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Trophodynamics of Select Demersal Fishes in the New York Bight

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NOTE ON SPECIES NAMES

The Northeast Fisheries Science Center's policy on the use of species names in technical publications and reports is to follow the American Fisheries Society's (AFS) lists of common and scientific names for fishes (Robins *et al.* 1991), mollusks (Turgeon *et al.* 1988), and decapod crustaceans (Williams *et al.* 1989). This policy applies to all issues of the *NOAA Technical Memorandum NMFS-F/NEC* series.

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ABSTRACT

The effects of waste disposal on the living marine resources and associated ecological processes in the coastal New York Bight apex are a prime concern for conserving and managing these resources. Until recently, there has been limited information on ecological processes related to fishery resources in the Bight apex, *e.g.*, food webs or trophodynamics, which could be affected by waste disposal. This report describes the diets of five common species of demersal fishes (*i.e.*, silver hake, red hake, winter flounder, windowpane, and fourspot flounder) collected in the New York Bight apex, with some preliminary notes on the diets of several other species from the area. The collections covered the period between 1982 and 1985, during the peak of sewage sludge disposal, in variably contaminated areas of the Bight apex. The results of this diet study, and comparisons with the results of previous diet studies since the 1950s, suggest neither temporal or spatial differences in diets because of sludge disposal. Mysid shrimps and small decapod crustaceans continue to be important components of most diets.

INTRODUCTION

The New York Bight apex, the coastal area at the mouth of New York Harbor, has been subject to multiple-use problems since colonial times (Squires 1981). The consequences of disposing various wastes in the apex on its living marine resources have been of concern to managers, at least since World War II. In the 1940s, the effects of disposing dredged harbor sediments, domestic garbage incineration ash, industrial wastes, or sewage sludge in the apex were mostly unknown, and opinions on possible harm varied. Some considered sewage to be beneficial, *i.e.*, providing a "fertilizing action"; however, the contamination and closure of local shellfish beds were well-known negative results. The need for research on the marine disposal of various wastes was evident, however, to keep "the serpent of pollution" in check (Westman 1949). Detailed studies on the effects of waste disposal on fishery resources, habitat, or ecology did not begin until the late 1940s, and these considered only industrial acid wastes (Arnold and Royce 1950; Redfield and Walford 1951). Comprehensive studies of other waste disposal activities did not truly begin until the late 1960s. These studies demonstrated that sediment quality and benthic invertebrate community structure in deeper portions of the apex had been substantially altered (National Marine Fisheries Service 1972; Steimle *et al.* 1982).

Information on the effects of this altered benthic habitat on its associated invertebrate communities and on fishery resources in the Bight apex, as well as information on the linkages (*e.g.*, trophodynamics) among the habitat, communities, and resources, is not well known. Information on the trophodynamics of fishery resources in the Bight apex is essential to understanding how polluted habitats can alter ecological processes or help define the potential pathways for fishery resource contamination (Pentreath 1976; Fletcher *et al.* 1981; Mohlenberg and Kiorboe 1983; Pizza and O'Connor 1983; Willis and Sunda 1984; Atchinson *et al.* 1987; and others).

Despite the importance or utility of dietary information for understanding linkages between waste-disposal-caused benthic alteration and fishery resources, there are few dietary studies for the Bight apex, *i.e.*, Schaefer (1960), Steimle and Ogren (1982), Luczkovich and Olla (1983), and Steimle (1985), and these have limitations. To improve our understanding of the ramifications of benthic alterations by waste disposal on fishery resources in the Bight apex, we report on the results of the examination of 1,225 stomach samples from several common fishery species. These results are compared to previous Bight apex studies or to more general studies for the New York - Southern New England area for evidence of a change in diets that could be related to waste disposal.

METHODS

The New York Bight apex, being a complex habitat, was stratified into seven areas (Figure 1) approximately representing major habitat types in the apex as defined by topography, water depth, sediment type, sediment contamination, and proximity to waste disposal sites and one "control" area, Z (Table 1). The many ship wrecks, bottom debris, lobster fishing gear, heavy shipping traffic, and other navigational/sampling problems in the Bight apex precluded the use of a cost-effective randomized sampling approach for each stratum. Specific operational trawling zones were found within each stratum and used to collect the stomachs examined for this study.

