NAFO Sci. Coun. Studies, 8: 39-48

Food Links of Some Fishes and Invertebrates on Flemish Cap*

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Abstract

The feeding spectrum of juvenile and adult Atlantic cod (*Gadus morhua*) on Flemish Cap was investigated from material collected during 1970–82, and the food of beaked redfish (*Sebastes mentella*) and American plaice (*Hippoglossoides platessoides*) were studied from material collected in 1979–82. Young cod (<40 cm) fed mainly on amphipods and calanoid copepods, the most frequently occuring organisms in the stomachs being gammarids and *Calanus* sp. in winter-spring and *Themisto* sp. in summer. Shrimps were also important as food of the largest juveniles in the spring. Adult cod fed mainly on amphipods (*Themisto* sp.) in summer, shrimps (*Pandalus borealis*) in spring and autumn, and various fishes (particularly young redfish) in winter-spring. There was considerable variability in the frequency of occurrence of the different food types by season, depth of capture and size of cod. Planktonic invertebrates (copepods, amphipods and euphausiids) prevailed as food of redfish in all months but were dominant in summer. Shrimps were generally less significant as food than planktonic invertebrates but they were significant in spring. Various echinoderms were the dominant food components of American plaice at all times of the year. The feeding intensity of cod, redfish and American plaice was highest in summer and lowest in winter.

Studies on the development of zooplankton in February–July, from plankton samples collected during 1971–81, indicated that Flemish Cap is a very productive area, with average abundance and biomass exceeding 3,000 organisms/m^3 and 550 mg/m^3 respectively in June. *Calanus finmarchicus* and *Oithona similis* were the dominant species (85–96% of total numbers of organisms) during March–July 1981. The prevalence of *C. finmarchicus* nauplii and copepodite stages I–III in March–April over the western and northern slopes of Flemish Cap coincides with major spawning of cod and redfish in the area. Year-to-year variation in the abundance of *C. finmarchicus* and other zooplankton organisms probably plays an important role in causing fluctuations in year-class strength of these fishes, whose larvae depend on an adequate food supply for survival.

Introduction

Large trawlers of the Soviet Union began fishing for Atlantic redfish (*Sebastes* sp.) on the southwestern slope of Flemish Cap in 1956 and expanded activities to include Atlantic cod (*Gadus morhua*) in the spring of 1957. Simultaneously, ichthyological and oceanographic studies were initiated in the area, first in the framework of a national research program and later as part of an international research project (ICNAF, 1977).

Flemish Cap was considered to be an ideal region for studying the dynamics of fish populations because of their isolation from those on other parts of the continental shelf, as has been shown by various studies which include tagging, parasitology and morphometrics (Postolaky, 1962; Yanulov, 1962; Templeman, 1962, 1974; Templeman and Fleming, 1963; Konstantinov, 1970; Shestov, 1970). However, fish eggs and larvae may sometimes be transported from the adjacent Grand Bank to Flemish Cap by currents; for example, a good year-class of haddock (*Melanogrammus aeglefinus*) appeared on the southern Grand Bank in 1981 and yearlings were caught on Flemish Cap in 1982 (Konstantinov, MS 1983), where in general haddock are rarely found. Nevertheless, conclusions concerning the isolation of the groundfish populations on Flemish Cap remain valid for the remaining parts of their life cycles from the time of settling on the bottom as juveniles to spawning as adults. Another advantage which favors Flemish Cap as an area for intensive fishery investigations is the absence of ice at all times of the year.

There is little information on feeding of cod on Flemish Cap. Some data on the subject were reported by Postolaky (1963) and Popova (1962), who concluded that cod feed on shrimps and amphipods during winter-spring and on plankton and various fish species during summer-autumn. The analysis of cod feeding in winter by Lilly (MS 1979) showed that adults preyed primarily on fish (mainly redfish) and planktonic crustaceans (hyperiids), that near-bottom crustaceans (mainly *Pandalus borealis*) were found more rarely and mostly in the stomachs of small cod, and that benthic organisms (crabs, echinoderms, polychaetes and gastropods) were relatively unimportant in the food of cod on Flemish Cap. A more recent study by Lilly (MS 1983) showed considerable annual variability in the relative importance of the major prey types. In this paper, an attempt is made to elucidate the relationships between the food resources and the major

* Based on a paper presented at the NAFO Special Session on "Trophic Relationships in Marine Species Relevant to Fisheries Management in the Northwest Atlantic", held at Leningrad, USSR, 14–16 September 1983.

fish species on Flemish Cap, with emphasis on cod but including beaked redfish (*Sebastes mentella*) and American plaice (*Hippoglossoides platessoides*).

Materials and Methods

Observations on the stomach contents of cod, redfish and American plaice were made during regular bottom-trawl surveys of Flemish Cap by Soviet research vessels. The field analysis involved determining the occurrence of different food items in the stomachs of 10,882 cod during 1970–82, 10,391 beaked redfish during 1979–82 and 2,083 American plaice during 1979–82. The degree of stomach fullness was estimated by the 5-point scale: 0 = empty, 1 = about one-quarter full, 2 = about half full, 3 = about three-quarters full, and 4 = full or nearly full. The average degree of stomach fullness, when summarized by month, depth range, etc., was calculated as the arithmetic mean of values for individual fish. All fish were measured as total length to the nearest centimeter, and, in the case of cod, the data were analyzed separately for young fish (<40 cm) and adults (≥40 cm).

