SILVER HAKE'S (*Merluccius bilinearis*) REGULATORY INFLUENCE ON THE FISHES OF THE NORTHWEST ATLANTIC

by

Ray E. Bowman

National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole Laboratory
Woods Hole, MA. 02543
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INTRODUCTION

Large scale fish-feeding studies were initiated in 1963 by the Woods Hole Laboratory of the Northeast Fisheries Center (NEFC) to identify the types of food eaten by various marine fishes found in the northwest Atlantic. The studies have become an ongoing part of the research being conducted by the NEFC. Recently much of the available dietary information gathered by the NEFC was summarized by Edwards and Bowman (1979) and Grosslein et al. (1978). Edwards and Bowman indicated that silver hake (*Merluccius bilinearis*) alone could potentially consume almost 10 percent of the standing crop of all fish within the study area annually; the bulk of which would be small or juvenile fish. They went on to suggest that silver hake, more than any other species, plays the principle predatory role in regulating the northwest Atlantic ecosystem.

Fishery biologists have studied the fluctuations of fish stocks since the beginning of fishery research. It is well known that natural changes in the environment are factors often responsible for large changes in fish abundance (McBride and Brown 1979). However, because the intensity of man's fishing effort can be the overriding determinant affecting fish abundance, the majority of research at the NEFC is directed towards stock assessment and setting limits on stock exploitation. This paper examines, aside from man's influence on fish populations, the silver hake's predatory potential to act as a natural regulatory mechanism on the fish stocks in the northwest Atlantic.

METHODS AND MATERIALS

Fish feeding data has been gathered during various research vessel cruises conducted by or in conjunction with the Northeast Fisheries

Center in Woods Hole, Massachusetts from 1963 to date. The area sampled (Figure 1) extends from Cape Hatteras to the western end of Nova Scotia (Browns Bank) and is routinely surveyed, by ships towing bottom trawls, during the spring and fall of each year (see Grosslein [1969] for details of the Groundfish Survey Program).

Food-habits studies were first initiated in 1963 simply to identify, at sea, the type of foods eaten by various marine fish species. The initial study was terminated in 1966 after the stomach contents of 18,500 fish representing 65 species were examined. In 1969 a quantitative approach was employed to better describe the prey biomass utilized by fish populations within the study area. Stomachs were excised aboard ship and preserved in 3.7 percent formaldehyde with a label noting species, cruise and station. At the laboratory the samples were opened and each prey species was identified, counted, damp dried and weighed. All data was recorded on a standard form. The contents of a total of 25,000 stomachs, representing 80 fish species, were analyzed from fish caught from 1969 through 1972. The most detailed fish feeding studies were initiated in 1973 to determine fish feeding chronology, digestion rate, consumption, and gross growth efficiency. Examination of the stomach contents of 17,000 fish representing 17 species of biological and/or commercial importance in the ecosystem has been carried out and a study of the remaining fish species is underway.

Feeding data on Georges Bank fishes are the most complete set of data available, and for this reason the following analyses deal mainly with Georges Bank fish. The stomach contents of 1,566 Georges Bank silver hake caught from 1963 through 1977 were examined. The food of silver hake is summarized as a percent occurrence for the 1963-1966 period, and

as a percentage weight for the years from 1969 through 1977. Fish predators found on Georges Bank (other than silver hake) and fish eaters identified in other areas are noted where applicable; however, where these fish and their prey are listed no quantitative data are presented.

The silver hake feeding data was used in conjunction with stock assessment data (Anderson, 1977) to evaluate the potential predator pressure of silver hake on other fish populations on a yearly basis (Figure 2). The relative abundance of two other species, namely haddock (*Melanogrammus aeglefinus*) and American sand lance (*Ammodytes americanus*) which have been identified as prey of silver hake, was available from Clark and Overholtz (1979), and Grosslein et al. (1978), respectively. The haddock data reflect the relative haddock year class strength from the estimated one year old stock sizes for the years 1963-1976, inclusive (Figure 3b). The American sand lance data are expressed as the stratified mean number caught per tow for the years from 1967 through 1976 (Figure 4b).

RESULTS AND DISCUSSION

Unusually successful year classes of such species as haddock (1963), Atlantic mackerel (1967), Atlantic herring (1966, 1970), and American sand lance (1976) have occurred in the northwest Atlantic during the past two decades (Clark and Overholtz, 1979; Anderson and Overholtz, 1979; Sissenwine and Waring, 1979; Smith et al., 1978; respectively). The haddock and American sand lance population upsurges are of particular interest (Figures 3b and 4b) because the extrinsic (physical or non-biological) and intrinsic (within populations) factors which cause variations in population size could be closely examined. The conditions that made this possible are:

1) The success of the 1963 year class of haddock occurred just prior to the heavy exploitation of fish stocks by foreign fishermen; while the American sand lance population "explosion" came at the end of the period of intense fishing pressure (1964-1976) by foreign fishing fleets.

2) A large accumulation of biological and oceanographical data is available. During the earlier years (including 1963) research on the haddock populations was conducted routinely because of the commercial importance of haddock as a food fish. Information concerning the American sand lance population was gathered during December of 1976 and subsequent months after the oil tanker *ARGO MERCHANT* ran aground on Fishing Rip.

