FEEDING HABITS OF TEN NORTHWEST ATLANTIC JUVENILE GROUNDFISH

by

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INTRODUCTION

The feeding habits of marine fish have been studied for many years (Verrill, 1871; Goode, 1884; Moore, 1898; Sumner, Osburn, and Cole, 1913; Nichols and Breder, 1934; Homans and Needler, 1944; Wigley, 1956; Bowman and Langton, 1978). The foods of commercially important fish or fish comprising a large portion of the fish biomass in the Northwest Atlantic have been and are presently being studied at the Woods Hole Laboratory of the Northeast Fisheries Center in Woods Hole, Massachusetts. The foods of many larval and adult fish species have already been identified by workers at the Northeast Fisheries Center (Marak, 1960; Laurence, 1974; Langton and Bowman, in press; Edwards and Bowman, 1979). However, little is known about the feeding habits of marine fish ranging in age from post-larvae to one year.

All fish dealt with in this paper have planktonic eggs as well as pelagic larvae, the eggs being laid into the sea where they are fertized and drift somewhere between the surface and the bottom until they hatch. The young fish larvae are wholly planktonic at first, growing until they either go to the bottom and become demersal or until they grow large enough and active enough to live independently of the currents (Graham, 1956). Most groundfish must make the transition from feeding mainly on the plankton to the benthos at some time during their first year of life. It has been noted for several fish species that the strength of a year-class may be determined to a significant extent by the food supply at the time when the larva is changing over from plankton to benthos feeding (Nikolsky, 1963). Although many, if not all, fish species have one or more "critical stages" as brought out by Nikolsky, few such stages have been established for fish in the Northwest Atlantic.

The purpose of this paper is to identify the types and quantities of food eaten by several juvenile groundfish, and to establish when they first begin bottom feeding and the food types potentially important for their survival when they make the transition from pelagic to benthic foods.

METHODS AND MATERIALS

Stomach contents were removed from fish collected during spring and fall bottom trawl survey cruises routinely carried out by the Northeast Fisheries Center between 1953 and 1976, although most data is from the years from 1969 to 1972 (Table 1). The groundfish surveys are based on a scheme of stratified random sampling within five geographic areas of the Northwest Atlantic (Figure 1). All sampling is conducted on a 24 hour-per-day basis[1].

A total of 3,065 stomachs from 10 juvenile fish species was collected. The fish sampled were either taken whole or their stomachs were excised and individually wrapped in gauze with a label denoting fork length, sex, species, station, cruise, and vessel and preserved in 10 percent Formalin[2]. These fish represent a subset of all juvenile fish collected by the NEFC which were available for feeding habits analyses. The species collected and their respective maximum lengths at approximately one year of age are as follows: Atlantic cod, *Gadus morhua*, 20 cm; haddock, *Melanogrammus aeglefinus*, 20 cm; silver hake, *Merluccius bilinearis*, 20 cm; pollock, *Pollachius virens*, 20 cm; red hake, *Urophycis chuss*, 20 cm; white hake, *Urophcis tenuis*, 20 cm; spotted hake, *Urophycis regius*, 10 cm; fourbeard rockling, *Enchelyopus cimbrius*, 10 cm; American plaice, *Hippoglossoides platessoides*, 7 cm; and yellowtail flounder, *Limanda ferruginea*, 12 cm.

In the laboratory, the preserved samples were analyzed as described below. Individual stomachs were either removed from their gauze wrapping

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[1]Further details of the bottom trawl survey techniques may be obtained from the Resource Surveys Investigation, NMFS, NEFC, Woods Hole Laboratory, Woods Hole, Massachusetts 02543.

[2]Reference to trade names does not imply endorsement by NMFS, NOAA.

Table 1. Number of fish stomachs examined listed by species, year, and geographic area.