Zooplankton distribution on Flemish Cap was determined from the analysis of 260 plankton samples which were collected in February (1978), March (1971, 1976, 1981), April (1971–74, 1977, 1981), May (1981), June (1975, 1977, 1978) and July (1978). Sampling before 1981 was carried out at hydrographic stations on the standard section across the bank at 47°N, whereas sampling during three surveys in 1981 (March, April, May) was carried out at stations on a grid which enveloped the entire bank. Zooplankton were collected with a Juday plankton net (diameter 37 cm, No. 38 gauze mesh) in depths of 50–0, 100–50 and 200–100 m, according to established VNIRO (All-Union Research Institute of Marine Fisheries and Oceanography) methods (Yashnov, 1934). Detailed methods of plankton collection and analysis were described by Kamotskaya and Plekhanova (1975). In this paper, the results are given for the 50–0 m tows because the main concentrations of zooplankton were found in that layer.

Feeding Characteristics

Atlantic cod

The composition of food types in cod stomachs from Flemish Cap is quite diverse and differs notably from the feeding spectrum of cod in other parts of the continental shelf off Newfoundland (Bulatova and Turuk, 1979). The main food items were classified into three main categories: plankton, benthos and fish. The most important of the planktonic organisms were amphipods, with copepods and ctenophores being observed occasionally. The benthic organisms consisted mainly of shrimps, with cephalopods, gastropods, echinoderms and polychaetes occurring sporadically at various times of the year. Of the identifiable fish food, young redfish and myctophids were the most important components. Because of the wide range in size of cod whose stomachs were examined in the field, the data were analyzed separately for juveniles (<40 cm) and adults.

Juvenile cod. The main food components in the stomachs of young cod (Fig. 1) were amphipods (*Themisto* sp. up to 100%, and gammarids up to 50% occurrence) and calanoid copepods (up to 50%). Young cod of all sizes fed on these organisms from February to August at depths of 100–350 m, but most frequently they fed on *Themisto* in summer (June–August) at all depths, gammarids in winter–spring (February and May) at 251–300 m, and calanoid copepods in winter (FebruaryMarch) at 201–300 m and in spring (April-June) at 100–200 m. *Calanus finmarchicus* were commonly found in the stomachs of small cod (<30 cm) but were less frequent in larger juveniles (31–40 cm). Euphausiids, polychaetes, bottom crustaceans and fish (young redfish and myctophids) were observed in the stomachs of young cod at various times but their frequency of occurrence was low. The larger juveniles (21–40 cm) fed on shrimps during March–May, the occurrence being highest in March at 100–150 m and in April at 301–350 m. In the spring of certain years, the smallest cod (≤20 cm) frequently fed on thaliaceans (*Oikopleura* sp.).

In general, the quantity of food in the stomachs of juvenile cod fluctuated greatly, with the mean degree of stomach fullness ranging from 1.0 to 2.5 (Fig. 1). The mean index was high in spring (March–April) and again in early summer (June–July) when many of the young cod had full stomachs.

Adult cod. The main food components of adult cod on Flemish Cap were amphipods (*Themisto* sp.), shrimps (mainly *Pandalus borealis*), fish (young redfish, cod and myctophids), and some planktonic organisms (copepods, sagittae and ctenophores) (Fig. 2). *Themisto* sp., the most common food item, were found in cod stomachs mainly during June–August over a wide range of depths. Their occurrence in large cod (≥72 cm) was much less than in the smaller fish. Unlike pelagic amphipods (*Themisto* sp.), bottom amphipods (gammarids) were seldom found in the stomachs. Shrimp constituted the second most frequent prey of adult cod, the occurrence generally increasing with depth and being higher in the smaller adults (<72 cm) than in the larger fish. Various types of fish were prevalent in the stomachs of cod throughout the year, being dominant in the largest cod at the greatest depths. Other organisms, such as polychaetes, ctenophores,