With haddock we have an example of a relatively "natural" (man's influence was minimal) phenomenon with the occurrence of their outstanding 1963 year class. Work by Bowman (in preparation), who examined the earlier data, indicates that the weather conditions on Georges Bank govern to a large extent the year class strength of haddock. Further, based on assessment data generated at the NEFC, potential predation by silver hake or any other species had little detrimental effect on the success of the 1963 haddock year class. It can be seen in Figure 2 that the adult silver hake population (age 2 years and older) had reached record levels during the 1963-1964 period. In addition, and as a consequence the 1962, 1963 and 1964 silver hake year classes were well above normal which resulted in many smaller sized silver hake being present on Georges Bank during the 1962-1964 period. Certainly silver hake predation pressure has little or no detrimental effect on the initial success of haddock year classes.

Smith et. al. (1978) has suggested that weather conditions during the 1974-1977 period were responsible for the marked increase in the American sand lance population. It is of interest to note that the silver hake population steadily increased from 1972 to 1976, and predation pressure on fish stocks must have increased correspondingly; but again no detrimental effects on initial year class strength were observed. Overall, the data indicates that weather conditions (an intrinsic factor) are more influential in determining the year class success of haddock and American sand lance than any other single factor.

It can be seen in Figure 5 that the diet of silver hake greater than 20 cm in length (age 2 years and older) is made up mostly of fish. The composition of the prey is presented in more detail in Table 1. The data represents the analysis of the stomach contents of 2,734 silver hake collected in the northwest Atlantic from 1973 through 1976. Considering the stock size of Georges Bank silver hake alone, the fish consumption by silver hake per year is substantial. Cohen et al. (1979) noted that consumption by silver hake exceeds the total productivity of the exploited finfish and squid community on Georges Bank. Not indicated in Table 1 but of considerable importance is that most fish eaten by silver hake are either juvenile fish or smaller sized fish species.

Determination of silver hake predation pressure on fish populations required a year by year analysis of the silver hake diet (Table 2). It was also necessary to consider the yearly abundance of silver hake (age 2+) and their prey during each year to arrive at estimates of potential predation. It can be seen in Figure 3a that haddock were eaten by 2 out of 87, and 2 out of 88 (2.3%), of the silver hake examined during the summer and fall of 1963, respectively. Interestingly, 1963 was the only

year haddock were identified in silver hake stomachs. Only the 1963 year class haddock were taken by silver hake (determined by the length of haddock found in the stomachs). The 1963 year class of haddock was estimated to be 464 million fish at age 1 (Figure 3b), which was well above the yearly average (for years from 1935 to 1976) of 70 million fish. A straightforward calculation of the percentage of silver hake examined which had eaten haddock during 1963 (2.3%) times the number of adult silver hake present on Georges Bank in 1963 (3764×10^6) yields 85.5 million haddock potentially in the stomachs of silver hake on any given day during either the summer or fall of 1963. This number of haddock represents more haddock than usually survive to one year of age during an average year (Clark and Overholtz, 1979). Admittedly it is only speculation to suggest that silver hake had consumed so many haddock, however, considering that silver hake and haddock are co-occurring species on Georges Bank throughout the year, and that silver hake feed many times per year (Bowman and Bowman, 1980), it is not unrealistic to assume that silver hake predation pressure was substantial. This serves as one example based on existing data, of how rapidly silver hake might reduce juvenile fish populations.

A similar pattern is to be seen in silver hake predation on American sand lance during 1976 (Figure 4). Samples collected during the spring of 1976 showed that 31.6 percent of the weight of all prey taken by silver hake was American sand lance. Sand lance were not identified in the stomachs of silver hake during any other year. It can be seen in Figure 4b that during 1976 the sand lance population was well above the population size noted in previous years. Calculations to determine the potential silver hake predation on sand lance result in 1400 metric tons of sand lance being eaten during each silver hake feeding period (1777 million silver hake - times the silver hake mean weight per stomach of 2.48 grams -

times the percentage weight of sand lance found in the stomachs [31.6 percent]-yields 1400 metric tons). It is readily seen that silver hake had the potential to consume enormous quantities of sand lance during 1976, and the data presented indicates that they were taking advantage of the increase in the American sand lance population.

Silver hake are largely opportunistic feeders. They take advantage of any population increases in either juvenile fish or smaller sized fish species. The importance of this is that because they have little dietary preference for any particular fish species; they act as a natural regulatory mechanism in the ecosystem. The reason this is so is because they tend to ensure that no one species dominates the ecosystem at the expense of others. Surprisingly, silver hake even regulate their own population size because they are highly cannabilistic during years of silver hake population increases.

Another aspect of the silver hake's role in the natural management of the ecosystem is that they prey mainly on smaller sized fish (mostly juveniles). Because adult silver hake are relatively small themselves, they are limited to rather small prey. This ensures that they will remove large numbers of juveniles and tend to maintain stability by preventing the accumulation of excessively large stocks.

