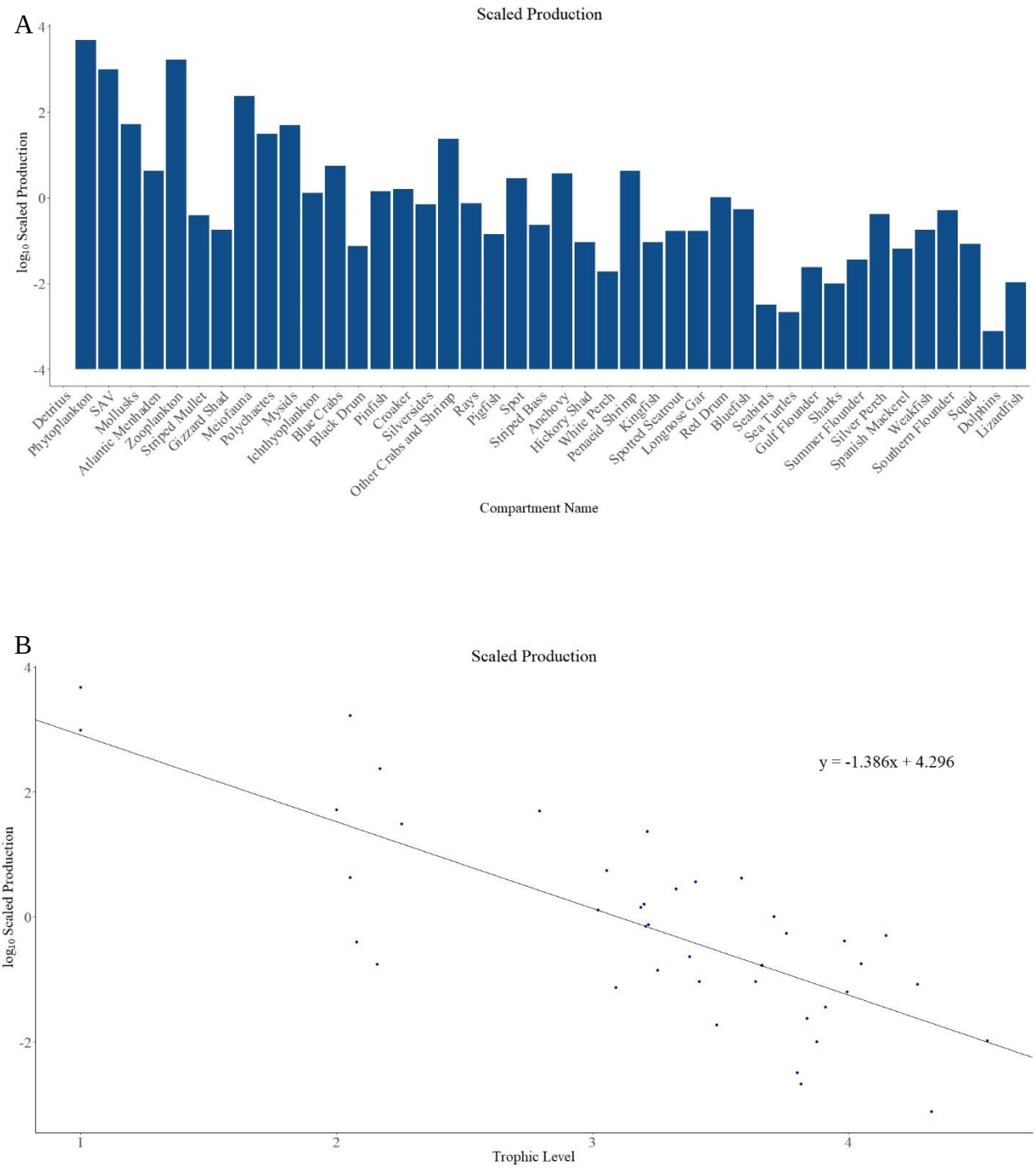


Fig 9: (A) Bar plot and (B) scatter plot for total production on $\log_{10}$ scale. In (A), the *x*-axis is arranged in order of increasing trophic level and the *y*-axis starts at -4 instead of 0.