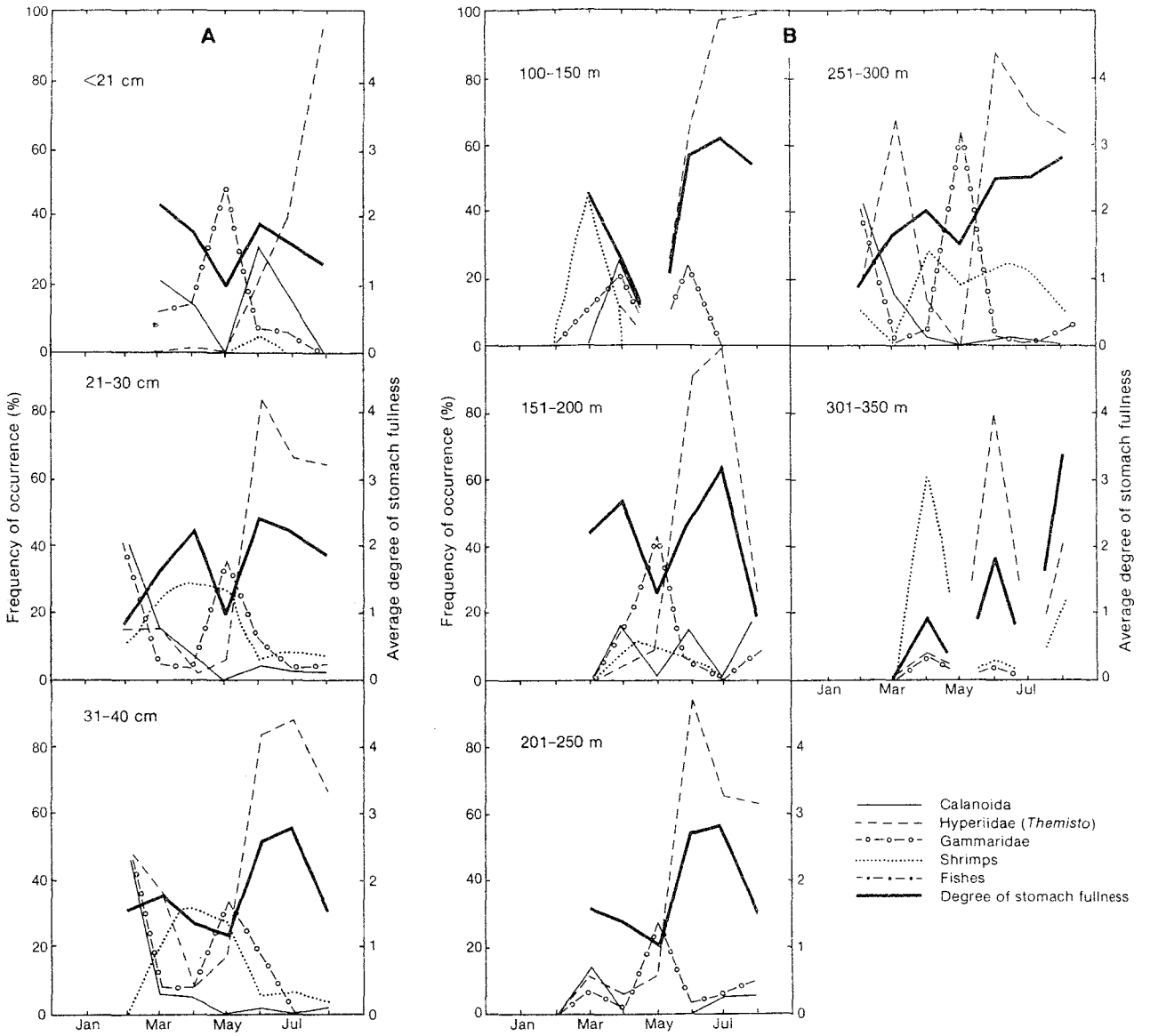

Fig. 1. Seasonal variation in the feeding of juvenile cod on Flemish Cap (1970-79) by (**A**) size group and (**B**) depth of capture. (The bold line represents average degree of stomach fullness.)

cephalopods and gastropods, were found in the stomachs sporadically.

The quantity of food in the stomachs of adult cod varied greatly, the mean degree of fullness ranging from about 0.5 to 3.0 (Fig. 2). Feeding was evidently much more intense in summer, and perhaps in autumn, than in the spring.

Yearly and seasonal variation in feeding. Because data on the feeding of redfish and cod were available only for the 1979-82 period, it was considered feasible to analyze the cod data (juveniles and adults combined) for the same years (Table 1). Year-to-year variation in the feeding spectrum of cod was considerable. The most frequently occurring food components were amphipods (*Themisto* sp.) in 1980 and 1982, shrimp in 1979 and 1980, and young redfish in 1979 and 1981. In years when the frequency of occurrence of young redfish was low, cod fed intensively on amphipods. There was very little year-to-year variation in the proportion of cod with food in their stomachs (76-86%) and in the mean degree of stomach fullness (1.8-2.2).

Seasonally during the 1979-82 period (Table 1), cod fed mainly on amphipods during June-August (62-81% occurrence), shrimps during February-May and August-September (31-68%), and fish during December-May (48-86%). The mean degree of stomach fullness varied from 1.5 to 2.9 on a monthly basis, with the highest values in summer (June-August).