There are several fish species which "assist" silver hake or "pick up where silver hake leave off." During the 1963 upsurge of the haddock population, species such as Atlantic cod, white hake and red hake were also feeding on haddock, and thereby "assisting" silver hake (Figure 6). In the period from 1964 through 1966, after the 1963 year class of haddock had probably grown too large for most silver hake to take them as prey, species such as pollock, goosefish, white hake and spiny dogfish were still

eating haddock. These fish eaters are all larger species capable of taking much larger prey than silver hake, and therefore maintain predation pressure on excessive population upsurges ("pick up where silver hake leave off"). The trend of other species "assisting" silver hake was also noted during the increase of the American sand lance population (Figure 7). Species such as Atlantic cod, pollock, spiny dogfish and winter skate were all feeding rather heavily on American sand lance during the 1976-1977 period (Bowman and Langton, 1978).

Silver hake are perfectly adapted for their predatory role. They have a very wide geographic range and maintain a large population size. They are also strong swift swimmers and voracious feeders (Bigelow and Schroeder, 1953; Fritz 1962). Good eyesight, sharp teeth, and an unusually large mouth for their size are other characteristics of silver hake which make them ideally suited for feeding on small fish. Finally, because they feed both on the bottom and in the water column there are few species, either demersal or pelagic, which are not taken as prey. Although all the other fish predators combined may have an impact equal to or even greater than silver hake on any increases of fish populations; silver hake alone stands out as the most influential natural regulatory mechanism on fishes in the northwest Atlantic.

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Table 1. Silver hake prey versus fish length for fish collected in the northwest Atlantic from 1973 through 1976. Note that the fish taken as prey (given in terms of percentage weight) increase with an increase in predator length. The data represents the stomach contents of 2734 silver hake. (+ indicates present but less than 0.1%.)

Prey	Length category (cm)												
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65
POLYCHAETA	--	0.4	0.5	--	0.1	0.3	0.2	+	0.1	--	--	--	
CRUSTACEA	89.7	80.3	81.6	77.3	28.0	55.5	21.3	2.3	0.5	0.2	--	0.8	
Amphipoda	58.7	18.9	6.1	1.2	1.7	1.3	0.7	+	+	--	--	+	
Ampeliscidae	11.0	4.9	0.1	0.5	0.6	0.5	0.2	+	--	--	--	+	
Oedicerotidae	3.1	3.4	4.1	0.1	+	-.2	0.1	+	--	--	--	--	
Hyperiidae	42.1	6.2	0.3	0.4	0.6	0.4	0.3	--	--	--	--	--	
Other Amphipoda	2.5	4.4	1.6	0.2	0.5	0.2	0.1	+	+	--	--	--	
Decapoda	11.8	23.9	31.1	7.0	16.2	20.0	10.5	1.6	0.3	0.1	0.1	0.2	
Crangonidae	7.7	16.0	18.7	3.7	4.3	6.1	4.3	0.3	0.1	--	+	0.2	
Pandalidae	--	1.7	5.3	2.1	10.7	12.0	4.3	1.2	0.2	--	0.1	--	
Pasiphaeidae	--	--	--	--	--	--	0.8	--	--	--	--	--	
Other Decapoda	4.1	6.2	7.1	1.2	1.2	1.9	1.1	0.1	--	0.1	--	--	
Euphausiacea	1.9	5.7	23.7	64.4	7.8	26.4	8.8	0.6	0.2	0.1	--	--	
Mysidacea	4.2	22.1	12.8	3.9	0.2	6.7	0.6	+	+	--	--	0.6	
Copepoda	1.7	+	+	--	+	--	--	--	--	--	--	--	
Other Crustacea	11.4	9.7	7.9	0.8	2.1	1.1	0.7	0.1	+	+	--		
CEPHALOPODA	--	--	--	--	17.8	3.4	14.9	14.3	0.1	12.0	--		
Loligo	--	--	--	--	15.3	--	13.5	10.0	--	12.0	--		
Other Cephalopoda	--	--	--	--	2.5	3.4	1.4	4.3	0.1	+	--		
PISCES	4.8	13.9	14.0	19.9	52.8	38.7	62.4	83.4	98.9	87.8	99.9	99.2	
Scomberesox saurus	--	--	--	--	--	--	--	5.6	--	--	--	--	
Clupeidae	--	--	--	--	--	--	3.5	3.5	8.0	--	--	--	
Merluccius bilinearis	--	2.0	4.0	--	22.1	5.0	6.9	24.2	5.9	--	--	--	
Phycis chesteri	--	--	--	--	--	--	1.2	--	--	--	--	--	
Ammodytes americanus	--	6.3	2.0	--	--	+	3.1	0.4	7.7	--	--	--	
Scomber scombrus	--	--	--	--	--	--	7.8	8.8	6.1	6.8	17.4	--	
Stenotomus chrysops	--	--	--	--	--	--	--	--	10.5	--	--	--	
Peprilus triacanthus	--	--	--	--	--	--	2.7	3.4	--	--	23.1	--	
Other Pisces	4.8	5.6	8.0	19.9	30.7	33.7	37.2	37.5	60.7	81.0	59.4	99.2	
MISCELLANEOUS	5.5	5.4	3.9	2.8	1.3	2.1	1.2	+	0.4	+	+	--	

Table 2. Diet of silver hake presented as a percent occurrence (1963) or percentage weight (1969-1976) for each year and season silver hake were collected for stomach content analyses from Georges Bank. (SP = Spring, S = Summer, F = Fall, W = Winter.)