Collections were based on 20-30 min tows at 1.5 knots by otter trawls with a 30-ft (9-m) mouth and a 1-inch (2.5-cm) stretched-mesh cod end. Upon collection, desired samples were segregated by species or, in the case of large collections, into subsamples of about 10 individuals per 10-cm length intervals, or into obvious size classes of each selected species. Samples were individually measured, stomachs removed, and their contents analyzed according to the standard, semiquantitative method used by the Northeast Fisheries Science Center (Langton *et al.* 1980; Bowman 1982). This analysis included carefully emptying the contents of each individual stomach sample into a petri dish to retain the contents' original size and shape in the stomach and estimating the total stomach volume (estimated to 0.1-cm^3 accuracy) by a side-by-side comparison with the most appropriate of a series of volume-graduated, variable-diameter (0.5-2.5 cm) cylinders. The contents were then sorted by type and identified, as far as possible. The percent contribution of each prey or other content item to the total stomach volume was estimated visually, each item type was counted and measured (if possible), and digestion state noted. Most prey in adult fish were readily identifiable by the unaided eye of an observer familiar with the limited prey types commonly encountered, or with a small degree of magnification provided by a 2-3X hand lens. Very small or questionable prey were preserved in shell vials for later microscopic examination. Small or juvenile fish, and the few lobsters collected, were not immediately examined, but preserved in 10-percent buffered formalin for later microscopic examination, because of the small size or masticated condition of items in their stomachs. The advantages and disadvantages of this diet analysis approach have been reviewed and found to provide reasonable results (Hyslop 1980; Bowman 1982).

To verify the reported daily feeding patterns of some common fish in the Bight apex, we collected specimens about every four hours and examined their stomach contents over a 24-hr period at area D.

RESULTS

Our analyses focused on five species: winter flounder, silver hake, red hake, windowpane, and fourspot flounder. These five species provided adequate data from several areas for comparisons; limited results from 17 other species examined are also briefly noted.

Winter flounder from the shoulders of the "Mud Hole" (Figure 1, areas B, D, and E) and from the cleaner "control" area (Figure 1, area Z) were feeding primarily on the tentacular crowns of the tube-dwelling anemone *Cerianteopsis americanus* and the large polychaete worms *Lumbrineris acicularum* and *Pherusa affinis* (Table 2). This prey trio was common in fish from siltier areas (Figure 1, areas C, F, and G), but with *Pherusa* being the overwhelming dominant (Table 2). The few samples at a shallower, sandy area off Sandy Hook (Figure 1, area A) suggested a different diet dominated by small bivalve mollusks and crustaceans; however, *Lumbrineris* was still important (Table 2).

Silver hake from all areas ate mainly the sevenspine bay shrimp (*Crangon septemspinosa*), mysid shrimp (mostly *Neomysis americanus*), and small fishes, including American sand lance and juvenile silver hake (Table 3). Various amphipods and unidentifiable small fishes were minor components of the diet.

Crangon shrimp were also the primary prey of red hake examined from all areas, but *Pherusa* was important at many of the siltier areas (Figure 1, areas B, C, and E-G; Table 4). Mysid shrimp, mostly *Neomysis*, and grammarid amphipods were important at inshore area A. Other dietary items of red hake included a range of benthic invertebrates, small fishes, and squids.

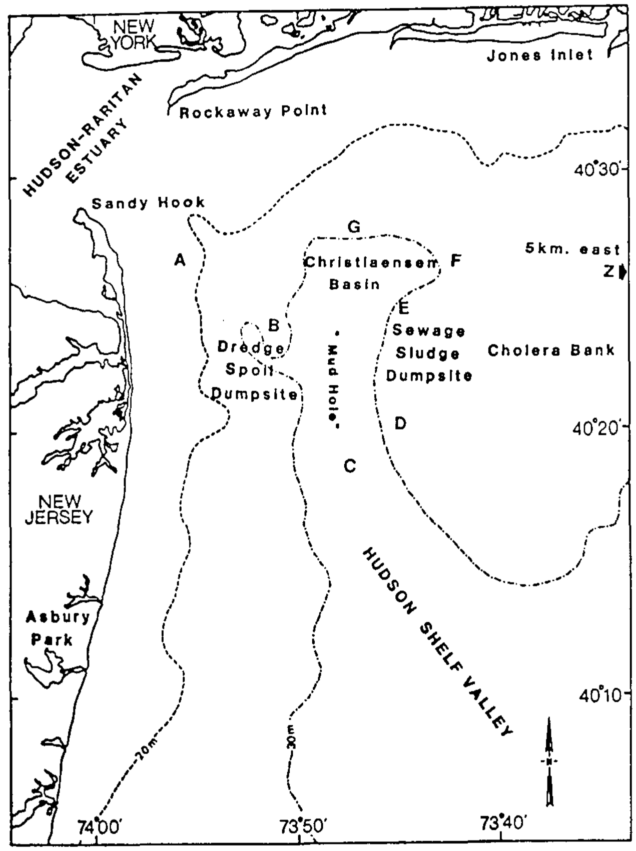

Figure 1. Locations of 1982-85 trawl collections for diet analysis and of reference areas in the New York Bight apex.

