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# Variability in the Quantity of Capelin and Other Prey in Stomachs of Atlantic Cod off Southern Labrador and Northeastern Newfoundland (NAFO Division 2J+3K) During the Autumns of 1978-85

by

G. R. Lilly

Department of Fisheries and Oceans, Fisheries Research Branch
P. O. Box 5667, St. John's, Newfoundland, Canada A1C 5X1

## ABSTRACT

Examination of the stomachs of 16787 Atlantic cod (Gadus morhua) collected off southern Labrador and northeastern Newfoundland (NAFO Div. 2J+3K) during the autumns of 1977-85 revealed that the major prey were capelin (Mallotus villosus), hyperiid amphipods, Arctic cod (Boreogadus saida), shrimp (primarily Pandalus borealis) and crabs (primarily Chionoecetes opilio). Total stomach fullness of Atlantic cod tended to be much higher and more variable on Hamilton Bank in Div. 2J than on Funk Island Bank in Div. 3K.

The rate of predation by Atlantic cod on capelin varied with capelin abundance. The only prey other than capelin to be preyed upon with considerable annual variability were hyperiid amphipods, but predation on hyperiids did not vary inversely with predation on capelin. During periods of low capelin abundance Atlantic cod did not compensate by preying more intensively on any other prey.

With the size structure of the Atlantic cod population in recent years, Atlantic cod of intermediate size (54-71cm) are the major predators on capelin in the offshore area of Div. 2J+3K.

## INTRODUCTION

Capelin (Mallotus villosus) is a major prey of Atlantic cod (Gadus morhua) off southern Labrador and eastern Newfoundland (Popova, 1962; Templeman, 1965; Turuk, 1968; Minet and Perodou, 1978). Since the initiation of a large offshore fishery for capelin in this area in the early 1970's, there has been a concern that a reduction in capelin abundance might affect the production of the cod stocks. An initial examination of the interaction between Atlantic cod and capelin off northeastern Newfoundland and southern Labrador failed to demonstrate any relationship between annual growth increments in Atlantic cod and biomass of capelin (Akenhead et al., 1982). Although the authors expressed serious reservations concerning the appropriateness of the available data for addressing this question, they also noted that Atlantic cod might not be strongly linked to capelin, and that other prey might provide adequate forage during periods of low capelin abundance.

Lilly (MS 1984a) noted that the influence of changes in capelin abundance on the feeding of cod might be profitably investigated in the autumn in Div. 2J+3K, where there are annual collections of Atlantic cod stomachs from bottom-trawl surveys by Canada and estimates of capelin abundance from acoustic surveys by both Canada and the USSR. An analysis of data collected during the period 1977-82 (Lilly, MS 1984a, b) revealed that the major prey of Atlantic cod were capelin, shrimp (primarily Pandalus borealis), crabs (primarily Chionoecetes opilio), hyperiid amphipods and Arctic cod (Boreogadus saida). Predation on capelin was most intensive on Hamilton Bank and southward along the adjacent coastal shelf. Predation on P. borealis was most intensive in the deep areas of the continental shelf and predation on C. opilio was most intensive in shallower water toward the coast. The rate of predation by Atlantic cod on capelin varied with capelin abundance. During the period of low capelin abundance in the late 1970's Atlantic cod did not compensate for reduced predation on capelin by preying more intensively on shrimp, crabs, or other benthic invertebrates, but there appeared to have been increased predation on Arctic cod and hyperiids. This increased predation on alternate prey only partially compensated for the reduction in predation on capelin.

The purpose of this paper is to examine once again the relationship between capelin abundance and cod feeding, adding data from three additional years (1983-85) to the data examined earlier. In addition, I shall provide preliminary estimates of the quantity of capelin in the stomachs of the Atlantic cod population at the time of sampling.