	Percent Occurrence									Percentage Weight								
	1963			1964			1965		1966	1969-1972	1973		1974		1975		1976	
Prey	S	F	W	S	F	W-SP	S	F	W	SP-F	SP	F	SP	F	SP	F	SP	F
CRUSTACEA	29.9	34.1	50.0	27.8	16.7	33.3	34.7	31.6	--	20.4	70.1	15.0	41.8	18.1	10.7	5.9	18.6	6.0
Amphipoda	11.5	1.1	--	--	5.6	--	--	5.3	--	0.1	1.3	0.4	0.3	1.2	0.1	0.3	0.9	0.1
Pandalidae	2.3	6.8	--	5.2	5.6	--	--	4.1	--	2.6	58.9	12.0	--	8.3	--	1.1	2.2	2.2
Euphausiacea	19.5	19.3	50.0	17.5	5.6	33.3	30.6	26.3	--	13.1	2.8	0.2	31.2	2.6	9.4	0.5	14.8	+
Other Crustacea	1.1	6.8	--	4.1	--	--	--	--	--	4.6	7.7	2.4	10.3	6.0	1.2	4.0	0.7	3.7
PISCES	12.6	19.3	6.3	2.1	33.3	--	--	31.6	50.0	78.2	23.7	84.9	57.9	81.9	88.2	94.1	68.6	35.8
Herring	2.3	4.5	--	--	5.6	--	--	--	50.0	--	--	--	--	--	--	39.2	--	--
Mackerel	--	--	--	--	5.6	--	--	5.3	--	--	--	31.0	--	--	63.7	--	--	--
Sand lance	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	31.6	--
Haddock	2.3	2.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Other Pisces	8.0	13.6	6.3	2.1	22.2	--	--	26.3	--	78.2	23.7	53.9	57.9	81.9	24.5	54.9	37.0	35.8
MISCELLANEOUS	--	--	--	1.0	--	--	--	--	--	4.4	5.6	0.1	0.3	+	1.1	+	12.8	58.2
No. examined	87	88	16	97	18	4	49	19	2	248	48	198	103	157	92	146	63	117
No. empty	52	40	7	64	9	3	33	8	1	61	24	39	39	27	18	39	33	48

