Interactions between adult migratory striped bass (*Morone saxatilis*) and their prey during winter off the Virginia and North Carolina Atlantic coast from 1994 through 2007

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Abstract—The migratory population of striped bass (*Morone saxatilis*) (>400 mm total length [TL]) spends winter in the Atlantic Ocean off the Virginia and North Carolina coasts of the United States. Information on trophic dynamics for these large adults during winter is limited. Feeding habits and prey were described from stomach contents of 1154 striped bass ranging from 373 to 1250 mm TL, collected from trawls during winters of 1994–96, 2000, and 2002–03, and from the recreational fishery during 2005–07. Nineteen prey species were present in the diet. Overall, Atlantic menhaden (*Brevoortia tyrannus)* and bay anchovy (*Anchoa mitchilli)* dominated the diet by biomass (67.9%) and numerically (68.6%). The percent biomass of Atlantic menhaden consumed increased from 50.3% during 1994–2003 to 87.0% during 2005–07. Demersal fish species such as Atlantic croaker (*Micropogonias undulatus)* and spot (*Leiostomus xanthurus*) represented <15% of the diet biomass, whereas alosines (*Alosa* spp.) were rarely observed. Invertebrates were least important, contributing <1.0% by biomass and numerically. Striped bass are capable of feeding on a wide range of prey sizes (2% to 43% of their total length). This study outlines the importance of clupeoid fishes to striped bass winter production and also shows that predation may be exerting pressure on one of their dominant prey, the Atlantic menhaden.

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Striped bass (*Morone saxatilis*) has a well documented history along the U.S. east coast, from its dramatic population declines during the 1980s to its subsequent recovery by the early 1990s (Field, 1997; Richards and Rago, 1999). Successful management efforts have resulted in a greater than tenfold increase in striped bass abundance between the 1980s and 1990s and a subsequent increase in population-level prey consumption (Hartman, 2003), and therefore a concern for coastal populations of prey species (Hartman, 2003; Overton, 2003; Uphoff, 2003). Under current management regimes, it may be difficult to maintain high population levels of striped bass and their prey (Hartman, 2003; Uphoff, 2003).

Typically, striped bass along the U.S. east coast spend their first years maturing in their natal estuaries and then emigrate to the Atlantic Ocean. Most striped bass along the Atlantic coast migrate northward during spring and summer to waters off the northeast coast of the U.S. During fall and winter, they return south to overwinter off the coasts of Virginia and North Carolina (Boreman and Lewis, 1997). These migratory fish are generally large (>500 total length [TL] mm) and feed prodigiously during their migrations. Theoretically, these large piscivores are capable of structuring prey fish populations through predation and prey selection (Bax, 1998; Harvey et al., 2003), and in turn they can potentially influence the recruitment success of prey species. Predators such as striped bass are capable of consuming prey that are a wide range of sizes (Hartman, 2000); therefore to understand trophic relationships it is important to examine their dietary habits. Multispecies fisheries and ecosystem management approaches require dietary information for upper-level predators such as striped bass (Latour et al., 2003).

The literature on diets and feeding habits of striped bass (see Walter et al., 2003) is voluminous. However, information on feeding habits during their oceanic migrations in winter is limited. Walter et al. (2003) identified the paucity of information on the foraging habits of striped bass along the Atlantic coast during their winter residency as one of the major gaps in the life history of this species. This paucity of information about feeding habits during winter is especially acute, given the importance of predator-prey interactions and their relation to the population base in the area. The objective of this paper was to gather and synthesize detailed information on annual feeding habits of striped bass during winter off the coasts of Virginia and North Carolina from 1994 through 2007. Therefore, we determined the important prey types and the prey-size spectrum of striped bass during winter.