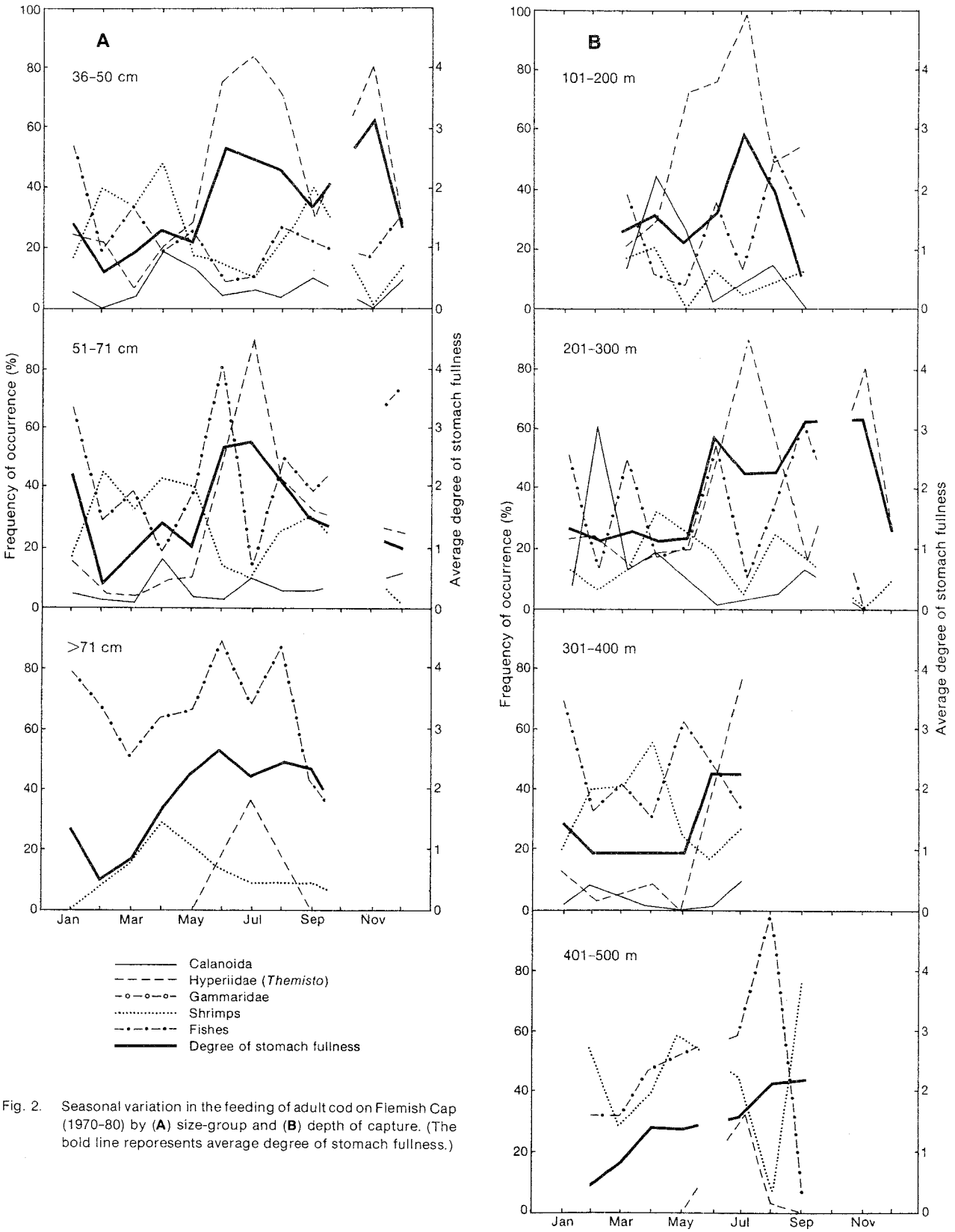

Fig. 2. Seasonal variation in the feeding of adult cod on Flemish Cap (1970-80) by (**A**) size-group and (**B**) depth of capture. (The bold line reporesents average degree of stomach fullness.)

TABLE 1. Monthly and yearly occurrence of various food items in the stomachs of Atlantic cod from Flemish Cap, 1979-82.

	Occurrence by month (%)												Occurrence by year (%)			
Food components	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1979	1980	1981	1982
Plankton																
Copepods	1	1	4	3	1	3	2	2	1	—	—	2	2	5	3	1
Amphipods (*Themisto*)	1	—	15	3	10	62	86	81	7	—	—	2	22	45	30	51
Euphausiids	—	—	—	1	2	2	—	—	—	—	—	1	—	1	1	—
Ctenophores	—	—	3	2	3	4	15	—	8	—	—	—	4	12	3	6
Thaliacea (*Oikopleura*)	—	—	11	7	—	—	—	—	—	—	—	—	5	—	—	—
Benthos																
Gammarids	—	—	2	1	1	1	—	—	4	—	—	3	2	1	1	—
Shrimps	18	36	31	44	38	12	13	68	37	—	—	26	32	39	19	17
Bottom crustaceans	1	1	2	1	3	1	1	—	2	—	—	1	2	3	1	—
Cephalopods	21	—	1	1	16	7	1	2	29	—	—	1	12	2	3	—
Gastropods	—	—	49	1	—	1	—	2	—	—	—	1				
Echinoderms	—	—	—	1	10	—	—	—	—	—	—	—	—	4	—	—
Polychaetes	—	—	2	2	11	1	—	—	3	—	—	1	2	5	1	1
Other benthos	—	—	1	—	3	1	—	4	—	—	—	—	1	3	2	—
Fish																
Young cod	—	—	1	3	—	—	1	—	1	—	—	3	1	—	1	3
Young redfish	—	53	35	12	—	22	4	—	7	—	—	46	31	1	31	11
Myctophids	—	—	2	—	—	1	5	6	2	—	—	4	2	6	—	—
Other fish	86	17	28	42	48	—	14	17	23	—	—	21	15	29	25	27
Digested food	1	1	1	3	—	—	—	—	—	—	—	6	1	2	3	1
No. of stomachs examined	100	177	692	865	312	826	948	48	374	—	—	518	1,277	999	1,450	1,134
Stomachs with food (%)	67	68	63	71	73	92	32	98	80	—	—	80	81	78	76	86
Degree of stomach fullness	1.6	1.6	1.5	1.6	2.2	2.5	2.5	2.9	2.0	—	—	1.9	2.1	1.9	1.8	2.2

Atlantic redfishes

After cod, redfishes are the next important species of the Flemish Cap ecosystem. Although golden redfish (*S. marinus*) are common in the area, beaked redfish (*S. mentella*) occur much more frequently, and the 1979-82 data for this species are used to demonstrate yearly and seasonal variations in feeding (Table 2). The main food items of beaked redfish were planktonic invertebrates (copepods, amphipods and euphausiids), which were significant in most months of the year but were dominant during the summer (June-August). On the average, shrimps were less significant as food, but they occurred more frequently than the other components in April-May and December. Fish generally occurred in less than 20% of the stomachs except in October and November, when fish remains were found in nearly all of the few stomachs that contained food.