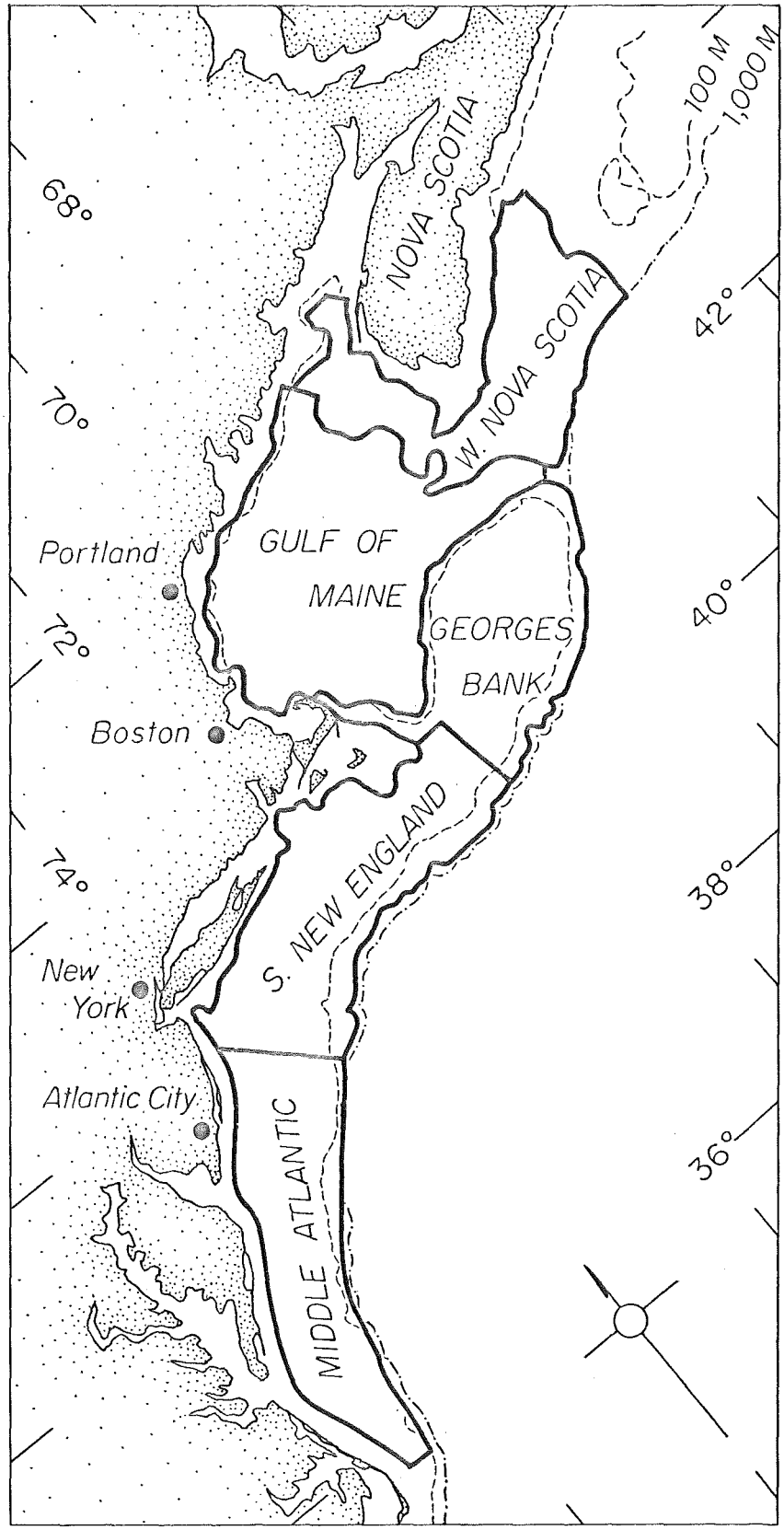

Figure 1. Offshore areas between Cape Hatteras, North Carolina, and western Nova Scotia where the NEFC conducts bottom trawl surveys. Silver hake are regularly caught throughout the entire region.

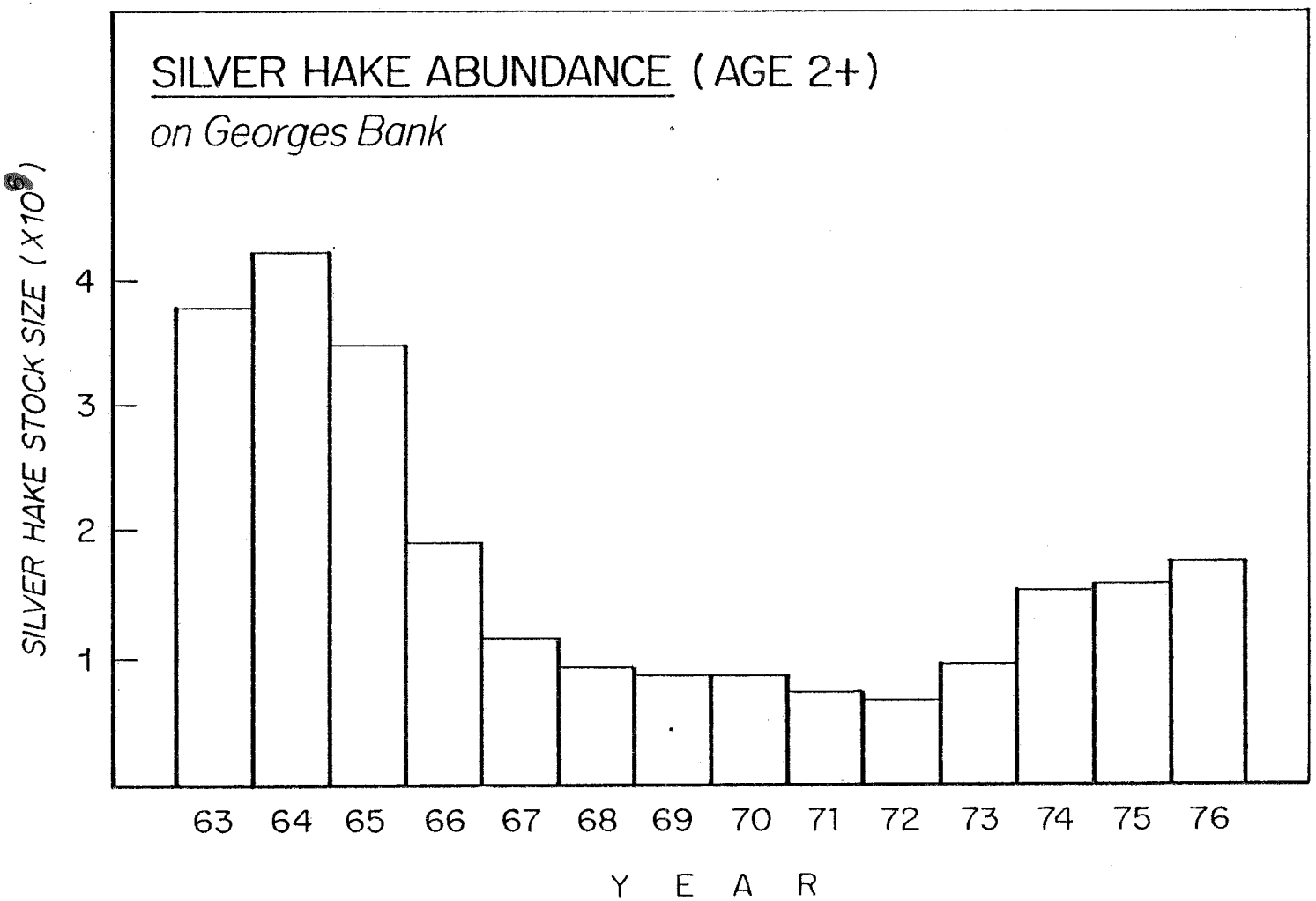

Figure 2. Estimated stock size of the Georges Bank silver hake stock (age 2+) derived from virtual population analysis (M=0.4). Data taken from Anderson (1977).

