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Food Habits of Fish and Squid Found in the Vicinity of the ARGO MERCHANT Oil Spill, August 1977

by

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ABSTRACT

The stomach contents of 21 species of fish and squid were analyzed to determine the potential impact of ARGO MERCHANT oil on the fish stocks in the Northwest Atlantic. Important prey groups found in the stomachs of predators sampled in the region of the oil spill included gammaridean amphipods, polychaete worms, rock crabs and American sand lance. The quantities and types of foods eaten by each predator were similar to data previously collected (Food Habits Project, NEFC, Woods Hole, MA). Gammaridean amphipods covered with the same type of oil which was carried by the ARGO MERCHANT had previously been found in the stomachs of Atlantic cod and little skate (Langton and Bowman, 1977). Although no oil was found in their stomachs, American sand lance were found to feed on the same genera of copepods previously noted to be contaminated with ARGO MERCHANT oil (Maurer, 1977). Predator-prey relationships found in this study showed that 81 percent of the predators represented ate gammaridean amphipods and 38 percent of the predators species fed on American sand lance, thus establishing two potential pathways for the oil to have been passed on to the higher trophic levels.

INTRODUCTION

Additional samples from the ARGO MERCHANT oil spill area were collected during cruise ALBATROSS IV 77-07, August 1977, to supplement data which had previously been gathered to evaluate the immediate impact of crude oil on the marine environment. Food habit information from a previous report (Langton and Bowman, 1977) had shown the stomachs of Atlantic cod and little skate contained food organisms coated with oil, which was subsequently identified as the same type oil carried by the ARGO MERCHANT (Personal Communication, Dr. William McCloud, NOAA, Seattle, Washington).

Food habits data on fish and squid collected eight months after the ARGO MERCHANT oil spill are presented in this report. The data are then compared with the foods noted in the previous report and the important prey groups found in the area of the oil spill are described. Predator-prey relationships and the potential pathways of oil through the marine food chain are discussed.

METHODS

Samples were obtained during cruise ALBATROSS IV 77-07 (August 1977) from fish and squid caught with an otter trawl in the immediate vicinity of the ARGO MERCHANT wreck (Figure 1, Tables 1 and 2). The stomachs were excised aboard the ship, individually labelled according to species, length, sex, and station, and preserved in 10 percent Formalin[1]. A total of 209 stomachs representing 14 species were collected.