Windowpane ate mostly mysid shrimp in all areas. The bristled longbeak shrimp (*Dichelopandalus leptocerus*) and, to a lesser degree, American sand lance were important in the eastern areas (Figure 1, areas D - Z; Table 5). Polychaete worms, small decapod crustaceans, the ribbon worm *Cerebratulus*, and small fishes were other notable components of the diet.

Fourspot flounder, collected only near the former 12-mile sewage sludge disposal site (Figure 1, areas D, E, and G), also ate mostly *Neomysis* and *Crangon* shrimps, small fishes, and juvenile *Cancer* crabs (Table 6).

The stomach contents from limited collections of five other predator species -- cunner, sea raven, summer flounder, yellowtail flounder, and American lobster (with n = 20+ for each species) -- are summarized in Table 7.

Of the species examined in smaller numbers, *e.g.*, spotted hake, Atlantic cod, black sea bass, tautog, ocean pout, and longhorn sculpin, all consumed mainly small or juvenile *Cancer* crabs, *Crangon* shrimp, other large benthic invertebrates, and small fishes. The few specimens of little skate examined generally ate the same diverse small benthic invertebrates that dominated the diets of winter and yellowtail flounder, but with the addition of some small fishes.

The preliminary study of the 24-hr feeding cycle sug-

Table 1. Habitat characteristics of New York Bight apex demersal predator collection areas (Figure 1) based on Reid *et al.* (1982), Steimle (1985), and others

Area	Characteristics
A	An inshore area, 15-25 m in depth, with mixed sand and silt sediments, influenced by the Hudson-Raritan estuarine plume. Benthic macrofaunal biomass levels were patchy and variable, 23-380 g/m^2 (wet wt), and dominated by the nutclam, *Nucula* sp., and the polychaetes *Nephtys incisa* and *Nereis virens*.
B	On the west shoulder of the Christiaensen Basin, in the dredge spoil dumpsite, 25-30 m in depth, variably silty, medium to fine sands. Benthic biomass was relatively low, 54-108 g/m^2, and variably dominated by *Nucula* sp., and by *Nephtys incisa* and several other species of polychaetes.
C	In the "Mud Hole," 50-70 m in depth with silty sediments having relatively high concentrations of toxic chemicals. Benthic biomass was relatively high, greater than 200 g/m^2, and dominated by *Nucula* sp., rhynchocoels, *Ceriantheopsis*, and the polychaetes *Pherusa affinis*, *Nephtys incisa*, and some smaller species.
D	On the east shoulder of the "Mud Hole" in 25-30 m with silty, medium-to-fine sand; just below the sewage sludge disposal area. Benthic biomass levels were relatively low, 26-82 g/m^2, and dominated by the polychaete *Spiophanes bombyx*.
E	In the northeast corner of the sewage sludge disposal site, 25-35 m in depth, with medium to silty fine sand. Benthic biomass levels ranged from 71 to 152 g/m^2, and were dominated by capitellid polychaetes and rhynchocoels.
F	At the northeast edge of the Christiaensen Basin, 30-40 m in depth, with moderately contaminated, silty, fine sands. Relatively high benthic biomass, generally above 200 g/m^2, dominated by the same species as at area C.
G	On the northern edge of the Christiaensen Basin, 20-30 m deep, with silty sand. Benthic biomass variable, 36-1,048 g/m^2, dominated by the anemone *Ceriantheopsis americanus*.
Z	An area about 10 km east of the Christiaensen Basin, 25 m deep, with medium sand and moderate biomass levels, greater than 100 g/m^2, dominated by sand dollars, *Echinarachnius*.

Table 2. Summary of the 1982-85 diets of 389 winter flounder from the New York Bight apex, per collection area, by percent frequency of occurrence (unidentifiable or nonorganic items not included). (See Table 16 for full taxonomic names and Figure 1 for area locations.)