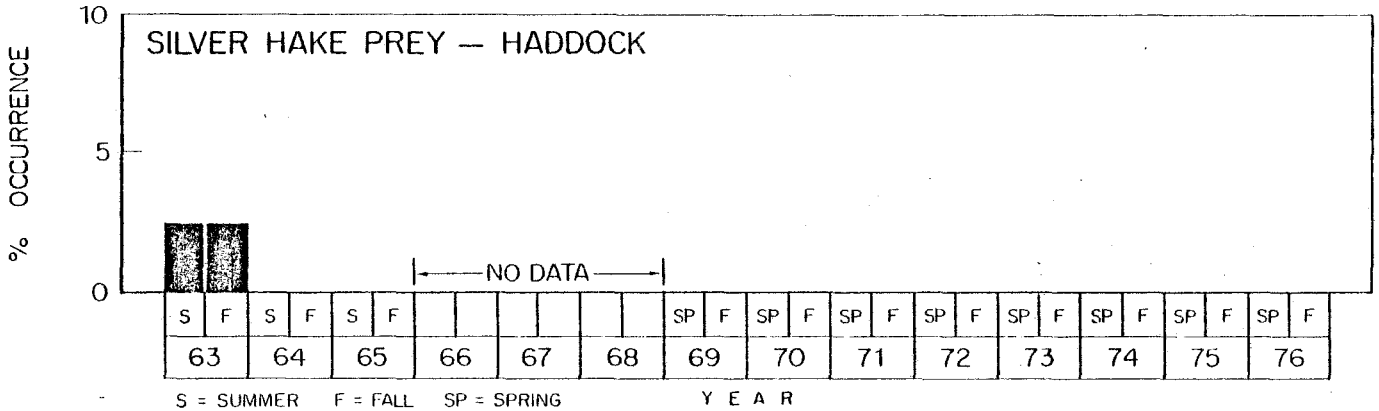

Figure 3a. Percent occurrence of haddock taken as prey by silver hake collected on Georges Bank during the years from 1963 through 1976. The contents of 1566 silver hake stomachs were analyzed.

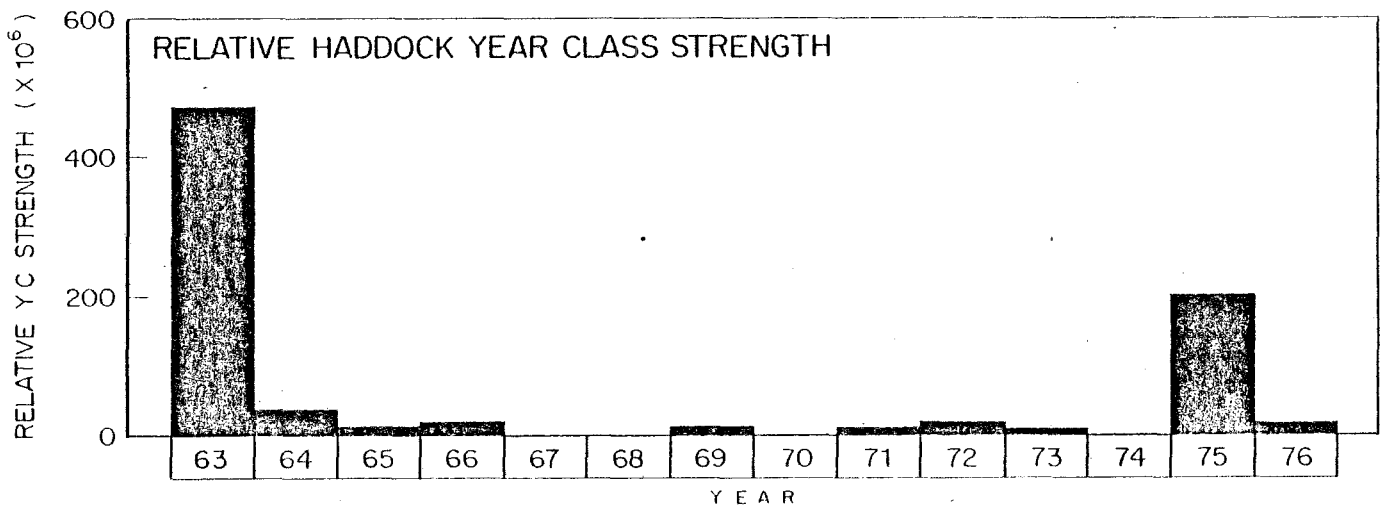

Figure 3b. Relative year class strength of Georges Bank haddock obtained from virtual population analysis assuming M=0.2 for the years from 1963 through 1976. Data taken from Clark and Overholtz (1979).