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

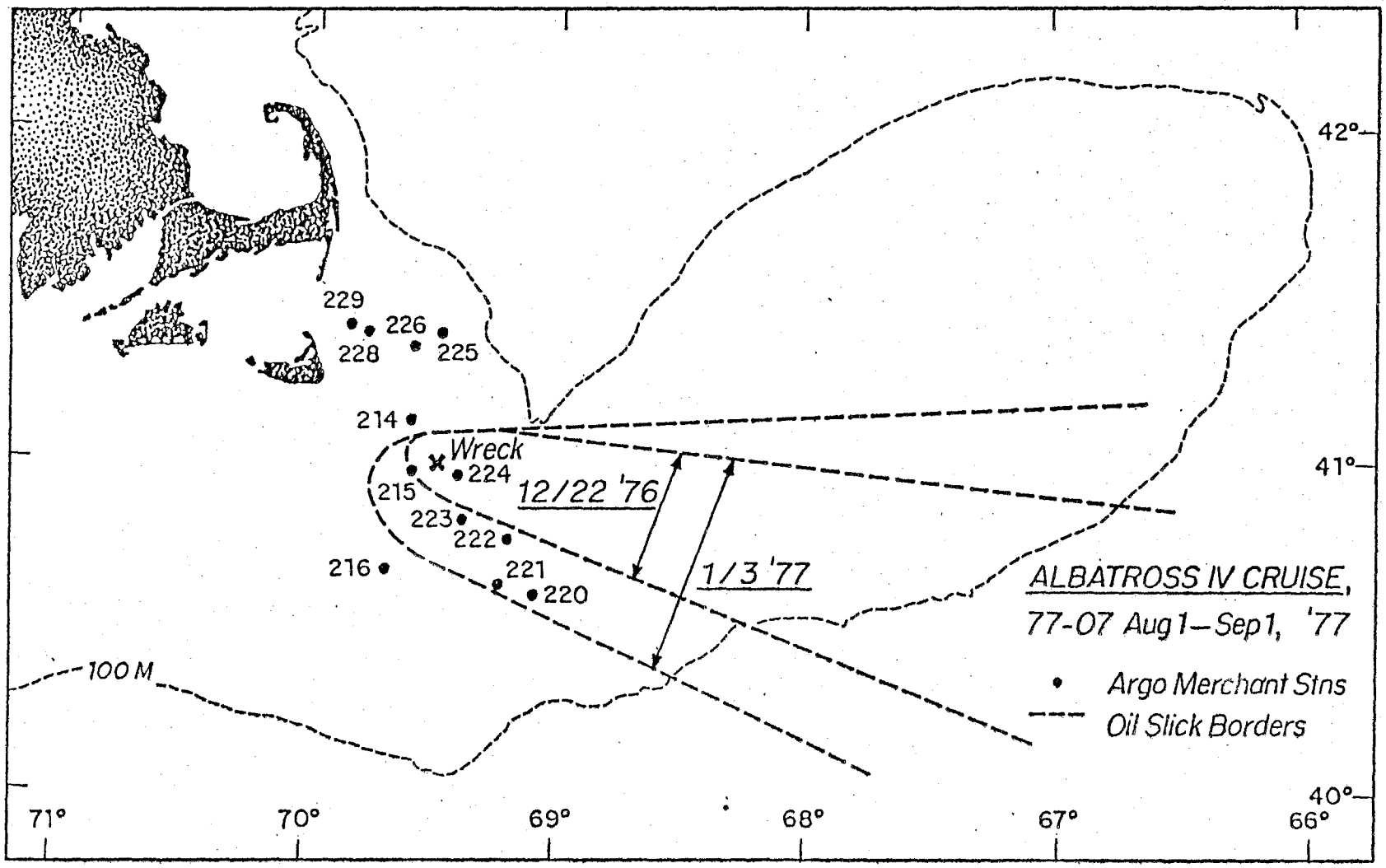

Figure 1. Location of stations in the vicinity of the ARGO MERCHANT wreck where fish and squid were collected for stomach content analysis during cruise ALBATROSS IV 77-07.

Table 1. Station data for ALBATROSS IV cruise 77-07 where fish and squid were collected for food habits analysis.

Station	Date Day	Date Month	Date Year	Time (EST)	Latitude	Longitude	Depth (M)	Wind Dir.	Wind Speed	Wave hgt. (M)	Air temp. (°C)	Surf. temp. (°C)	Bot. temp. (°C)
214	2	8	77	2157	41°08'	69°35'	24	300	4	0.3	17.0	13.0	12.6
215	3	8	77	0004	41°00'	69°33'	37	260	6	0.3	15.0	14.1	15.2
216	3	8	77	0342	40°42'	69°41'	46	180	5	0.6	15.0	17.6	11.9
220	3	8	77	1530	40°38'	69°06'	73	160	5	0.3	24.0	20.7	9.2
221	3	8	77	1726	40°40'	69°16'	55	260	5	0.3	23.0	13.3	11.7
222	3	8	77	2107	40°49'	69°13'	64	160	4	0.3	17.0	12.4	11.7
223	3	8	77	2225	40°52'	69°25'	37	220	5	0.6	16.0	12.5	11.6
224	4	8	77	0031	40°59'	69°26'	42	210	12	0.3	16.0	12.6	12.6
225	4	8	77	0402	41°24'	69°28'	31	300	7	0.3	13.0	9.9	9.3
226	4	8	77	0522	41°22'	69°34'	27	300	5	0.3	13.0	10.0	10.0
228	4	8	77	0583	41°24'	69°44'	31	245	6	0.3	19.0	10.6	12.8
229	4	8	77	1037	41°26'	69°48'	37	250	4	0.3	17.0	12.3	11.6

Table 2. Stations and number of stomachs analyzed from cruise ALBATROSS IV 77-07.