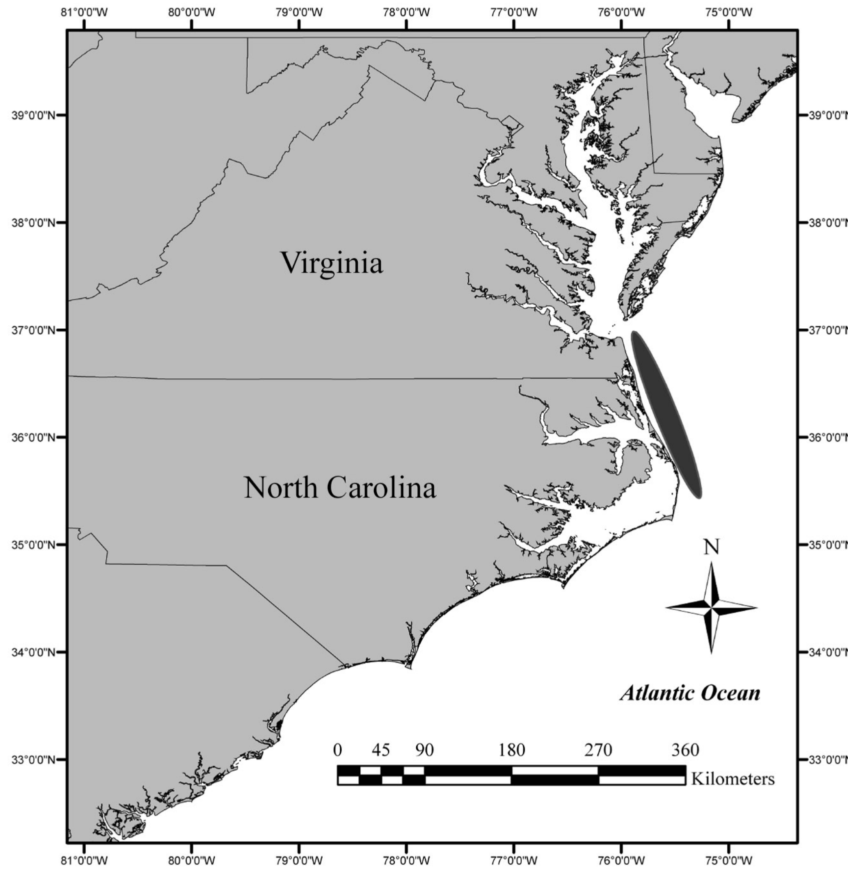

Figure 1

Map of U.S. east coast and the general sampling area (shaded oval shape) for striped bass (*Morone saxatilis*) collected in trawl and recreational catch samples from 1994 through 2007.

Materials and methods

Striped bass were collected by two methods: trawls and dockside sampling of the catch of recreational fishermen. Beginning in 1988, a number of fisheries management agencies (National Marine Fisheries Service, United States Fish and Wildlife Service, North Carolina Department of Marine Fisheries, Maryland Department of Natural Resources, and Virginia Marine Resource Commission) organized a trawl survey for striped bass from federal research vessels during winter off the coast of Virginia and North Carolina (Fig. 1). The primary objective of the survey was to tag and release striped bass to assess annual mortality of the coastal migratory stock. The trawl specification and trawl duration varied over the years. Generally, trawl sampling occurred around the clock during mid-January. Once the trawl was recovered, most striped bass were tagged and released; however, dead or moribund fish not selected for tagging were sacrificed and processed for aging or food habit analyses. Few fish (n<19) were examined for stomach contents from 1997–99, 2001, and 2004–07; therefore data from these years were excluded from our analyses.

From December to March 2004–07, striped bass were collected weekly at the Oregon Inlet Fishing Center (OIFC) in Manteo, North Carolina. Fish were sampled from recreational fishermen who brought their daily catches to the fish cleaning station at the OIFC. We randomly selected fish once they were cleaned (generally filleted), measured the carcasses for total length (±1.0 mm), and identified the sex of each individual. Stomachs were removed and frozen for later analysis. Additional samples were obtained from Virginia Beach Fishing Center, Virginia Beach, Virginia and processed in the same manner as that used to process fish from the OIFC. All stomach samples presumably came from fish captured in the Atlantic Ocean 0–4.8 km from the shoreline because no fishing for striped bass is permitted in the U.S. Exclusive Economic Zone (EEZ), beyond 4.8 km (3 miles) from shore.

In the laboratory, stomach contents were thawed and all prey items removed, sorted, identified (to the lowest taxon possible, usually to species for fish and decapod crustaceans and family for other invertebrates), enumerated, weighed to the nearest 0.1 g, and measured to the nearest mm (standard, carapace, or total length). The percentage of prey by number and percent composition by weight (wet weight-biomass) were determined. A quantitative assessment of number and weight of each prey item was used, as well as the respective percentage values for each (Markle and Grant, 1970; Macdonald and Green, 1983). Percent weight is a measure of the nutritional value of the prey (Macdonald and Green, 1983) and is calculated as the total weight of each prey category divided by the total weight of all prey categories. Frequency distributions of prey total length to predator total length (prey-to-predator ratios; PPR) were examined. We used one-way analysis of variance (ANOVA) to test for differences in mean length (Log_{10} transformed) between the fish from the trawl and recreational samples ($P \leq 0.05$). We also fitted a least squares linear regression of prey total length and striped bass total length.