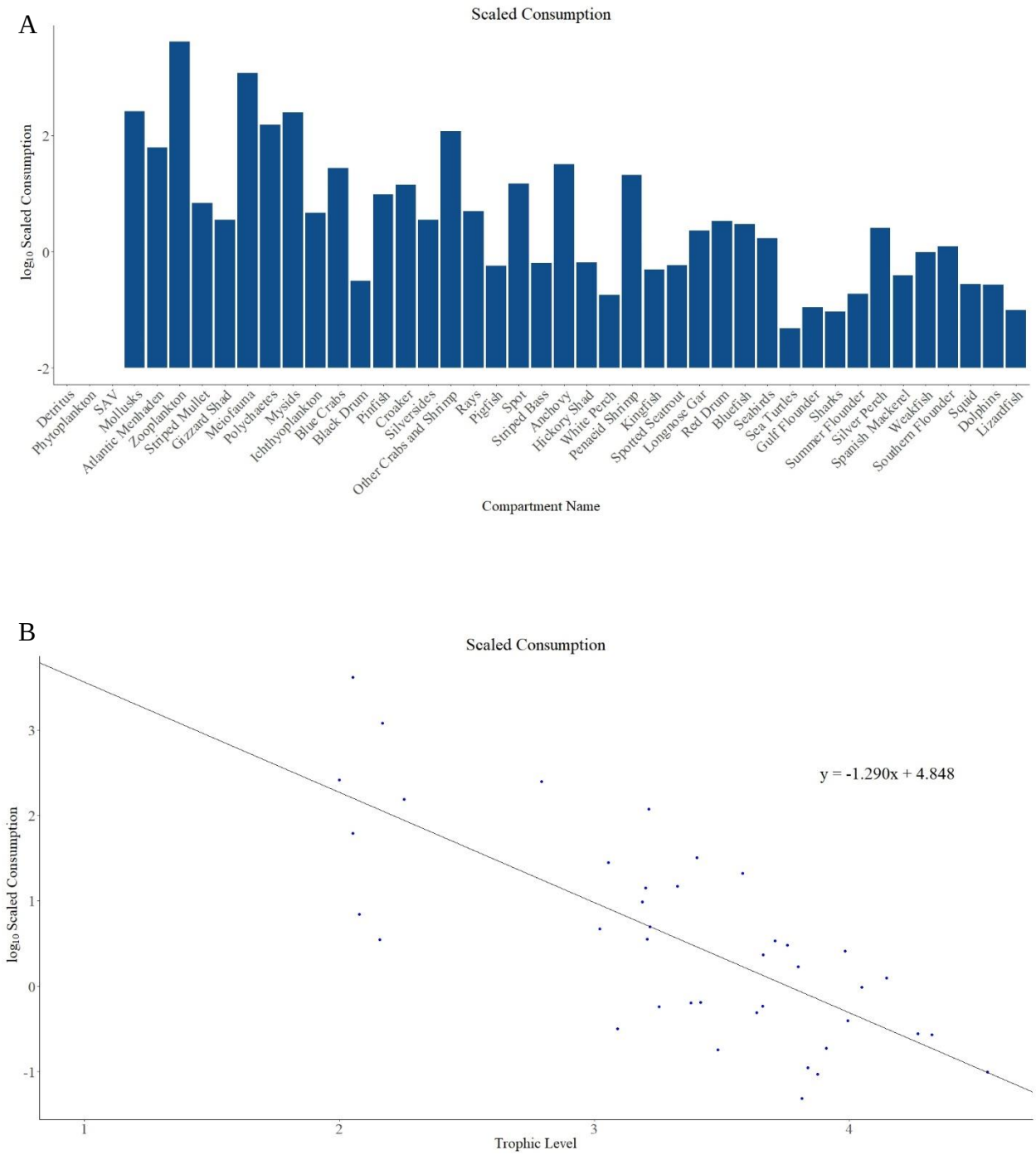
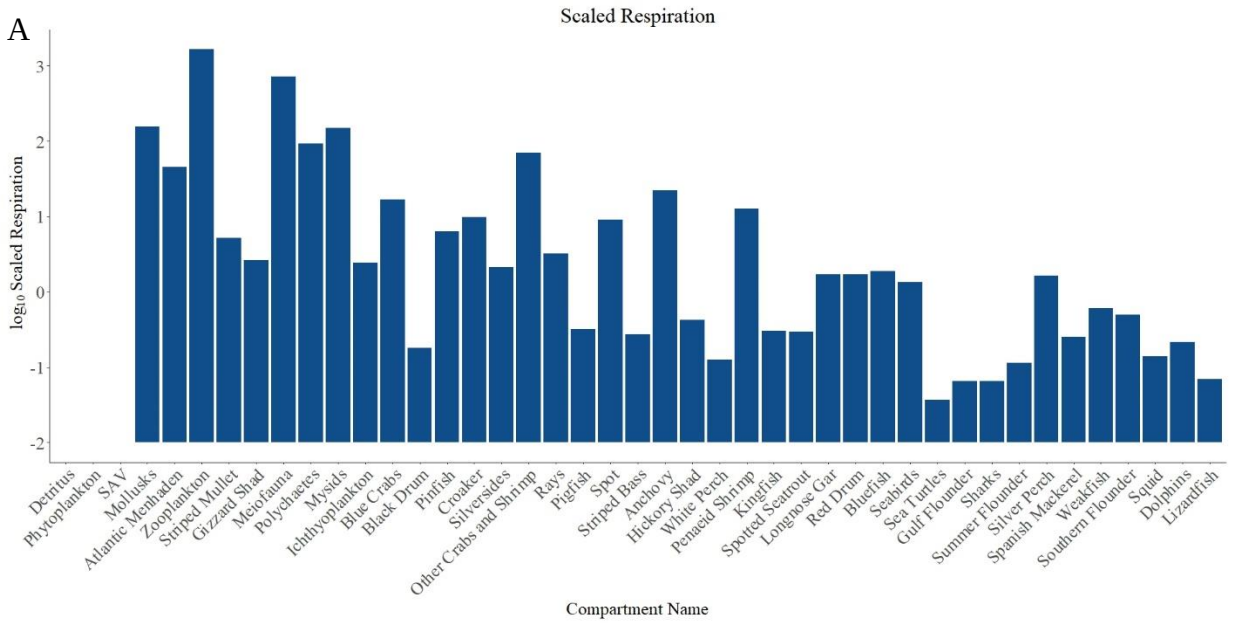