Feeding was much more intense in summer (June-August) than at other times of the year, as indicated by the proportions of specimens with food in their stomachs (53-55%) and by the highest values for degree of stomach fullness (1.0-1.2). However, these mean values are quite low when it is considered that the scale for degree of stomach fullness ranges from 0 (empty) to 4 (full). On a yearly basis, there was little variation in the percentages of stomachs with food and in the mean degree of stomach fullness.

American plaice

Unlike cod and redfish, American plaice are typical benthophages (Table 3). Echinoderms, which were found in practically 100% of the stomachs, consisted mainly of Echinoidea (sea urchins and sand dollars) and Ophiuroidea (brittle stars). Molluscs and polychaetes were observed occasionally, but planktonic organisms and fish were rare. There was very little variation in the occurrence of different food components by season and year.

The proportions of American plaice stomachs with food were similar to those for cod but much higher than those for redfish. The mean degree of stomach fullness ranged from 1.0 to 2.2, with the highest values (2.0-2.2) in summer (June-August), when most of the stomachs (86-94%) were observed to contain food.

Zooplankton Abundance and Biomass

Average distribution, 1971-81

The analysis of plankton samples from hydrographic stations on the 47°N section across Flemish Cap in 1971-81 (Table 4) indicated that the abundance of zooplankton peaked much earlier in the western part of the region (3,262 organisms per m^3 in April) than in the eastern part (4,237 m^3 in June). However, the zooplankton biomass peaked in June in both areas, with

TABLE 2. Monthly and yearly occurrence of various food items in the stomachs of beaked redfish from Flemish Cap, 1979-82.

	Occurrence by month (%)												Occurrence by year (%)			
Food components	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1979	1980	1981	1982
Plankton																
Copepods	21	23	23	24	17	86	71	86	35	—	—	29	39	56	59	43
Amphipods (*Themisto*)	16	25	25	9	13	40	28	26	27	—	17	18	28	25	27	22
Euphausiids	49	11	22	6	—	9	10	—	17	—	—	10	13	11	9	14
Ctenophores	—	1	—	1	—	1	3	—	1	—	—	1	2	—	1	2
Thaliacea (*Oikopleura*)	—	—	—	—	—	4	—	—	—	—	—	—	5	—	—	—
Benthos																
Gammarids	2	2	1	1	—	1	2	—	—	—	—	2	1	—	2	2
Shrimps	22	11	13	38	67	10	5	11	18	—	—	36	23	14	21	17
Bottom crustaceans	3	—	2	—	—	—	—	—	2	—	—	—	2	—	—	1
Cephalopods	—	1	—	1	—	1	—	1	1	—	—	—	1	1	1	—
Polychaetes	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fish																
Young redfish	—	1	4	10	—	1	—	—	—	—	—	8	7	—	5	1
Myctophids	17	5	—	8	9	4	8	6	7	100	—	3	7	10	3	7
Other fish	10	9	7	18	9	2	4	7	16	—	83	13	9	7	9	10
Digested food	2	16	13	4	—	1	—	3	2	—	—	6	3	5	4	1
No. of stomachs examined	1,166	1,334	806	1,560	301	833	1,556	125	1,413	347	150	800	1,524	3,141	2,579	3,147
Stomachs with food (%)	17	9	20	23	15	53	53	55	21	1	8	42	24	24	28	32
Degree of stomach fullness	0.2	0.3	0.3	0.4	0.3	1.2	1.0	1.2	0.3	0.0	0.1	0.9	0.6	0.4	0.6	0.5

TABLE 3. Monthly and yearly occurrence of various food items in the stomachs of American plaice from Flemish Cap, 1979-82.

	Occurrence by month (%)												Occurrence by year (%)			
Food components	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1979	1980	1981	1982
Plankton																
Copepods	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—
Amphipods (*Themisto*)	—	—	—	—	—	5	—	—	—	—	—	—	—	—	5	—
Benthos																
Shrimps	—	—	3	—	6	—	—	13	1	—	—	—	1	2	—	—
Bottom crustaceans	—	—	1	—	—	1	—	4	1	—	—	12	1	—	—	—
Bivalve molluscs	—	—	9	11	8	3	9	4	11	—	—	2	7	15	3	6
Gastropods	—	—	1	1	—	1	—	4	—	—	—	2	1	1	4	—
Echinoderms	—	—	98	96	100	100	100	100	100	—	—	100	100	100	98	97
Polychaetes	—	—	9	10	4	1	2	13	3	—	—	—	5	2	2	7
Fish																
Young redfish	—	—	2	—	—	2	—	—	1	—	—	—	1	—	2	—
Other fish	—	—	2	3	—	—	—	—	1	—	—	4	—	—	—	2
Digested food	—	—	3	1	—	2	—	—	—	—	—	2	1	—	3	1
No. of stomachs examined	—	—	210	435	100	594	494	25	125	—	—	100	508	388	544	643
Stomachs with food (%)	—	—	73	64	51	86	94	92	72	—	—	4	80	80	77	75
Degree of stomach fullness	—	—	1.6	1.3	1.0	2.0	2.2	2.2	2.0	—	—	1.2	2.2	2.0	1.5	1.5

values of 440 and 721 mg/m^3 for the western and eastern sectors respectively. The seasonal trends in abundance and biomass of total zooplankton was approximately paralleled by *Calanus finmarchicus*, which persisted as the most numerous of the zooplankton organisms during the spring and early summer months.

Although the mean abundance and biomass of zooplankton for the 47°C section as a whole were highest in June, the mean abundance of *C. finmarchicus* continued to decline from the peak value in April, because the decline from April to June in the western sector was much greater than the increase in the eastern sector (Table 4). This implies that *C. finmarchicus* spawning begins and terminates earlier in the western sector than in the eastern sector. Also, the intensity of spawning is probably greater in the west than in the east.

