Food Habits of Atlantic Cod, Haddock, and Silver Hake in the Northwest Atlantic, 1969-1972

by

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ABSTRACT

Stomach contents of 1,250 Atlantic cod, *Gadus morhua*; 952 haddock, *Melanogrammus aeglefinus*; and 1,937 silver hake, *Merluccius bilinearis* from five broad ecological zones extending from Cape Hatteras northward to Nova Scotia were analyzed. Fish were obtained by otter trawl from the fall of 1969 to the spring of 1972. The mean weight per stomach was 28.6 g for cod, 6.3 g for haddock, and 2.5 g for silver hake.

Cod fed on fish, crustaceans, mollusks, polychaetes, and echinoderms, in decreasing order of importance. Female cod consumed 75% more food by weight than the males, but no major differences were noted in the composition.

Haddock prey consisted of echinoderms, crustaceans, polychaetes, mollusks, and fish. Echinoderms made up a large portion of the diet of haddock from the Gulf of Maine and western Nova Scotia areas. A comparison of the food habits in the fall and spring revealed that during the spring echinoderms were consumed in smaller quantities, and crustaceans and polychaetes were eaten in larger quantities.

Silver hake fed mostly on fish, crustaceans, and mollusks. One-third of the stomachs examined were empty. The diet of males consisted mainly of crustaceans; the diet of females was largely fish. Cannibalism accounted for 7% of the silver hake food in the southern New England area.

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INTRODUCTION

Quantitative information about the food habits of Atlantic cod, *Gadus morhua* (Linnaeus); haddock, *Melanogrammus aeglefinus* (Linnaeus); and silver hake, *Merluccius bilinearis* (Mitchill) in the waters from Cape Hatteras to Nova Scotia has been insufficient for understanding the interrelationships between these fish and their environment. Such information is needed to provide basic ecological data which may be a useful tool in developing a better understanding of their distribution and abundance.

The abundance of fish such as cod, haddock, and silver hake can be directly related to food availability. Nikolsky (1958) states that the most important factor determining (to a considerable degree) the size of a population, and especially the survival rate, is the food supply. Dementeva (1953) noted that the relationship between a species and its feeding area is a factor which may limit the abundance of that fish. It follows that quantitative diet information is useful when developing management strategies for demersal fish stocks.

The importance of food habit studies has long been realized. Past work in the northwest Atlantic showed that cod fed mainly on fish, crustaceans, and mollusks; haddock on echinoderms, crustaceans, annelids, and mollusks; and silver hake on fish and crustaceans (Verrill, 1871), (Verrill and Smith, 1871-1872), (Goode, 1884), (Kendall, 1898), (Moore, 1898), (Sumner, Osburn, and Cole, 1911), (Nichols and Breder, 1934). More detailed studies were conducted in recent years. Homans and Needler (1944) studied the geographical variations in the food of haddock from 15,000 stomachs collected off Nova Scotia. Wigley (1956), studying Georges Bank haddock, found crustaceans to be the primary food. Wise (1958) noted the growth and feeding of cod, and later (1961) prepared a synopsis of biological data on cod. Wigley and Theroux (1965) studied the seasonal variation in the diet of haddock off Cape Cod, Massachusetts, and Vinogradov (1971) examined the food habits of silver hake off eastern United States.

In addition to the body of data from the northwest Atlantic, important material from Canadian waters and the North and Baltic Seas has been compiled. Several of the more pertinent papers include: Daan (1973) and Arntz (1973) who studied cod in the North Sea and western Baltic, respectively, and Tyler (1971) who observed the monthly changes in the stomach contents of demersal fish in Passamaquoddy Bay, New Brunswick.

This paper presents food habit data on cod, haddock, and silver hake populations found in the waters on the continental shelf from Cape Hatteras to Nova Scotia. Emphasis is placed on quantitative data from five broad ecological areas to determine the predator-prey relationships in each area.

METHODS AND MATERIALS

Samples were obtained aboard the *Albatross IV* from fish caught with an otter trawl during spring and fall groundfish surveys. The survey extends from Cape Hatteras to western Nova Scotia and comprises five major ecological zones: the Middle Atlantic, southern New England, Georges Bank, the Gulf of Maine, and western Nova Scotia (Figure 1). These divisions were delineated because of differences in hydrography, geography, and biology (Grosslein, 1969).[1] Water depth ranges from 17 m to 366 m with the deeper boundary following the 366 m contour along the continental slope. Stomachs were collected from the fall (Sept.-Nov.) of 1969 to the spring (Feb.-Apr.) of 1972. When catches were large a random subsample was taken from the total catch. Stomachs that showed signs of regurgitation (everted or hemorrhaged) were not used. The stomachs from 1,250 cod, 952 haddock, and 1937 silver hake were excised, labeled by station and species, pooled regardless of size, and preserved in 10% Formalin.[2] Length information (fork length) was obtained from the groundfish data collected during the surveys. This information is presented as an appendix at the end of the paper. No samples were taken in the spring of 1970, and additional sampling occurred in the winter of 1972.

At the laboratory of the Northeast Fisheries Center, National Marine Fisheries Service, NOAA, in Woods Hole, Massachusetts, the preserved stomachs were opened, and the contents washed onto a 0.25 mm mesh screen. The various organisms eaten by each predator species were manually sorted and counted, identified to the lowest taxa possible (using a dissecting microscope when necessary), and damp-dried on bibulous paper. The prey species were then individually weighed to the nearest 0.001 g on a Mettler p-163[3] balance (or to the nearest 0.01 g on a Mettler p-1210[4] for items heavier than 160 g) no longer than

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[1]Grosslein, M. D. 1969. Groundfish survey methods. Bur. Comm. Fish., Woods Hole, MA. Ref. No. 69-2.

[2], [3], [4]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

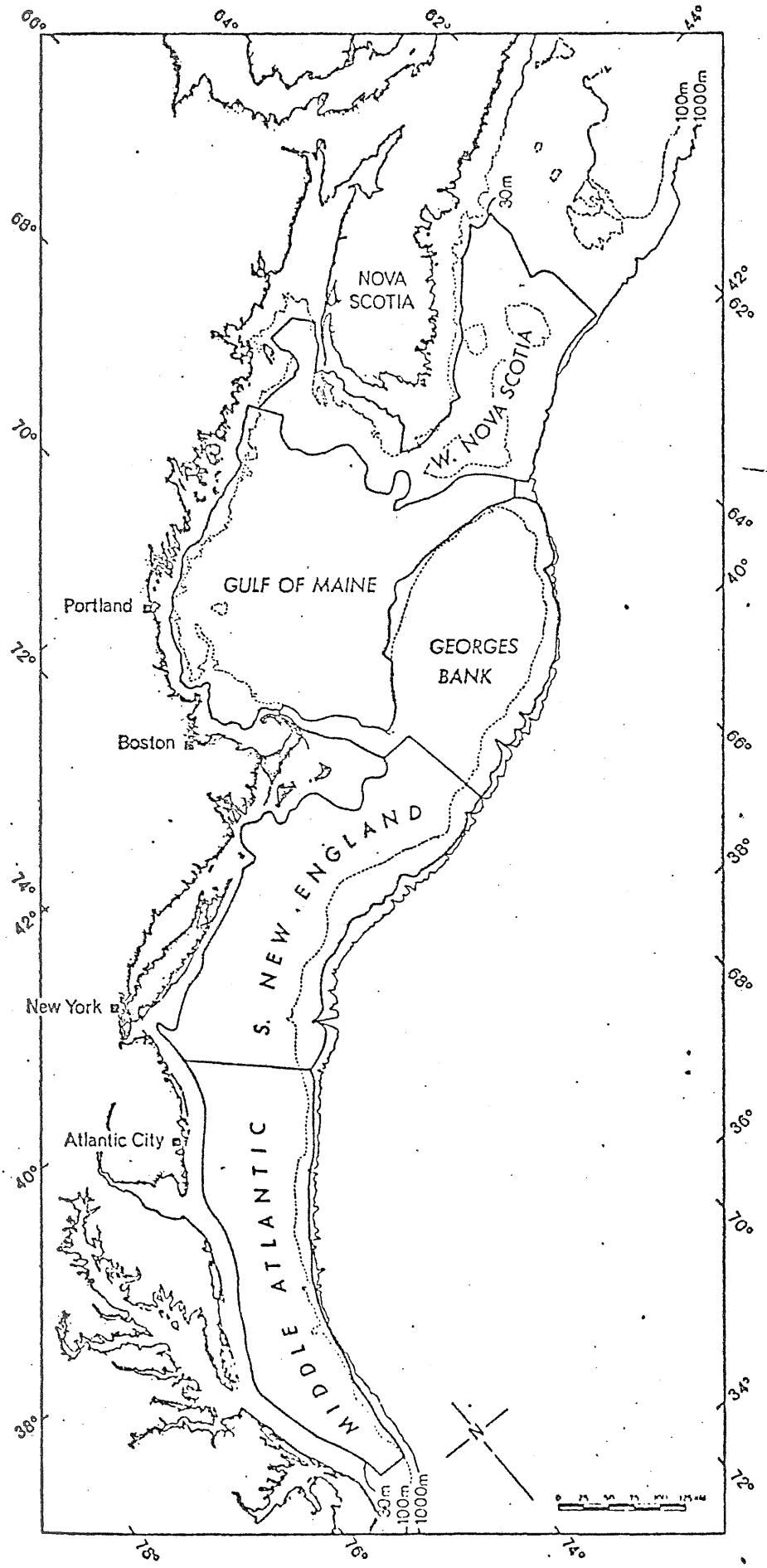

Figure 1. The five broad ecological areas between Cape Hatteras and Nova Scotia.

one minute after being damp-dried. If large numbers of small food organisms were present, a subsample of the total sample was examined. The results were then multiplied by the appropriate expansion factor, determined by the ratio of the subsample weight to the total weight. Parasitic groups were included as part of the stomach contents. The debris remaining after all identifiable organisms or parts of organisms had been removed was classified as: animal, plant, unidentified or nonorganic. Items found in the stomachs which were not major diet constituents have been grouped into broad taxa or are listed as miscellaneous. Computer facilities at the laboratory were used to reduce the data for analysis.

All results are presented as a percent of the total stomach contents weight or as a mean weight of the total contents per stomach. The percent of the total stomach contents was derived by dividing each particular prey category by the total stomach contents weight. The mean weight of contents per stomach was calculated by summing the total amount of stomach contents and then dividing that sum by the total number of stomachs, including the empty ones. Of all stomachs collected, 7% of the cod, 8% of the haddock, and 33% of the silver hake were empty.

Sexual differences in food habits are based on the analysis of 397 female and 366 male cod, 338 female and 242 male haddock, and 592 female and 396 male silver hake.

Only subadult and adult fish of 20 cm in length (fork length) and larger were selected for this study. Cod and haddock 20 cm long are generally between one and two years old. Silver hake 20 cm long are between two and three years (Bigelow and Schroeder, 1953). Food habits of fish less than 20 cm long will be described in a separate report.

ATLANTIC COD, *Gadus morhua* (Linnaeus)

Cod occur in the western Atlantic from just north of Cape Hatteras, North Carolina to west Greenland, with the outer continental shelf as the offshore boundary (Bigelow and Schroeder, 1953). Most (94%) of the cod stomachs taken for this study were from Georges Bank, western Nova Scotia, and the Gulf of Maine. The samples (Figure 2) are representative of the distribution of cod (Grosslein and Bowman, 1973).

Major foods

Cod fed predominantly on fish and various crustaceans (Table 1). These two groups accounted for over 80% of the total stomach contents by weight. Other food items were mollusks, polychaetes, and echinoderms. The mean stomach content weight of all cod analyzed for this study was 28.6 g.

Food by ecological area

The food consumed in each ecological area is shown in Table 2. The weight percentages indicated represent all cod sampled within each area (all years combined). Because of the dietary differences each area is considered separately below. All prey items mentioned hereafter are listed in decreasing order of importance (percent weight) within the major food groups.

Middle Atlantic

Cod are uncommon in the Middle Atlantic, thus only seven stomachs were examined. Fish comprised 87% of the diet. Yellowtail flounder (*Limanda ferruginea*) was the main food item (33%). Other fish eaten were squirrel hake (*Urophycis chuss*), winter flounder (*Pseudopleuronectes americanus*), beardfish (Polymixiidae), and cusk eels (Ophidiidae). Crustaceans were of less importance (10%), and were composed mostly of hermit crabs (Paguridae) and rock crabs (*Cancer*).