Species	Year	GEOGRAPHIC AREA					Totals
		Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Western Nova Scotia	
Atlantic cod	1971			48	45	8	101
	1972				5	1	6
							(107)
Haddock	1953-1968		87	263	398	275	1023
	1969		25			34	59
	1970		1				1
	1971		1	38	8	230	277
	1972			55	14	65	134
	1973-1976			224	83	358	665
							(2159)
Silver hake	1969		8				8
	1971	87	39	29	62	60	277
	1972		115	10	21	9	155
							(440)
Pollock	1971		4	1	2	2	9
	1972					13	13
							(22)
Red hake	1969			55			55
	1971	27		106	4		137
	1972		17		13	7	37
							(229)
White hake	1969			11			11
	1971				1	9	10
	1972				1	1	2
							(23)
Spotted hake	1971	15					15
							(15)
Fourbeard rockling	1969	2					2
	1972			1			1
							(3)
American plaice	1971			5		3	8
	1972			1	1		2
							(10)
Yellowtail flounder	1969			3			3
	1971		21	30			51
	1972		2				2
							(56)

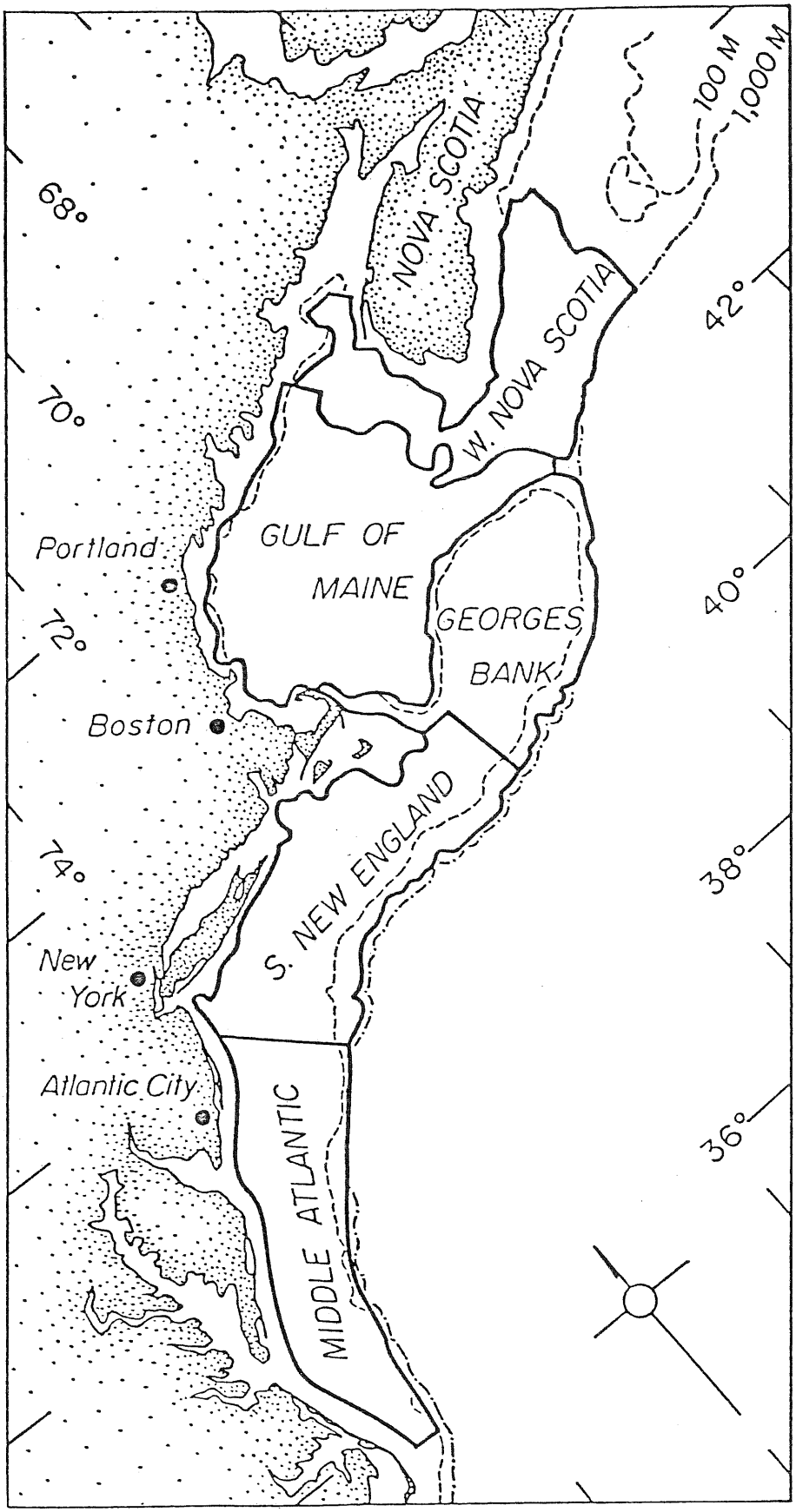

Figure 1. Geographical areas, located between Cape Hatteras and Western Nova Scotia, in which the feeding habits of juvenile fish were studied.

or excised from the whole fish. The stomach contents were removed and rinsed in a 0.18 mm mesh screen sieve with seawater to remove the odor of Formalin. The material in the sieve was washed into a dish and the various prey organisms were sorted and counted. All prey were identified to the lowest taxonomic grouping possible and damp dried on absorbant paper (parasites found in the stomach contents were treated as prey). The various prey groups were individually weighed to the nearest 0.001 g no longer than one minute after being damp dried. The data was then recorded on a standard data recording form, and computer facilities at the laboratory were used to summarize the stomach content information.

The results are presented as a percent weight, percent occurrence or mean stomach content weight. The percent weights were calculated by dividing the weight of each prey group by the total weight of all prey combined and multiplying by 100. The precent occurrence was calculated by dividing the number of fish which had eaten a particular prey by the total number of fish and then converting to a percent. The mean weights were determined by adding the weights of all prey eaten by a group of fish and then dividing that weight by the total number of fish in the group. Other data such as the number of fish examined, number of empty stomachs and mean fish length are given at the bottom of Table 2.