		Area							
		A	B	C	D	E	F	G	Z
No. of samples		11	31	96	77	48	52	42	32
Percent empty		34	13	10	14	2	21	9	20
Major items	*Ceriantheopsis*		73	30	50	47	10	3	50
	Hydrozoans	50	5		20	2		3	13
	Cerebratulus			1	1	25	3	4	9
	Solen sp.	50			1				
	Tellina	25							
	Polychaetes	17	8	3	3	15			
	Lumbrineris sp.	25	26	7	27	21	13	2	20
	Pherusa		5	63	21	35	63	62	27
	Nephtys sp.		33	2		20	5	9	
	Amphipods	17	5	1	3		1		8
	Ovalipes	17							
Minor items	*Yoldia*, *Echinarachnius parma*, *Cancer* juveniles, *Glycera* sp., *Diopatra*, *Crangon*, *Unciola* sp., *Ampelisca* sp., and *Leptocheirus*.								

Table 3. Summary of the 1982-85 diets of 215 silver hake from the New York Bight apex, per collection area, by percent frequency of occurrence (unidentified or nonorganic items not included). (See Table 16 for full taxonomic names and Figure 1 for area locations.)

		Area							
		A	B	C	D	E	F	G	Z
No. of samples		17	16	37	32	24	69	10	10
Percent empty		46	10	27	13	0	20	30	0
Major items	*Crangon*	20	12	28	21	30	42	14	70
	Unidentified fish	25	40	22		4	14	29	
	Dichelopandalus		8	5	4	23	3		10
	Silver hake	25			4		4		50
	American sand lance		13	6	3		5	14	10
	Mysids	10	26	12	34	4	27	43	20
	Unidentified decapods		40		2	3	9		10

Minor items cumaceans, *Leptocheirus*, *Ampelisca* sp., scup, anchovy, unidentified amphipods, gadid spp., and *Unciola* sp.

Table 4. Summary of the 1982-85 diets of 144 red hake from the New York Bight apex, per collection area, by percent frequency of occurrence (unidentified or nonorganic items not included). (See Table 16 for full taxonomic names and Figure 1 for area locations.)

		Area							
		A	B	C	D	E	F	G	Z
No. of samples		10	15	61	4	14	37	2	1
Percent empty		0	18	40	0	16	17	0	100
Major items	*Crangon*	80	72	4	100	59	28	50	
	Mysids	80		4	17		8		
	Leptocheirus	20	11	5					
	Pherusa		28	33		22	48	50	
	American sand lance		50	3					
	Cancer juveniles		50	18		9	5		
	Dichelopandalus		50			33	2		
	Amphipods (?)	50							
	Ceriantheopsis			21					

Minor items unidentified fish, unidentified polychaetes, squid, *Pagurus* sp., *Nucula* sp., holothurian, *Ampelisca* sp., unidentified decapod, and *Unciola* sp.

Table 5. Summary of the 1982-85 diets of 131 windowpane from the New York Bight apex, per collection area, by percent frequency of occurrence (unidentified or nonorganic items not included). (See Table 16 for full taxonomic names and Figure 1 for area locations.)

		Area						
		A	C	D	E	F	G	Z
No. of samples		10	16	37	25	15	11	17
Percent empty		0	87	8	5	30	30	25
Major items	Mysids	100	50	79	36	70	50	50
	Crangon			28	18			40
	Dichelopandalus			5	10	75	25	20
	American sand lance				14	5	13	10
	Unidentified decapod				29			

Minor items rhynchocoel, anchovy, silverside, unidentified polychaetes, and gadid.

Table 6. Summary of the 1982-85 diets of 73 fourspot flounder from the New York Bight apex, per collection area, by percent frequency of occurrence (unidentified or nonorganic items not included). (See Table 16 for full taxonomic names and Figure 1 for area locations.)

		Area		
		D	E	G
No. of samples		50	14	9
Percent empty		12	50	44
Major items	Mysids	23	25	40
	Crangon	25	5	20
	Cancer juveniles	21	15	
	Unidentified fish	3	5	40
Minor items	*Ensis*, squid, American sand lance, unidentified flatfish, and unidentified decapods.			

Table 7. Summary of the 1982-85 principal prey of other predators, with n = 20-40, in the New York Bight apex and the areas of collection

		Predator				
		Cunner	Sea Raven	Summer Flounder	Yellowtail Flounder	American Lobster
No. of samples		39	32	20	31	33
Areas collected		ABC	B-F	CDG	CFZ	C
Principal prey	*Neomysis*	X		X		
	Crangon	X	X			
	Cancer adults					X
	Cancer juveniles	X	X			
	Nucula sp.	X				X
	Ovalipes					X
	Pherusa				X	X
	Homarus juveniles					X
	Fish		X	X		X
	Squid					X
	Polychaetes	X			X	X
	Amphipods	X		X		
	Unidentified decapods					X

Table 8. Results of the July 1983, area D, 24-hr feeding study for winter flounder; prey listed in relative order of importance based on percent frequency of occurrence. (See Table 16 for full prey names; UOM = unidentified organic matter.)

