

The Importance of Artificial Reef Epifauna to Black Sea Bass Diets in the Middle Atlantic Bight

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Abstract—The effective use of artificial reefs to enhance populations of black sea bass *Centropristis striata* along the Atlantic coast of North America requires an understanding of the species' habitat requirements, including food. We examined the diets of adult black sea bass collected from two artificial reefs off New Jersey during August - October 1993 to assess the importance of reef epifauna to the predator. One reef was mature and colonized by an epifauna typical for this habitat in the area. The other reef, 20 km away and in a similar environment, was new and uncolonized by this epifauna. There was no significant difference between reefs in black sea bass diets, which were dominated by early benthic instar, juvenile rock crabs *Cancer irroratus*. Most of the prey, including the rock crabs, were not specifically associated with the reefs or can be equally common off the reefs. These results and those from similar studies indicate that black sea bass use reefs for shelter but may not depend on the reef-specific epifauna for food. Thus, the availability of nonreef forage can be important when artificial reefs and special fishery management zones or refuges are planned to support black sea bass and other reef species with similar diets.

Black sea bass *Centropristis striata* support valuable commercial and recreational fisheries, and they appear to occur in several distinct populations along the western Atlantic and Gulf of Mexico coasts (Shepherd 1991). The species is currently considered fully or overexploited in the Middle Atlantic Bight (Northeast Fisheries Science Center 1993), where the population has declined since the 1950s (Shepherd and Terceiro 1994). To maintain these fisheries, artificial habitats ("reefs") are being constructed because black sea bass, and other species, are found closely associated with hard bottoms and structured coastal habitats such as rocky reefs, soft coral and sponge live bottom, and shipwrecks (Musick and Mercer 1977; Briggs 1978). An expanding use of artificial reefs to maintain fisheries requires a better understanding of the role of reefs in supporting exploited reef fish populations. This understanding is essential for improving the planning and use of artificial reefs, defining boundaries of special reef fishery management zones or refuges, and developing reef ecosystem models linking habitat with sustainable use of resources (Kurz 1995).

Artificial reefs may improve harvests by aggregating animals, enhancing their production, or both. The exact nature of benefits (if any) that a target species derives from reefs must be learned and documented, not assumed. Such information is usually inferred from limited diver observations or harvest results that provide assessments of fish occurrence and abundance on reefs. Few quantitative studies of the functional value of artificial reefs to fish populations have been done.

Among the potential benefits of artificial reefs is an enhanced availability of food. The types and sources of prey eaten by reef-associated fishery resources (fish and shellfish such as lobsters) is important information for artificial reef planning (Bohnsack and Sutherland 1985).

Preliminary data on diets of several commercially or recreationally important fish species collected off artificial reefs in the New York Bight, including black sea bass, suggest that only tautog *Tautoga onitis* made more than a little use of prey closely associated with hard bottom or reeflike structures (Steimle and Ogren 1982). Lindquist et al. (1994) also found that black sea bass in North Carolina made substantial use of prey found on sandy bottoms.

Our study addressed the question of whether the epifaunal community typically found on artificial reefs in the Middle Atlantic Bight is an important source of food for black sea bass. If the availability of nonreef prey is more important to black sea bass than reef prey, then future artificial reefs intended to be more than fishery resource aggregators should be deployed in areas with a natural abundance of prey. Biologically "unproductive" areas have been often targets of artificial reef development, but such areas may not support management objectives in all cases.