Fig 10: (A) Bar plot and (B) scatter plot for total consumption on $\log_{10}$ scale. In (A), the *x*-axis is arranged in order of increasing trophic level and the *y*-axis starts at -2 instead of 0.



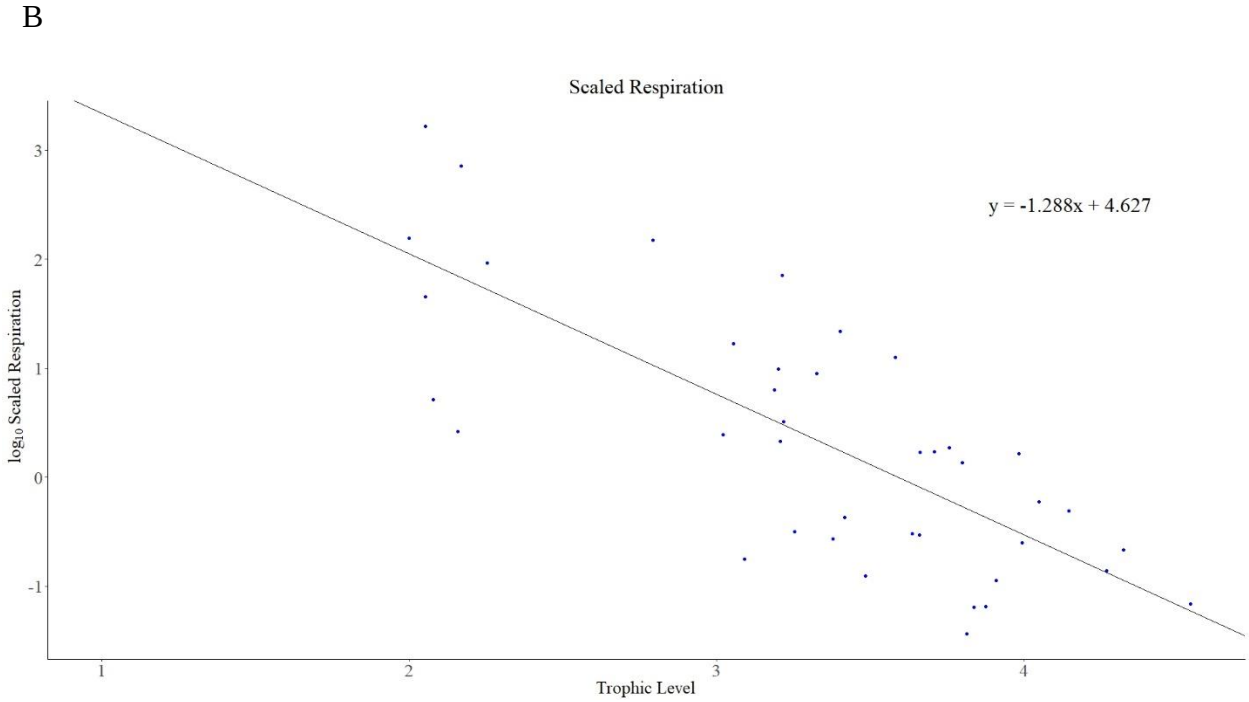


Fig 11: (A) Bar plot and (B) scatter plot for total respiration on $\log_{10}$ scale. In (A), the *x*-axis is arranged