Southern New England

Fifty-nine stomachs were examined. Cod in this area fed chiefly on fish (57%) such as Atlantic mackerel (*Scomber scombrus*), herring (Clupeidae), and wrymouth (Cryptacanthodidae). The main crustaceans

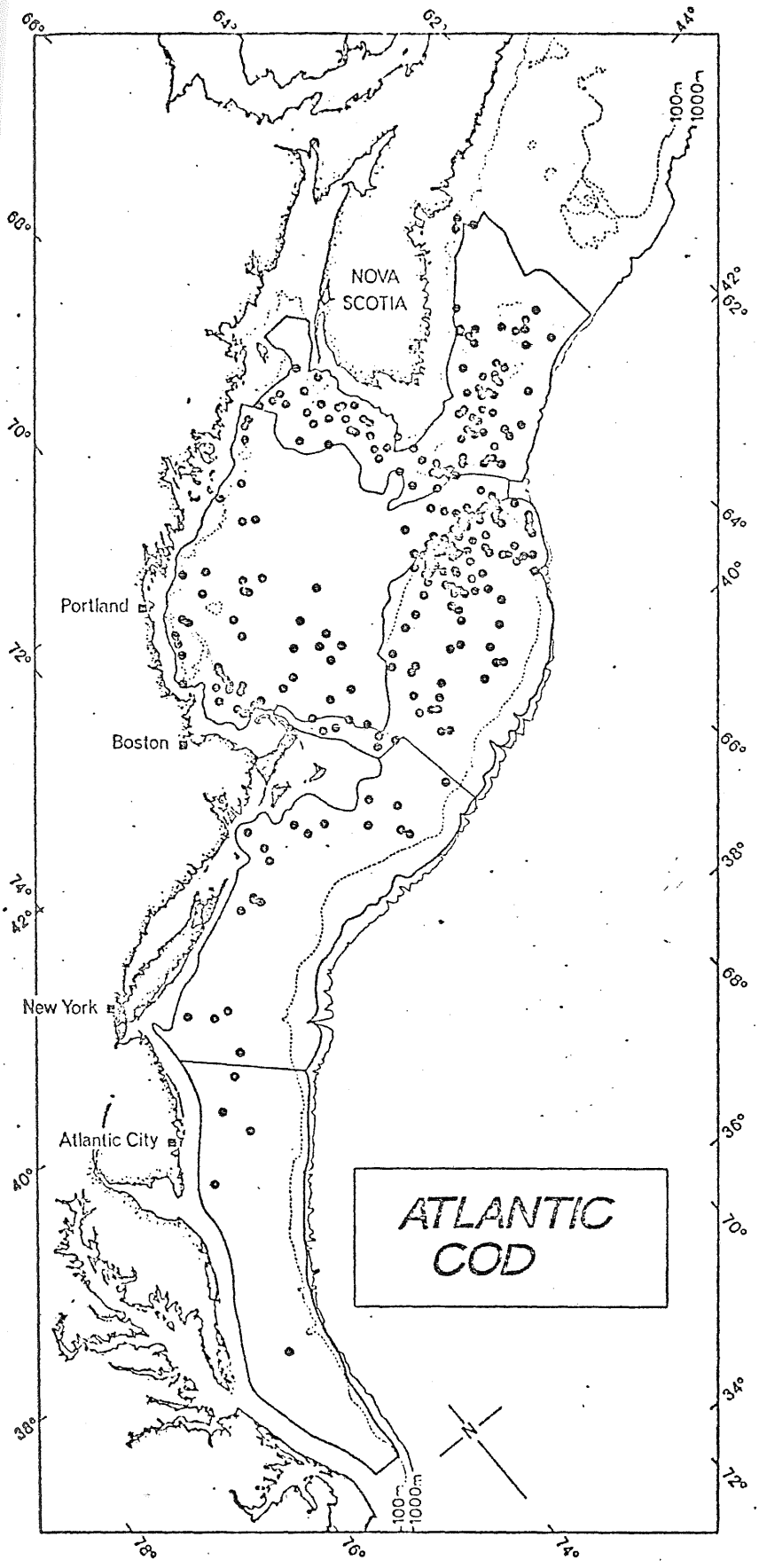

Figure 2. Stations where Atlantic cod samples were obtained, 1969-1972.

Table 1. Stomach contents of Atlantic cod, as percent of total weight (combined for all areas and years).

Stomach content categories	Percent of weight per stomach
	% wt
Polychaeta	1.59
Crustacea	23.52
Mollusca	10.62
Echinodermata	1.05
Pisces	57.70
Miscellaneous	3.68
Sand and rock	1.84
No. of predator fish sampled	1250
Percent empty	6.96
	wt(g)
Mean weight per stomach	28.63

Table 2. Stomach contents of Atlantic cod, as percent of weight, by ecological area (all years combined).

Stomach content categories	Percent of weight per stomach				
	Ecological area				
	Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Western Nova Scotia
	% wt	% wt	% wt	% wt	% wt
PORIFERA	-	-	0.29	-	-
COELENTERATA	-	<0.01	1.14	0.16	0.28
Hydrozoa	-	<0.01	0.04	<0.01	<0.01
Anthozoa	-	-	1.10	0.10	0.28
Scyphozoa	-	-	-	0.06	-
POLYCHAETA	0.08	9.65	1.57	0.22	0.96
Nereidiformia	0.08	9.58	1.35	0.16	0.71
Aphrodita	-	9.53	1.05	0.13	0.65
Other Nereidiformia	0.08	0.05	0.30	0.03	0.06
Other Polychaeta	-	0.07	0.22	0.06	0.25
ARTHROPODA	10.36	25.07	21.62	22.68	28.70
Crustacea	10.36	25.07	21.59	22.54	28.70
Amphipoda	0.03	2.48	0.55	0.08	0.06
Gammaridea	0.03	2.45	0.51	0.07	0.04
Other Amphipoda	-	0.03	0.04	0.01	0.02
Decapoda	8.22	21.75	18.19	19.90	17.21
Axiidae	-	3.73	0.11	0.05	1.39
Cancridae	2.85	14.43	5.62	5.25	-
Cancer	2.85	14.43	5.62	5.25	-
Crangonidae	1.43	0.50	0.59	0.08	0.10
Geryonidae	-	-	-	7.03	-
Geryon	-	-	-	7.03	-
Hippolytidae	-	0.17	0.19	0.09	0.55
Homaridae	-	-	0.20	-	-
Majidae	-	-	2.21	0.06	7.73
Hyas	-	-	2.21	0.06	7.73
Paguridae	3.81	1.09	4.34	0.14	2.36
Pagurus	-	1.09	4.15	0.07	1.76
Other Paguridae	3.81	-	0.19	0.07	0.60
Palaemonidae	-	-	-	0.01	-
Pandalidae	0.13	0.24	3.63	2.91	3.80
Pasiphaeidae	-	-	-	1.22	0.04
Portunidae	-	-	0.03	-	-
Other Decapoda	-	1.59	1.27	3.06	1.24
Isopoda	0.48	0.01	0.09	0.01	0.01
Euphausiacea	-	-	0.29	1.26	9.41
Mysidacea	-	<0.01	1.02	0.01	<0.01
Other Crustacea	1.63	0.83	1.45	1.28	2.01
Other Arthropoda	-	-	0.03	0.14	-
MOLLUSCA	0.62	2.15	23.31	0.46	0.72
Pelecypoda	-	0.55	14.15	0.06	<0.01
Chlamys	-	-	3.45	-	-
Placopecten	-	0.51	9.59	-	-
Other Pelecypoda	-	0.04	1.11	0.06	<0.01
Scaphopoda	-	-	1.18	-	-
Gastropoda	-	1.41	6.59	0.08	0.37
Cephalopoda	-	0.03	<0.01	0.31	<0.01
Other Mollusca	0.62	0.16	1.39	0.01	0.35
ECHINODERMATA	-	0.77	0.15	0.39	4.04
Asteroidea	-	-	0.01	-	0.56
Echinoidea	-	<0.01	0.02	0.02	0.27
Ophiuroidea	-	-	0.01	0.11	2.07
Holothuroidea	-	0.77	0.06	0.25	1.04
Other Echinodermata	-	-	0.05	0.01	0.10

Stomach content categories	Percent of weight per stomach — Ecological area: Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Western Nova Scotia
	% wt	% wt	% wt	% wt	% wt
PISCES	86.50	57.15	45.92	73.68	58.90
Osteichthyes	76.21	30.67	20.52	59.85	30.05
Berycoidei	9.01	-	-	-	-
Polymixiidae	9.01	-	-	-	-
Isospondyli	-	8.83	3.99	26.75	9.27
Argentinidae	-	-	1.51	4.46	-
Argentina	-	-	-	3.47	-
Unid Argentinidae	-	-	1.51	0.99	-
Clupeidae	-	8.83	2.48	22.29	9.27
Anacanthini	12.93	-	3.89	6.37	7.06
Gadidae	12.93	-	3.89	6.37	7.06
Melanogrammus aeglefinus	-	-	-	-	0.82
Merluccius bilinearis	-	-	-	1.80	1.89
Urophycis chuss	12.93	-	-	-	-
Other Gadidae	-	-	3.89	4.57	4.35
Perciformes	10.57	15.88	4.89	26.37	13.72
Ammodytidae	2.72	-	0.12	-	12.42
Anarhichadidae	-	-	-	3.68	0.22
Cottidae	1.46	1.71	4.21	0.02	-
Cryptacanthodidae	-	4.27	-	0.40	-
Ophidiidae	6.39	-	-	-	-
Scombridae	-	9.90	-	9.59	-
Scomber scombrus	-	9.90	-	9.59	-
Scorpaenidae	-	-	0.10	12.67	0.94
Helicolenus dactylopterus	-	-	0.10	2.13	-
Sebastes marinus	-	-	-	10.54	0.94
Other Perciformes	-	-	0.46	0.01	0.14
Pleuronectiformes	43.70	5.70	7.74	0.36	-
Bothidae	-	2.94	0.26	-	-
Scophthalmus aquosus	-	2.94	0.26	-	-
Pleuronectidae	43.70	-	5.48	-	-
Limanda ferruginea	33.71	-	4.33	-	-
Pseudopleuronectes americanus	9.99	-	-	-	-
Hippoglossoides platessoides	-	-	1.15	-	-
Other Pleuronectiformes	-	2.76	2.00	0.36	-
Other Osteichthyes	-	0.26	0.08	-	-
Pisces remains	10.29	26.47	11.78	13.49	28.40
Pisces eggs	-	0.01	13.54	0.34	0.45
OTHER PHYLA	0.04	0.05	0.09	0.03	0.08
ANIMAL REMAINS	2.37	5.06	2.59	1.84	4.56
NON-ANIMAL REMAINS	-	-	0.02	0.04	0.53
SAND AND ROCK	0.03	0.10	3.30	0.53	1.23
No. of predator fish sampled	7	59	537	268	379
	wt(g)	wt(g)	wt(g)	wt(g)	wt(g)
Mean weight per stomach	69.69	40.29	28.95	37.77	19.13

eaten were rock crabs (*Cancer*), mud shrimp (Axiidae), and gammaridean amphipods. The sea mouse (*Aphrodita*), a marine polychaete, was also an important item in the diet (10%).

Georges Bank

Five hundred and thirty-seven cod stomachs were analyzed. Fish eggs (mostly Cottidae), the most predominant food, accounted for 14% of the total stomach contents weight from this area. Yellowtail flounder (*Limanda ferruginea*), sculpins (Cottidae), and codfishes (Gadidae) were the most common fish eaten (12%). Mollusks and crustaceans were of approximately equal importance in the diet. The mollusks were mainly scallops (*Placopecten* and *Chlamys*), and snails and slugs (Gastropoda). Predominant crustaceans consisted of rock crabs (*Cancer*), hermit crabs (*Pagurus*), and deep water shrimp (Pandalidae).

Gulf of Maine

Two hundred and sixty-eight fish were examined. The primary food was herring (Clupeidae), which made up 22% of the stomach contents examined from this area. The remainder of the fish eaten were mostly redfish (*Sebastes marinus*), Atlantic mackerel (*Scomber scombrus*), and codfishes (Gadidae). Crustaceans in the diet amounted to 23% of the total stomach contents weight; they were primarily the deep-sea red crab (*Geryon*) and rock crabs (*Cancer*).

Western Nova Scotia

Three hundred and seventy-nine stomachs were examined. Sand lance (Ammodytidae) was the chief food (12%). Other fish in the diet included herring (Clupeidae) and codfishes (Gadidae). Crustaceans, the secondary food group, were composed of krill shrimp (Euphausiacea), toad crabs (*Hyas*), and deep-water shrimp (Pandalidae). Echinoderms accounted for 4% of the total stomach contents weight; brittle stars (Ophiuroidea) and sea cucumbers (Holothuroidea) were the main food items in this group.

Yearly food habits

An evaluation of the foods eaten by cod from year to year, within ecological areas, revealed no major differences or trends of a changing diet (Table 3). The quantity and quality of the food

Table 3. Stomach contents of Atlantic cod, as percent of weight, by ecological area and year.