Methods

The two artificial reefs used in this study were the Barnegat Light Reef, 7.5 km east of Barnegat Inlet, New Jersey, and the Garden State South Reef, 9.2 km east of Spray Beach, New Jersey, and about 20 km south of the first reef (Figure 1). Both reefs are 17–18 m deep and usually below the summer thermocline that develops in the area. The Barnegat Light Reef was a new reef constructed of concrete-ballasted, recycled automobile tire units deployed between May and August 1993 on a gravelly sand bottom. Each tire unit consists of 32 compressed tires filled with concrete (unit volume, 0.9 m³). The material used to build this reef had a total volume of about 463 m³ and it covered about 900 m² of the seabed. The Garden State South Reef, an older and established reef, was

developed incrementally between 1986 and 1991 with the same type of concrete-ballasted, 32-tire units, but it includes two steel vessels 15 and 40 m long and six fiberglass boat hull molds 10—15 m long. Its total volume is 3,730 m³ and it covers about 3,400 m² of silty sand bottom. Both reefs are large enough to attract a population of black sea bass and we do not believe that reef size affected our dietary analysis in any important way.

At the time of our sampling, mid-August to October 1993, the Barnegat Light Reef had not been submerged long enough to develop a visible epifaunal community. The Garden State South Reef was well colonized; hydroids covered 60% of the surface area and blue mussels *Mytilus edulis* 11 % (Figley 1989). During summer 1993 divers confirmed the presence of black sea bass, the persistence of an epifaunal community on this reef, and the absence of visible epifaunal colonization on the new reef.

Black sea bass were collected by hook and line on both reefs during midday on various dates between mid-August and October. Vessels were anchored over the reefs for

fishing. Black sea bass are daytime feeders, so midday stomach contents from these fish should represent recent feeding. The digestion and stomach evacuation rates of black sea bass, although unknown, should be several hours for the primary types of prey this relatively inactive fish consumes. We did not use traps because confinement and extended fishing time could have biased the stomach data. The bait was squid strips dyed pink to distinguish them from natural prey. Stomach content regurgitation because of air bladder expansion was not a problem because fishing depths were relatively shallow. Shortly after they were collected, the fish were measured (total length) and sexed, and their stomachs were removed. Stomachs that appeared to contain food were placed in individual labeled plastic bags. These samples were maintained on ice for 1-2 h aboard the vessel until they could be frozen in the laboratory. The number of apparently empty stomachs was also noted; some stomachs retained as containing food were later found to be empty.

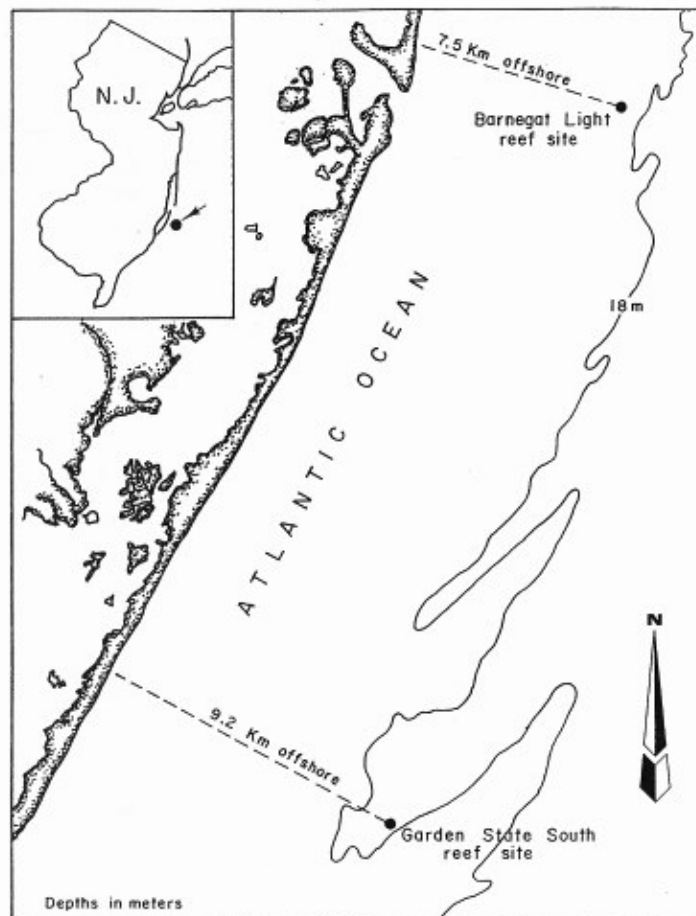


FIGURE 1. Locations of the two reef sites off New Jersey where black sea bass were collected for stomach content analysis.