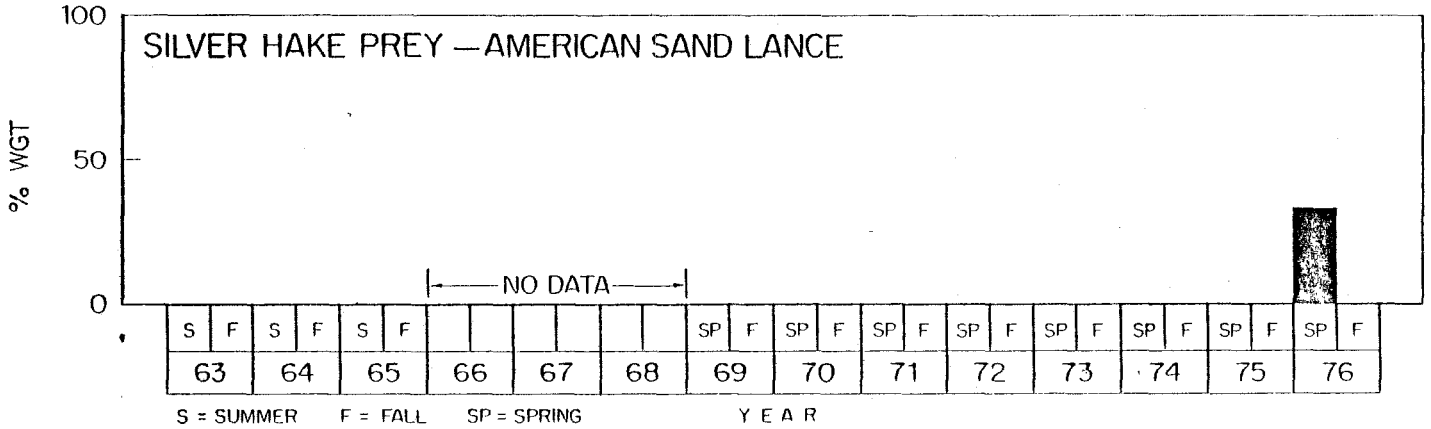

Figure 4a. Percentage weight of American sand lance found in the stomachs of silver hake collected on Georges Bank during the years from 1963 through 1976.

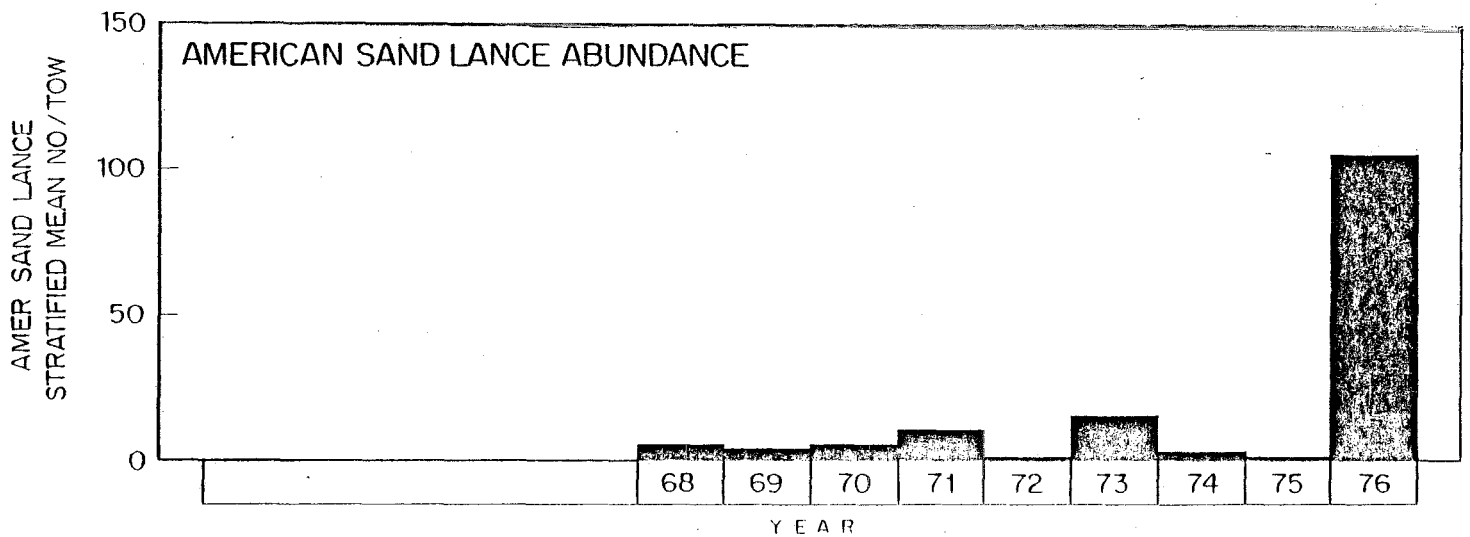

Figure 4b. Annual spring bottom trawl survey catch data of adult American sand lance for the years from 1968 through 1976. Data are expressed as the stratified mean number caught per tow (data from Grosslein et al., 1978).