Except in February, when echinoderm larvae were dominant (Table 5), copepods constituted 88-98% of total zooplankton by number, with *C. finmarchicus* and *Oithona similis* being the main species in all months. Although *C. finmarchicus* constituted only 13% of the total number of zooplankton organisms in February,

TABLE 4. Monthly abundance and biomass of zooplankton and *Calanus finmarchicus* in the western and eastern parts of the 47° N oceanographic section (0-50 m) on Flemish Cap, 1971-81.

Flemish Cap area	Month	Abundance (No./m³)		Biomass (mg/m³)	
		Plankton	*Calanus*	Plankton	*Calanus*
West	Feb	684	73	109	98
	Mar	274	154	176	158
	Apr	3,262	2,564	340	172
	May	2,807	2,100	284	170
	Jun	2,248	1,097	440	239
	Jul	1,166	465	316	241
East	Feb	171	53	64	54
	Mar	299	105	93	74
	Apr	2,558	1,312	274	134
	May	2,558	1,525	378	132
	Jun	4,237	2,032	721	482
	Jul	1,725	651	324	278
Mean	Feb	484	63	87	67
	Mar	280	133	153	131
	Apr	2,910	1,944	302	153
	May	2,674	1,795	334	180
	Jun	3,063	1,480	555	339
	Jul	1,445	558	321	260

TABLE 5. Percentage abundance of zooplankton organisms on Flemish Cap (0-50 m) at stations along the 47° N oceanographic section in February to July, 1971-81. (+ indicates insignificant numbers.)

Zooplankton organisms	Feb	Mar	Apr	May	Jun	Jul
Copepods						
Calanus finmarchicus	13	50	62	66	48	39
Calanus glacialis	—	—	1	+	—	—
Calanus hyperboreus	—	1	2	2	1	—
Metridia longa	+	1	1	+	—	+
Metridia lucens	+	1	—	—	—	—
Microcalanus sp.	2	1	—	—	—	—
Oithona atlantica	—	—	—	1	—	2
Oithona similis	16	35	30	28	37	57
Parachaeta norvegica	—	—	—	+	+	+
Pseudocalanus elongatus	—	1	2	1	1	—
Other copepods	—	—	—	—	1	—
Amphipods	+	+	+	+	+	+
Euphausiids	+	+	+	+	+	+
Ostracods	—	—	+	—	—	—
Gastropods	4	4	—	—	9	1
Chaetognaths	—	+	+	+	+	+
Echinoderms (larvae)	65	5	—	—	3	1
Thaliacia (*Oikopleura* sp.)	—	—	1	2	—	—
Other organisms	—	—	1	—	—	—

this copepod accounted for 77% of the biomass with the presence of mainly copepodite stages V and VI (females). No *C. finmarchicus* eggs were found, nauplii occurred only sporadically, and only 2-8% of the *C. finmarchicus* were males in the February sample. As the abundance of *C. finmarchicus* declined from May to July, the abundance of *Oithona similis* increased.

Distribution in 1981

From the more comprehensive coverage of Flemish Cap in the spring of 1981, zooplankton biomass increased from March to April and declined in June (Fig. 3). In March, moderately dense concentrations (201–500 mg/m^3) were distributed widely in the western half of the region, with peak densities (501–1,000 mg/m^3) to the west and southwest of the bank plateau. A similar concentration was evident over the eastern slope of the bank. However, the lowest densities (<100 mg/m^3) were found over the central part of the bank. Zooplankton biomass increased greatly in April, particularly in the western sector, with two large patches exceeding 1,000 mg/m^3. A wide band with density of 501–1,000 mg/m^3 extended across the northern part of the region. The zone of lowest density (101–200 mg/m^3) was now located over the southwestern slope of the bank. In May, the zone of greatest density was located over the northwestern slope of the bank, but zones of moderate density (501–1,000 mg/m^3) were found around the perimeter of the bank except in the south where the density was lowest (<50 mg/m^3).

C. finmarchicus was by far the most numerous of the zooplankton organisms during the surveys in the spring of 1981, and its distribution by age (growth stages) varied from month to month (Fig. 4). In March, the *Calanus* population was concentrated mainly in the western half of the region, with peak abundance of nauplii (>1,000/m^3) in the northwest and southwest quadrants and copepodite stages I–III (101–200/m^3) in the southwest quadrant. Copepodite stage IV–V were sparse, but stage VI females were dispersed widely with peak concentrations (201–400/m^3) over the center of the bank and in the southeast quadrant. In the southwest quadrant, where the largest numbers of nauplii and copepodite stages occurred, there was an abundance of phytoplankton, particularly the diatoms *Thallasiothrix longissima* and *Thalasiosira nordenskioldii*.

In April 1981, the *C. finmarchicus* population was much larger than in March, with maximum concentrations (>1,000/m^3) of nauplii in the western half and copepodite stages I–III throughout most of the region (Fig. 4). *Calanus* eggs were commonly observed in the samples from the western part of the area. Copepodite stages IV–V were abundant (>1,000/m^3) in the northeast quadrant but sparse (<200/m^3) in other parts of the region. Copepodite stage VI females were less abundant in March and were concentrated mainly over the center of the bank. In the western and northern parts of the region, where peak concentrations of *Calanus* nauplii and copepodite stages I–III occurred, there was mass development of phytoplankton, which consisted mainly of *Coscinodiscus oculus viridis*, *Ceratium longipes*, *Peridium depressum*, and the two diatoms observed in March.