Stomach content categories	Percent of weight per stomach — Ecological area				
	Middle Atlantic	S.New England	Georges Bank	Gulf of Maine	Western Nova Scotia
Fall 1969	% wt	% wt	% wt	% wt	% wt
Polychaeta	—	0.33	0.51	0.12	0.04
Crustacea	—	10.31	29.10	8.60	18.51
Mollusca	—	0.10	7.18	—	0.13
Echinodermata	—	—	0.03	0.05	0.21
Pisces	—	84.70	55.02	88.59	75.62
Miscellaneous	—	4.01	5.62	1.83	5.45
Sand and Rock	—	0.55	2.54	0.81	0.04
No. of predator fish sampled	—	15	57	52	35
Mean weight per stomach	wt(g) —	wt(g) 5.95	wt(g) 20.43	wt(g) 46.28	wt(g) 20.04
Fall 1970	% wt.	% wt	% wt	% wt	% wt.
Polychaeta	—	0.55	0.68	0.05	3.91
Crustacea	—	81.34	17.57	17.59	58.52
Mollusca	—	0.40	23.20	0.56	8.86
Echinodermata	—	—	<0.01	<0.01	8.74
Pisces	—	16.52	39.82	80.13	18.48
Miscellaneous	—	—	3.95	1.66	1.06
Sand and Rock	—	1.19	14.78	0.01	0.43
No. of predator fish sampled	—	4	94	42	24
Mean weight per stomach	wt(g) —	wt(g) 3.16	wt(g) 22.25	wt(g) 40.79	wt(g) 8.74
Spring 1971	% wt	% wt	% wt	% wt	% wt
Polychaeta	0.09	12.86	2.22	2.08	1.09
Crustacea	6.91	33.94	20.05	75.30	13.88
Mollusca	0.64	2.46	34.17	0.96	1.47
Echinodermata	—	0.93	0.22	1.06	6.68
Pisces	90.19	46.67	39.43	5.72	69.61
Miscellaneous	2.13	3.08	2.99	11.51	4.57
Sand and Rock	0.04	0.06	0.92	3.37	2.70
No. of predator fish sampled	6	29	158	29	88
Mean weight per stomach	wt(g) 77.57	wt(g) 46.79	wt(g) 44.41	wt(g) 9.91	wt(g) 17.79

Table 3. (continued)

Stomach content categories	Percent of weight per stomach — Ecological Area				
	Middle Atlantic	S. New England	Georges Bank	Gulf of Maine	Western Nova Scotia
Fall 1971	% wt	% wt	% wt	% wt	% wt
Polychaeta	—	—	0.92	0.03	0.13
Crustacea	—	—	40.54	27.94	35.56
Mollusca	—	—	6.64	0.98	0.12
Echinodermata	—	—	0.02	0.39	1.89
Pisces	—	—	47.03	69.10	57.97
Miscellaneous	—	—	1.60	0.92	2.93
Sand and Rock	—	—	3.25	0.64	1.40
No. of predator fish sampled	—	—	21	74	121
Mean weight per stomach	wt(g) —	wt(g) —	wt(g) 22.37	wt(g) 44.25	wt(g) 22.70
Winter 1972	% wt	% wt	% wt	% wt	% wt
Polychaeta	—	—	1.37	0.04	—
Crustacea	—	—	21.74	5.79	—
Mollusca	—	—	13.75	—	—
Echinodermata	—	—	0.16	0.45	—
Pisces	—	—	56.49	93.34	—
Miscellaneous	—	—	4.46	0.38	—
Sand and Rock	—	—	2.03	—	—
No. of predator fish sampled	—	—	147	13	—
Mean weight per stomach	wt(g) --	wt(g) --	wt(g) 32.22	wt(g) 23.84	wt(g)
Spring 1972	% wt	% wt	% wt	% wt	% wt
Polychaeta	—	5.93	0.04	0.60	2.01
Crustacea	81.21	12.72	93.83	29.78	31.23
Mollusca	—	1.85	—	0.11	0.32
Echinodermata	—	0.63	0.44	0.97	5.76
Pisces	9.83	70.49	2.39	65.02	50.24
Miscellaneous	8.96	8.26	3.19	3.39	10.09
Sand and Rock	—	0.12	0.11	0.13	0.35
No. of predator fish sampled	1	11	60	58	111
Mean weight per stomach	wt(g) 22.39	wt(g) 83.48	wt(g) 1.12	wt(g) 36.76	wt(g) 18.26

consumed remained relatively stable. Fish and crustaceans (and on Georges Bank, mollusks) were the main foods consumed every year from 1969 to 1972. However, several items of dietary importance are worth noting (this analysis refers only to those areas and years where more than twenty stomachs were obtained): stomachs collected in southern New England contained more polychaetes than those from any other area during 1971 and 1972; during all years larger quantities of mollusks were found in the stomachs from Georges Bank; cod sampled in the Gulf of Maine fed almost exclusively on fish or crustaceans; larger amounts of echinoderms were found in the stomachs examined from western Nova Scotia; and fish sampled from the Gulf of Maine contained more food in their stomachs (except during the spring of 1971).

Seasonal variation in the diet

Only slight differences were noted in the diet of cod between fall and spring. The stomach contents of cod sampled during the fall of 1970 and 1971, and the spring of 1971 and 1972 were combined by area for analysis. The totals shown in the right-hand columns of Table 4 are the percent of the total stomach content weight of all areas, for each stomach content category and season. Larger amounts of polychaetes and echinoderms were eaten during the spring in all areas. Fish and crustaceans, however, remain the primary food, except on Georges Bank where mollusks are also an important food. The mean weight of contents per stomach from Georges Bank increased in the spring (22.3 g to 32.5 g) while it decreased during the same period for cod sampled from the Gulf of Maine (43.0 g to 27.8 g) and western Nova Scotia (20.4 g to 18.1 g). Also of interest, the amount of sand and rock ingested by cod from Georges Bank in the fall was 13% compared to only 1% in the spring.

Sexual differences in the food habits

Stomach contents by predator sex within ecological areas are shown in Table 5. The values in the right-hand columns are the percent total weight of all areas combined, for each stomach content category. The Middle Atlantic and southern New England data are excluded because of insufficient information. There were marked differences in the quantity of food eaten by each sex. The mean weight of contents per stomach for female cod was 75% more than the males when the three areas sampled were combined. The mean stomach weight of all males and females are 20.4 g and 35.6 g, respectively. No substantial differences in the kinds of food males and females consumed were observed. Fish and crustaceans were the main food groups for both sexes examined from the Gulf of Maine and western Nova Scotia. Mollusks, fish, and crustaceans comprised the major foods eaten in the Georges Bank area.

Table 4. Stomach contents of Atlantic cod, as percent of weight, by ecological area and season. (Fall 1970-1971, Spring 1971-1972)

Stomach content categories	Percent of weight per stomach							
	Ecological area							
	Georges Bank		Gulf of Maine		Western Nova Scotia		Total for all areas	
	% wt		% wt		% wt		% wt	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Polychaeta	0.72	2.19	0.04	0.77	0.40	1.61	0.31	1.77
Crustacea	21.78	20.75	24.38	35.19	37.19	23.66	27.35	24.22
Mollusca	20.16	33.85	0.84	0.21	0.74	0.82	5.52	18.57
Echinodermata	0.01	0.22	0.26	0.98	2.38	6.16	0.79	1.99
Pisces	41.14	39.08	72.89	57.98	55.17	58.68	60.16	47.95
Miscellaneous	3.53	3.00	1.17	4.36	2.79	7.70	2.21	4.54
Sand and rock	12.66	0.91	0.42	0.51	1.33	1.37	3.66	0.96
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
No. of predator fish sampled	115	218	116	87	145	199	376	504
	wt(g)		wt(g)		wt(g)		wt(g)	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Mean weight per stomach	22.27	32.49	43.00	27.81	20.39	18.05	27.94	25.98

Table 5. Stomach contents of Atlantic cod, as percent of weight, by ecological area and sex (all seasons combined).

Stomach content categories	Percent of weight per stomach							
	Ecological area							
	Georges Bank		Gulf of Maine		Western Nova Scotia		Total for all areas	
	% wt		% wt		% wt		% wt	
	Male	Female	Male	Female	Male	Female	Male	Female
Polychaeta	3.00	1.08	0.14	0.31	1.21	0.96	1.81	0.83
Crustacea	30.75	14.11	17.10	35.48	41.52	25.90	29.88	23.50
Mollusca	33.19	24.64	1.77	0.08	1.14	0.73	17.08	10.95
Echinodermata	0.01	0.04	1.40	0.21	8.79	2.32	2.55	0.73
Pisces	26.62	56.42	76.53	61.51	43.27	61.72	43.70	59.36
Miscellaneous	5.61	2.24	2.45	1.88	3.89	6.24	4.37	3.24
Sand and rock	0.82	1.47	0.61	0.53	0.18	2.13	0.61	1.39
	Male	Female	Male	Female	Male	Female	Male	Female
No. of predator fish sampled	156	137	77	91	133	169	366	397
	wt(g)		wt(g)		wt(g)		wt(g)	
	Male	Female	Male	Female	Male	Female	Male	Female
Mean weight per stomach	23.54	44.85	25.13	44.26	13.93	23.37	20.38	35.57

DISCUSSION

The diet of cod consists mostly of fish and crustaceans. Differences noted in the diet between ecological areas suggest cod are opportunistic feeders. They feed mostly on whatever fish and crustaceans are available in an area, and may also utilize other forms such as mollusks, echinoderms, and polychaetes.

Their distribution can be directly related to the availability of food. In such areas as Georges Bank, the Gulf of Maine, and western Nova Scotia, which are known to be biologically productive (Graham and Edwards, 1961) cod populations are more dense. Wise (1961), who completed an extensive synopsis of biological data on cod, found: "the distribution of feeding cod is more dependent on the distribution of prey than it is directly on temperature."

Occasionally when a wide variety of foods are available cod prefer some foods over others. Brawn (1969) found cod took food falling through the water column in preference to food on the bottom. This observation may explain why mollusks were consumed in large amounts by cod from Georges Bank, since the majority of the mollusks were scallop viscera. Very little shell or adductor muscle was found in the cod stomachs. Investigations suggested the scallop viscera were discarded by scallop fishermen, and consumed by cod as they fell to the bottom. A study by Tyler (1971) showed cod fed heavily on 5 cm to 6 cm Atlantic sea herring for a brief period in May, the time of the year when young herring move into Passamaquoddy Bay from open water. Experiments dealing with food selection indicated cod only eat brittle stars when forced to do so (Astaf'eva, 1967), and the relationship between the vertical migrations of cod and available foods was investigated by Brunel (1965). Lastly, a study by Daan (1973) indicated the geographical variation in the abundance of prey may also be responsible for sharp seasonal shifts in the food spectrum of migrating cod. The above studies provide evidence that cod do show a preference for certain foods, but their chief prey are various forms of fish and crustaceans.

HADDOCK (*Melanogrammus aeglefinus*)

The distribution of haddock in the northwest Atlantic ranges northward from the waters off Cape Hatteras to West Greenland, with the outer margin of the continental shelf as the offshore boundary (Bigelow and Schroeder, 1953). The majority (96%) of haddock stomachs collected for this study were from Georges Bank, the Gulf of Maine, and the Nova Scotian Shelf (Fig. 3). No haddock were found in the Middle Atlantic and few were found in southern New England because of the scarcity of haddock in those areas.

Major foods

Haddock fed mainly (35%) on echinoderms, with crustaceans and polychaetes following in dietary importance. Sand and rock accounted for 11% of the total stomach contents weight. The mean weight per stomach was 6.3 g (Table 6).

Food by ecological area

The variability between food items of the haddock from each ecological area sampled is shown in Table 7. Quantitative analyses from each area will be presented in the same manner as the cod data (p. 9).

Middle Atlantic

No haddock stomachs were collected from this area.

Southern New England

Twenty-seven stomachs were analyzed. Amphipods, the primary food, comprised 75% of the total weight of all food from this area. Decapods, another crustacean group, were of lesser dietary importance. Worms, mostly Nereidiformia, were the second most important food (4%).

Georges Bank

Three hundred and thirty stomachs were examined. Polychaetes and crustaceans were of nearly equal dietary importance, 24% and 23% by weight, respectively. The polychaetes eaten consisted mainly of Terebelliformia, Sabelliformia, and Nereidiformia. Crustaceans found in the stomachs were mostly gammaridean amphipods, and krill shrimp (*Meganyctiphanes*). The third main food group was echinoderms, which was composed largely of brittle

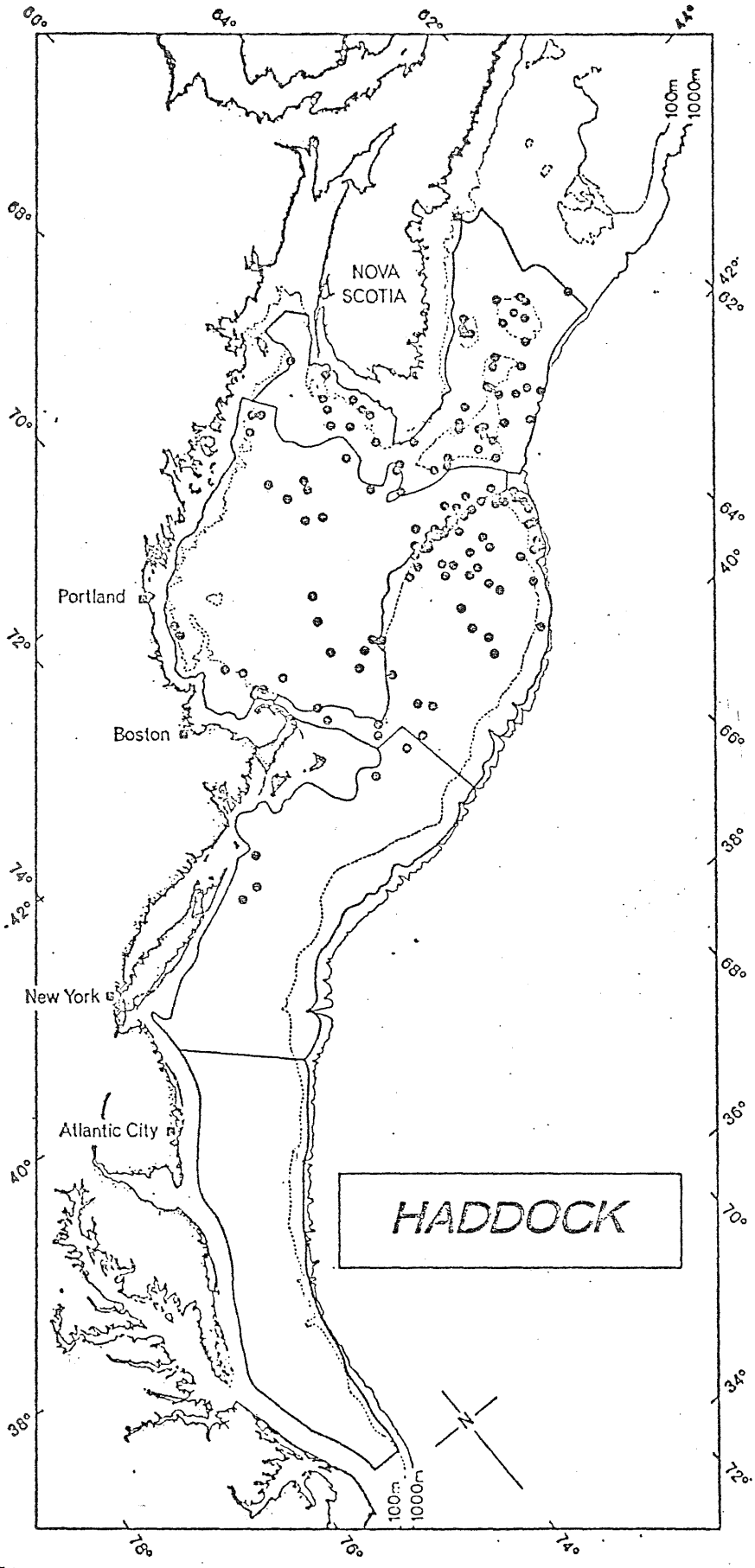

Figure 3. Stations where haddock samples were obtained, 1969-1972.