RESULTS

Table 2 summarizes the stomach contents of ten juvenile groundfish collected during the years from 1969 through 1972. In Table 2 the percent weights of major taxonomic groups such as Crustacea or Pisces are offset and underlined. The "Miscellaneous" category includes parasites and phyla of little dietary importance. The following text considers the prey (in terms of percent weight unless otherwise specified) at the lowest taxonomic level possible for each predator. Also presented below is the approximate fish length at which each predator began feeding predominantly on bottom living organisms (given only when sufficient food data is available). The juvenile haddock food data shown in Figure 2 serves as an example of how the above lengths were determined.

Only small numbers of juveniles of such species as fourbeard rockling and spotted hake were available for stomach content analyses. However since few, if any, juveniles of many species are caught and since so little is known about their feeding habits it seemed appropriate to include them in this analysis.

Atlantic Cod

Crustacea represented the largest portion of the juvenile cod diet (81.6%). Amphipods were the largest contributor to the crustacean prey (22.5%) and those identified were comprised of Gammaridae (6.5%) and Caprellidae (12.9%). Euphausiids, none of which were identified at the species level, made up 18.0% of the stomach contents. Two other prey groups were the Mysidacea (12.9%) which were primarily *Neomysis americana* (3.7%), and the Decapoda (11.2%) which were mainly *Crangon septemspinosa* (2.8%). Copepods (4.8%) and cumaceans (0.2%) made up the

Table 2. Summary of the stomach contents of juvenile fish, expressed as a percent weight, for fish collected between the years of 1953 through 1976. (+ indicates <0.1%)