Results

We collected 263 stomachs from striped bass in the trawl samples from 1994 through 2003 (Table 1); specimens ranged from 373 to 955 mm TL (mean=662.2 ±129.1 standard deviation (SD); Fig. 2). The percentage of stomachs that contained food ranged from 73.5% to 100% (mean=84.6%). From the recreational samples (2005–07), 891 fish were examined (Table 1). The striped bass size ranged from 509 to 1250 mm TL (mean=918.9 ±93.8 SD; Fig. 2). The size of fish collected from the recreational catch were significantly larger (ANOVA, P=<0.0001; df =1) than those collected by trawl.

The percentage of stomachs containing food items was more variable for striped bass caught by recreational anglers (23.6–80.7%), than for the fish caught by trawl (73.5–100.0%). In 2005, 23.6% of the stomachs contained food; increased to 24.4% in 2006, and to 80.7% by 2007. Collectively, 19 fish and invertebrate species constituted the diet of striped bass (Table 2), and fish predominated.

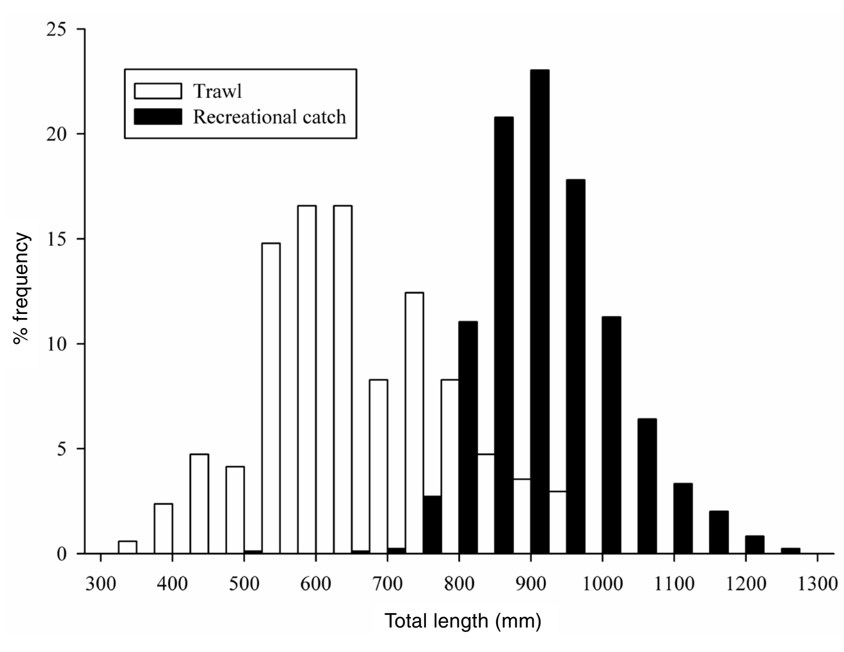

Figure 2

Length-frequency histogram for striped bass (*Morone saxatilis*) collected during the winter off the coasts of Virginia and North Carolina during 1994–2007.

Feeding habits (trawl samples 1994–2003)

Atlantic menhaden and bay anchovy were the most abundant species present in striped bass stomachs in all years sampled; they also dominated the diet in biomass and numerically. Atlantic menhaden accounted 9.5% of the diet numerically and 50.3% by biomass (Fig. 3). The biomass of Atlantic menhaden was constant (40%) from 1994 to 2000; this contribution nearly doubled to 73.8% in 2002 and 72.4% by 2003. Atlantic menhaden showed no consistent pattern numerically and was generally <15%.

Concurrent with the increase in the biomass of Atlantic menhaden consumed was a decline in the percent biomass of bay anchovy found in the diet of striped bass. Bay anchovy accounted for 16.5% of the biomass to 29.9% of the diet numerically throughout the study period (Fig. 3). Between 1994 to 2000 mean percent biomass for bay anchovy was 43.4% and they represented 71.3% of the diet numerically. However, by 2002, the percent biomass declined to 16.7% and represented <6.6% in 2003. Bay anchovy dominated the diet by number, representing 94.5% in 1995 and remained >80% from 1996 through 2002 (Fig. 3).