Table 6. Stomach contents of haddock, as percent of total weight (combined for all areas and years).

Stomach content categories	Percent of weight per stomach
	% wt
Polychaeta	17.12
Crustacea	19.34
Mollusca	3.61
Echinodermata	35.30
Pisces	1.66
Animal remains	9.79
Miscellaneous	1.61
Sand and Rock	11.57
No. of predator fish sampled	952
Percent empty	7.69
Mean weight per stomach	6.30

Table 7. Stomach contents of haddock, as percent of weight, by ecological area (all years combined).

Stomach content categories	Percent of weight per stomach — Ecological area				
	Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Western Nova Scotia
	% wt	% wt	% wt	% wt	% wt
ANTHOZOA	-	-	0.16	0.29	0.11
Zoantharia	-	-	0.16	0.29	0.04
Other Anthozoa	-	-	<0.01	<0.01	0.07
NEMERTINA	-	-	0.25	0.02	0.04
POLYCHAETA	-	4.47	24.45	14.05	11.91
Spioniformia	-	-	0.52	<0.01	<0.01
Scoleciformia	-	-	0.43	0.36	0.30
Terebelliformia	-	-	3.48	0.02	1.76
Sabelliformia	-	-	3.44	-	0.97
Nereidiformia	-	2.51	1.49	3.14	2.84
Aphroditidae	-	-	0.09	0.92	0.94
Aphrodita	-	-	0.09	0.92	0.94
Eunicidae	-	-	<0.01	0.25	0.47
Other Nereidiformia	-	2.51	1.40	1.97	1.43
Polychaeta Tubes	-	0.09	3.27	1.67	0.86
Other Polychaeta	-	1.87	11.82	8.86	5.18
SIPUNCULIDA	-	-	-	0.03	0.31
ARTHROPODA	-	82.11	23.46	15.24	14.61
Crustacea	-	82.11	23.44	15.24	14.52
Amphipoda	-	75.25	11.08	2.31	4.65
Gammaridea	-	2.14	9.65	1.97	3.53
Other Amphipoda	-	73.11	1.43	0.34	1.12
Decapoda	-	4.01	1.98	9.83	6.70
Axiidae	-	-	0.25	0.23	2.53
Axius	-	-	-	-	2.06
Calocaris	-	-	0.25	0.23	0.47
Cancridae	-	0.18	0.23	-	-
Crangonidae	-	0.55	0.12	-	0.08
Hippolytidae	-	-	0.15	0.29	0.32
Majidae	-	0.62	0.18	0.58	0.51
Hyas	-	0.62	0.18	0.58	0.51
Paguridae	-	0.93	0.52	0.06	0.82
Pagurus	-	0.93	0.37	<0.01	0.28
Other Paguridae	-	-	0.15	0.06	0.54
Pandalidae	-	0.73	0.27	3.14	1.09
Pandalus	-	0.73	0.17	2.21	0.74
Other Pandalidae	-	-	0.10	0.93	0.35
Pasiphaeidae	-	-	-	5.35	-
Callianassidae	-	-	-	-	0.25
Other Decapoda	-	1.00	0.26	0.18	1.10
Isopoda	-	0.01	0.19	0.12	0.11
Cirolana	-	-	0.09	<0.01	0.01
Other Isopoda	-	0.01	0.10	0.12	0.10
Euphausiacea	-	-	5.70	1.65	1.82
Meganyctiphanes	-	-	5.57	0.09	0.55
Other Euphausiacea	-	-	0.13	1.56	1.27
Other Crustacea	-	2.84	4.49	1.33	1.24
Other Arthropoda	-	-	0.02	<0.01	0.09

Table 7 (Continued)

Stomach content categories	Percent of weight per stomach — Ecological area: Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Western Nova Scotia
	% wt	% wt	% wt	% wt	% wt
MOLLUSCA	-	0.73	6.44	1.54	2.05
Pelecypoda	-	0.67	5.44	0.81	1.56
Eulamellibranchia	-	0.06	0.29	0.17	0.12
Astarte	-	-	0.29	0.04	-
Other Eulamellibranchia	-	0.06	<0.01	0.13	0.12
Filibranchia	-	-	0.71	0.36	0.03
Chlamys	-	-	0.14	<0.01	-
Placopecten	-	-	0.56	0.03	<0.01
Other Filibranchia	-	-	0.01	0.33	0.03
Protobranchia	-	-	<0.01	0.23	1.27
Yoldia	-	-	-	0.07	1.15
Other Protobranchia	-	-	<0.01	0.16	0.12
Other Pelecypoda	-	0.61	4.44	0.05	0.14
Gastropoda	-	0.03	0.41	0.53	0.27
Other Mollusca	-	0.03	0.59	0.20	0.22
ECHINODERMATA	-	1.41	12.49	53.30	50.13
Asteroidea	-	0.08	0.19	0.02	0.87
Echinoidea	-	1.19	2.58	11.20	9.06
Strongylocentrotus	-	-	0.65	1.65	6.33
Echinarachnius	-	1.19	1.54	<0.01	1.13
Other Echinoidea	-	-	0.39	9.55	1.60
Ophiuroidea	-	0.05	9.22	38.85	35.34
Amphipholis	-	-	-	-	0.23
Ophiopholis	-	-	3.17	0.20	12.51
Ophiopholis aculeata	-	-	2.51	0.06	-
Other Ophiopholis	-	-	0.66	0.14	12.51
Ophiura	-	-	0.99	13.56	8.07
Ophiura sarsi	-	-	-	3.03	-
Other Ophiura	-	-	0.99	10.53	8.07
Other Ophiuroidea	-	0.05	5.06	25.09	14.53
Holothuroidea	-	0.09	0.49	3.16	4.82
Cucumaria	-	-	-	0.27	0.67
Thyone	-	-	0.02	2.08	<0.01
Psolus	-	-	0.18	0.54	1.15
Molpadia	-	-	-	-	0.85
Other Holothuroidea	-	0.09	0.29	0.27	2.15
Other Echinodermata	-	-	0.01	0.07	0.04
OIKOPLEURA	-	-	-	-	1.30
ASIDIACEA	-	-	<0.01	0.23	0.05
PISCES	-	<0.01	0.13	2.15	3.05
OTHER PHYLA	-	0.07	0.22	0.03	0.23
ANIMAL REMAINS	-	8.24	8.25	10.11	13.09
NON ANIMAL REMAINS	-	-	<0.01	<0.01	-
SAND AND ROCK	-	2.97	24.15	3.01	3.12
No. of predator fish sampled	-	27	330	182	413
	wt(g)	wt(g)	wt(g)	wt(g)	wt(g)
Mean weight per stomach	-	4.06	7.04	7.75	5.29

stars (*Ophiophilis aculeata* and *Ophiura*) and sea urchins (*Strongylocentrotus* and *Echinarachnius*). Mollusks, mostly bivalves (Pelecypoda), were consumed more heavily in this area (6%) than in any other area. Sand and rock comprised 24% of the total stomach-content weight.

Gulf of Maine

One hundred and eighty-two stomachs were examined. The most common food items were echinoderms (53%), of which brittle stars (*Ophiura*), sea urchins (Echinoidea), and sea cucumbers (*Thyone*) were the chief forms eaten. Crustaceans, the secondary food group (15%), consisted mostly of shrimp (Pasiphaeidae and Pandalidae) and gammaridean amphipods. Worms (Polychaeta) were the third most important food (14%). Mollusks and fish made up the remaining food items. Stomachs from this area contained the largest quantity of food per stomach (7.8 g).

Western Nova Scotia

Four hundred and thirteen stomachs were examined. Echinoderms were the chief food eaten in this area; they were mostly brittle stars (*Ophiopholis* and *Ophiura*), sea urchins (*Strongylocentrotus*), and sea cucumbers (*Psolus*). Crustaceans were of secondary importance, and were composed of gammaridean amphipods, mud shrimp (*Axius*), krill shrimp (Euphausiacea), and deep water shrimp (*Pandalus*). The important polychaetes found in the stomachs were Nereidiformia, Terebelliformia, and Sabelliformia. The remaining food consisted mostly of fish and mollusks.

Yearly food habits

No yearly trends were noted in the food habits within each area (Table 8). (This analysis refers only to areas and years where more than twenty stomachs were obtained). The predominant food of haddock collected from southern New England was crustaceans. The diet of haddock from Georges Bank revealed no regularity. Crustaceans, polychaetes, and echinoderms fluctuated in importance as foods from 1969 to 1972. Echinoderms were the primary food in the Gulf of Maine and western Nova Scotia areas during most years. The exceptions--1971 (spring), western Nova Scotia; and 1972 (spring), Gulf of Maine--show crustaceans and polychaetes are also important foods in those areas, but to a lesser extent than echinoderms.

Seasonal variation in the diet

Seasonal differences in the stomach contents of haddock are shown in Table 9. During the spring, in all areas, the amount of echinoderms eaten decreased, while the polychaetes and crustaceans consumed increased. In the total for all areas column (right hand side of the table) these changes amount to a 75% decrease for the echinoderms and a 93% and 166% increase for the polychaetes and crustaceans, respectively. The quantity of food per

Table 8. Stomach contents of haddock, as percent of weight, by ecological area and year.

Stomach content categories	Percent of weight per stomach — Ecological area: Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Western Nova Scotia
Fall 1969	% wt	% wt	% wt	% wt	% wt
Polychaeta	-	1.28	16.03	20.72	24.23
Crustacea	-	52.50	65.59	8.32	18.28
Mollusca	-	1.06	0.65	1.49	1.49
Echinodermata	-	0.75	7.29	51.25	36.76
Pisces	-	<0.01	0.29	3.53	0.21
Animal remains	-	17.19	3.44	11.56	11.12
Miscellaneous	-	0.60	0.16	0.75	4.41
Sand and Rock	-	26.62	6.55	2.38	3.50
No. of predator fish sampled	-	3	33	52	78
Mean weight per stomach	wt(g) -	wt(g) 3.86	wt(g) 11.03	wt(g) 8.84	wt(g) 4.00
Fall 1970	% wt	% wt	% wt	% wt	% wt
Polychaeta	-	-	15.68	25.18	5.02
Crustacea	-	-	2.60	37.16	9.33
Mollusca	-	-	2.46	0.72	0.63
Echinodermata	-	-	9.81	30.70	64.58
Pisces	-	-	0.18	-	12.61
Animal remains	-	-	18.24	5.77	4.38
Miscellaneous	-	-	2.48	0.32	0.18
Sand and Rock	-	-	48.55	0.15	3.27
No. of predator fish sampled	-	-	59	14	25
Mean weight per stomach	wt(g) -	wt(g) -	wt(g) 7.47	wt(g) 16.20	wt(g) 13.28
Spring 1971	% wt	% wt	% wt	% wt	% wt
Polychaeta	-	4.90	33.11	0.46	21.09
Crustacea	-	86.21	22.77	72.34	27.47
Mollusca	-	0.70	12.20	-	5.73
Echinodermata	-	1.49	2.92	0.30	19.19
Pisces	-	-	-	8.66	0.56
Animal remains	-	6.60	2.25	18.24	12.06
Miscellaneous	-	-	0.03	-	9.60
Sand and Rock	-	0.10	26.72	-	4.30
No. of predator fish sampled	-	22	101	3	123
Mean weight per stomach	wt(g) 3.18	wt(g) 4.41	wt(g) 9.25	wt(g) 10.97	wt(g) 2.80

Table 8. (Continued)

Stomach content categories	Percent of weight per stomach Ecological area Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Western Nova Scotia
Fall 1971	% wt	% wt	% wt	% wt	% wt
Polychaeta	-	-	26.32	5.43	8.90
Crustacea	-	-	7.50	3.58	9.86
Mollusca	-	-	1.36	3.28	0.82
Echinodermata	-	-	40.09	64.53	64.83
Pisces	-	-	0.08	2.92	0.20
Animal remains	-	-	9.73	12.80	10.63
Miscellaneous	-	-	0.14	1.81	1.91
Sand and Rock	-	-	14.78	5.65	2.85
No. of predator fish sampled	-	-	36	35	120
Mean weight per stomach	wt(g) -	wt(g) -	wt(g) 9.67	wt(g) 10.54	wt(g) 7.73
Winter 1972	% wt	% wt	% wt	% wt	% wt
Polychaeta	-	-	18.09	1.25	-
Crustacea	-	-	18.50	3.18	-
Mollusca	-	-	8.32	0.39	-
Echinodermata	-	-	24.27	89.22	-
Pisces	-	-	0.47	0.25	-
Animal remains	-	-	16.81	3.76	-
Miscellaneous	-	-	3.41	0.05	-
Sand and Rock	-	-	10.13	1.90	-
No. of predator fish sampled	-	-	73	22	-
Mean weight per stomach	wt(g) -	wt(g) -	wt(g) 3.01	wt(g) 9.67	wt(g) -
Spring 1972	% wt	% wt	% wt	% wt	% wt
Polychaeta	-	<0.01	1.63	20.92	5.26
Crustacea	-	24.30	94.39	45.24	17.14
Mollusca	-	-	0.15	0.54	4.24
Echinodermata	-	-	0.89	16.90	36.89
Pisces	-	<0.01	0.26	<0.01	7.64
Animal remains	-	66.67	2.19	9.96	26.66
Miscellaneous	-	1.07	0.13	0.65	0.28
Sand and Rock	-	7.96	0.36	5.79	1.89
No. of predator fish sampled	-	2	28	56	67
Mean weight per stomach	wt(g) -	wt(g) 0.47	wt(g) 0.60	wt(g) 1.96	wt(g) 3.99

Table 9. Stomach contents of haddock, as percent of weight, by ecological area and season (Fall 1970, 1971 - Spring 1971, 1972).