## MATERIALS AND METHODS

Atlantic cod were caught during stratified-random bottom-trawl surveys by the chartered research stern trawler Gadus Atlantica in NAFO Div. 2J+3K in autumn, 1977-85 (Table 1). The survey pattern changed several times during this period. In 1977 and 1978 the area was surveyed during a single cruise. In 1979 and 1980 the area was surveyed twice, the first cruise fishing depths of 200-1500m and the second fishing 100-400m. The first cruise in both 1979 and 1980 was earlier in the autumn than cruises in other years. The area was surveyed by 2 consecutive nonoverlapping cruises in 1981 and 1982 and 3 such cruises in 1983-85.

Stomachs were collected from Atlantic cod caught on all cruises except the second one in 1979 (Gadus Atlantica 29). There are therefore no stomachs from depths <200m in 1979. Stomachs were collected opportunistically in 1977. In 1978 a stratified-random sample of 5 fish per 10-cm length group was sampled from the catch of every set. The sampling rate was reduced to 3 per 10-cm length group for 1979-82, and changed to 3 per 9cm group in 1983-85.

The stomachs from 25 fishing sets in northern 3K in 1981 (GADUS ATLANTICA 59) were lost.

Cod stomachs were individually tagged, and fixed and preserved in 10% formalin: sea water solution prior to examination in the laboratory. Examination involved separation of food items into taxonomic categories. Fish and decapod crustaceans were identified to species, but other groups were combined into higher order taxa (eg. Polychaeta, Euphausiacea). Items in each taxon were placed briefly on absorbent paper to remove excess liquid, and then weighed to the nearest 0.1 g. The relative quantity of food in the stomachs and the relative importance of individual prey types was assessed using three indices:

1) Percent occurrence (number of stomachs with specific prey as percentage of total number of stomachs).

2) Percent weight (total weight of specific prey in all stomachs as percent of total weight of all prey) (gravimetric method).

3) Stomach fullness index:
Mean partial fullness index was calculated as:

$$PFI_i = \frac{1}{n} \sum_{j=1}^{n} \frac{W_{ij}}{L_j^3} \times 10^4$$

where $W_{ij}$ is the weight of prey i in fish j, $L_j$ is the length of fish j, and n is the number of fish in the sample. Mean total fullness index was calculated as:

$$TFI = \frac{1}{n} \sum_{j=i}^{n} \frac{W_{tj}}{L_j^3} \times 10^4 = \sum_{i=1}^{m} PFI_i$$

where $W_{tj}$ is the total weight of prey in fish j and m is the number of prey categories. Fullness indices were used for interannual and spatial comparisons because they emphasize changes in both the quantity of prey in the stomachs and the contribution of specific prey categories.

A first examination of spatial differences in prey composition was restricted to a comparison between Hamilton Bank in the northwest in Div. 2J and Funk Island Bank in the southeast in Div. 3K. For this study, Hamilton Bank was defined as the area bounded by 53°00'N, 56°10'W, 55°20'N (the 2J-2H boundary), and the 400 m isobath. The Funk Island Bank area included only the area bounded by the 300 m isobath (strata 634-637; Doubleday, 1981).

The weight of capelin in the stomachs of the cod population at the time of sampling in Div. i (Wi) was estimated as:

$$W_i = \sum_{j=1}^{n} S_{ij} N_{ij}$$

where $S_{ij}$ is the mean weight of capelin in the stomachs of cod of length-group j in Div. i, $N_{ij}$ is the number of cod of length-group j in the population in Div. i, and n is the number of 9-cm length-groups. $S_{ij}$ is the unweighted mean weight of capelin in the stomachs examined; there was no weighting by catch or stratum. $N_{ij}$ was calculated by areal expansion of the stratified arithmetic mean number per 3-cm length-group per tow (Smith and Somerton, 1981) using strata defined in Doubleday (1981). Numbers per 3 cm group were combined into 9 cm groups.

## RESULTS

The prey spectrum was very similar in two selected years, 1982 and 1985 (Table 2). Fish and crustaceans were dominant. The most important fish in both years was capelin, but Arctic cod, flatfishes (F. Pleuronectidae), eelpouts (F. Zoarcidae) and redfish (Sebastes sp.) were also important in one or both years. Unidentified fish was a large proportion (21% by weight) of the stomach contents in both years. The major crustacea in terms of weight were shrimp, mainly Pandalus borelis, and crabs, mainly Chionoecetes opilio. Several invertebrate groups, such as polychaetes, gammarid amphipods, mysids, and euphausiids, occurred frequently but were not important in terms of weight. Hyperiid amphipods occurred more frequently and contributed far more to stomach content weight in 1985 than in 1982. The prey spectrum was similar in other years. Annual variability in the importance of these prey taxa will be described using fullness indices only.