	Atlantic Cod	Haddock	Silver Hake	Pollock	Red Hake	White Hake	Spotted Hake	Fourbeard Rockling	American Plaice	Yellowtail Flounder
POLYCHAETA	0.4	13.6	0.3	0.7	2.4	2.9	-	-	72.1	3.0
CRUSTACEA	81.6	62.3	89.0	68.2	90.1	94.9	85.9	33.3	21.1	94.4
Amphipoda	22.5	27.6	6.6	1.5	19.4	15.4	77.1	33.3	17.3	38.8
Decapoda	11.2	11.5	30.4	0.3	41.6	58.2	+	-	+	3.7
Isopoda	-	0.7	+	1.2	0.1	-	-	-	-	1.0
Cumacea	0.2	0.7	0.1	-	0.5	-	-	-	+	10.2
Euphausiacea	18.0	13.0	44.4	55.8	6.4	-	-	-	-	-
Mysidacea	12.9	1.5	2.6	-	3.6	-	-	-	3.8	33.4
Copepoda	4.8	0.6	0.1	0.2	1.3	-	7.0	-	+	+
Other Crustacea	12.0	6.7	4.8	9.2	17.2	21.3	1.8	+	+	7.3
MOLLUSCA	0.1	0.1	+	-	0.2	-	-	-	+	-
CHAETOGNATHA	+	0.2	0.8	-	0.3	-	+	-	-	-
ECHINODERMATA	-	1.2	-	-	+	-	-	-	-	-
Echinoidea	-	0.1	-	-	-	-	-	-	-	-
Ophiuroidea	-	1.1	-	-	+	-	-	-	-	-
Other Echinodermata	-	-	-	-	-	-	-	-	-	-
PISCES	16.0	5.0	8.5	+	1.9	-	-	-	-	-
Atlantic herring	-	+	-	-	-	-	-	-	-	-
Silver hake	-	2.2	-	-	-	-	-	-	-	-
Bothidae	-	+	-	-	-	-	-	-	-	-
Other Pisces	16.0	2.8	8.5	+	1.9	-	-	-	-	-
MISCELLANEOUS	0.1	0.6	0.7	5.8	0.2	0.1	+	-	+	0.2
UNIDENTIFIED	1.6	15.5	0.7	24.9	4.9	1.3	14.1	66.7	3.9	2.0
SAND	0.2	1.5	+	0.4	+	0.8	-	-	2.9	0.4
Number examined	107	2159	440	22	229	23	16	3	10	56
Number empty	21	144	74	1	6	1	6	2	5	3
Mean wt. per stomach (g)	0.064	0.107	0.086	0.271	0.061	0.085	0.038	0.020	0.010	0.043
Mean fish length (cm)	7	13	9	17	7	9	6	8	5	7
Length range (cm)	3 - 19	2 - 20	3 - 20	4 - 20	2 - 20	5 - 20	4 - 10	6 - 9	4 - 7	4 - 9

rest of the crustacean portion of the cod diet. None of the species of fish, the next most important prey category, were identified (16.0%). The remaining prey of cod were the Polychaeta (0.4%), Mollusca (0.1%), and Chaetognatha (+).

The first signs of juvenile cod feeding predominantly on the benthos appear at fish lengths of 8 cm to 9 cm. Copepods, euphausiids, and mysids, the main food at fish lengths less than 8 cm are eaten progressively less as cod grow in length, being replaced by more benthic food types such as Gammaridae, Caprellidae and Cumacea at fish lengths over 9 cm. Sand and gammarid amphipods were found in the stomachs of juvenile cod of lengths of only 3 cm, an indication that they had fed on the bottom, to some degree, at even the smallest lengths sampled (3 cm).

Haddock

Small crustaceans, the most important haddock food, accounted for 62.3% of the haddock diet. Amphipod crustaceans were the single most important food (27.6%). Amphipods of the family Corophiidae (primarily *Unciola* sp.) were by far the most common amphipod identified in the stomach contents (5.0%). Other amphipod groups frequently found as prey were, in order of dietary importance, Caprellidea (mainly *Aeginina longicornis*), Ampeliscidae, Aoridae, Hyperiidae, Gammaridae, and Pontogeniidae. Another crustacean group, Euphausiacea (chiefly *Meganyctiphanes norvegica*), accounted for 13.0% of the juvenile haddock diet. *Crangon septemspinosa* made up the largest part of the decapod prey (2.6%). Crustaceans of lesser dietary importance to haddock were the Mysidacea (1.5%), Isopoda (0.7%), Cumacea (0.7%), and Copepoda (0.6%).

The largest contributor to the identified polychaete prey (13.6%) was Nereidiformia worms (almost 5%). *Eunice* sp. was the most common

nereidiform found in the stomach contents (1.0%). Other polychaete groups identified in the stomach contents included the suborders Spioniformia, Scoleciformia, Capitelliformia, Terebelliformia, and Sabelliformia.