Stomach content categories	Percent of weight per stomach							
	Ecological area							
	Georges Bank		Gulf of Maine		Western Nova Scotia		Total for all areas	
	% wt		% wt		% wt		% wt	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Polychaeta	20.37	32.56	12.95	16.19	7.87	14.16	12.74	24.60
Crustacea	4.76	24.04	16.37	51.50	9.72	22.95	9.74	25.94
Mollusca	1.97	11.99	2.31	0.41	0.77	5.08	1.48	8.54
Echinodermata	23.17	2.88	51.65	13.07	64.76	26.93	49.40	12.36
Pisces	0.14	<0.01	1.81	2.00	3.47	3.66	2.10	1.48
Animal remains	14.49	2.25	10.12	11.87	8.98	18.45	10.88	8.86
Miscellaneous	1.45	0.02	1.24	0.51	1.47	5.52	1.41	2.03
Sand and Rock	33.65	26.26	3.55	4.45	2.96	3.25	12.25	16.19
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
No. of predator fish sampled	95	129	49	59	145	190	289	378
	wt(g)		wt(g)		wt(g)		wt(g)	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Mean weight per stomach	8.30	7.38	12.16	2.41	8.69	3.22	9.15	4.51

stomach, averaged for all areas, decreased by over 50% in the spring when compared to the fall.

Sexual differences in the food habits

Differences in food habits between the sexes are listed by ecological area in Table 10. The totals in the right hand columns show, in general, the food habits of the two sexes. The mean weight of contents per stomach is approximately the same for both males and females. Female haddock, from all areas, ate slightly more mollusks and fish than males. Male haddock from Georges Bank and western Nova Scotia ate somewhat more worms than the females.

DISCUSSION

The haddock diet is composed chiefly of small invertebrate forms associated with the bottom. The main food groups were echinoderms, crustaceans, and polychaetes.

Haddock are physically limited to particular food types. Homans and Needler (1944) noted the small ventrally placed mouth of haddock. They also mentioned the muscular lips of haddock, used for picking small animals off or out of the bottom, and the heavily built anterior portion of their body, which serves to hold them in a forwardly tilted position. The anatomy of haddock is well suited for a specialized form of feeding. Small, slow moving animals of benthic or epi-benthic habit are the main prey items.

Seasonal differences in the food habits of haddock have been shown in investigations by Wigley and Theroux (1965), Tyler (1972), and Homans and Needler (1944). The present investigation also found seasonal differences; crustaceans and polychaetes were present in the stomachs more often during the spring than the fall from all areas sampled. Also of interest was the small amount of food in the stomachs during the spring.

The prey eaten within the ecological areas described in this report may vary when those areas are further divided or from year to year. Kohler and Fitzgerald (1968) found fish and crustaceans to be the more important food items of haddock on the Nova Scotian Shelf during their study. Homans and Needler (1944) found large variations in the haddock diet between different areas on the Nova Scotian Shelf. They reported that haddock from Emerald Bank ate mostly fish, and those from Roseway Bank ate mostly brittle stars. Echinoderms were the major food of the haddock from western Nova Scotia in this study (Table 9). Wigley (1956) recorded crustaceans as the major food item of haddock from Georges Bank. He also showed dietary differences in the food of the haddock from various geographical divisions of Georges Bank. The present study demonstrated that both polychaetes and crustaceans were important foods of the haddock from Georges Bank between 1969 and 1972.

Table 10. Stomach contents of haddock, as percent of weight, by ecological area and sex (all seasons combined).

Stomach content categories	Percent of weight per stomach							
	Ecological area							
	Georges Bank		Gulf of Maine		Western Nova Scotia		Total for all areas	
	% wt		% wt		% wt		% wt	
	Male	Female	Male	Female	Male	Female	Male	Female
Polychaeta	63.80	15.01	2.90	5.27	20.74	5.54	30.83	9.12
Crustacea	5.27	16.88	2.77	12.05	17.16	14.44	10.18	15.00
Mollusca	3.49	15.47	0.46	3.23	1.37	3.27	1.86	7.93
Echinodermata	16.17	18.68	80.76	61.69	39.62	53.85	40.94	41.63
Pisces	0.02	0.15	0.23	0.89	0.45	2.30	0.26	1.26
Animal remains	5.66	6.93	11.02	10.33	14.57	13.82	10.92	10.68
Miscellaneous	<0.01	<0.01	0.18	2.07	1.63	4.49	0.79	2.35
Sand and Rock	5.59	26.88	1.68	4.47	4.46	2.29	4.22	12.03
	Male	Female	Male	Female	Male	Female	Male	Female
No. of predator fish sampled	61	126	37	50	144	162	242	338
	wt(g)		wt(g)		wt(g)		wt(g)	
	Male	Female	Male	Female	Male	Female	Male	Female
Mean weight per stomach	6.36	6.22	7.01	6.39	3.81	5.84	4.94	6.06

SILVER HAKE (*Merluccius bilinearis*)

Silver hake are found in continental shelf waters of eastern North America, ranging northwest to the Newfoundland Banks and southward to the offing of South Carolina (Bigelow and Schroeder, 1953). Samples of silver hake stomachs were collected from all ecological areas (Fig. 4). Although almost two thousand stomachs were examined, the analyses revealed that approximately one third of these were empty. As previously mentioned (p.), stomachs were not collected if they showed signs of regurgitation. However, because a large number of the fish used for this investigation had empty stomachs, it appears that regurgitation of all, or part of the stomach contents may have biased the silver hake data. In all tables, the data was compiled using the previously described methods, but the number of empty stomachs is listed in Table 13 to indicate where and when they occurred.

Major foods

Fish and crustaceans (96%) were the most common food items found in silver hake stomachs. The remainder of food was composed mostly of mollusks (2%). The mean weight of stomach contents per fish was 2.5 g (Table 11).

Food by ecological area

The diet of silver hake from each ecological area is given in Table 12. Each area is discussed separately below.

Middle Atlantic

Three hundred and twenty-two stomachs were examined. Fish, most of which were unidentifiable because of being partially digested, were the main food item. Silver hake (*Merluccius bilinearis*) and lanternfish (Myctophidae) comprised most of the identifiable fish found in the stomachs. Crustaceans, the secondary food group, consisted mostly of krill shrimp (Euphausiacea), sand shrimp (*Crangon*), and deep water shrimp (*Dichelopandalus*). Most of the remaining food eaten was squid (*Loligo*).

Southern New England

Six hundred and eighty-nine silver hake stomachs were analyzed. Mackerel (Scombridae) was the most common food found in the stomachs from this area. Other fish eaten were the codfish and hakes (Gadidae) and butterfish (Stromateidae). Cannibalism was highest in this area (7% of their diet by weight). The crustaceans consumed in this area were krill shrimp (Euphausiacea), caridean shrimp (Hippolytidae), and deep water shrimp (Pandalidae). Small amounts of worms (Polychaeta) and squid (Mollusca) comprised most of the remaining food.

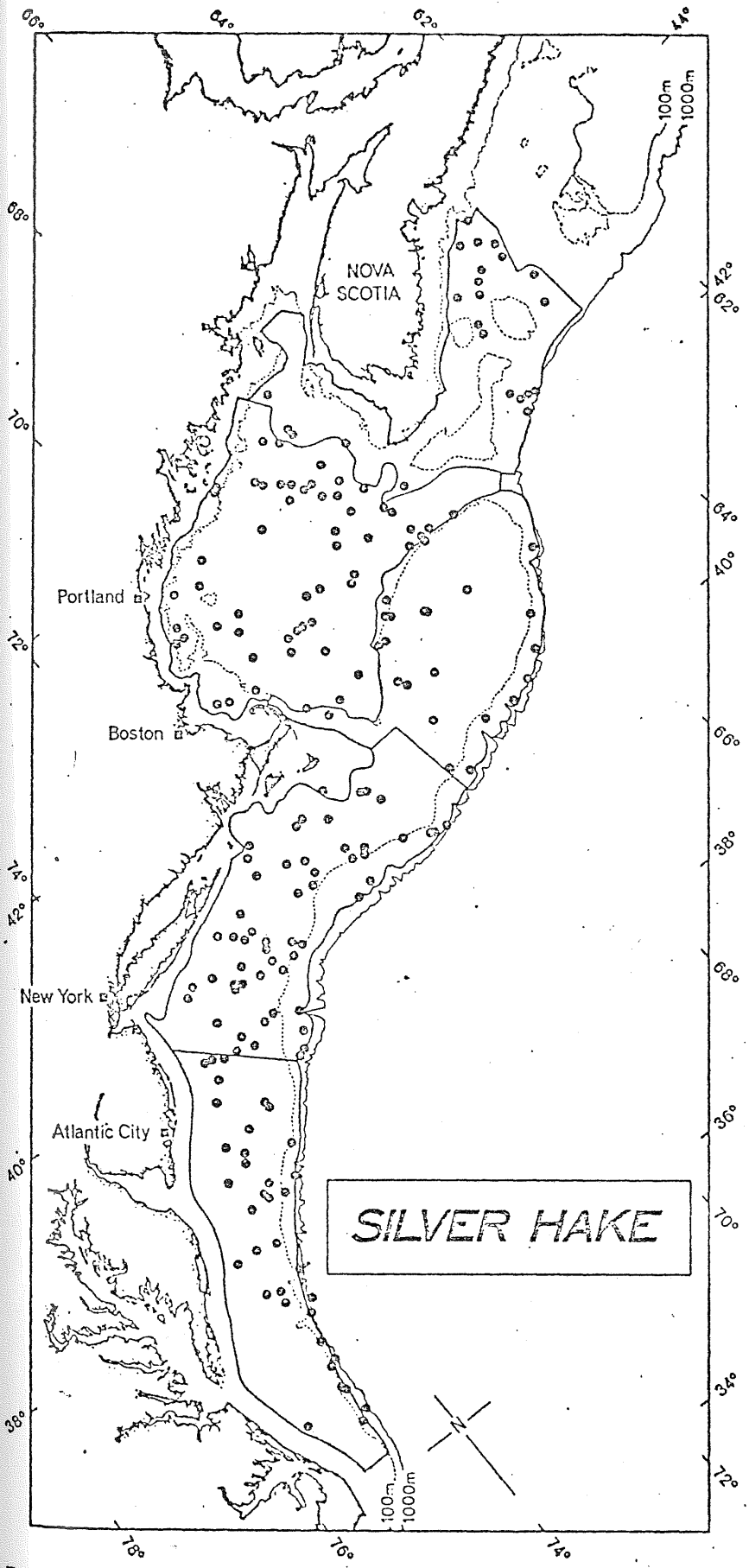

Figure 4. Stations where silver hake samples were obtained, 1969-1972.

Table 11. Stomach contents of silver hake, as percent of total weight (combined for all areas and years).

Stomach content categories	Percent of weight per stomach
	% wt
Crustacea	27.55
Mollusca	2.06
Pisces	68.58
Miscellaneous	1.81
No. of predator fish sampled	1937
Percent empty	33.25
	wt(g)
Mean weight per stomach	2.45

Table 12. Stomach contents of silver hake, as percent of weight, by ecological area (all years combined).