in order of increasing trophic level and the *y*-axis starts at -2 instead of 0.

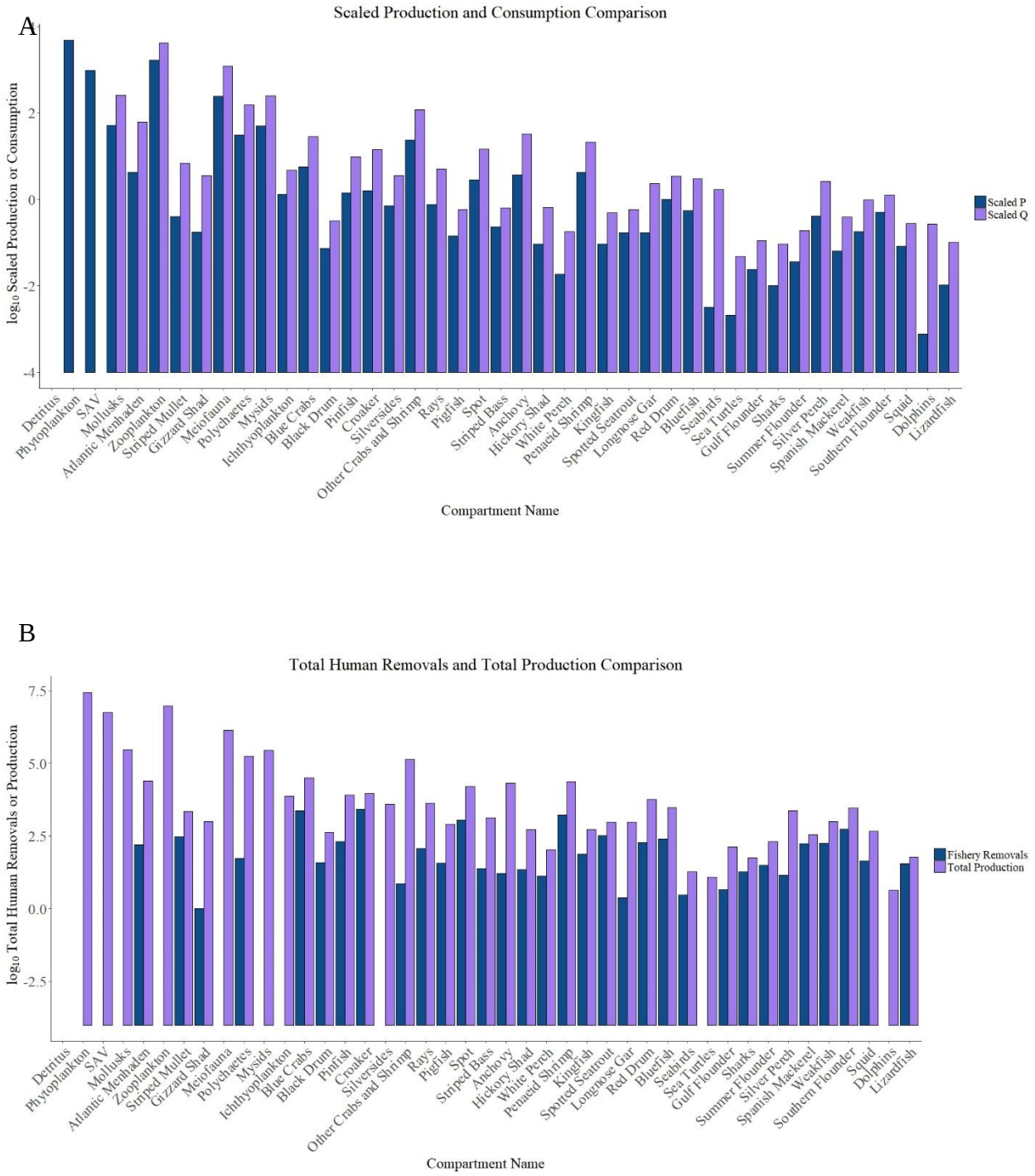


Fig. 12: Comparison of total production and (A) total consumption and (B) total human removals. The *x*-axis is arranged in order of increasing trophic level. The *y*-axis is on the $\log_{10}$-scale and starts below 0 for both (A) and (B).