### Annual variability

Fullness indices calculated for all stomachs in each year are shown in Table 3. Because capelin is the major prey for only medium-sized cod (Lilly, MS 1984a), the study of interannual variability was restricted to cod in the length range 36-71 cm (Table 4; Fig. 1). The years 1977 and 1979 are not included because sample sizes were relatively small. In addition, most sampling in 1977 was in Div. 2J. Sampling in 1979 was restriced to depths >200 m and was earlier in the autumn than most sampling in other years (Table 1).

The total fullness index varied from 0.94 in 1978 to 2.58 in 1985. Most of the variability was due to capelin, which rose from a very low level in 1978 to a peak in 1981, declined in 1982 and 1983, and then increased again in 1984 and 1985. A large proportion of the fish was unidentified, and much of this was probably capelin. Fish identified as Arctic cod were not important, except in 1985. However, many prey were identified as Gadidae. Almost all of these were of the same size as Arctic cod found in the stomachs and caught by the trawl. Since very few Atlantic cod of comparable size were taken by the trawl, it may be assumed that most prey identified as Gadidae were Arctic cod. Gadidae and Arctic cod combined were more important than capelin in 1978 and 1980 but the PFI values in those years were much lower than those of capelin in 1981-85. Other fish prey combined were relatively unimportant and did not vary greatly. All shrimp combined and all crabs combined remained fairly constant throughout the period. The only taxon other than capelin to vary considerably was hyperiid amphipods, which declined from 0.32 in 1978 to 0.05 in 1982 and then gradually increased to 0.38 in 1985.

### Hamilton Bank vs. Funk Island Bank

Annual variability on Hamilton Bank (Table 5; Fig. 2) was similar to that found in 2J+3K as a whole. However, compared with 2J+3K as a whole, the PFI for capelin was much higher in any given year on Hamilton Bank, and the PFI for hyperiids was much higher during the period 1983-85. On Hamilton Bank the highest total fullness index exceeded the lowest by 4.0 times, compared with 2.7 times in 2J+3K as a whole.

In contrast to the high variability on Hamilton Bank, the total fullness index on Funk Island Bank was always low (Table 6, Fig. 3). The major prey in most years were hyperiid amphipods, which varied much less than on Hamilton Bank. Capelin was far less important than on Hamilton Bank, crabs were of little importance, and Arctic cod were not identified at all.

### Influence of capelin abundance on cod feeding

Estimates of capelin abundance are available from acoustic surveys conducted by both the USSR and Canada (Table 7). The USSR did not conduct a survey in 1981, and the Canadian series started in 1981 and excluded 1982. For the three years of overlap (1983-85) correspondence between the estimates was not good ($r = 0.53$).

Partial fullness indices of capelin from stomachs of Atlantic cod (36-71cm only) in 2J+3K as a whole varied from <0.01 to 1.02 (Table 4). Much of the fish in the stomachs was unidentified, and a portion of this would have been highly digested capelin. Thus, a second estimate of the PFI for capelin ($PFI_c^*$) may be derived by assuming that the ratio of capelin to other fish is the same in the unidentified fish as it is in the identified fish. A third estimate ($PFI_c^{**}$), the maximum value, was obtained by assuming that all unidentified fish was capelin. The choice of index does not affect the rank order of years.

The PFI for capelin, modified by assuming a portion of unidentified fish was capelin (i.e. $PFI_c^*$), was positively correlated with the USSR acoustic biomass estimates ($r = 0.94$; $n = 6$; $P < 0.01$) but not with the Canadian acoustic biomass estimates ($r = 0.59$; $n = 4$; $P > 0.05$) (Fig. 4). In years when predation on capelin was low, Atlantic cod did not compensate by feeding more intensively on other prey. A negative correlation was not found between $PFI_c^*$ and the PFI for all other prey combined, nor was a negative correlation found with three smaller prey groupings: shrimp, hyperiid amphipods, and Arctic cod plus Gadidae (Fig. 5).