Stomach content categories	Percent of weight per stomach — Ecological area: Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Western Nova Scotia
	% wt	% wt	% wt	% wt	% wt
POLYCHAETA	-	0.97	<0.01	0.05	<0.01
Nereidiformia	-	0.86	-	<0.01	-
Aphrodita	-	0.11	-	-	-
Other Nereidiformia	-	0.75	-	<0.01	-
Capitelliformia	-	-	-	0.03	-
Other Polychaeta	-	0.11	<0.01	0.02	<0.01
ARTHROPODA	26.09	36.61	19.10	25.80	32.92
Crustacea	26.09	36.61	19.10	25.80	32.92
Amphipoda	0.90	1.00	0.11	<0.01	0.04
Decapoda	12.53	17.43	4.17	8.17	0.60
Crangonidae	8.11	1.02	1.35	0.09	-
Crangon	8.11	0.96	1.35	0.09	-
Other Crangonidae	-	0.06	-	-	-
Hippolytidae	-	8.33	0.04	-	0.14
Pandalidae	3.64	6.91	2.50	2.11	0.36
Dichelopandalus	3.56	-	1.65	0.69	-
Pandalus	-	0.27	0.06	1.03	-
Other Pandalidae	0.08	6.64	0.79	0.39	0.36
Pasiphaeidae	0.34	-	-	5.40	-
Other Decapoda	0.44	1.17	0.28	0.57	0.10
Euphausiacea	9.21	14.70	13.16	15.08	28.37
Meganyctiphanes	0.16	6.06	10.15	9.75	13.44
Other Euphausiacea	9.05	8.64	3.01	5.33	14.93
Mysidacea	0.30	0.70	<0.01	0.18	0.14
Other Crustacea	3.15	2.78	1.66	2.37	3.77
MOLLUSCA	15.39	0.76	<0.01	1.53	-
Cephalopoda	15.34	0.76	<0.01	1.53	-
Loligo	11.00	0.19	-	1.53	-
Rossia	0.65	-	-	-	-
Other Cephalopoda	3.69	0.57	<0.01	-	-
Other Mollusca	0.05	-	-	<0.01	-
PISCES	54.45	59.20	80.70	70.98	64.94
Osteichthyes	12.05	46.91	1.23	54.70	52.07
Isospondyli	-	-	-	39.38	-
Clupeidae	-	-	-	39.38	-
Alosa pseudoharengus	-	-	-	11.39	-
Clupea harengus	-	-	-	27.99	-
Anacanthini	6.04	11.89	0.02	1.68	51.06
Gadidae	6.04	11.89	0.02	1.68	51.06
Merluccius bilinearius	4.94	7.02	0.02	1.68	1.10
Other Gadidae	1.10	4.87	-	-	49.96
Myctophiformes	3.68	-	1.21	-	1.01
Perciformes	1.41	34.93	-	13.64	-
Scombridae	-	30.19	-	12.34	-
Stromateidae	1.25	4.61	-	1.30	-
Other Perciformes	0.16	0.13	-	-	-
Pleuronectiformes	0.92	0.09	-	-	-
Pisces remains	42.40	12.29	79.47	16.28	12.87
OTHER PHYLA	0.16	0.17	0.07	0.09	0.10
ANIMAL REMAINS	3.91	2.12	0.27	1.55	2.04
NON-ANIMAL REMAINS	<0.01	<0.01	-	<0.01	<0.01
No. of predator fish sampled	322	689	193	449	284
	Wt(g)	Wt(g)	Wt(g)	Wt(g)	Wt(g)
Mean weight per stomach	1.20	1.61	5.21	4.36	0.98

Georges Bank

One hundred and ninety-three stomachs were analyzed. Fish, the chief food, amounted to 80% of the total weight of all the food eaten in this area. Only lanternfish (Myctophidae) and silver hake (*Merluccius bilinearis*) were identifiable, the remaining portion of the weight had to be listed under fish remains. The most common crustaceans eaten were krill shrimp (*Meganyctiphanes*) and deep water shrimp (Pandalidae). Stomachs collected from Georges Bank contained a larger amount of food (average of 5.2 g) than those from any other area.

Gulf of Maine

Four hundred and forty-nine stomachs were examined. Atlantic sea herring (*Clupea harengus*) was the major food (28%) in the silver hake diet. Other fish of dietary importance were mackerel (Scombridae) and alewife (*Alosa pseudoharengus*). The second most important food group in this area was Crustacea, which was composed mostly of krill shrimp (*Meganyctiphanes*), glass shrimp (Pasiphaeidae), and deep water shrimp (Pandalidae).

Western Nova Scotia

Two hundred and eighty-four stomachs were examined. The codfish and hakes (Gadidae) made up over 50% of the weight of all the food eaten in this area. The only other food of substantial quantity (28%) was krill shrimp (Euphausiacea). This area had the lowest mean weight of stomach contents per fish (1.0 g).

Yearly food habits

A quantitative listing of stomach contents itemized proportionately for each year and area is given in Table 13. The analysis of this data showed no major differences or trends in the diet from year to year. Fish and crustaceans were the predominant food of silver hake from all areas (except the Gulf of Maine during 1971 when mollusks accounted for a larger portion of their diet). Mollusks were of less dietary importance and were eaten in the Middle Atlantic during 1971 and 1972.

Seasonal variation in the diet

Data from the analysis of seasonal differences in the food habits of silver hake are listed in Table 14. Smaller amounts of crustaceans were eaten in the spring from waters of the Middle Atlantic and southern New England, whereas the amount of mollusks and fish increased, when compared to the fall. Also, the average weight of food in each stomach from these

Table 13. Stomach contents of silver hake, as percent of weight, by ecological area and year.

Stomach content categories	Percent of weight per stomach				
	Ecological area				
	Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Western Nova Scotia
Fall 1969	% wt	% wt	% wt	% wt	% wt
Crustacea	100.00	78.59	3.90	100.00	-
Mollusca	-	-	-	-	-
Pisces	-	4.20	96.10	-	-
Miscellaneous	-	17.21	<0.01	-	-
	Total Empty	Total Empty	Total Empty	Total Empty	Total Empty
No. of predator fish sampled	8 -	82 27	62 14	58 16	- -
	wt(g)	wt(g)	wt(g)	wt(g)	wt(g)
Mean weight per stomach	0.21	0.56	13.01	0.53	-
Fall 1970	% wt	% wt	% wt	% wt	% wt
Crustacea	99.41	32.69	61.41	95.28	99.92
Mollusca	-	-	-	-	-
Pisces	0.59	58.69	36.62	0.13	0.04
Miscellaneous	<0.01	8.62	1.97	4.59	0.04
	Total Empty	Total Empty	Total Empty	Total Empty	Total Empty
No. of predator fish sampled	50 10	103 49	62 19	123 52	63 28
	wt(g)	wt(g)	wt(g)	wt(g)	wt(g)
Mean weight per stomach	0.70	0.61	1.11	0.36	0.65
Spring 1971	% wt	% wt	% wt	% wt	% wt
Crustacea	20.27	69.78	74.59	27.21	32.74
Mollusca	17.69	3.95	-	38.35	-
Pisces	58.95	22.14	18.83	32.49	66.01
Miscellaneous	3.09	4.13	6.58	1.95	1.25
	Total Empty	Total Empty	Total Empty	Total Empty	Total Empty
No. of predator fish sampled	113 52	215 85	7 2	26 7	63 17
	wt(g)	wt(g)	wt(g)	wt(g)	wt(g)
Mean weight per stomach	2.25	0.89	0.16	3.00	1.20

Percent of weight per stomach

Stomach content categories	Ecological area				
	Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Western Nova Scotia
Fall I 1971	% wt	% wt	% wt	% wt	% wt
Crustacea	-	78.99	-	-	-
Mollusca	-	-	-	-	-
Pisces	-	20.44	-	-	-
Miscellaneous	-	0.57	-	-	-
	Total Empty	Total Empty	Total Empty	Total Empty	Total Empty
No. of predator fish sampled	- -	50 4	- -	- -	- -
	wt(g)	wt(g)	wt(g)	wt(g)	wt(g)
Mean weight per stomach	-	1.60	-	-	-
Fall II 1971	% wt	% wt	% wt	% wt	% wt
Crustacea	7.73	43.93	90.85	18.52	16.19
Mollusca	1.45	0.26	0.01	-	-
Pisces	78.44	52.68	8.86	80.11	82.68
Miscellaneous	12.38	3.13	0.28	1.37	1.13
	Total Empty	Total Empty	Total Empty	Total Empty	Total Empty
No. of predator fish sampled	39 13	175 51	59 14	140 31	150 47
	wt(g)	wt(g)	wt(g)	wt(g)	wt(g)
Mean weight per stomach	0.32	1.82	2.20	11.93	1.05
Winter 1972	% wt	% wt	% wt	% wt	% wt
Crustacea	-	-	-	-	-
Mollusca	-	-	-	-	-
Pisces	-	-	-	95.37	-
Miscellaneous	-	-	-	4.63	-
	Total Empty	Total Empty	Total Empty	Total Empty	Total Empty
No. of predator fish sampled	- -	- -	3 3	5 3	- -
	wt(g)	wt(g)	wt(g)	wt(g)	wt(g)
Mean weight per stomach	-	-	-	1.64	-
Spring 1972	% wt	% wt	% wt	% wt	% wt
Crustacea	14.46	3.83	-	83.83	98.89
Mollusca	17.22	-	-	-	-
Pisces	60.84	95.04	-	14.08	<0.01
Miscellaneous	7.48	1.13	-	2.09	1.11
	Total Empty	Total Empty	Total Empty	Total Empty	Total Empty
No. of predator fish sampled	112 43	64 21	- -	97 33	8 3
	wt(g)	wt(g)	wt(g)	wt(g)	wt(g)
Mean weight per stomach	0.74	6.46	-	1.30	0.45

Table 14. Stomach contents of silver hake, as percent of weight, by ecological area and season (Fall 1970, 1971 - Spring 1971, 1972).

Stomach content categories	Percent of weight per stomach											
	Ecological area											
	Middle Atlantic		Southern New England		Georges Bank		Gulf of Maine		Western Nova Scotia		Total for all areas	
	% wt		% wt		% wt		% wt		% wt		% wt	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Crustacea	75.19	18.85	42.08	24.68	80.65	74.59	20.49	62.15	33.38	35.73	30.46	30.07
Mollusca	0.38	17.58	0.22	1.25	0.01	-	-	14.68	-	-	0.04	7.89
Pisces	21.15	59.41	53.67	72.00	18.48	18.83	78.06	21.13	65.72	63.02	67.71	59.45
Miscellaneous	3.28	4.16	4.03	2.07	0.86	6.58	1.45	2.04	0.90	1.25	1.79	2.59
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
No. of predator fish sampled	89	225	278	279	121	7	263	123	213	71	964	705
	wt(g)		wt(g)		wt(g)		wt(g)		wt(g)		wt(g)	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Mean weight per stomach	0.53	1.50	1.37	2.17	1.64	0.16	6.52	1.66	0.93	1.12	2.63	1.74

two areas increased from fall to spring (Middle Atlantic from 0.5 g to 1.5 g and southern New England from 1.4 g to 2.2 g). Silver hake sampled from the Gulf of Maine and western Nova Scotia consumed more crustaceans in the spring, while the amount of fish in their diet decreased. No mollusks were eaten during the fall in the Gulf of Maine, but they accounted for 15% of the diet in the spring. The mean weight per stomach was less in the spring (6.5 g) than in the fall (1.7 g) for fish from the Gulf of Maine, however, it was slightly higher for fish from western Nova Scotia. Insufficient samples were collected in the spring from Georges Bank (7) to be useful for a comparison with the fall data.

Sexual differences in the food habits

The food habits of male and female silver hake are strikingly different. The males preyed predominantly on crustaceans, and the females preyed mostly on fish in all areas except Georges Bank (Table 15). Mollusks were eaten in small amounts by both sexes. The mean weight of stomach contents was 4.9 g for the females and 0.6 g for the males (listed in the right hand columns of Table 15). The data from Georges Bank is not representative because of the small number of stomachs examined.

DISCUSSION

"Silver hake are strong, swift swimmers and at times voracious feeders" (Fritz, 1962). This statement about silver hake is well supported by the food items found in their stomachs. Schaefer (1960) found fish constituted the main portion (72% by volume) of the silver hake diet. Fritz (1962), Dexter (1969), and Jensen and Fritz (1960) also reported fish as the major food of silver hake. This study also shows fish are the most important food of silver hake.

Vinogradov (1971) analyzed more than 42,000 silver hake stomachs taken from the same areas (1965-1967) as the present study. His data clearly indicate that female silver hake grow larger and that they feed more heavily on fish than the males. His results also show that smaller silver hake (up to 21 cm) feed mostly on crustaceans, and at larger lengths (over 40 cm) the females feed exclusively on fish. The present study shows the silver hake diet has not changed substantially in more recent years.

Table 15. Stomach contents of silver hake, as percent of weight, by ecological area and sex (all years combined).

Stomach content categories	Percent of weight per stomach											
	Ecological area											
	Middle Atlantic		Southern New England		Georges Bank		Gulf of Maine		Western Nova Scotia		Total for all areas	
	% wt		% wt		% wt		% wt		% wt		% wt	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Crustacea	43.32	14.46	86.70	22.56	98.91	99.42	74.44	20.77	80.17	10.29	77.25	19.89
Mollusca	-	19.89	8.12	-	-	-	-	1.66	-	-	3.00	3.01
Pisces	54.00	61.64	3.27	75.22	0.83	-	24.95	76.11	15.83	88.79	18.06	75.25
Miscellaneous	2.68	4.01	1.91	2.22	0.26	0.58	0.61	1.46	4.00	0.92	1.69	1.85
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
No. of predator fish sampled	94	108	126	209	22	4	61	166	93	105	396	592
	wt(g)		wt(g)		wt(g)		wt(g)		wt(g)		wt(g)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean weight per stomach	0.40	2.64	0.74	2.92	1.13	0.30	1.19	10.85	0.26	1.73	0.64	4.86

SUMMARY OF THE FOOD HABITS OF ATLANTIC COD, HADDOCK, AND SILVER HAKE

No diurnal differences were found in the food habits of the cod, haddock, or silver hake. Several methods were utilized in attempting to observe any day-night differences in their feeding behavior. The first method treated the time at which all empty stomachs occurred. However, empty stomachs were present at all times of the day. Another method examined the presence of certain prey in the stomachs during selected time periods (1-6 hr.) within the day. This method did not reveal any pattern of feeding. The last method examined the correlation between the fullness of stomachs with time of day. Again, no particular feeding behavior was noticed. Daan (1973) noted that cod had a digestion rate ranging to three days. If haddock and silver hake have similar digestion rates, it is probable that any diurnal differences in the feeding habits of the three species examined would be masked.