After about a month, the frozen stomachs were rapidly thawed by placing small groups of samples as needed in a container of cool, running water for a few minutes. Total stomach content volume was estimated by a side-by-side visual comparison of the bolus with a series of variable-diameter, volume-calibrated cylinders, that approximated a range of typical stomach bolus volumes. Sorting, identification, and quantification of prey items in the stomachs were done macroscopically and with a microscope when necessary to confirm the identification of small or well-fragmented items (Steimle et al. 1994). After prey were sorted and counted, each prey taxon was aggregated and the volume of each prey aggregate was estimated visually as a percentage of the total bolus volume. This method had been shown to provide acceptably reliable results (Steimle et al. 1994). Prey volume, which numerically approximates prey weight (1 mL ~ 1 g live weight) for common prey found in this study (Steimle et al. 1994), is an appropriate variable for estimating the value of a prey to a predator, especially if energy budgets are a consideration (Pearre 1986).

To assess the importance of reef epifauna as food for black sea bass, we calculated the degree of similarity, or diet overlap, between diets at the old and new artificial reef as a percent similarity index (PSI) value (Ivlev 1961). Within each reef diet, we recorded the percentage of total stomach content volume represented by each prey taxon found. Then for each taxon, we compared this percentage between reefs and selected the smaller value. The sum of all smaller percentages without regard to reef source is the PSI. Nonoccurrence of a taxon in one reef diet or the other entered the summation as a zero. The PSI ranges from 0% (no prey taxon in common; each taxon contributes zero to the sum) to 100% (each taxon is identically represented in both diets). Values over 60% are considered to indicate a high degree of diet similarity or overlap (Langton and Bowman 1980). This comparison is most appropriate when sample sizes and total numbers of prey species are about equal for each population (Kohn and Riggs 1982), as was the case in this study. Rank correlation analysis was also used to compare diets (Fritz 1974). The degree of association or similarity between the two reef-specific diets was tested with the Kendall rank correlation coefficient tau (Siegel 1956; Ghent 1983), for which we ignored unidentified taxa and taxon fragments.

TABLE 1. Percent frequency of occurrence and percent total volume of items in nonempty black sea bass stomachs collected from an established (Garden State South, $N = 136$) and a new (Barnegat Light, $N = 129$) artificial reef off southern New Jersey, August - October 1993.

Item or prey	Percent frequency of occurrence			Percent total volume		
	Garden State South	Barnegat Light	Combined	Garden State South	Barnegat Light	Combined
Polychaetes						
<i>Pherusa affinis</i>		0.78	0.38		0.07	0.05
Fragments	2.94		1.51	0.81		0.25
Molluscs						
<i>Spisula solidissima</i>	0.73	1.55	1.13	0.10	0.03	0.05
<i>Ensis directus</i>	3.68	0.78	2.26	0.58	0.04	0.21
<i>Tellina agilis</i>	0.73		0.38	0.03		0.01
Fragments	1.47	3.10	2.26	0.26	0.54	0.45
<i>Euspira heros</i>		0.78	0.38		0.51	0.35
Unidentified squid	0.73	3.88	2.26	0.42	0.94	0.78
Crustaceans						
Hyperiid amphipod	3.68		1.51	0.13		0.04
<i>Crangon septemspinosa</i>	2.94		1.51	0.23		0.07
Unidentified shrimp		0.78	0.38		0.01	0.01
<i>Lihinia emarginata</i>	0.73	0.78	0.75	0.35	0.22	0.26
<i>Cancer irroratus</i>	83.82	94.57	89.06	65.07	84.69	78.62
<i>Cancer borealis</i>	1.47		0.76	1.29		0.40
Unidentified crab		0.78	0.38		0.26	0.18
Crab fragments	0.73	0.78	0.75	0.06	0.22	0.17
<i>Pagurus pollicaris</i>	0.73		0.38	5.80		1.80
<i>Pagurus longicarpus</i>	2.21	1.55	1.89	0.68	0.22	0.36
<i>Pagurus</i> sp.	1.47		0.75	0.39		0.12
Fish						
<i>Tautoglabrus adspersus</i>	3.68		1.89	3.39		1.05
<i>Peprilus triacanthus</i>		5.43	2.64		5.60	3.87
<i>Syngnathus fuscus</i>		0.78	0.38		0.58	0.40
Fish remains	8.82	2.33	5.66	10.80	1.85	4.52
Other						
Well-digested material	24.26	13.95	19.25	9.05	4.01	5.57
Sediment	5.15	3.10	4.15	0.43	0.19	0.26