	Time					
	0800	1100	1500	1830	2300	0300
No. of samples	11	10	10	10	10	10
Mean length (cm)	25.4	24.6	25.8	25.6	28.3	29.6
Percent empty	44	20	50	40	60	60
Mean total volume (cm^3)	2.40	1.52	0.90	1.54	0.60	0.03
Relative fullness	0.09	0.07	0.03	0.07	0.10	<0.01
Prey	*Ceriantheopsis* *Lumbrineris* sp. *Cancer* *Solen* sp. *Pherusa* *Glycera* sp. *Edotea* Rhynchocoel	*Lumbrineris* sp. UOM *Ceriantheopsis* Polychaete (?) *Cancer*	*Ceriantheopsis* *Lumbrineris* sp. *Cancer* Polychaete (?)	UOM Polychaete (?) *Ceriantheopsis*	UOM	UOM *Cancer*

Table 9. Results of the July 1983, area D, 24-hr feeding study for windowpane; prey listed in relative order of importance based on percent frequency of occurrence. (See Table 16 for full prey names.)

	Time					
	0800	**1100**	**1500**	**1830**	**2300**	**0300**
No. of samples	4	10	10	3	8	0
Mean length (cm)	28.3	27.6	26.6	28.8	25.9	-
Percent empty	0	60	60	100	38	-
Mean total volume (cm^3)	0.55	0.66	0.85	0	1.03	-
Relative fullness	0.02	0.02	0.03	0	0.04	
Prey	*Crangon* Anchovy	Mysids *Crangon*	*Crangon* Mysids		Mysids *Crangon*	

Table 10. Results of the July 1983, area D, 24-hr feeding study for fourspot flounder; prey listed in relative order of importance based on percent frequency of occurrence. (See Table 16 for full prey names.)

	Time					
	0800	**1100**	**1500**	**1830**	**2300**	**0300**
No. of samples	10	10	10	7	10	0
Mean length (cm)	27.6	27.3	28.9	26.3	27.2	-
Percent empty	60	0	80	29	40	-
Mean total volume (cm^3)	0.66	0.86	4.50	3.40	0.62	-
Relative fullness	0.02	0.03	0.16	0.13	0.02	
Prey	Mysids *Crangon*	*Cancer* Mysids Fish(?) *Crangon* *Dichelopandalus* *Ensis*	Squid *Crangon* Squid Fish(?) Mysids	American sand lance *Cancer* Fish (?) *Crangon* Decapod(?) Mysids	American sand lance	

gested that winter flounder fed primarily in the morning, prior to 1100, when there were the highest average stomach volumes, greatest prey diversity, and relatively low percent of empty stomachs (Table 8). There also appears to be a lesser, secondary feeding effort in the early evening (before 1900) as evidenced by a slight increase in average stomach volume and decrease in the percentage of empty stomachs. Unidentifiable material, mostly well digested, dominated stomach contents from 1830 to 0300.

Preliminary data for windowpane (Table 9) suggested more constant feeding from early morning to near midnight. Unfortunately, no samples were collected at 0300, and a small collection at 1830 with empty stomachs renders the results inconclusive.

The fourspot flounder had the highest stomach volumes during the afternoon collections, 1500 to 1830, but the percentage of empty stomachs and prey diversity were variable (Table 10).

DISCUSSION

These preliminary results suggest little qualitative difference between diets of the five primary fish species examined in the most contaminated areas of the Bight apex (Figure 1, areas C and E-G) relative to other areas in the apex. For example, winter flounder consumed the same major prey *(Ceriantheopsis, Lumbrineris,* and *Pherusa)* in almost all areas (Table 2). The frequency of empty stomachs, an index used to suggest possible feeding inhibition such as from any adverse conditions in the most altered apex habitat, was not greater in the more contaminated areas compared to less contaminated areas (Table 2); in fact, there were fewer empty stomachs in the more contaminated areas (*i.e.*, the mean frequency in more contaminated areas was 10 percent compared with a mean frequency in less contaminated areas of greater than 30 percent). The between-area comparisons of the diets of the other four common species also suggest more similarities than differences (Tables 3-6).