	Species total	Station											
		214	215	216	220	221	222	223	224	225	226	228	229
Smooth dogfish	8	6	2	-	-	-	-	-	-	-	-	-	-
Spiny dogfish	49	5	5	4	1	5	5	4	5	-	5	5	5
Little skate	26	3	6	-	-	-	5	3	4	-	-	-	5
Winter skate	14	4	5	-	-	-	-	-	5	-	-	-	-
Atlantic cod	16	4	2	-	-	-	-	-	5	5	-	-	-
Silver hake	14	-	-	4	4	5	-	-	1	-	-	-	-
Red hake	13	-	-	4	4	5	-	-	-	-	-	-	-
American sand lance	8	-	-	-	-	-	-	-	8	-	-	-	-
Butterfish	2	-	-	-	2	-	-	-	-	-	-	-	-
Sea raven	4	-	-	-	-	-	-	-	4	-	-	-	-
Longhorn sculpin	10	-	-	-	-	-	5	-	5	-	-	-	-
Yellowtail flounder	21	-	5	5	-	5	5	1	-	-	-	-	-
Winter flounder	14	-	-	-	1	2	-	2	5	-	-	-	-
Short-finned squid	10	-	-	5	-	-	5	-	-	-	-	-	-
Total	209												

At the laboratory of the Northeast Fisheries Center, NMFS, Woods Hole, Massachusetts, the stomachs were opened and the contents washed onto a 0.25 mm mesh screen. The various food organisms were manually sorted, counted, and identified to the lowest possible taxa. Each taxonomically distinct prey group was blotted dry and immediately weighed to the nearest 0.001 g on a Mettler balance[1], model P163. Items of little dietary importance or which were unidentifiable because of their advanced state of digestion were classified as miscellaneous.

For comparative purposes the methods of analyses used in this report are similar to those used by Langton and Bowman, 1977 which described the food habits of fish collected during cruises DELAWARE II 76-13 and DELAWARE II 77-01. The quantity of prey consumed by each predator is presented as a percentage of the total stomach contents weight and as a mean weight per stomach. The mean weight per stomach was calculated by dividing the total stomach contents weight by the total number of stomachs examined.

RESULTS

Food habits of fish and squid sampled during cruise ALBATROSS IV 77-07

Fish and squid collected for this report are considered below in phyletic groups. However, three species, the American sand lance, butterfish, and short-finned squid do not fall into a phyletic group but have been combined, for convenience, and are discussed in the last section of the results as a single category. Table 3 presents the food habits data in general taxonomic

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Table 3. Part I. Stomach contents of fish and squid represented as percent total weight, collected during ALBATROSS IV cruise 77-07.

Stomach content group	Predator species				
	Smooth dogfish %wt	Spiny dogfish %wt	Little skate %wt	Winter skate %wt	Atlantic cod %wt
CNIDARIA	+	4.2	-	0.2	-
Hydrozoa	+	+	-	0.2	-
Anthozoa	-	4.2	-	-	-
POLYCHAETA	0.2	0.1	2.8	4.2	-
Nephtyidae	0.1	-	-	4.0	-
Nereidae	-	0.1	1.7	-	-
Maldanidae	-	-	0.2	-	-
Other Polychaeta	0.1	+	0.9	0.2	-
CRUSTACEA	98.9	23.3	68.6	28.2	18.6
Caprellidea	-	-	0.2	-	-
Gammaridea	+	0.9	12.1	+	1.0
Cancridae	88.5	19.1	48.8	1.1	13.5
Crangonidae	-	-	1.3	1.0	0.1
Paguridae	10.4	0.7	2.9	-	0.5
Other Decapods	-	2.6	0.3	24.8	2.8
Isopoda	-	-	1.4	1.3	-
Other Crustacea	+	+	1.6	-	0.7
MOLLUSCA	-	39.7	1.3	0.1	0.1
Pelecypoda	-	15.3	1.3	0.1	0.1
Gastropoda	-	-	-	-	-
Cephalopoda	-	24.4	-	-	-
ECHINODERMATA	-	-	-	-	-
ASCIDIACEA	-	-	-	-	-
SALPIDA	-	0.1	-	-	-
PISCES	0.8	27.4	15.2	66.1	78.7
Rajidae	-	7.4	-	-	-
Clupeidae	-	3.1	-	-	-
Ammodytidae	0.2	0.9	10.3	43.8	76.7
Cottidae	-	-	4.5	-	-
Pleuronectiformes	-	2.5	-	-	-
Other Pisces	0.6	13.5	0.4	22.3	2.0
MISCELLANEOUS	0.1	4.9	8.6	1.2	2.1
SAND AND ROCKS	-	0.3	3.5	+	0.5
No. of stomachs	8	49	26	14	16
Percent empty	0.0	16.3	0.0	28.6	0.0
$\bar{x}$ wt. per stomach(g)	91.78	7.69	1.76	2.16	38.19
Length range (cm)	93-101	30-100	38-51	59-104	45-94

Table 3. Part II. Stomach contents of fish and squid represented as percent total weight, collected during ALBATROSS IV cruise 77-07.