Consumption of capelin by the Atlantic cod population

The details of an estimate of the quantity of capelin present in the stomachs of the Atlantic cod population at the time of sampling in 1982 are given in Table 8. Cod of intermediate size (54-71 cm) had the greatest predator impact. The total quantity of capelin estimated to be present in stomachs was 941 t. Larger quantities were estimated to be present in 1981 and 1983 (Table 9). In all 3 years the consumption of capelin was much higher in Div. 2J than in Div. 3K.

## DISCUSSION

The addition of data from 1983 to 1985 to the time series previously examined (Lilly, MS 1984a,b) has not changed the impression of which prey are most important for Atlantic cod in Div. 2J+3K in autumn. The dominant prey is capelin, which has undergone large changes in abundance. These changes are reflected in changes in the partial fullness index for capelin from stomachs of Atlantic cod, but the functional feeding response of Atlantic cod to changes in capelin abundance is still not well described. A continuation of the monitoring is necessary. Good stomach sampling during years of low capelin abundance is critical. An additional problem with describing the functional feeding response is obtaining reliable measures of capelin abundance, for there are recognized problems with all methods currently in use, and the various indices are not highly correlated (Carscadden, et al., 1985).

The additional data from the sampling in 1983-85 support the earlier conclusion that during times of low capelin abundance Atlantic cod do not compensate by preying more intensively on benthic invertebrates, the most important of which are shrimp and crabs. However, the tentative conclusions regarding predation on pelagic prey are not supported. It was postulated that the decline in PFI for hyperiids in the period 1978-82 reflected a decline in hyperiid standing stock, and that the decline was caused by increased predation by capelin as capelin biomass increased over the same period. However, the PFI for hyperiids increased from 1982 to 1985, even though the biomass of capelin remained high and reached the highest level in the series in 1985. The increase in predation on hyperiids was very pronounced on Hamilton Bank, where capelin abundance was highest. There is thus no evidence from this time series that Atlantic cod feed more heavily on hyperiids when capelin abundance is low.

The other pelagic prey which appeared to have been preyed upon more intensively in the early part of the 1978-82 period was Arctic cod. However, the PFI for Arctic cod increased in 1984 and especially in 1985, and thus there is no longer support for an inverse relationship between predation on capelin and predation on Arctic cod. Most of the Arctic cod found in Atlantic cod stomachs came from two groups with modes at 5cm and 9-11cm (unpublished). These modes correspond to ages 0 and 1 (Lear, MS 1979; Miller, MS 1979; Wells, MS 1980). Thus, changes in intensity of Atlantic cod predation on Arctic cod could reflect changes in year-class strength of Arctic cod. Alternatively, the changes in predation on Arctic cod might result from a southward shift of the Arctic cod population in some years.

Because the feeding rate of Atlantic cod on capelin varies with capelin abundance, and Atlantic cod apparently do not feed more intensively on other prey in years of low capelin abundance, one might predict that the interannual variability in capelin abundance would be reflected in changes in Atlantic cod vital rates, such as growth rate, fecundity, age (or size) at maturity, and mortality. The changes might be more pronounced in Div. 2J than in Div. 3K because capelin concentrate on Hamilton Bank and the coastal shelf just to the south, at least in the autumn. However, the rate of feeding by Atlantic cod in autumn may not be a good index of the rate of energy accumulation by cod throughout the year. For example, during the preceeding spring and early summer Atlantic cod would have preyed on maturing capelin both offshore and inshore. The rate of consumption of maturing capelin offshore will probably increase with the magnitude of the maturing biomass. The rate of consumption inshore may be less dependent on the magnitude of the mature biomass, because the mature capelin are highly aggregated in a relatively small area close to shore just prior to and during spawning. Additional variability may be caused by variability in the proportion of the Atlantic cod stock coming inshore. The proportion coming inshore might be affected by the magnitude of the mature capelin biomass and by other factors, such as the temperature of the Labrador Current (Lear et al., in prep.). Thus an examination of the influence of capelin abundance on cod vital rates will require information on the abundance of capelin both before and after capelin spawning. Derivation of an adequate index of capelin availability will require not only improved understanding of the functional feeding response of Atlantic cod in autumn, but also some knowledge of the intensity and variability of Atlantic cod predation on capelin in spring and summer, both offshore and inshore.