Sciaenids and alosine species were minor contributors to the diet of striped bass. Weakfish (*Cynoscion regalis*) was absent from the diet before 2002 and represented <0.5% of the diet during the study (Table 2). From 1994 to 2003, Atlantic croaker (*Micropogonias undulatus*) was absent, except in 1995 and 2003 when it represented 10.1% and 14.7% of the diet biomass, respectively. Alosines (American shad [*Alosa sapidissima*]; blueback herring [*A. aestivalis*]; and hickory shad [*A. mediocris*]) were a minor part of the diet of striped bass, and they occurred only during 1994 and 1996. American shad were found once in 1996 (4.5% biomass, 6.8% numerically). Blueback herring were present in 1994 and 1996 and represented 3.1% and 8.1% of the diet biomass, respectively. Invertebrates were a minor portion of the diet of large striped bass generally contributing <1.0% to the diet (Table 2).

Feeding habits (determined from recreational catch samples 2005–07)

In the recreational catches, Atlantic menhaden and bay anchovy dominated striped bass diet both by biomass (88.9%) and numerically (93.6%). Biomass of Atlantic menhaden remained consistent

Table 1

Mean size (total length [TL] mm ±standard deviation [SD]), size range, and number of striped bass (*Morone saxatilis*) with food in their stomachs collected off the coasts of North Carolina and Virginia from trawl and hook-and-line samples during 1994–2007.

Collection year and gear type	Mean TL (mm, ±SD)	Size range (TL mm)	Number of fish examined (% with food in the stomach)
1994, trawl	613.1 (72.3)	425–765	73 (99)
1995, trawl	639.7 (57.0)	525–718	19 (100)
1996, trawl	805.9 (75.6)	666–955	34 (74)
2000, trawl	561.3 (90.5)	465–770	50 (84)
2002, trawl	616.2 (180.0)	373–941	60 (77)
2003, trawl	836.6 (80.6)	745–953	19 (84)
2005, hook-and-line	881.2 (94.5)	509–1150	253 (23)
2006, hook-and-line	914.6 (87.9)	720–1200	450 (28)
2007, hook-and-line	994.2 (99.0)	760–1250	140 (81)

Table 2

Diet summary of prey contributions (%B=biomass, %N=number) and mean prey size (total length [TL] ±standard deviation [SD]) of striped bass (*Morone saxatilis*) during the winter off the coast of North Carolina from 1994 through 2007. Asterisk represents only one prey item.

		Year									
		1994		1995		1996		2000		2002	
Fish	Scientific name	%B	%N	%B	%N	%B	%N	%B	%N	%B	%N
American eel	*Anguilla rostrata*										
American shad	*Alosa sapidissima*					4.5	6.8				
Atlantic croaker	*Micropogonias undulatus*			10.1	0.9						
Atlantic herring	*Clupea harengus*									4.1	0.4
Atlantic menhaden	*Brevoortia tyrannus*	38.8	10.6	29.9	4.5	30.5	2.2	31.8	13.7	73.8	7.3
Bay anchovy	*Anchoa mitchilli*	34.3	55.2	60.1	94.5	40.4	85.2	58.9	85.8	16.7	79.4
Blueback herring	*Alosa aestivalis*	3.1	6.1			8.1	0.5				
Butterfish	*Peprilus triacanthus*										
Hickory shad	*Alosa mediocris*										
Round herring	*Etrumeus teres*										
Sciaenid sp.		14.1	13.7								
Silver perch	*Bairdiella chrysoura*									1	0.4
Spot	*Leiostomus xanthurus*										
Tonguefishes	*Symphurus* sp.										
Unknown clupeid		1.6	2.1			16.2	4.8				
Fish remains		1.5	2.7			0.3	0.6	9.3	0.5	0.3	0.7
Weakfish	*Cynoscion regalis*									1.4	0.2
Menticirrhus spp.										0.3	0.2
Invertebrates											
Gastropod shell	Gastropod									2.4	11.4
Decapods	Decapoda	2.1	2.2								
Sand shrimp	*Crangon septimspinosa*	2.8	4.7								
Mud crab	*Panopeus herbstii*										
Longfin squid	*Loligo pealeii*										

continued

Table 2 (continued)