Stomach content group	Predator species				
	Silver hake	Red hake	Sea raven	Longhorn sculpin	Yellowtail flounder
	%wt	%wt	%wt	%wt	%wt
CNIDARIA	-	9.4	-	-	+
Hydrozoa	-	-	-	-	+
Anthozoa	-	9.4	-	-	-
POLYCHAETA	-	12.0	-	-	46.2
Nephtyidae	-	-	-	-	-
Nereidae	-	-	-	-	-
Maldanidae	-	-	-	-	-
Other Polychaeta	-	12.0	-	-	46.2
CRUSTACEA	97.8	70.4	87.5	93.9	38.1
Caprellidea	-	26.7	+	3.3	0.3
Gammaridea	83.8	13.4	-	17.2	36.0
Cancridae	-	-	87.5	7.1	-
Crangonidae	4.6	3.1	-	2.9	-
Paguridae	-	0.6	-	7.8	1.1
Other Decapods	6.4	1.7	-	38.0	0.3
Isopoda	0.3	2.6	-	1.0	0.2
Other Crustacea	2.7	22.3	+	16.6	0.2
MOLLUSCA	-	-	-	0.5	4.0
Pelecypoda	-	-	-	0.5	3.5
Gastropoda	-	-	-	-	0.5
Cephalopoda	-	-	-	-	-
ECHINODERMATA	-	-	-	-	-
ASCIDIACEA	-	-	-	-	-
SALPIDA	-	-	-	-	-
PISCES	0.1	0.7	3.7	3.1	+
Rajidae	-	-	-	-	-
Clupeidae	-	-	-	-	-
Ammodytidae	-	-	-	3.1	-
Cottidae	-	-	-	-	-
Pleuronectiformes	-	-	-	+	+
Other Pisces	0.1	0.7	3.7	-	-
MISCELLANEOUS	2.1	5.8	+	2.5	7.5
SAND AND ROCKS	-	1.7	8.8	-	4.2
No. of stomachs	14	13	4	10	21
Percent empty	42.9	0.0	0.0	10.0	42.9
$\bar{x}$ wt. per stomach(g)	0.39	0.56	19.75	1.34	1.30
Length range (cm)	20-38	26-39	20-32	24-29	23-42

Table 3. Part III. Stomach contents of fish and squid represented as percent total weight, collected during ALBATROSS IV cruise 77-07.

Stomach content group	Predator species							
	Winter flounder		American sand lance		Butterfish		Short-finned squid	
	%wt		%wt		%wt		%wt	
CNIDARIA	32.8		-		-		-	
Hydrozoa		32.8		-		-		-
Anthozoa		-		-		-		-
POLYCHAETA	5.1		-		-		-	
Nephtyidae		0.4		-		-		-
Nereidae		-		-		-		-
Maldanidae		-		-		-		-
Other polychaeta		4.7		-		-		-
CRUSTACEA	54.3		50.0		1.0		5.1	
Caprellidea		0.3		-		-		-
Gammaridea		51.0		-		-		+
Cancridae		0.2		-		-		-
Crangonidae		-		-		-		-
Paguridae		0.1		-		-		-
Other decapods		2.6		-		-		0.3
Isopoda		+		-		-		-
Other Crustacea		0.1		50.0		1.0		4.8
MOLLUSCA	0.4		-		-		-	
Pelecypoda		0.3		-		-		-
Gastropoda		0.1		-		-		-
Cephalopoda		-		-		-		-
ECHINODERMATA	+		-		-		-	
ASCIDIACEA	4.4		-		-		-	
SALPIDA	+		-		99.0		-	
PISCES	+		-		-		66.9	
Rajidae		-		-		-		-
Clupeidae		-		-		-		-
Ammodytidae		-		-		-		-
Cottidae		-		-		-		-
Pleuronectiformes		-		-		-		-
Other Pisces		+		-		-		66.9
MISCELLANEOUS	1.5		50.0		-		28.0	
SAND AND ROCKS	1.5		-		-		-	
No. of stomachs		14		8		2		10
Percent empty		14.3		37.5		0.0		30.0
$\bar{x}$ wt. per stomach(g)		1.42		0.001		0.30		0.92
Length range(m)		18-40		13-19		18		21-24

groups for each predator. The number of stomachs examined, the percent of the stomachs which were empty, the mean weight per stomach and the length range of each predator species are shown at the bottom of Table 3. In the text the percent weight is included in parentheses after the first mention of a prey group to quantify the importance of that particular prey in the diet.