Results

The collections comprised 129 black sea bass stomachs with prey from the Barnegat Light Reef (plus 14 empty ones) and 136 stomachs from the Garden State South Reef (plus 8 empty ones). The mean total lengths of the fish examined were 24 cm for the Barnegat Light Reef collection and 26 cm for fish from the Garden State South Reef; the size range was limited to 18-46 cm for both, but most fish collected and examined were 20-32 cm long.

We do not consider the variance in predator size important in this dietary comparison. We do not know how well this range represents the true size structure of black sea bass populations on the reefs, but a large variance is not expected based on diver observations.

Twenty-three prey taxa were found in black sea bass stomachs from both reefs (Table 1). By percent frequency of occurrence (FO), the diets of fish collected at both reefs were dominated (84- 95% FO) by early benthic instar, juvenile rock crabs *Cancer irroratus*. Other prey taxa were of minor importance (<5% FO) except unidentified fish remains and butterflyfish *Peprilus triacanthus*. Juvenile rock crabs also constituted 65-85% of total stomach volumes (Table 1). Half the prey taxa found in the stomachs were shared in the diets at both reefs. These shared prey taxa constituted 91% of the combined total diet volumes.

The PSI for stomach volumes was 72%, which suggests a strong similarity in diets of black sea bass from the two artificial reefs despite the absence of epifauna on the new reef. Kendall's tau was -0.11 (z-test, $P = 0.27$) indicating no significant difference between reef diets. Thus, presence or absence of reef epifauna was not a strong determinate of black sea bass diets.

Overall, 84% of black sea bass diet volume consisted of benthic invertebrates (polychaetes, molluscs, crustaceans; Table 1) that are typically found in sandy coastal habitats (Caracciolo and Steimle 1983; Steimle 1990). Minor components of the diet (<1% by stomach volume) were hyperiid amphipods and squid (Table 1), which are planktonic or nektonic. Of the fish in the diet, only cunner *Tautoglabrus adspersus*, found in a few stomachs of black sea bass from the Garden State South Reef, are common associates of coastal reefs. The other identifiable fish prey were butterflyfish *Peprilus triacanthus*, a pelagic species, and northern pipefish *Syngnathus fuscus*, which are most common in estuarine vegetation beds.

TABLE 2. Comparison of principal prey taxa of black sea bass from Atlantic states studies. The “~” symbol indicates a value estimated from available published data; the “+” sign means present in diets at low (<1%) or unclear levels.