There are several assumptions to be considered that relate to the validity of the conclusions suggested above, *i.e.*, of little effect of solid-waste-contaminated benthic habitat and forage on diets. For example, it is assumed that stomach contents are reasonably representative of the forage and environmental conditions in the areas where they were collected. The predators examined here are not static or stationary. Winter flounder have been reported to "shamble" across the bottom at an average speed of about 1.44 km/hr, if constantly moving (MacDonald 1983). The preliminary conclusions of this study assume that the predators we examined were not constantly on the move between or through areas. Instead, they were feeding or resting in the general area at the time of collection; several species, *e.g.*, flounders and red hake, have been reported to feed where food is abundant, and to slow down or rest in or near the feeding area after a large meal (Pearson *et al.* 1980).

Dietary data are also influenced by factors such as differential digestion rates for various prey types (Klein-MacPhee 1978; Durbin and Durbin 1980; MacDonald *et al.* 1982) which are known to affect most diet studies. The stomach contents of daylight feeders, such as winter flounder (Olla *et al.* 1969), collected between 1000 to 1500, when most collections were made, most probably included items eaten within a few hours, as per the results of the 24-hr study (Table 8). Thus, differential digestion as a factor in interpreting the results would be minimal.

The diet data for the most contaminated areas, *i.e.*, B-G, compiled for overall comparison with data for less contaminated or uncontaminated areas of the Bight or with data from previous diet studies in the apex, also suggest little differences in diet. The compiled diet data for winter flounder from contaminated habitat, for example, compared with the only previous diet study for this species in the Bight apex, that of 1968-70 (Steimle 1985), suggest only minor differences based on percent frequency of occurrences of major prey (Table 11). The polychaete worm *Pherusa* was the major prey in both data sets, with some variability in the contribution of amphipod crustaceans and the burrowing anemone *Ceriantheopsis*. The abundance of the latter may have been underestimated in the earlier study, as their banded, purple tentacular crowns, the part usually nipped off and eaten, are easy to identify in fresh stomachs, but lose color and disintegrate, to some degree, when preserved, as they were in the stomachs of the early study. The results of both Bight apex studies are similar to those reported in other diet studies for winter flounder in the New York Bight - Southern New England area (Table 11) or Long Island Sound (Richards 1963). Langton and Bowman's (1981) data based on percent total stomach weight should be reasonably comparable to the volumetric data we report; the proportional comparisons from either variable should be similar.

Table 11. Comparison of the results of this winter flounder diet study with the results of previous studies in the New York Bight apex's Christiaensen Basin (Steimle 1985) and outside the apex in Southern New England waters (Langton and Bowman 1981). Data for the apex are presented as percent frequency of occurrence or percent total stomach volume (in parentheses); data for Southern New England are presented as percent total stomach weight. ("+" indicates less than one-percent contribution.)

		Data Source		
		Steimle (1985)	1982-85	Langton and Bowman (1981)
No. of samples		196	346	154
Prey	Polychaetes	83[a]	75 (45)[b]	39[c]
	Isopods	13	+ (+)	
	Amphipods	39[d]	3 (2)[e]	4
	Crangon	4	2 (+)	
	Bivalve mollusks	17[f]	1 (+)[g]	13
	Ceriantheopsis	1	36 (26)	10
	Hydrozoans	2	5 (2)	+
	Rhynchocoels		6 (1)	
	Cancer juveniles	3	+ (+)	8

[a] Mostly *Pherusa affinis* and *Nephtys incisa*.
[b] Mostly *Lumbrineris* sp., *Pherusa*, and *Nephtys* sp.
[c] Mostly sabellids, lumbrinerids, and nephtids.
[d] Various species, including *Unciola* sp., *Anonyx*, *Photis*, *Gammarus*, *Leptocheirus*, and caprellids.
[e] Mostly *Unciola* sp., *Ampelisca* sp. and *Leptocheirus*.
[f] Mostly siphons, but also whole *Spisula*, *Nucula* sp., *Yoldia*, and *Arctica*.
[g] Mostly *Nucula* sp.

Comparison of the silver hake data from this study with those of Schaefer (1960), the only previous study for the apex, also shows no major differences or changes (Table 12). Schaefer's data were from trawl-collected fish taken during winter through spring of 1957-58 from the "Mud Hole," essentially area C (Figure 1). *Crangon* shrimps and small fishes were major prey during both study periods, with minor differences in the contributions of other prey, *e.g.*, polychaete worms, mysid shrimps, and squids (Table 12). Other silver hake diet studies in the New York Bight, *e.g.*, Jensen and Fritz (1960) and Richards (1963), also report small crustaceans and fishes as major prey. The results of the Southern New England study of Bowman and Michaels (1984) differ from both Bight apex data sets, especially in the contribution of mysid and *Crangon* shrimps, squids, and fishes (Table 12).