The first group of fish to be discussed are the chondrichthyes, which are represented by the smooth dogfish (Mustelus canis), spiny dogfish (Squalus acanthias), little skate (Raja erinacea), and winter skate (Raja ocellata). Smooth dogfish consumed predominantly decapod crabs (89.9% of their diet by weight). The crabs were identified as Cancer borealis (37.0%), Cancer irroratus (30.9%), and Pagurus acadianus (8.6%). The spiny dogfish diet was composed mostly of fish (27.4%), decapod crabs (19.8%), and scallops (15.3%). Prey fish species included skate (Raja, 7.4%), herring (Clupeidae, 3.1%), flatfish (Pleuronectiformes, 2.5%), and American sand lance (Ammodytes americanus, 0.9%). Illex illecebrosus (24.4%) was the only squid identified. The majority of the crabs belonged to the genus Cancer (19.1%). Scallop viscera were the only part of the scallops found in the stomachs. Previous investigations (Bowman, 1975; Wigley, 1956) suggest scallop viscera discarded by scallop fishermen are the source of this prey. The primary prey of little skate was the rock crab, Cancer (48.8%), and American sand lance, Ammodytes americanus (10.3%). The winter skate diet consisted mainly of American sand lance, Ammodytes americanus (43.8%) and unidentified decapod crabs and shrimp (24.8%).

Gadids sampled included Atlantic cod (Gadus morhua), silver hake (Merluccius bilinearis), and red hake (Urophycis chuss). Atlantic cod fed almost exclusively on American sand lance (76.7%). The remaining portion of their diet was mostly rock crabs, Cancer (13.5%). In one cod stomach, taken at Station 225, several gammarids (Leptocheirus pinguis) were noted to have black particles within their bodies. The specimens have been sent to specialists for chemical analysis. Gammaridean amphipods (83.8%), mostly of the species Gammarus annulatus, were found to be the most important component in the diet of silver hake. The foods of red hake were more diverse than those of Atlantic cod and silver hake. Amphipods (40.1%) and polychaetes (12.0%) were the chief constituents of the red hake diet. Caprellids, mostly Aeginina longicornus (17.1%), and gammarids, mainly Gammarus annulatus (2.8%), were the principal amphipods consumed. The polychaetes found in the stomachs could not be identified because of their state of digestion.

The cottids represented in this study are the sea raven, Hemitripterus americanus, and the longhorn sculpin, Myoxocephalus octodecemspinosus. The primary food of the sea raven was rock crabs, Cancer, which made up 87.5% of the stomach contents. Various crustaceans accounted for over 93% of the longhorn sculpin diet, with more important groups being decapod crabs (52.8%), decapod shrimp (3.1%), and gammaridean amphipods (17.2%).

Two species of pleuronectids, the yellowtail flounder (Limanda ferruginea) and the winter flounder (Pseudopleuronectes americanus), were analyzed. Prey found in the yellowtail stomachs was mostly polychaete worms (46.2%), mainly Drilonereis (8.9%), and Phyllodoce (2.0%), and gammarids (36.0%), chiefly

Dulichia (13.8%), and Gammarus (20.6%). Gammaridean amphipods, predominantly Gammarus annulatus, accounted for 51% of the weight of the stomach contents of winter flounder. Necrosis of the carapace and appendages of several Gammarus annulatus was observed in one winter flounder stomach taken at Station 223. The organisms were sent for analysis to see if the necrosis was oil related. Halecium, a hydrozoan, was of secondary importance (32.8%) as a food of the winter flounder.

The last group of predators to be discussed include the American sand lance (Ammodytes americanus), butterfish (Peprilus triacanthus), and the short-finned squid (Illex illecebrosus). The major food items found in American sand lance stomachs were copepods (50%), of the genera Calanus, Centropages, and Pseudocalanus, and unidentified chaetognaths (40%). Butterfish consumed mainly salps (99%) which were partially digested and could not be identified. Unidentified fish accounted for 66.9% of the short-finned squid diet. The remainder of their diet was composed of decapods and gammaridean amphipods. Squid do not swallow their food whole, as most fish, but bite off and swallow small pieces of their prey, making accurate identification of the food items very difficult.