Fish	Scientific name	2003 %B	2003 %N	2005 %B	2005 %N	2006 %B	2006 %N	2007 %B	2007 %N	Overall %B	Overall %N	Mean TL mm (±SD)
American eel	*Anguilla rostrata*			0.3	0.7			0.8	0.1	1.4	<0.1	334 (62)
American shad	*Alosa sapidissima*									0.4	0.5	154 (42)
Atlantic croaker	*Micropogonias undulatus*	14.7	1.5	0.8	1.4	5	1.3	1.7	0.6	3.4	0.4	126 (51)
Atlantic herring	*Clupea harengus*			7.3	10.4					1.4	0.2	217 (24)
Atlantic menhaden	*Brevoortia tyrannus*	72.4	17.8	82.8	60.4	71.1	4.9	94.5	81.8	67.9	17.3	183 (73)
Bay anchovy	*Anchoa mitchilli*	6.7	63.4	0.9	11.8	11.9	92.1	0.2	12.6	16.5	68.6	55.9 (13)
Blueback herring	*Alosa aestivalis*									1.1	1.7	99.1 (67)
Butterfish	*Peprilus triacanthus*			3.1	2.8			0.5	3.41	0.3	0.4	179 (35)
Hickory shad	*Alosa mediocris*					5.4	0.1			0.3	<0.1	442*
Round herring	*Etrumeus teres*					3.5	0.5			0.5	0.5	135 (9)
Sciaenid sp.										1.9	3.7	85.9 (28)
Silver perch	*Bairdiella chrysoura*			0.6	2.1	0	0			0.1	0.1	112*
Spot	*Leiostomus xanthurus*			0.5	0.7	2	0.6	<0.1	0.1	0.1	0.3	122 (14)
Tonguefishes	*Symphurus* sp.	5.9	14.9							0.5	0.4	
Unknown clupeid										1.1	0.9	391 (1.4)
Fish remains		0.4	2.5	0.1	2.1	0.2	0.9	1	0.9	1.5	1.2	
Weakfish	*Cynoscion regalis*			3.6	6.3	0.4	0	1.1	0.3	0.7	0.2	159 (15)
Menticirrhus spp.						0.4	0.1	0.3	0.1	0.2	0.1	137 (8.3)
Invertebrates												
Gastropod shell	Gastropod									0.2	0.7	
Decapods	Decapoda									0.3	0.6	
Sand shrimp	*Crangon septimspinosa*									0.4	1.3	
Mud crab	*Panopeus herbstii*			<0.1	0.7	0.1	0.1			<0.1	<0.1	
Longfin squid	*Loligo pealeii*					<0.1	<0.1			<0.1	<0.1	

(>70%) from 2005 through 2007 and was highest in 2007 (94.5%). Contribution of Atlantic menhaden by number, however, was quite variable: in 2005 they contributed 60.4%, declining to <5.0% in 2006, and increasing to 81.1% in 2007. Percent by number of bay anchovy was variable during 2005–07. In 2005 and 2007 their contribution by number was <15%. However, in 2006 they contributed >90% to the diet numerically.

Weakfish and Atlantic croaker were present in stomachs of recreationally caught striped bass for all years (Table 2). There were no clear patterns to their contributions, and collectively represented a small portion <5.0% (biomass) of the diet. Only one alosine, a hickory shad (2006), was found in the samples (2.7% biomass, 0.1% number). Other clupeoids, including Atlantic herring (7.3% of the biomass in 2005) and round herring (*Etrumeus teres*) (3.5% of the biomass in 2006), were found sporadically in the diet. Invertebrates were unimportant to the diet of large striped bass, generally representing <1.0% by weight and by number in the diet (Table 2).

Predator-prey size relationships

Prey consumed by striped bass ranged from 35 to 423 mm TL (mean=102.5 mm ±79.3 SD), although most prey items (86.7%) were less than 125.0 mm long. Mean length of Atlantic menhaden consumed was 204.2 TL mm (±76.2 mm SD). Prey length showed a significantly positive relationship with striped bass total length ($P<0.001$, $r^2=0.31$) (Fig. 4). The distribution of prey-to-predator ratios (PPR) ranged from 0.02 to 0.43 but had a skewed distribution toward the lower end of the range (75% of PPRs <0.15) (Fig. 5). This PPR distribution had a bimodal pattern with peaks at 0.07 and 0.14. Mean PPR for all prey was 0.12 (±0.07 SD) but the mean PPR for Atlantic menhaden was 0.19 and for bay anchovy, 0.06.