In May 1981, as a result of growth, the *C. finmarchicus* population consisted mainly of copepodite stages

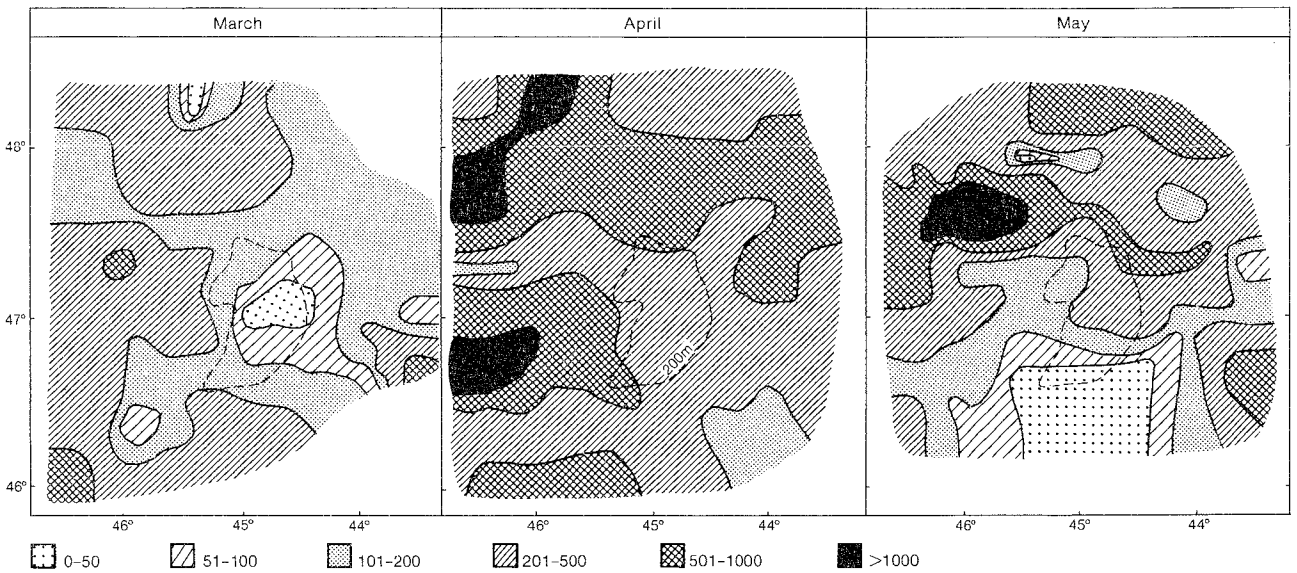

Fig. 3. Distribution of zooplankton biomass (mg/m³) in 0–50 m layer on Flemish Cap during March, April and May 1981.

IV–V (Fig. 4), with peak concentrations (>1,000/m^3) to the west and north of the bank and a smaller concentration (500–1,000/m^3) on the eastern margin. No eggs were observed, and nauplii were distributed sparsely (<50/m^3) throughout the region. Copepodite stages I–III, with peak concentrations (201–500/m^3) to the west and north of the bank, were much less abundant than in April. Stage VI females were distributed sparsely (<50/m^3) throughout the region, with the largest concentration (51–100/m^3) to the north of the bank where copepodite stages I–III and IV–V occurred in abundance.

In general, the growth of *C. finmarchicus* in the Flemish Cap area during the spring of 1981 is clearly evident, with the progression from nauplii in March to copepodite stages I–III in April and to copepodite stages IV–V in May (Fig. 4). The apparent scarcity and declining abundance of copepodite stage VI females are most likely due to their movement from the 0–50 m layer to greater depths, as they progress from stage V to stage VI.

Food Links of Fishes and Invertebrates

In addition to being isolated from the adjacent Grand Bank, Flemish Cap is a highly productive area (Vladimirskaya *et al.*, 1976; Plekhanova, MS 1980). The seasonal and year-to-year variations in abiotic factors are not as great as in other parts of the Newfoundland region. However, fluctuations in year-class abundance of commercial fishes, particularly cod, are very significant on Flemish Cap (Konstantinov, MS 1983), and the reasons for this are undoubtedly connected with the nutritive base and food relations of fish and invertebrates in the area.

The comparion of data on the feeding of cod, redfish and American plaice in different seasons illustrates greater plasticity in the feeding of cod than of the other two species. Shrimp, young redfish and various other fishes prevailed in the diet of cod during winter and spring. In summer and autumn, amphipods (*Themisto*), shrimp, squid and ctenophores were quite significant, together with fish (young redfish, myctophids and others). Capelin, which constitute a major component of the food of cod in the Barents Sea and on the continental shelf from Labrador to the Grand Bank (Popova, 1962; Bulatova and Turuk, 1979), were not found in the stomachs of cod from Flemish Cap, where plankton plays a greater role in their feeding. In contrast, beaked redfish fed throughout the year on planktonic organisms (copepods, amphipods and euphausiids) and also on fish, whereas American plaice fed almost entirely on echinoderms (sea stars, brittle stars and sea urchins).

The mean index of stomach fullness of cod, redfish and American plaice was generally highest during the summer and lowest during the winter months. There was a much higher degree of similarity in the diets of cod and redfish than between these species and American plaice. For example, shrimps and various fish species were common components of the diets of cod and redfish in all months and both species fed heaviiy on *Themisto* during the summer.