Prey taxon	Percent frequency of occurrence from:		Percent total volume or weight from:			
	South Carolina and Georgia a	New Jersey b	South Carolina and Georgia a	Virginia c	New Jersey b	Massachusetts d
Coelenterates	~12		1.4	+		+
Polychaetes	12	2	1.8		0.3	1.5
Molluscs	~9	7	9.5	34.1	1.9	27.0
Cephalopods	4		6.8	+	0.8	19.2
Crustaceans	~70	1	27.5	54.4	82.0	59.5
Amphipods	~20		~1	+	+	+
Barnacles	5	+	0.3	+		+
Decapods	62		26.2	51.4	82.0	59.3
Rock crab		89		26.2	78.6	29.1
Echinoderms	~10		1.9	+		+
Tunicates	15		13.4			+
Fish, total			42.7	2.7	9.8	0.2
Reef fish	~2	2	3.3		1.0	
Nonreef fish	7	3	18.0		4.3	0.2
Undefined	20	6	21.4		4.5	+

a Sedberry (1988); $N = 313$.

b Present study; $N = 265$.

c Chee (1977); $N = 520$.

d Mack and Bowman (1983); $N = 356$.

Discussion

The dominant taxa in stomachs of adult black sea bass we examined are similar to those found by others (Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Chee 1977; Link 1980; Steimle and Ogren 1982; Mack and Bowman 1983; Sedberry 1988; Hood et al. 1994; Lindquist et al. 1994). One of us (F.W.S., unpublished) has had similar results from examining black sea bass diets over several years at an artificial reef and a 60-year-old shipwreck in Delaware Bay.

Among the more detailed studies of black sea bass diets undertaken from Georgia to Massachusetts, including ours, the principal agreement has been on the dietary importance of decapod crustaceans, particularly of rock crabs (Table 2). Most rock crabs found in black sea bass stomachs from both our reef sites were megalops or recently settled, early instar juveniles. Rock crab megalops show little preference in settling sites or in post-settlement survival among habitats (M. Clancy, University of Rhode Island, and C. A. Gibeault, University of New Hampshire, personal communications). Chee (1977) found that Atlantic jackknife (razor) clams *Ensis directus*, an inhabitant of sandy sediments, were also volumetrically as important (25%) as rock crabs (26%) in black sea bass diets, which included only minor amounts of reef epifauna, at a Virginia artificial reef.

Black sea bass do not necessarily ignore reef prey, which have been important parts of their diets in North Carolina (Lindquist et al. 1994) and South Carolina (Sedberry 1988). The weight of evidence, however, is that adult black sea bass do not usually depend on the epifauna associated with artificial reefs. Although they are undoubtedly opportunistic, they typically feed to a high degree on prey that are not strictly associated with reefs or that are found on the open bottom or can be ubiquitous, such as juvenile rock crabs. This type of prey use might be

expected for a reef species like black sea bass that also migrates across the continental shelf to winter offshore (at least the population north of Cape Hatteras), traversing open, sandy areas that offer few reeflike habitats to winter offshore (Musick and Mercer 1977).

Analogous use of and possible dependence on off-reef food resources by reef-associated predators have also been documented in studies of other temperate and tropical reefs (Hueckel and Buckley 1987; Sedberry 1989; Bortone and Nelson 1995; Kurz 1995).

Reefs may enrich an area of sea bottom near them with organic materials they export (waste products or detached organisms). The eddies and sheltered areas formed by the interference of the reef profile with current flow promote the local deposition of planktonic material (Ambrose and Anderson 1990). To the extent that this enrichment enhances the nearby prey base, a reef system may be able to sustain additions to local populations of black sea bass and other fish with similar diets (Lindberg et al. 1990; Kurz 1995). More knowledge of this relationship is needed to fully understand the ecosystem effects of artificial reefs and to insure that the most valuable reef fish forage grounds are also within management zones.

Our study and others suggest that black sea bass use reef structure primarily for shelter and not as a major source of food. Fishery managers choosing artificial reef sites, or special management zones or refuges involving reefs, in the Middle Atlantic Bight to primarily support or enhance local black sea bass populations should consider the availability of nonreef prey at proposed sites. Open coastal areas that have low natural abundance of appropriate prey and that are not substantially enriched by organic exports or imports from the reef probably will not sustain a large population of black sea bass or other reef-associated species with similar diets.

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