Discussion

This study concentrated on migratory adult striped bass that reside in nearshore waters of the Atlantic Ocean

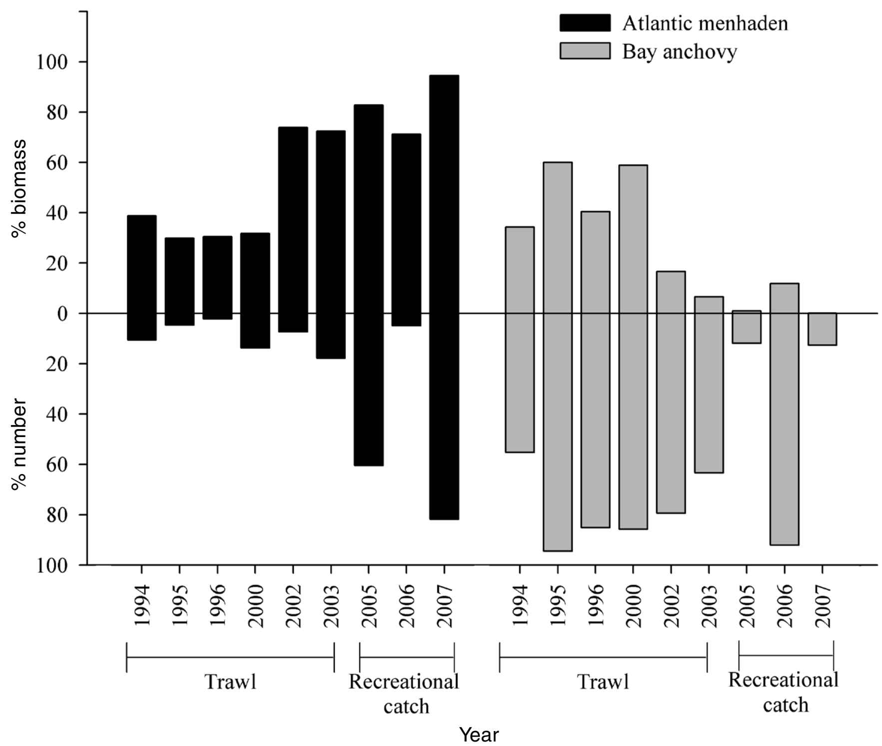

Figure 3

Percent biomass and number of Atlantic menhaden (*Brevoortia tyrannus*) and bay anchovy (*Anchoa mitchilli*) in the diet of striped bass (*Morone saxatilis*) collected in trawl and recreational catch samples during winter off the coasts of Virginia and North Carolina during 1994–2007.

off the coasts of Virginia and North Carolina in winter. We present the first published description of the diet of large striped bass, generally >400 mm TL, during their ocean residency in winter. The predominance of fish in the diet of striped bass in this study agrees with the findings of other published studies (Manooch, 1973; Overton, 2003; Walter et al., 2003; Walter and Austin, 2003). Several species of clupeoid fishes (e.g., Atlantic menhaden, Atlantic herring, and bay anchovy) dominated diet biomass of striped bass. This dependency on clupeoids, particularly Atlantic menhaden, has been well-documented throughout the range of striped bass (Walter et al., 2003). The only other study to address the diet of striped bass >500 mm TL was conducted in Chesapeake Bay by Walter and Austin (2003). They showed that Atlantic menhaden contributed 58% of the diet biomass. In the present study, Atlantic menhaden represented a higher biomass (67.9%) of the striped bass diet, indicating a greater dependency on Atlantic menhaden during the period of ocean residence in winter.

Anadromous species, particularly alosines, contribute substantially to the diet of striped bass (Nelson et al., 2003; Walter et al., 2003; Savoy and Crecco, 2004). In our study, there were less than five occurrences of alosines, which would indicate that anadromous alosines contribute little to the production of striped bass during their ocean residency in winter. Striped bass share similar migration patterns of other anadromous species (Walter et al., 2003) and we commonly observed alosines in the same trawls in which striped bass were collected.

Invertebrates were seemingly unimportant to large striped bass winter production because they contributed little to the diet. However, throughout their range, large striped bass routinely feed on a wide variety invertebrate prey. In New England waters during summer and fall, striped bass consumed large amounts of invertebrate prey such as sand shrimp (*Crangon septemspinosa*), rock crabs (*Cancer irroratus*), and American lobster (*Homarus americanus*) (Nelson et al., 2003). Large striped bass in Chesapeake Bay routinely fed on invertebrate prey, primarily blue crab (*Callinectes sapidus),* in summer (Walter and Austin, 2003). Presumably, these differences among studies due to differences in prey availability.

The percentage of stomachs with food varied among years but ranged from 23% in 2005 to 100% in 1995. In Chesapeake Bay, the percentage of large striped bass with food in their stomach during fall and early winter (November and December) was greater than 75%

(Walter and Austin, 2003). Similarly, the percentage of striped bass stomachs with food during winter in our study was generally greater than 75%.