DISCUSSION

Comparison of winter and summer food habit data

The stomach contents of eight fish species sampled during the winter, cruise DELAWARE II 77-01, and the summer, cruise ALBATROSS IV 77-07, months are available for comparison. They are the spiny dogfish, little skate, winter skate, Atlantic cod, red hake, sea raven, yellowtail and winter flounder.

Spiny dogfish consumed less fish during the summer than in the winter, 27.4% versus 97.3%. The major components accounting for the difference were squid, Illex (24.4%), scallop viscera (12.4%), and the rock crab, Cancer (19.1%), which were consumed in the summer but not during the winter.

The little skate prey were mostly crustaceans and fish, which were consumed in nearly equal amounts during the two seasons (crustaceans, 68.6% in summer versus 48.1% in winter and fish 15.2% in summer versus 15.5% in winter). A more detailed account of the crustacean components, however, revealed that during the summer the rock crab (Cancer, 48.8%) was the main food, while during the winter gammarids (28.0%) were the major prey.

Winter skate ate mostly fish (66.1%), mainly Ammodytes (43.8%), during the summer whereas in the winter the winter skate consumed mostly polychaete worms (60.7%).

The Atlantic cod diet changed little between the two sampling periods. Fish, mainly Ammodytes, was the most important part of their diet during both the winter (53.3%) and the summer (78.7%).

Red hake stomachs contained chiefly crustaceans during both seasons (winter 81.8% and summer 70.4%). In the winter the predominant crustacean prey was Cancer (23.7%) while in the summer caprellid (26.7%) and gammarid (13.4%) amphipods were the most important prey.

Sea ravens ate fish, mostly other cottids during the winter (99.3%) whereas in the summer their diet was almost exclusively rock crabs (87.5%). The stomach of one large sea raven (fork length of 38 cm) from the winter cruise DELAWARE II 77-01, contained mostly fish, which accounted for the large difference between seasons.

Winter flounder food habit data were not available from the winter cruise because the five stomachs examined were empty. Stomach samples obtained from the summer cruise contained gammarids (51.0%), predominantly Gammarus (40.6%) and hydrozoans (32.8%) of the genus Halecium.

The stomachs of yellowtail flounder, collected during both cruises, contained chiefly crustaceans and polychaetes. Crangon was the predominant crustacean consumed during the winter (60.8%) while gammaridean amphipods were eaten in the summer (36.0%). Polychaete worms accounted for 12.5% of the yellowtail flounder's winter diet compared to 46.2% of their summer prey.

The above discussion of the food habits data does not suggest a direct correlation between the effects of ARGO MERCHANT oil on the environment and changes in the food habits of marine fish. Any differences or similarities noted are of limited value because of the small number of samples collected. To clarify, the food habits may only reflect the foods of one or two fish when the dietary items are presented as a percent of the total weight consumed. Further, local abundance of certain prey items may cause artificial differences to be noted in the food habits of marine fish (Langton and Bowman, 1977). Also the data were collected at different times of the year (winter versus summer months), and seasonal changes in the food habits of marine fish may account for any of the observed differences (see Tyler, 1971; Wigley and Theroux, 1965; Homans and Needler, 1944). The data does, however, serve as an indication of what foods are being eaten by fish during the summer and winter months in the oil spill area.

Major Prey

The stomach contents of fish and squid analyzed from three cruises, DELAWARE II 76-13, DELAWARE II 77-01, and ALBATROSS IV 77-07, show that the majority of the predators studied from the area of the ARGO MERCHANT shipwreck utilize four main prey groups, gammarid amphipods, polychaete worms, rock crabs, and American sand lance. The significance of these foods was established by determining how many of the predator fish had utilized the same prey and the quantity (% weight) of that prey consumed. Only fish which consumed more than 10% by weight, for any one of the cruises, of a given prey will be listed below.