The rate of consumption of capelin by Atlantic cod at the time of each autumn survey may be estimated from the quantity of capelin present in the stomachs, the rate of gastric evacuation, and the size of the cod population. Estimates of the average weight of capelin in the stomachs are available from sampling during the bottom-trawl surveys (eg. Table 8), and may be improved by considering spatial variability more explicitly and by weighting for catch. Variances are expected to be high. Studies on the rate of evacuation of capelin from stomachs of Atlantic cod at low temperatures (0-6°C) are in progress. Estimates of Atlantic cod abundance are available from the surveys (eg., Table 8), but such estimates are known to have high variances, and probably underestimate actual abundance because the catchability quotient is usually less than the assumed value of 1 (see, for example, Sinclair, et al., 1984). Thus, estimates of the rate of predation by Atlantic cod on capelin in Div. 2J+3K in the autumn may soon be available, but the estimates are expected to have considerable imprecision and unknown accuracy.

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Table 1. Dates of sampling and numbers of Atlantic cod stomachs collected during stratified-random bottom trawl surveys by the R.V. GADUS ATLANTICA off southern Labrador and northeastern Newfoundland (NAFO Div. 2J+3K) during the autumns of 1977-85.

| Year | Trip number | Sampling period | NAFO Div. | Number of[a] tows | Number of stomachs |
|---|---|---|---|---|---|
| 1977 | 3 | Nov. 11-Dec. 2 | 2J | 43 | 392 |
| | | | 3K | 5 | 72 |
| | | | | 48 | 464 |
| 1978 | 15 | Nov. 11-27 | 2J | 26 | 346 |
| | | | 3K | 48 | 689 |
| | | | | 74 | 1035 |
| 1979 | 27 | Sept. 29-Oct. 13 | 2J | 28 | 252 |
| | | | 3K | 34 | 290 |
| | | | | 62 | 542 |
| 1980 | 42 | Oct. 4-18 | 2J | 26 | 174 |
| | | | 3K | 44 | 331 |
| | 44 | Nov. 22-Dec. 8 | 2J | 53 | 756 |
| | | | 3K | 72 | 1059 |
| | | | | 195 | 2320 |
| 1981 | 58 | Nov. 15-29 | 2J | 76 | 785 |
| | | | 3K | 7 | 54 |
| | 59 | Dec. 3-13 | 3K | 56 | 564 |
| | | | | 139 | 1403 |
| 1982 | 71 | Oct. 30-Nov. 15 | 2J | 127 | 1707 |
| | | | 3K | 12 | 121 |
| | 72 | Nov. 20-Dec. 8 | 3K | 106 | 1248 |
| | | | | 245 | 3077 |
| 1983 | 86 | Oct. 28-Nov. 9 | 2J | 63 | 781 |
| | 87 | Nov. 10-22 | 2J | 30 | 564 |
| | | | 3K | 50 | 589 |
| | 88 | Nov. 27-Dec. 7 | 3K | 61 | 816 |
| | | | | 204 | 2750 |
| 1984 | 101 | Oct. 27-Nov. 7 | 2J | 45 | 558 |
| | | | 3K | 9 | 130 |
| | 102 | Nov. 9-20 | 2J | 33 | 525 |
| | | | 3K | 43 | 447 |
| | 103 | Nov. 24-Dec. 5 | 3K | 83 | 1100 |
| | | | | 213 | 2760 |
| 1985 | 116 | Oct. 23-Nov. 3 | 2J | 76 | 920 |
| | 117 | Nov. 5-17 | 2J | 19 | 231 |
| | | | 3K | 83 | 595 |
| | 118 | Nov. 21-30 | 3K | 62 | 691 |
| | | | | 240 | 2437 |
| Totals 1977-85 | | | 2J | 645 | 7991 |
| | | | 3K | 775 | 8796 |
| | | | 2J+3K | 1420 | 16787 |

[a]Number of tows from which at least one stomach was collected.