A comparison of the main food groups in each area, for each predator species, is given in Table 16. By looking at the lower taxa listed in the table, or by referring to previous tables (2, 7, and 12) which show even lower taxonomic levels, it is found that minimal competition for prey exists among the three predators. Haddock fed mostly on benthic animals; cod on benthic and pelagic organisms; and silver hake almost exclusively on pelagic species. A few crustaceans (*Meganictiphanes, Pandalus,* and *Crangon*) are eaten by all three species, but not in large amounts. Also, silver hake feed on smaller silver hake and cod, and cod feed on smaller cod and silver hake. Silver hake were more selective in their feeding habits, and consequently, their prey was less diverse than the cod or haddock prey.

The fish listed as prey of Atlantic cod and silver hake deserve special attention. The results revealed substantial predation on fishes of commercial importance, such as: Atlantic sea herring, alewife, Atlantic mackerel, yellowtail flounder, silver hake, butterfish, and redfish. Furthermore, predation on non-commercial species has an impact on myctophids, sand lance, blackbelly rosefish, and longhorn sculpin. The latter species was especially affected by predation on their eggs by cod, where it constituted almost 14% of the diet in the Georges Bank region.

(all years combined).

Stomach content categories	Percent of weight per stomach														
	Middle Atlantic			Southern New England			Georges Bank			Gulf of Maine			Western Nova Scotia		
	COD	HAD.	S.H.	COD	HAD.	S.H.	COD	HAD.	S.H.	COD	HAD.	S.H.	COD	HAD.	S.H.
POLYCHAETA	0.1	-	-	9.7	4.5	1.0	1.6	24.5	<0.1	0.2	14.1	0.1	1.0	11.9	<0.1
CRUSTACEA	10.4	-	26.1	25.1	82.1	36.6	21.6	23.4	19.1	22.7	15.2	25.8	28.7	14.5	32.9
Amphipoda	-	-	0.9	2.5	75.3	1.0	0.6	11.1	0.1	0.1	2.3	<0.1	0.1	4.7	<0.1
Decapoda	8.2	-	12.5	21.8	4.0	17.4	18.2	2.0	4.2	19.9	9.8	8.2	17.2	6.7	0.6
Euphausiacea	-	-	9.2	-	-	14.7	0.3	5.7	13.2	1.3	1.7	15.1	9.4	1.8	28.4
Other Crustacea	2.2	-	3.5	0.8	2.8	3.5	2.5	4.6	1.6	1.4	1.4	2.5	2.0	1.3	3.9
MOLLUSCA	0.6	-	15.4	2.2	0.7	0.8	23.3	6.4	<0.1	0.5	1.5	1.5	0.7	2.1	-
Pelecypoda	-	-	-	0.6	0.7	-	14.2	5.4	-	0.1	0.8	-	<0.1	1.6	-
Gastropoda	-	-	0.1	1.4	<0.1	-	6.6	0.4	-	0.1	0.5	-	0.4	0.3	-
Cephalopoda	-	-	15.3	<0.1	-	0.8	<0.1	-	<0.1	0.3	-	1.5	<0.1	-	-
ECHINODERMATA	-	-	-	0.8	1.4	-	0.2	12.5	-	0.4	53.3	-	4.0	50.1	-
Echinoidea	-	-	-	<0.1	1.2	-	<0.1	2.6	-	<0.1	11.2	-	0.3	9.1	-
Ophiuroidea	-	-	-	-	0.1	-	<0.1	9.2	-	0.1	38.9	-	2.1	35.3	-
PISCES	86.5	-	54.5	57.1	<0.1	59.2	45.9	0.1	80.7	73.8	2.2	71.0	59.0	3.1	64.9
Berycoidei	9.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isospondyli	-	-	-	8.8	-	-	4.0	-	-	26.8	-	39.4	9.3	-	-
Anacanthini	12.9	-	6.0	-	-	11.9	3.9	-	<0.1	6.4	-	1.7	7.1	0.9	51.1
Perciformes	10.6	-	1.4	15.9	-	34.9	4.9	<0.1	-	26.4	-	13.6	13.7	0.1	-
Pleuronectiformes	43.7	-	0.9	5.7	-	0.1	7.7	<0.1	-	0.4	-	-	-	-	-
Other Pisces	-	-	3.8	0.3	-	-	0.1	-	1.2	-	0.3	-	-	-	0.9
Pisces remains	10.3	-	42.4	26.5	<0.1	12.3	11.8	<0.1	79.5	13.5	1.9	16.3	28.4	2.1	12.9
Pisces eggs	-	-	-	<0.1	-	-	13.5	<0.1	-	0.3	-	-	0.5	<0.1	-
OTHER CATEGORIES	<0.1	-	0.1	<0.1	0.1	0.3	4.8	0.6	<0.1	0.6	0.6	<0.1	1.5	2.1	0.2
ANIMAL REMAINS	2.4	-	3.9	5.1	8.2	2.1	2.6	8.3	0.3	1.8	10.1	1.6	4.6	13.1	2.0
NON ANIMAL REMAINS	-	-	<0.1	-	3.0	<0.1	<0.1	24.2	-	<0.1	3.0	<0.1	0.5	3.1	<0.1
No. of predator fish sampled	7	-	322	59	27	689	537	330	193	268	182	449	379	413	284
Mean weight per stomach (g)	69.7	-	1.2	40.3	4.1	1.6	29.0	7.0	5.2	37.8	7.8	4.4	19.1	5.3	1.0

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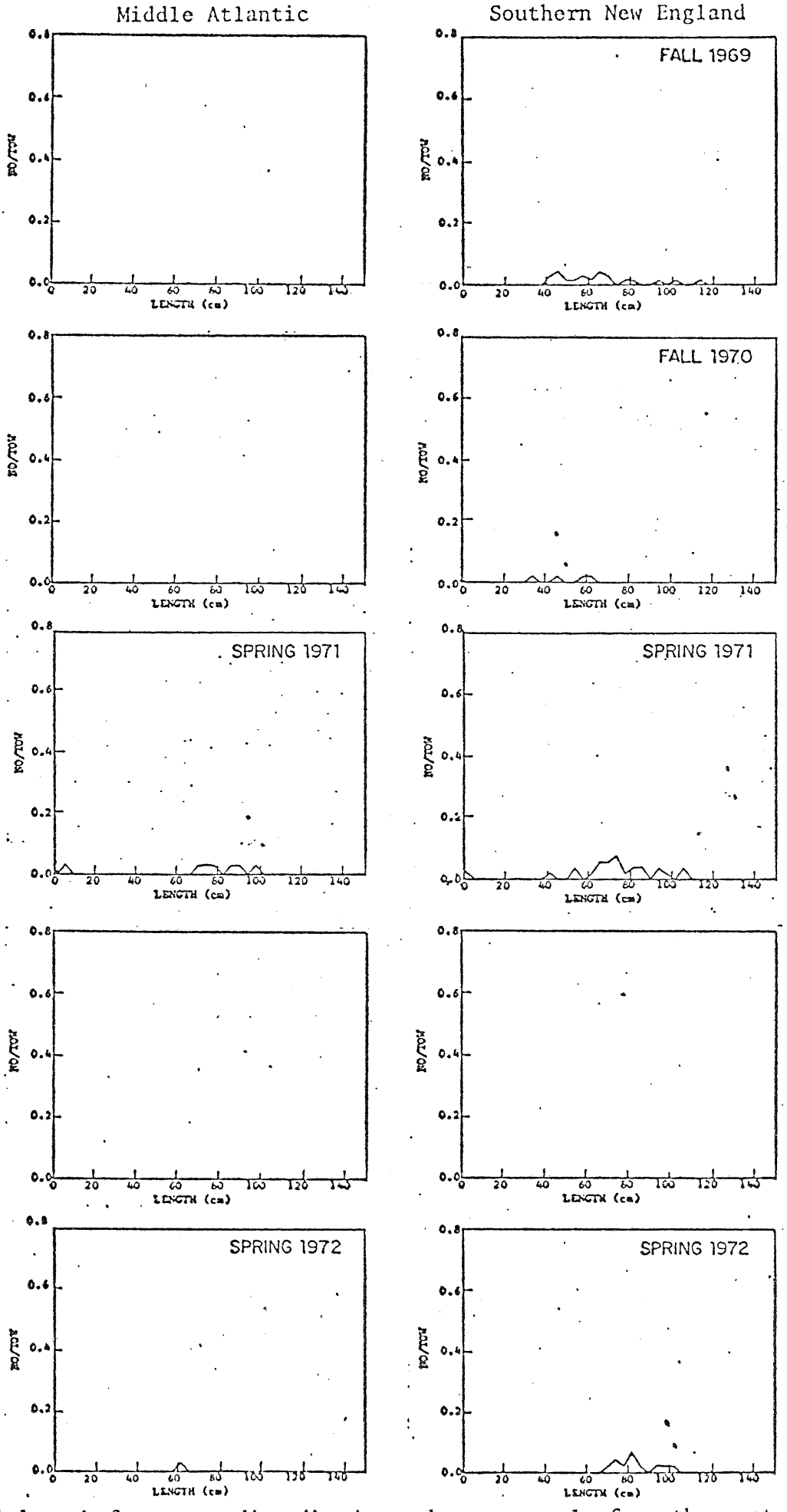
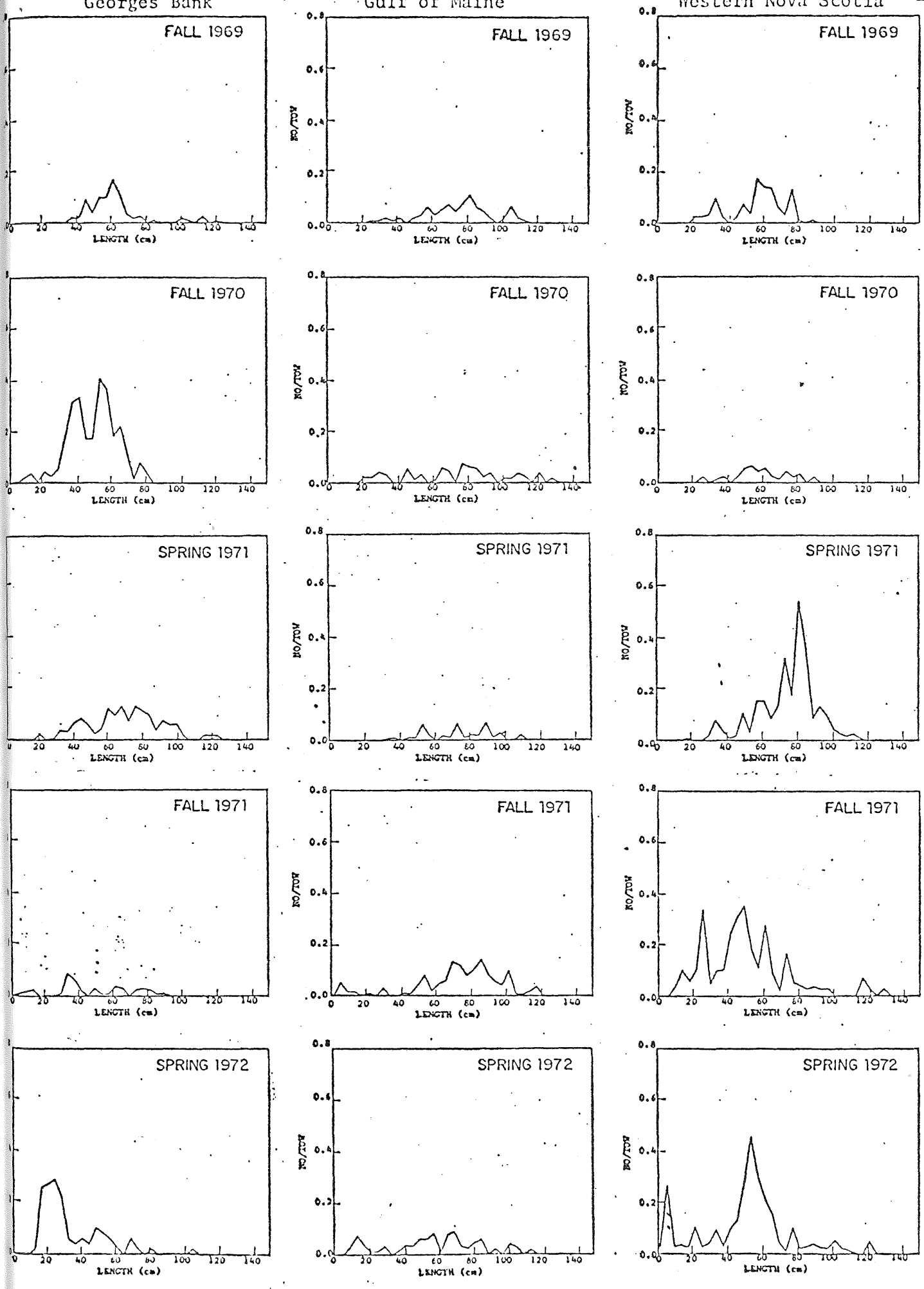
Appendix Figure 1.- Length frequency distribution* of Atlantic cod taken from the Middle Atlantic and southern New England, 1969-1972.