The first and by far the most important food, gammaridean amphipods (mostly Gammarus), was found in the stomachs of 17 of the 21 predator species examined. The largest quantities occurred in the stomachs of alewife (DELAWARE II 77-01, 96.4%), windowpane flounder (DELAWARE II 76-13, 90.2%), silver hake (ALBATROSS IV 77-07, 83.8%), little skate (DELAWARE II 76-13, 63.8%), winter flounder (ALBATROSS IV 77-07, 51.0%), Atlantic cod (DELAWARE II 76-13, 47.8%), yellowtail flounder (ALBATROSS IV 77-07, 36.0%), longhorn sculpin (ALBATROSS IV 77-07, 17.2%) and red hake (ALBATROSS IV 77-07, 13.4%).

Polychaete worms, second in importance as a food, were found in the stomachs of 14 of the 21 predators. They were preyed on heavily by American plaice (DELAWARE II 77-01, 93.5%), winter skate (DELAWARE II 77-01, 60.7%), yellowtail flounder (ALBATROSS IV 77-07, 46.2%), thorny skate (DELAWARE II 77-01, 29.5%), haddock (DELAWARE II 77-01, 24.2%), little skate (DELAWARE II 77-01, 19.5%), ocean pout (DELAWARE II 76-13, 16.9%), and red hake (ALBATROSS IV 77-07, 12.0%).

The third prey group, rock crabs (Cancer), was found in the stomachs of ten predator species. Large quantities of Cancer were found in diets of smooth dogfish (ALBATROSS IV 77-07, 88.5%), sea raven (ALBATROSS IV 77-07, 87.5%), little skate (ALBATROSS IV 77-07, 48.8%), ocean pout (DELAWARE II 76-13, 28.7%), red hake (DELAWARE II 77-01, 23.7%), spiny dogfish (ALBATROSS IV 77-07, 19.1%), and Atlantic cod (ALBATROSS IV 77-07, 13.5%).

The last major prey is the American sand lance, which was found in the stomachs of eight of the 21 predators. Sand lance constituted a significant proportion of the diet of Atlantic cod (ALBATROSS IV 77-07, 76.7%), pollock (DELAWARE II 77-01, 68%), winter skate (DELAWARE II 76-13, 50.3%), windowpane flounder (DELAWARE II 77-01, 28.2%), and little skate (ALBATROSS IV 77-07, 10.3%).

A comparison between the stomach contents of the predators collected for this study and data available on the same species in the Food Habits Project, at the Northeast Fisheries Center in Woods Hole, Massachusetts, showed that the taxonomic groups, the proportions (% weight), and the quantities (mean weight per stomach) of the foods eaten, were generally similar.

Transport of Oil Through the Food Chain

The previous study (Langton and Bowman, 1977) noted the occurrence of oil covered Gammarus annulatus, a gammaridean amphipod, in the stomachs of Atlantic cod and little skate. Subsequent analysis identified the oil as the same type as that carried by the ARGO MERCHANT. Because the oil was not found as isolated clumps, it suggests the prey was contaminated with oil before consumption. The fish, apparently, did not avoid the oily prey. This is particularly important since gammaridean amphipods were identified as the major prey of the fish collected in the vicinity of the ARGO MERCHANT. Furthermore over 40 species of marine fish have been shown to feed on gammaridean amphipods (Maurer and Bowman, 1975), and more importantly, juvenile fish such as Atlantic cod, haddock, silver hake, red hake, yellowtail flounder, American plaice, winter flounder, and little skate depend heavily on amphipods as a food source (Food Habits Project, NEFC, Woods Hole, MA). Gammaridean amphipods are one of the most important components of the food web in the Northwest Atlantic.

Maurer (1977) identified several species of copepods which were contaminated with oil from the ARGO MERCHANT. Three of those same genera, Calanus, Centropages, and Pseudocalanus were found in the stomachs of American sand lance (page 11). The importance of American sand lance as a food of marine fish has previously been discussed (page 15). It should also be noted that humpback and finback whales have been observed in a feeding mode while located in dense concentrations of American sand lance (Personal Communication, John R. Nicolas, NEFC, Woods Hole, MA).

Data presented in this report has identified two pathways by which ARGO MERCHANT oil may have entered the food chain. One possible route begins with gammaridean amphipods which are consumed by over 40 species of marine fish, including such species as cod and haddock, which as the basis of a large commercial fishery extend this pathway to man. The other pathway begins with copepods, which are then consumed by American sand lance. Sand lance, as well as the other fish which prey on them, are then potential prey for top predators such as sharks and whales, thus concentrating oil residues in the highest marine trophic levels.

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