Table 2. The food of Atlantic cod off southern Labrador and northeastern Newfoundland in the autumns of 1982 and 1985.

| | Percent Occurrence | | Percent by weight[a] | | Mean PFI[a] | |
|---|---|---|---|---|---|---|
| | 1982 | 1985 | 1982 | 1985 | 1982 | 1985 |
| Invertebrata (misc.) | 7.02 | 14.44 | 0.56 | 0.87 | 0.01 | 0.02 |
| Anthozoa | 4.94 | 0.33 | 1.01 | 0.11 | 0.01 | + |
| Ctenophora | 5.07 | 2.22 | 1.16 | 0.20 | 0.01 | + |
| Gastropoda | 4.49 | 2.63 | 0.31 | 0.17 | + | + |
| Cephalopoda | 3.74 | 3.98 | 0.44 | 0.58 | 0.01 | 0.01 |
| Polychaeta | 28.75 | 14.85 | 0.86 | 0.41 | 0.03 | 0.02 |
| Ophiuroidea | 2.15 | 0.16 | 0.06 | + | + | + |
| Crustacea (total) | 87.54 | 89.99 | 23.20 | 23.42 | 0.37 | 0.64 |
| Hyperiidae | 29.14 | 63.11 | 1.73 | 12.14 | 0.04 | 0.35 |
| Gammaridea | 43.25 | 31.43 | 0.79 | 0.44 | 0.04 | 0.02 |
| Mysidacea | 22.83 | 23.27 | 0.15 | 0.23 | 0.01 | 0.02 |
| Euphausiacea | 10.57 | 12.88 | 0.18 | 0.33 | 0.01 | 0.02 |
| Natantia | | | | | | |
| *Pandalus borealis* | 24.39 | 18.14 | 4.80 | 2.95 | 0.08 | 0.07 |
| *Pandalus montagui* | 3.41 | 5.42 | 0.54 | 0.84 | 0.01 | 0.02 |
| Others and unid. | 40.46 | 36.52 | 3.93 | 3.55 | 0.07 | 0.10 |
| Reptantia | | | | | | |
| *Chionoecetes opilio* | 15.28 | 5.29 | 8.34 | 2.17 | 0.08 | 0.03 |
| *Hyas coarctatus* | 3.15 | 0.82 | 1.44 | 0.14 | 0.01 | + |
| Others and unid. | 8.88 | 5.13 | 0.92 | 0.49 | 0.01 | 0.01 |
| Others and unid. | 11.25 | 6.11 | 0.40 | 0.15 | 0.01 | 0.01 |
| Pisces (total) | 50.70 | 62.74 | 66.65 | 71.81 | 0.74 | 1.80 |
| *Mallotus villosus* | 9.85 | 26.59 | 15.95 | 36.17 | 0.28 | 0.95 |
| *Boreogadus saida* | 0.68 | 5.83 | 0.25 | 5.47 | + | 0.15 |
| Gadidae (unid.) | 0.39 | 1.03 | 1.45 | 1.21 | 0.01 | 0.02 |
| Zoarcidae | 1.27 | 0.66 | 5.74 | 0.35 | 0.03 | + |
| *Sebastes* sp. | 2.80 | 0.41 | 2.15 | 3.42 | 0.02 | 0.03 |
| Pleuronectidae | 2.60 | 2.59 | 16.24 | 1.79 | 0.08 | 0.02 |
| Others | 2.73 | 4.19 | 3.91 | 2.36 | 0.02 | 0.03 |
| Unid. | 40.36 | 51.09 | 20.98 | 21.05 | 0.30 | 0.59 |
| Unidentified and misc. | 54.99 | 23.64 | 5.77 | 2.41 | 0.09 | 0.06 |
| Total | | | | | 1.27 | 2.55 |
| No. of stomachs | 3075 | 2437 | | | | |
| Percent empty | 2.6 | 0.8 | | | | |

[a] + indicates presence but <0.005.