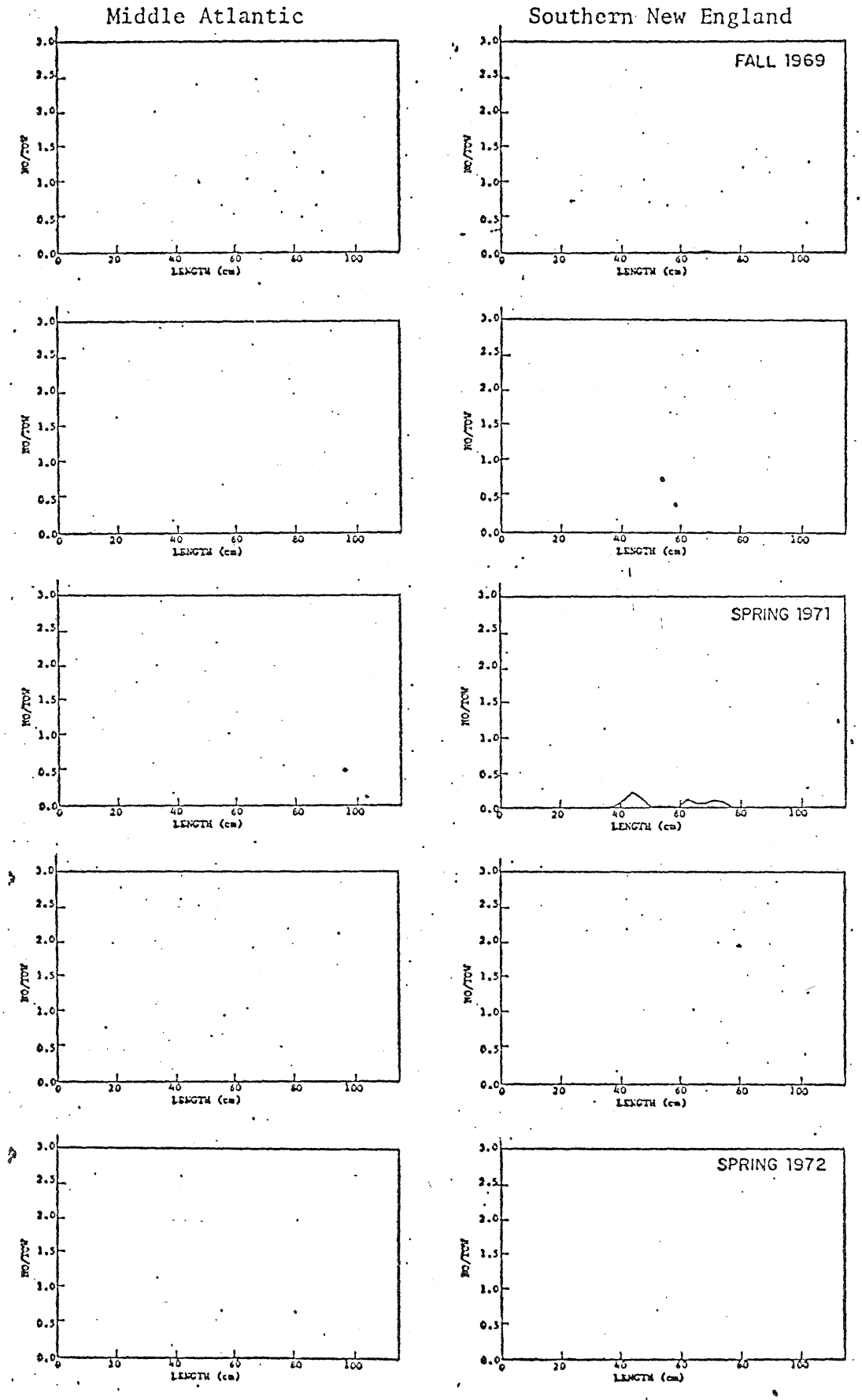


*All length frequency distributions shown are only from those stations where stomachs were collected.

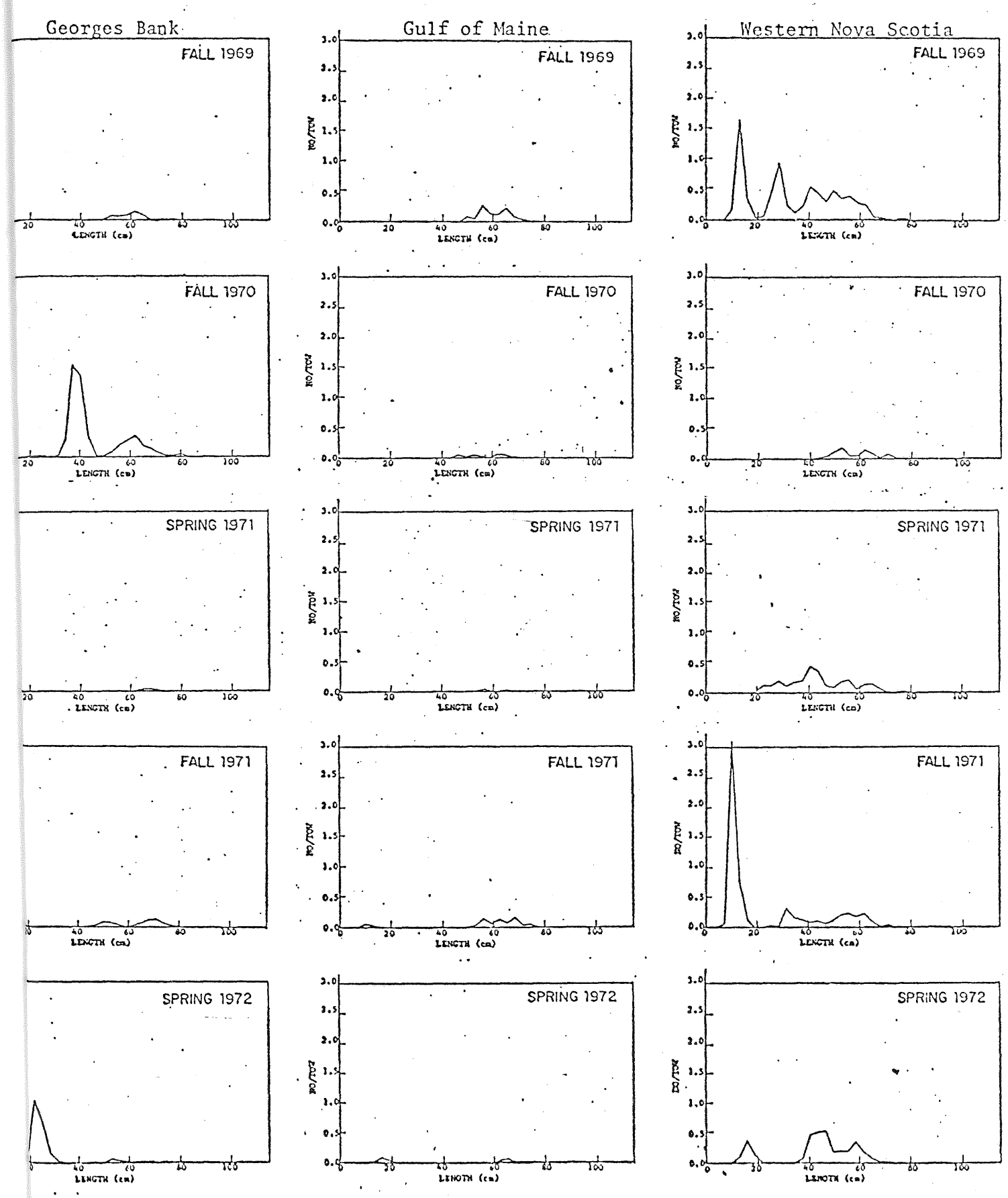
Appendix Figure [illegible] Cod from Georges Bank, the Gulf of Maine and western Nova Scotia, 1969-1972



Appendix Figure 3.- Length frequency distribution of haddock taken from the Middle Atlantic and southern New England, 1969-1972.

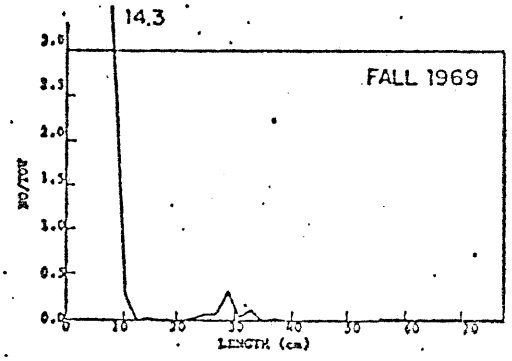


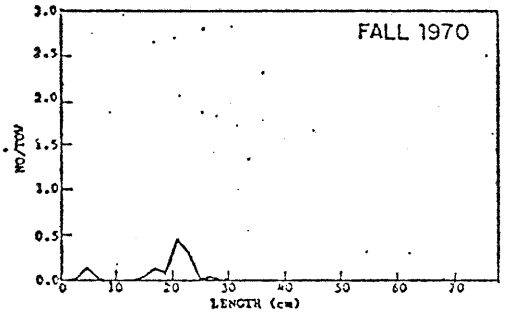
Appendix Figure 4.- Length frequency distribution of haddock taken from Georges Bank, the Gulf of Maine, and western Nova Scotia, 1969-1972.

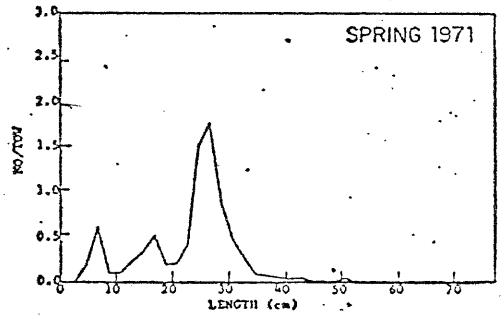


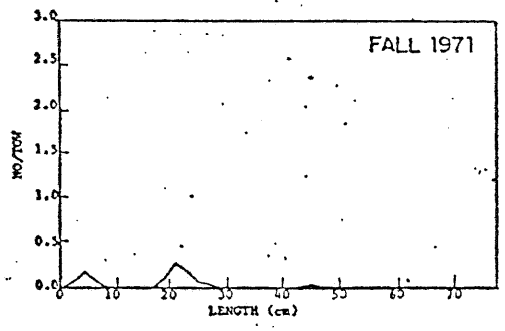
Appendix Figure 5.- Length frequency distribution of silver hake taken from the Middle Atlantic and southern New England, 1969-1972.

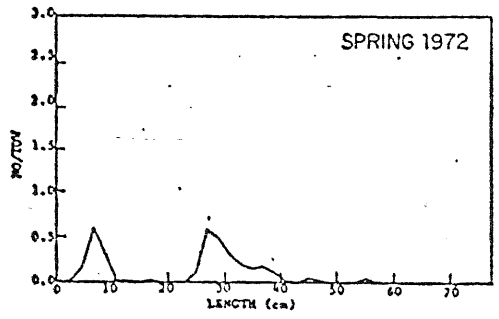
Middle Atlantic



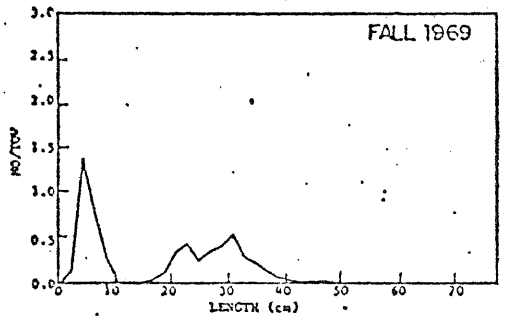


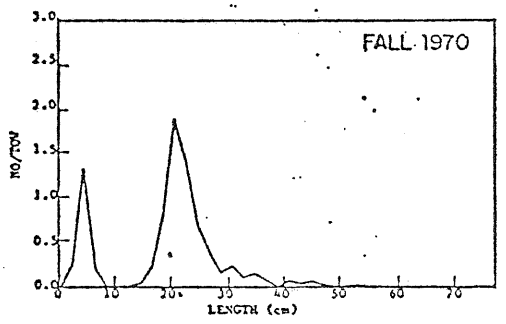


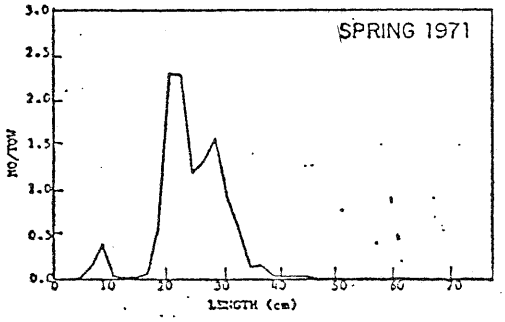


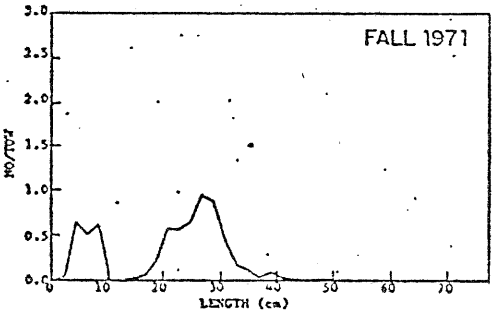


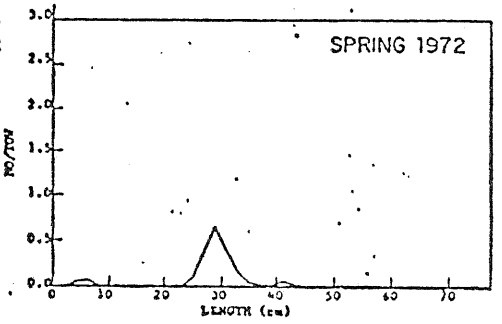
Southern New England











Appendix Figure 6.- Length frequency distribution of silver hake taken from Georges Bank, the Gulf of Maine and western Nova Scotia, 1969-1972.