Fish made up 5.0% of the diet, with small silver hake (Merluccius bilinearis) comprising almost half (2.2%) of this prey group. Small quantities of Atlantic herring (Clupea harengus) and Bothidae were the only other fish identified. Echinodermata (1.2%), Chaetognatha (0.2%), and Mollusca (0.1%) were of little quantitative importance to the juvenile haddock diet.

Juvenile haddock begin feeding heavily on benthic foods such as amphipods, decapods, and polychaetes when approximately 8 cm in length (see Figure 2). The decrease of pelagic prey found in the stomachs, such as the copepods and euphausiids, is obvious in Figure 2 as the fish increase in length. For comparative purposes the percent occurrence is given (on the left side of Figure 2) alongside the percent weight data (on the right side). Amphipods and cumaceans, two foods considered part of the benthos, were found in the stomachs of haddock only 2 cm in length.

Silver Hake

Silver hake prey heavily on Crustacea (89.0%). Euphausiids were by far the single most important food (44.4%). Meganyctiphanes norvegica (22.8%) and Thysanoessa sp. (2.0%) were the most common euphausiids identified in the stomach contents. The decapods (30.4%), another important part of the crustacean prey, were comprised of Crangon septemspinosa (21.5%) and pandalid shrimp (7.9%). Most of the pandalid shrimp were identified as Dichelopandalus leptocerus (3.8%). Amphipods (6.6%) identified as prey were most often species from the families Ampeliscidae (1.9%) such as Ampelisca sp. (0.4%), or Tironidae (0.6%) which were