Both studies of red hake diets in the deep, most contaminated part of the Bight apex showed similar diets, based primarily on polychaete worms, *Crangon* shrimps, and small or juvenile *Cancer* crabs (Table 13); however, there were proportional differences for other prey. This diet is also similar to that reported elsewhere for red hake (Richards 1963; Sedberry 1983; Luczkovich and Olla 1983). Outside the apex, however, other prey such as squids and small fishes were important (Bowman and Michaels 1984).

There are no reliable diet data prior to those of 1982-

Table 12. Comparison of the results of this silver hake diet study with the results of previous studies in the New York Bight apex's Christiaensen Basin (Schaefer 1960; Steimle 1985) and outside the apex in Southern New England waters (Bowman and Michaels 1984). Data for the apex are presented as percent frequency of occurrence or percent total stomach volume (in parentheses); data for Southern New England are presented as percent total stomach weight. ("+" indicates less than one-percent contribution.)

		Data Source			
		Schaefer (1960)	Steimle (1985)	1982-85	Bowman and Michaels (1984)
No. of samples		261	235	188	918
Prey	Polychaetes	+	7		+
	Mysids	10	64	24 (19)	1
	Amphipods	1	3	+ (+)	+
	Crangon	33	44	25 (15)	1
	Squid	9	+		14
	Herring	5			1
	Silverside	1			
	American sand lance	2		7 (7)	+
	Silver hake	21		1 (1)	8
	Red hake	5			
	Unidentified fish	19	25	18 (14)	57

85 for the remaining two common predators, windowpane and fourspot flounder, in the Bight apex. Comparison of diet data for windowpane in the Bight apex with data in other areas shows little differences in the dominant prey (Table 14), with mysid and decapod shrimps being major prey. These results are consistent with those of Moore (1947), Richards (1963), and Hickey (1975), as well. The results for fourspot flounder suggest some dietary differences between studies (Table 15); outside the Bight apex, squids, euphausids, or Dichelopandalus shrimps were the dominant prey.

The results and comparisons discussed above are preliminary and may not be adequate to address the tentative hypotheses of no difference or change in diets of the predators examined. For example, Pennington *et al.* (1982) suggest that over 300 Atlantic cod must be examined to detect confidently a difference of at least 50 percent in the means between two areas for a single size class, 90 percent of the time with 95-percent confidence. Only the pooled data for winter flounder might approach satisfying the criteria used for cod; the sample size required for winter flounder to detect a difference at the above level of confidence could be different.

One result of the 1982-85 study is the prominence of a few crustacean species, *e.g.*, mysid and decapod shrimps, in the diets of most predators. Although the importance of epibenthic crustaceans in fish diets has been noted by others (Whitfield 1988), they appear to be more prominent in the Bight apex diets than outside the apex for some predator species, *e.g.*, silver hake, red hake, and fourspot flounder (Tables 12, 13, and 15). Whether this is a consequence of abundance or a factor of environmental conditions in the apex, *e.g.*, seasonal hypoxia that could inhibit burrowing by *Crangon*, as suggested by Minello *et al.* (1987) for other shrimp, or factors such as turbidity, is unknown at present.

Although some fresh or brackish water mysid shrimps are highly sensitive to toxic chemicals and commonly used in toxicity bioassays, the coastal species commonly used as food by many fish in the Bight apex appear to be tolerant of ambient conditions, as they have persisted as major dietary components since at least the 1950s (Schaefer 1960). Chapman *et al.* (1988) report that some marine species commonly use sewage particles as food. Because mysids require special epibenthic or suprabenthic sampling equipment, little is known of their abundance or distribution in the New York Bight apex. Their high frequency in diets can suggest a high abundance in the apex, however (Allen 1988). This may apply to other important dietary crustaceans not effectively sampled by the grab or trawl samplers commonly used in biological assessment surveys. The importance of these prey to fishery resources suggests that they deserve more attention in studies of the potential effects of habitat alterations.

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Table 13. Comparison of the results of this red hake diet study with the results of previous studies in the New York Bight apex's Christiaensen Basin (Steimle 1985) and outside the apex in Southern New England waters (Bowman and Michaels 1984). Data for the apex are presented as percent frequency of occurrence or percent total stomach volume (in parentheses); data for Southern New England are presented as percent total stomach weight. ("+" indicates less than one-percent contribution.)