Less than 30% of stomachs sampled during 2005–06 from the recreational catch contained prey, but 80% did during 2007. Striped bass likely expel some stomach contents while being reeled to the surface or while in the codend of a trawl. We did not determine the factors that influence regurgitation with respect to capture method. The alimentary canal musculature is stronger in larger fish and would result in lower regurgitation rates (Staniland et al., 2001). Regurgitation of stomach contents from striped bass collected by hook and line generally consisted of slurry (Overton, 2003). Regurgitation rates for adult striped bass captured in gillnets was 8.3% (Sutton et al., 2004). For 2007, the percentage of stomachs with food was greater than 80%. The high frequency of nonempty stomachs in this study may indicate that the winter feeding period for the migratory stock may play an important role in providing energy for growth and gonadal development.

Striped bass consumed small prey and the mean size of prey consumed was 12% of their total length and ranged from 2% to 43%. This mean percentage was lower than the predicted optimal size of prey (21%) predicted for striped bass (Overton, 2003), but was within the range of the predicted minimum profitable prey lengths (7%), peak profitable (12%) and maximum (40%) for striped bass (Hartman, 2000). In Albemarle Sound, North Carolina, striped bass consumed prey up to 60% of their body length, although mean prey size consumed was 20% of body length (Manooch, 1973). In a more recent study, age 1–3 striped bass in Albemarle Sound, North Carolina, on average consumed prey about 21% of their body length (Rudershausen et al., 2005). Piscivores generally select for smaller-size prey (Juanes and Conover, 1994). The differences among the studies indicate that larger striped bass include smaller prey in their diet. It may also indicate that there are fewer large prey available to striped bass during the winter. However, we observed that the finfish bycatch during the striped bass survey comprised prey larger than what was observed in the stomachs of striped bass.

There was a significant positive relationship between prey size and predator size which suggests that larger striped bass consumed larger prey. Nevertheless, the fit of the regression was weak (r^2=0.31), indicating a wide variation of prey size was included in the diet. The invertebrate prey in the stomachs was generally <5.0% of the predator total length. About 75% of all prey consumed were less than 15% of the total predator length. These percentages were primarily driven by the large number of bay anchovy consumed by striped bass. The average size of Atlantic menhaden that were found in the stomach of striped bass was 204 mm TL. Atlantic menhaden undergo an extensive coastal migration southward around the Virginia and North Carolina capes in fall and winter (Reintjes and Pacheco, 1966). All ages in the population participate in this migration; however, younger fish tend to be found within a few miles of the shoreline, while older individuals may be found farther offshore (Reintjes and Pacheco, 1966). Thus, the age-specific distribution of Atlantic menhaden probably influences prey-size availability to striped bass in nearshore ocean waters. In turn, striped bass potentially have significant impacts through the reduction of age-0 fish on the spawning stock of Atlantic menhaden.

The frequency of Atlantic menhaden in the diet has increased from 1997 through 2007 and likely represents an increase in the competition between other predators and the existing commercial fishery (Uphoff, 2003). Given that Atlantic menhaden provide up to 60% of the diet for age 3+ striped bass in Chesapeake Bay (Hartman and Brandt, 1995) and 69% of the diet for striped bass in this study, and given the increased population levels of striped bass, it is likely that striped bass predation represents a large part of the natural mortality for Atlantic menhaden (Hartman, 2003; Hartman and Margraf, 2003; Uphoff, 2003).