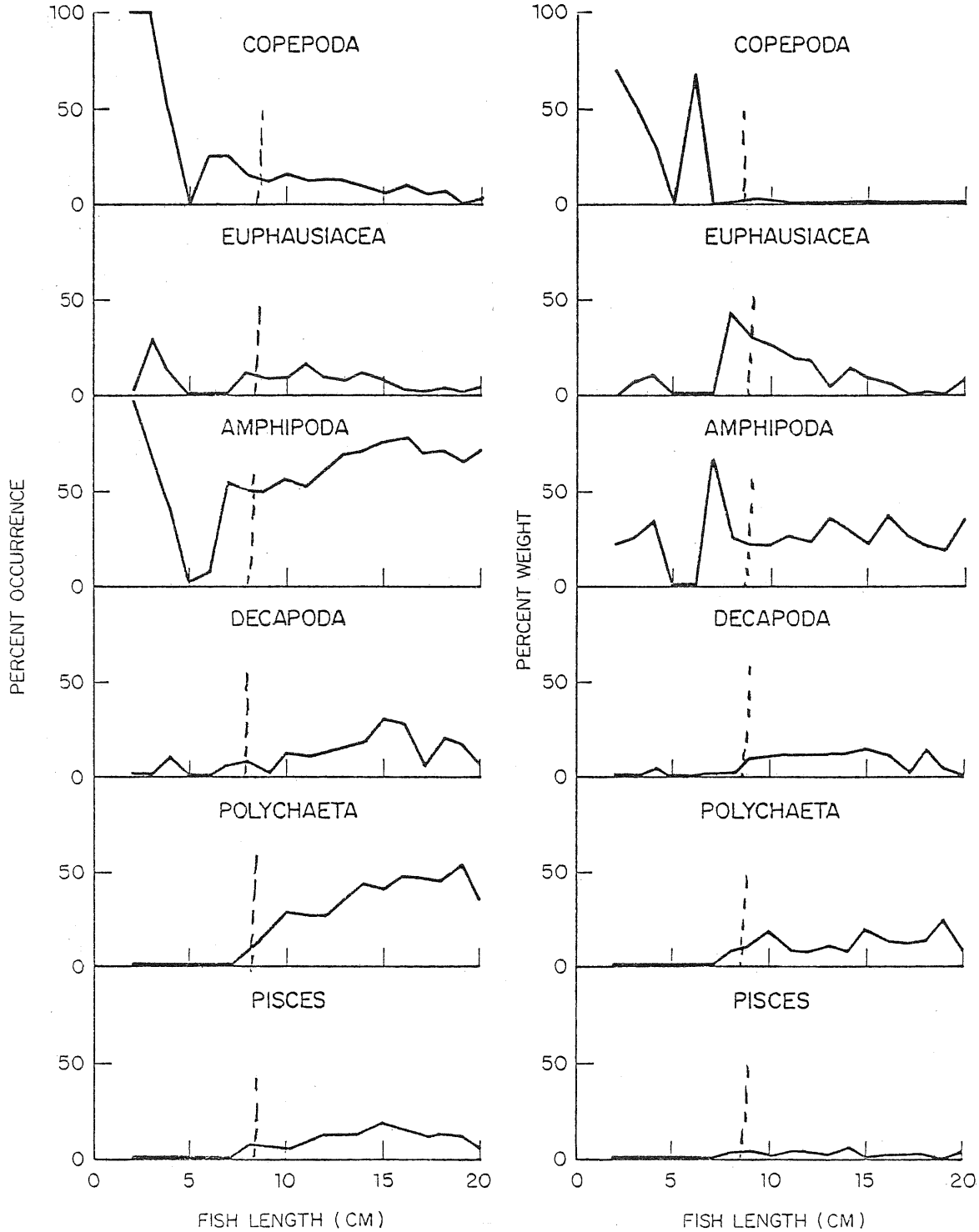

Figure 2. The percent occurrence and percent weight of selected juvenile haddock prey. The dotted lines in the figure indicate the length of haddock when they begin to feed predominantly on the benthic organisms such as polychaete worms and amphipods.

identified as Syrrhoe crenulata (0.6%). Mysids (2.6%) which were eaten by silver hake were identified as Neomysis americana (2.0%). Cumaceans (0.1%), copepods (0.1%), and isopods (+) contributed little to the silver hake diet.

Small fish and fish larvae comprised 8.5% of the silver hake food. The American sand lance (Ammodytes americanus, 3.0%), sculpins (2.3%) and hakes (2.1%) were the only fish identified. Other prey groups such as the Chaetognatha (0.8%), Polychaeta (0.3%), and Mollusca (+) were not important contributors to the food of juvenile silver hake.

Crangon septemspinosa and bottom living species of Amphipoda were found in the stomachs of the smallest (3 cm) silver hake collected, thus indicating they are associated with the bottom early in life. However, the proportions of the foods of the larger silver hake (up to 20 cm) don't suggest that silver hake become dependant on the benthos as a food source when they are juveniles. Euphausiids (here considered as pelagic prey) remain the most important food of silver hake at all fish lengths.

Pollock

Crustaceans (68.2%) were the most important food of pollock. Euphausiacea, mainly Meganyctiphanes norvegica (40.9%) and small amounts of Thysanoessa inermis (2.3%), made up 55.8% of the crustaceans found in the stomachs. Byblis serrata (1.3%) along with small amounts of Caprellidae and Haustoriidae comprised the majority of the Amphipoda (1.5%). Decapod larvae (0.3%), isopods (1.2%), and calanoid copepods (0.2%) account for the remainder of the crustacean prey. Polychaetes (0.7%) and fish scales (+) contributed little to the juvenile pollock diet.

Only one small pollock (4 cm) was collected for stomach content analysis. The remainder of the fish ranged in length from 15 cm to 20 cm.

Since only unidentified Crustacea was found in the stomach of the 4 cm fish, no data is available to indicate at what length they first feed on the bottom. The larger fish feed almost solely on pelagic euphausiids, which implies that juvenile pollock feed off the bottom throughout their first year of life.