Final Parameter Estimates

Table 16: Final parameter estimates for B, P/B, Q/B, P/Q, and EE after model balancing and PREBAL diagnostics. *Italicized* parameters were estimated by Ecopath.

Compartment Number and Name		B (t/km^2)	P/B (yr^{-1})	Q/B (yr^{-1})	P/Q (yr^{-1})	EE
1	Seabirds	0.0168	0.193	100.63	*0.002*	*0.682*
2	Dolphins	0.0191	0.040	14.170	*0.043*	*0*
3	Sea turtles	0.0138	0.153	3.500	*0.04*	*0*
4	Sharks	0.0320	0.312	2.931	*0.11*	*0.324*
5	Rays	2.4017	0.311	*2.073*	0.15	*0.027*
6	Lizardfish	0.0160	0.655	6.226	*0.11*	*0.588*
7	Bluefish	0.7780	0.702	3.875	*0.18*	*0.132*
8	Longnose gar	0.6541	0.257	3.551	*0.07*	*0.002*
9	Weakfish	0.2661	0.675	3.664	*0.18*	*0.935*
10	Spotted seatrout	0.1586	1.055	3.664	*0.29*	*0.501*
11	Red drum	1.2334	0.822	2.762	*0.30*	*0.032*
12	Kingfish	0.0896	1.024	5.500	*0.19*	*0.602*
13	Striped Bass	0.1674	1.397	3.792	*0.37*	*0.237*
14	Hickory Shad	0.1114	0.824	5.822	*0.14*	*0.043*
15	Southern flounder	0.3616	1.408	3.463	*0.41*	*0.280*
16	Summer flounder	0.0482	0.752	3.890	*0.19*	*0.155*
17	Gulf flounder	0.0253	0.949	4.389	*0.22*	*0.034*
18	Spanish mackerel	0.0739	0.863	5.339	*0.16*	*0.482*
19	Black drum	0.0852	0.866	3.704	*0.23*	*0.093*
20	Croaker	2.5322	0.630	5.617	*0.11*	*0.992*
21	Spot	2.4567	1.149	5.996	*0.19*	*0.868*
22	Silver perch	0.3006	1.376	8.556	*0.16*	*0.783*
23	White perch	0.0386	0.486	4.644	*0.10*	*0.927*
24	Pigfish	0.1030	1.376	5.573	*0.25*	*0.369*
25	Pinfish	1.9413	0.729	5.021	*0.15*	*0.412*
26	Striped mullet	0.4525	0.874	15.342	*0.06*	*0.735*
27	Gizzard shad	0.2965	0.594	11.839	*0.05*	*0.040*
28	Atlantic menhaden	3.8624	1.104	15.999	*0.07*	*0.747*
29	Anchovy	2.0425	1.791	15.673	*0.11*	*0.666*
30	Silversides	*0.2722*	2.596	13.029	*0.2*	0.5
31	Penaeid shrimp	1.0770	3.92	*19.00*	0.2	*0.530*
32	Blue crabs	1.3939	4	*20.00*	0.2	*0.827*
33	Other crabs and shrimp	*4.5779*	5.15	*25.75*	0.2	0.9
34	Polychaetes	8.1728	3.76	*18.80*	0.2	*0.825*
35	Squid	0.0140	5.92	*19.73*	0.3	*0.735*
36	Mollusks	*5.2399*	9.95	*49.75*	0.2	0.9
37	Meiofauna	*24.4615*	9.79	*48.95*	0.2	0.9
38	Mysids	*9.2616*	5.39	*26.95*	0.2	0.9
39	Ichthyoplankton	0.0265	48.50	176.091	*0.28*	*0.918*

Compartment Number and Name		B (t/km^2)	P/B (yr^{-1})	Q/B (yr^{-1})	P/Q (yr^{-1})	EE
40	Zooplankton	11.6535	142.809	*357.023*	0.4	*0.291*
41	Phytoplankton	22.2141	214.621	NA	NA	*0.918*
42	SAV	99.1649	9.849	NA	NA	*0.499*
43	Detritus	1342	NA	NA	NA	*0.185*

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