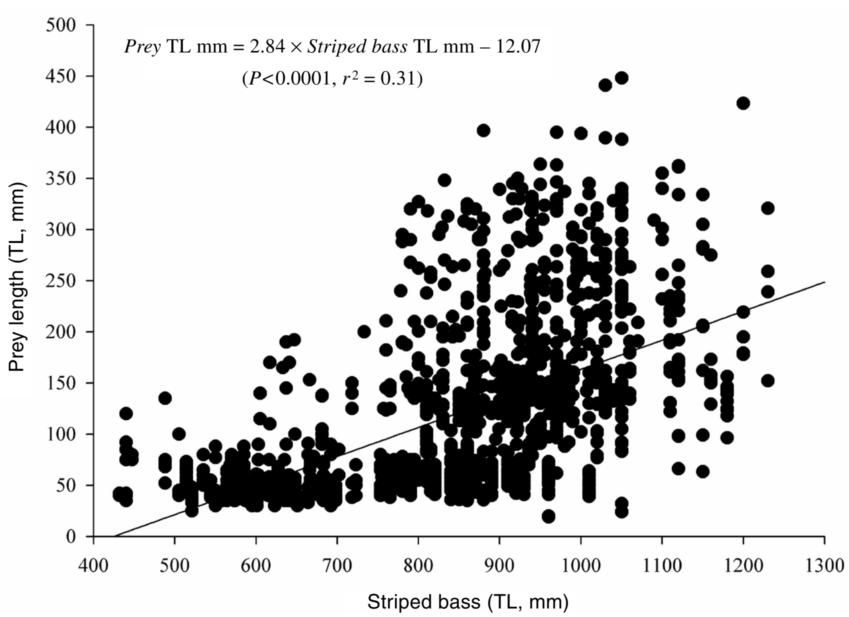

Figure 4

Relationship between striped bass (*Morone saxatilis*) total length (TL, mm) and prey length (prey TL mm=−12.07 + 2.84 (striped bass TL); P=<0.0001, r^2=0.31)

Coastwide population-level consumption of Atlantic menhaden by striped bass in the Atlantic Ocean increased from 50×10^3 t in 1982 to over 250×10^3 t in 2000 (Overton, 2003). Striped bass are capable of exerting considerable pressure on prey populations through predation (Hartman, 2003; Grout, 2006). With concerns over Atlantic menhaden recruitment, it is essential to quantify its role as a prey fish and its major sources of mortality.

Our diet data were collected by using two different methods during two separate time periods; therefore we were unable to test the effects of collection methods on the diet composition. Nevertheless, we feel that the two collection methods complement each other. For example, the trawl samples (1994–2003) show an increasing trend in the amount of Atlantic menhaden consumed; these data are supported by the recreational catch data. Simultaneously, the trawl data show a decline in the consumption of bay anchovy diet, which is also supported by the recreational catch data. These results indicate that the recreational catch data provide a reasonable representation of the diet of striped bass during the winter off the coasts of North Carolina and Virginia.

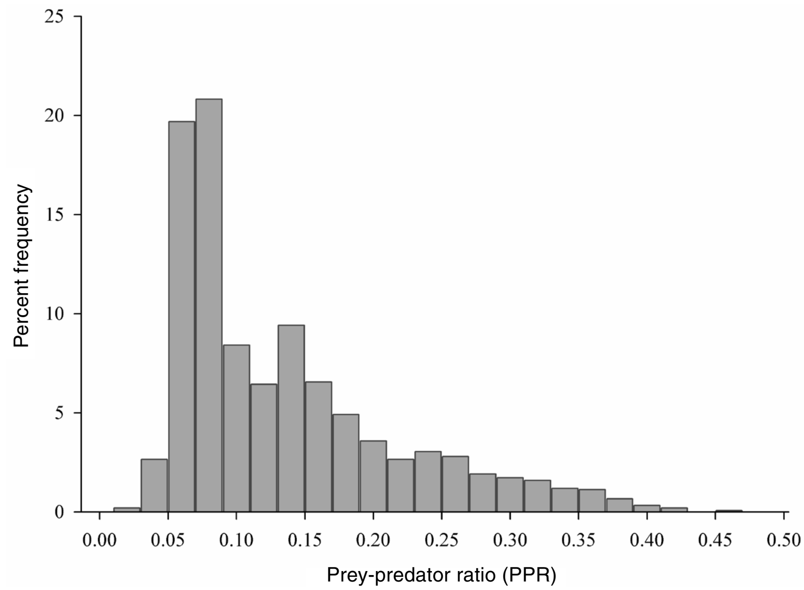

Figure 5

Prey-to-predator ratio (PPR) frequency distributions determined from the diet of striped bass (*Morone saxatilis*) collected in trawl and recreational catch samples during winter off the coasts of Virginia and North Carolina during 1994–2007.

To further understand the predator-prey interactions of striped bass, we suggest a continued low-frequency monitoring of predator diets along the Atlantic coast. Low-frequency monitoring approaches have been used to estimate the consumption of commercially important fish by predatory fish in the western North Atlantic and can provide important insights regarding the importance of prey types (Overholtz et al., 2000). These data can be used to calibrate different predator-prey, bioenergetic, and multispecies models for different management systems. This information could provide data that would add significantly to knowledge of trophic interactions of striped bass and other predators.

This analysis of the foraging behavior of large migratory striped bass during their winter residency in the Atlantic Ocean contributes to the increasing literature on the foraging dynamics of predatory fishes. Whether the patterns observed during our study period were the result of prey dynamics or predator function is unclear. However, striped bass feed on a large number of prey during winter and are also capable of feeding on a wide range of prey sizes. This work outlines the importance of clupeoid fishes to striped bass winter production and also shows that predation may be exerting prey pressure on Atlantic menhaden stocks.

Acknowledgments

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