Red Hake

Crustaceans (90.1%) accounted for the majority of the red hake diet. The single most important crustacean prey was the decapod shrimp *Crangon septemspinosa*, which made up 40.6% by weight of all food eaten by red hake. Hermit crabs (0.4%) and *Hyas* sp. were the only other decapods identified in the stomach contents. Amphipods (10.4%) found in red hake stomachs consisted mostly of Oedicerotidae (5.9%), Corophiidae (2.3%) mainly *Unciola* sp. (1.9%), and a large amount of other unidentified Gammaridea (7.1%). Euphausiids (6.4%), primarily *Meganyctiphanes norvegica* (1.6%), and mysids (3.6%) were the only other crustacean prey of importance to red hake. Only small quantities of copepods (1.3%), cumaceans (0.5%), and isopods (0.1%) were found in the stomach contents.

Polychaeta (2.4%), Pisces (1.9%), Chaetognatha (0.3%), Mollusca (0.2%), and Echinodermata (+) contributed little to the food of red hake.

Red hake begin to feed predominantly on benthic foods such as Gammaridae, *Crangon septemspinosa*, and Cumacea when they are approximately 6 cm in length. At lengths less than 6 cm red hake food is comprised mostly of large quantities of copepods and chaetognaths. The stomach contents of fish 3 cm in length contained *Crangon septemspinosa*, amphipods, and sand. Red hake 3 cm in length and possibly smaller apparently feed on organisms of benthic origin very early in life, however their main food source is the pelagic prey types mentioned above.

White Hake

White hake prey almost exclusively on crustaceans (94.9%). The decapod *Crangon septemspinosa* (57.9%) was by far the food of major dietary importance to white hake. Hermit crabs (0.3%) were the only other decapod eaten. Amphipods (15.4%) found in white hake stomachs included Corphiidae of the species *Leptocheirus pinguis* (4.6%), Aoridae (2.0%), Hyperiidae (0.5%), Pontogeneiidae (0.4%), Ampeliscidae (0.3%), and Caprellidae (0.2%). Polychaete worms, the only other white hake food identified, made up 2.9% of the diet.

Sand and gammarid amphipods were included as part of the stomach contents of white hake 5 cm in length. No pelagic prey such as copepods or euphausiids were found in any of the fish collected. White hake apparently depend on benthic prey at fish lengths of 5 cm or less.

Spotted Hake

The most important prey of spotted hake are Crustacea (85.9%). Amphipods (all identified as Gammaridea) comprised 77.1% of this juvenile fishes diet. Other crustacean groups found in their stomachs were calanoid copepods (7.0%), small amounts of the decapod shrimp *Crangon septemspinosa* (+), and hermit crabs (+). The only other prey group identified as part of the spotted hake diet was the Chaetognatha (+).

Although only 16 spotted hake were collected the stomach content data showed that they were eating small quantities of benthic prey (hermit crabs) at fish lengths of 4 cm. Calanoid copepods however, were their primary food when the fish were 4 cm long. At 5 cm in length juvenile spotted hake were eating mainly benthic prey such as gammarid amphipods and *Crangon septemspinosa*.

Fourbeard Rockling

Crustacea (33.3%) was the only food identified in fourbeard rockling stomachs. This group consisted of gammarid amphipods (33.3%) and small amounts of hermit crabs (+).

The smallest fish collected (6 cm) had an empty stomach. Therefore, the only data concerning fourbeard rockling's benthic feeding habits is from a 9 cm fish. This fish's stomach contained only the benthic prey types listed above.

American Plaice

Polychaeta (72.1%) was the primary food of juvenile American plaice. Only two families of polychaetes were identified, and they were the Capitellidae (10.6%) and the Sabellidae (2.9%).

Crustacea (21.1%) and Mollusca (+) were the only other prey identified in American plaice stomachs. The crustacean dietary components were gammarid amphipods (17.3%), mysids (3.8%), small amounts of copepods (identified as Centropages sp. [+]), cumaceans (+), and hermit crabs (+). The Mollusca (+) portion of the diet was identified as Dentalidae.

Worms (Sabellidae) and other benthic organisms such as cumaceans and dentalids made up the majority of the American plaice diet at the smallest fish lengths collected (4 cm).