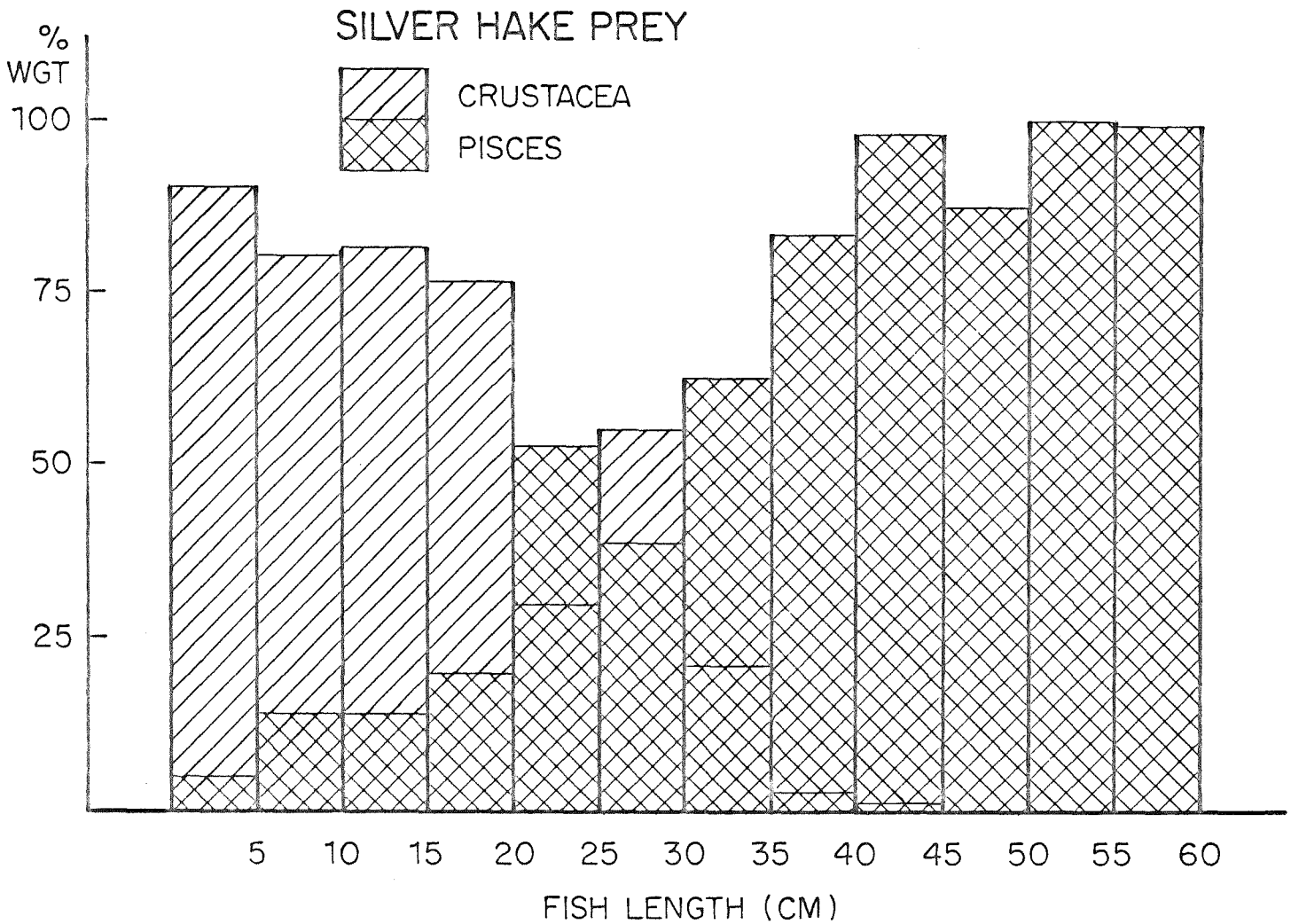

Figure 5. Percentage weight of crustaceans and fish found in the stomachs of northwest Atlantic silver hake. The data is broken down by fish length and represents the analysis of the stomach contents of 2734 silver hake collected from 1973 through 1976.

HADDOCK PREDATORS

	1963	1964	1965	1966	1967 — 1968	1969 — 1972	1973 — 1976
SOUTHERN NEW ENGLAND	*Atlantic Cod*	*Silver Hake*					
GEORGES BANK	*Silver Hake* *Atlantic Cod* *Red Hake* *White Hake*	*Pollock* *Goosefish*	*White Hake* *Barndoor Skate*	*Spiny Dogfish*			
GULF OF MAINE	*Silver Hake* *Atlantic Cod* *Haddock*	*Atlantic Cod* *Haddock* *Cusk* *Sea Raven* *Halibut* *Spiny Dogfish* *Thorny Skate*	*Goosefish*		← *No Data* →	← *No recorded Haddock predators* →	← *Preliminary results :- no recorded Haddock predators* →
WESTERN NOVA SCOTIA	*Red Hake* *White Hake* *Haddock* *Pollock* *Cusk*	*Atlantic Cod* *Cusk* *Goosefish* *Halibut* *Spiny Dogfish* *Barndoor Skate*	*Atlantic Cod* *White Hake*	*Sea Raven*			

Figure 6. Various northwest Atlantic fish species which have been identified as haddock predators. The 1963 year class of haddock was preyed on during the years from 1963 through 1966; no haddock have been identified in the stomachs of fish since 1966 (1969-1976).

AMERICAN SAND LANCE PREDATORS (1976 – 1977)	
Silver Hake	*Windowpane*
Atlantic Cod	*Spiny Dogfish*
Longhorn Sculpin	*Smooth Dogfish*
Haddock	*Winter Skate*
Pollock	*Little Skate*

Figure 7. Various fish species identified as predators of American sand lance during the 1976-1977 period. The data was gathered during cruised conducted to assess the biological damage caused by the *ARGO MERCHANT* oil spill.