Comparison of the distributions of larval redfsih and cod (Serebryakov *et al.*, MS 1984) with the distributions of *Calanus* stages from the 1981 spring surveys indicated that the hatching of redfish larvae and the appearance of cod larvae coincided with *Calanus* spawning, and that the fish larvae were concentrated in areas of highest abundance of *C. finmarchicus* (eggs,

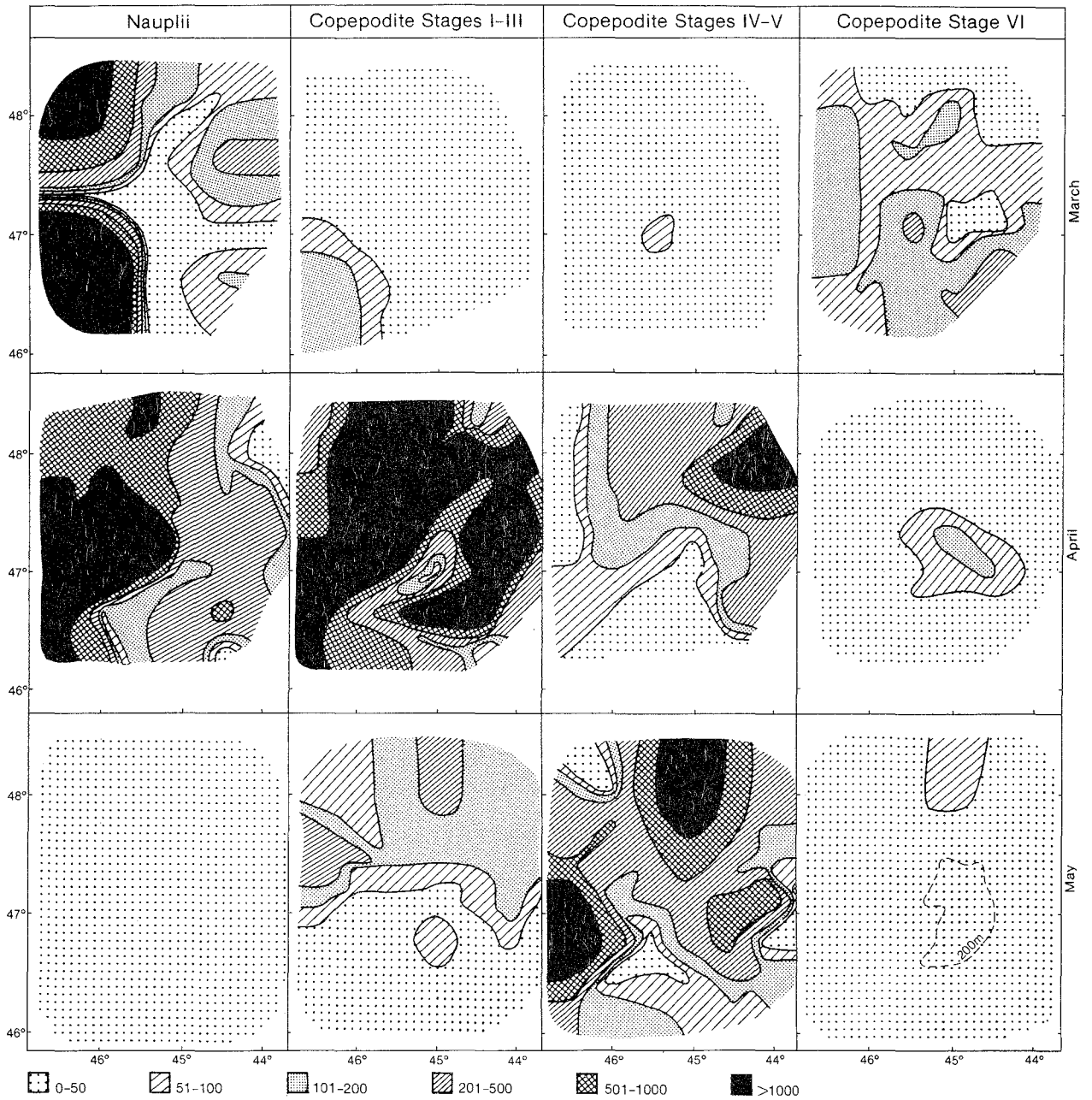

Fig. 4. Distribution of *C. finmarchicus* nauplii and copepodite stages (number/m³) in 0–50 m layer on Flemish Cap during March, April and May 1981.

nauplii and copepodite stages I–III). As noted by Serebryakov *et al.* (MS 1984), spawning of redfish occurred on all slopes of Flemish Cap but hatching of larvae was observed to be most intense on the southwestern slope in March and on the northern and northeastern slopes in April. Spawning of *C. finmarchicus* evidently occurs in the same areas at about the same time, as indicated by the high abundance of nauplii and copepodite stages I–III in April 1981 (Fig. 4). The spawning of cod also occurs on the southwestern slope in March.

The survival of cod and redfish larvae on Flemish Cap depends critically on the availability of an adequate food supply during April and May, and it is reasonable to suppose that variation in the abundance of copepods, especially *C. finmarchicus* which occurs in the same areas at the same time, play an important role in causing the fluctuations in year-class abundance of these fishes. Thus, in order to elucidate the reasons for fluctuations in year-class strength of the major fish species of the area, systematic research

should include, in addition to surveys aimed at estimating the abundance of young fish, studies on the feeding of larvae and juveniles and on the distribution of food resources for these young fish.

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