Yellowtail Flounder

Crustacea, the predominant prey of juvenile yellowtail flounder, accounted for 94.4% of their food. Amphipod crustaceans (38.8%) were represented in the stomachs by such groups as Gammaridae (5.2%), Caprellidae (0.5%), Aoridae (+), Ampeliscidae (+), and Oedicerotidae (+). Another crustacean prey group, the Mysidacea (33.4%), were identified as Erythrops

sp. (9.9%). Cumaceans (10.2%), decapods (comprised of Crangon septem-spinosa, 3.4%; and hermit crabs, 0.3%), isopods (1.0%) and copepods (+) made up the rest of the identified Crustacea prey. Polychaeta (3.0%) was the only other dietary item noted in yellowtail flounder stomachs. This prey group consisted mainly of Nereidiformia (2.1%), with the only genera identified as Phyllodoce sp. (0.9%).

The smallest yellowtail flounder flounder collected (3 cm) ate predominantly benthic organisms such as gammarid amphipods, cumaceans, and hermit crabs.

DISCUSSION

Arntz (1974) studied the feeding of juvenile cod in the western Baltic. His work showed that juvenile cod feed mostly on small crustaceans at fish lengths of 11 cm to 20 cm. Daan's (1973) results from studies on cod in the North Sea also indicate that juvenile cod feed predominantly on the smaller crustaceans. Homans and Needler (1944) and Wigley (1956) included juvenile haddock food data in their investigations on the feeding of haddock. They found that small haddock (less than 20 cm) generally eat crustaceans and polychaete worms. The results presented here are similar to earlier reports on the foods of juvenile cod and haddock. The foods of five flatfish species were listed by Braber and DeGroot (1973). Their data indicates juvenile flatfish in the North Sea have similar feeding habits as the flatfish studied in the Northwest Atlantic. However, none of the above mentioned studies identify the food of post larval fish in detail (either because so few or none were collected). Similarly little detailed information is available concerning other species of juvenile groundfish.

Many larval fish food studies have been conducted (Rae, 1953; Marak, 1960; 1974; Laurence, 1974; 1977; Last, 1978). They establish that most larval and post larval groundfish feed predominantly on planktonic organisms. The post larval fish (up to 5 cm in length) examined here, although they were caught with a bottom trawl, also showed that the majority of species were feeding mainly on pelagic food such as copepods and euphausiids.

Fish such as cod have been described as "seeking the bottom" when just over 2 cm in length (Hardy, 1959). It should be noted here that cod

stomachs from fish 3 cm in length examined during this study contained small amounts of sand and gammarid amphipods, an indication that they had been feeding to some extent on the bottom. However, because their food was mostly copepods and euphausiids it suggests that the transition from feeding on the plankton to the benthos is a gradual change rather than an abrupt one. The data presented here shows cod are not dependent on the benthos until they have grown to approximately 9 cm in length.

Only the two flatfish (American plaice and yellowtail flounder) were found to be dependent on the benthos as a food source at the smallest fish lengths collected (3 cm to 4 cm). Since plaice and other flatfish metamorphose early in life (most have completed metamorphosis by 11 weeks of age when they are between 1 cm and 2 cm in length) they take up life on the bottom at very small sizes (Hardy, 1959). Silver hake and pollock fed primarily on the plankton at all fish lengths. Atlantic cod and haddock tended to eat less pelagic food and more of the benthos at fish lengths greater than 8 cm to 9 cm. The remaining fish (except fourbeard rockling for which there was to little data to determine its feeding pattern), red hake, white hake, and spotted hake ate mainly foods such as copepods, euphausiids and chaetognaths up to fish lengths of 5 cm to 6 cm, when they began to feed more heavily on bottom living organisms.

The analysis of the juvenile fish stomach contents showed that few prey make up a large portion of juvenile fish food. Before the fish begin to depend on the benthos as a food source calanoid copepods and euphausiids (mostly *Meganyctiphanes norvegica*) are extremely important foods. The diet of larger juvenile fish, which depend on benthic animals as food, includes gammarid amphipods such as *Unciola sp.*, *Leptocheirus*

pinguis, and *Byblis serrata* along with the caprellid amphipod *Aeginina longicornis*. Decapods found in the diet were represented by *Crangon septemspinosa* more than any other species. The only other prey which stands out as important in the diet of juvenile fish was the mysid *Neomysis Americana*.

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