		Data Source		
		Steimle (1985)	1982-85	Bowman & Michaels (1984)
No. of samples		219	133	481
Prey	*Ceriantheopsis*	3	4 (1)	
	Polychaetes	43[a]	33 (22)	4
	Amphipods	24	3 (1)	5
	Mysids	39	5 (3)	
	Crangon	70	52 (23)	3
	Dichelopandalus		14 (6)	8
	Crabs[b]	17	14 (4)	4
	Bivalve mollusks	2	+ (+)	3
	Squid	1	+ (+)	11
	Fish	5	10 (3)[c]	38

[a] Mostly *Pherusa* and *Nephtys incisa*.
[b] Mostly *Cancer* juveniles.
[c] Mostly American sand lance.

Table 14. Comparison of the results of this windowpane diet study in the New York Bight apex's Christiaensen Basin with the results of a previous study outside the apex in Southern New England waters (Langton and Bowman 1981). Data for the apex are presented as percent total stomach volume; data for Southern New England are presented as percent total stomach weight. ("+" indicates less than one-percent contribution.)

		Data Source	
		1982-85	Langton and Bowman (1981)
No. of samples		104	318
Prey	Mysids	79	51
	Crangon	3	3
	Dichelopandalus	17	34
	American sand lance	5	
	Crabs	5	+
	Squid		2
	Fish	+	3

Table 15. Comparison of the results of this fourspot flounder diet study in the New York Bight apex's Christiaensen Basin with the results of a previous study outside the apex in Southern New England waters (Langton and Bowman 1981). Data for the apex are presented as percent total stomach volume; data for Southern New England are presented as percent total stomach weight. ("+" indicates less than one-percent contribution.)

		Data Source	
		1982-85	Langton & Bowman (1981)
No. of samples		73	768
Prey	Mysids	25	+
	Crangon	14	3
	Cancer juveniles	8	7
	Fish	16	35
	Dichelopandalus		8
	Euphausids		6
	Squid	+	25

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Table 16. List of common prey of fish and lobster in the New York Bight apex from pre-1986 data, based on greater than 10-percent frequency of occurrence in overall collections

- Phylum Coelenterata
  - Class Hydrozoa
  - Class Anthozoa
    - Order Ceriantharia
      - *Ceriantheopsis americanus*
- Phylum Rhynchocoela
  - Class Anopla
    - Order Heteronemertea
      - Family Lineidae
        - *Cerebratulus lacteus*
- Phylum Mollusca
  - Class Bivalvia
    - Order Nuculoida
      - Family Nuculidae
        - *Nucula* sp.
      - Family Nuculanidae
        - *Yoldia limatula*
    - Order Veneroida
      - Family Mactridae
        - *Spisula solidissima*
      - Family Solenidae
        - *Ensis directus*
        - *Solen* sp.
      - Family Tellinidae
        - *Tellina agilis*
      - Family Dreissenidae
        - *Arctica islandica*
  - Class Cephalopoda
    - Order Teuthoidea
      - (either) Family Loliginidae: *Loligo pealeii*
      - (or) Family Ommastrephidae: *Illex illecebrosus*
- Phylum Annelida
  - Class Polychaeta
    - Order Phyllodocidae
      - Family Glyceridae
        - *Glycera* sp.
      - Family Nephtyidae
        - *Nephtys* sp.
      - Family Nereidae
        - *Nereis virens*
    - Order Spionida
      - Family Spionidae
        - *Spiophanes bombyx*
    - Order Eunicida
      - Family Onuphidae
        - *Diopatra cuprea*
      - Family Lumbrinereidae
        - *Lumbrineris* sp.
    - Order Flabelligerida
      - Family Flabelligeridae
        - *Pherusa affinis*
- Phylum Arthropoda
  - Class Crustacea
    - Order Cumacea
    - Order Isopoda
      - Family Idoteidae
        - *Edotea triloba*
    - Order Amphipoda
      - Family Ampeliscidae
        - *Ampelisca* sp.
      - Family Corophiidae
        - *Unciola* sp.
      - Family Photidae
        - *Leptocheirus pinguis*
    - Order Mysidacea
      - Family Mysidae
        - (mostly) *Neomysis americanus*
    - Order Euphausidacea
    - Order Decapoda
      - Family Pandalidae
        - *Dichelopandalus leptocerus*
      - Family Crangonidae
        - *Crangon septemspinosa*
      - Family Cancridae
        - *Cancer irroratus*
      - Family Paguridae
        - *Pagurus* sp.
      - Family Portunidae
        - *Ovalipes ocellatus*
- Phylum Echinodermata
  - Class Holothuroidea
  - Class Echinoidea
    - Order Clypeasteroida
      - Family Echinarachnidae
        - *Echinarachnius parma*

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