Table 3. The food of Atlantic cod off southern Labrador and northeastern Newfoundland in the autumns of 1977-85. All stomachs collected are included. Values are mean partial fullness indices.

| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|
| Invertebrata (misc.) | + | 0.01 | 0.01 | 0.01 | + | 0.01 | 0.01 | 0.01 | 0.02 |
| Anthozoa | + | + | + | 0.01 | 0.01 | 0.01 | + | + | + |
| Ctenophora | + | + | | 0.02 | 0.01 | 0.01 | + | 0.01 | + |
| Gastropoda | + | 0.01 | + | 0.01 | + | + | + | 0.01 | + |
| Cephalopoda | 0.03 | 0.01 | 0.14 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Polychaeta | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 |
| Ophiuroidea | + | + | + | + | + | + | + | + | + |
| Crustacea (total) | 0.45 | 0.53 | 0.78 | 0.44 | 0.45 | 0.37 | 0.45 | 0.57 | 0.64 |
| Hyperiidae | 0.10 | 0.28 | 0.49 | 0.14 | 0.14 | 0.04 | 0.12 | 0.22 | 0.35 |
| Gammaridea | 0.02 | 0.01 | 0.01 | 0.02 | 0.03 | 0.04 | 0.04 | 0.04 | 0.02 |
| Mysidacea | + | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.03 | 0.02 |
| Euphausiacea | + | + | 0.01 | + | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| Natantia | | | | | | | | | |
| *Pandalus borealis* | 0.11 | 0.06 | 0.10 | 0.08 | 0.07 | 0.08 | 0.09 | 0.09 | 0.07 |
| *Pandalus montagui* | 0.01 | 0.02 | + | 0.01 | 0.02 | 0.01 | 0.03 | 0.03 | 0.02 |
| Others and unid. | 0.14 | 0.10 | 0.14 | 0.10 | 0.07 | 0.07 | 0.11 | 0.10 | 0.10 |
| Reptantia | | | | | | | | | |
| *Chionoecetes opilio* | 0.03 | 0.02 | 0.01 | 0.05 | 0.05 | 0.08 | 0.04 | 0.05 | 0.03 |
| *Hyas coarctatus* | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | + |
| Others and unid. | 0.01 | 0.01 | + | 0.01 | 0.02 | 0.01 | + | 0.01 | 0.01 |
| Others and unid. | + | + | 0.01 | + | + | 0.01 | + | + | 0.01 |
| Pisces (total) | 0.53 | 0.34 | 0.65 | 0.54 | 1.13 | 0.74 | 0.64 | 1.05 | 1.80 |
| *Mallotus villosus* | 0.02 | + | 0.10 | 0.07 | 0.74 | 0.28 | 0.34 | 0.61 | 0.95 |
| *Boreogadus saida* | 0.01 | 0.01 | 0.03 | 0.03 | 0.01 | + | + | 0.05 | 0.15 |
| Gadidae (unid.) | 0.03 | 0.01 | 0.06 | 0.09 | 0.02 | 0.01 | 0.02 | 0.09 | 0.02 |
| Zoarcidae | 0.02 | 0.08 | 0.03 | 0.02 | 0.03 | 0.03 | 0.01 | + | + |
| *Sebastes* sp. | + | 0.03 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | + | 0.03 |
| Pleuronectidae | 0.23 | 0.06 | 0.07 | 0.05 | 0.06 | 0.08 | 0.04 | 0.07 | 0.02 |
| Others | 0.01 | 0.04 | 0.06 | 0.03 | 0.02 | 0.02 | 0.05 | 0.06 | 0.03 |
| Unid. | 0.21 | 0.13 | 0.28 | 0.24 | 0.24 | 0.30 | 0.15 | 0.17 | 0.59 |
| Unidentified and misc. | 0.12 | 0.13 | 0.16 | 0.18 | 0.18 | 0.09 | 0.15 | 0.04 | 0.06 |
| Total | 1.18 | 1.05 | 1.76 | 1.22 | 1.80 | 1.27 | 1.28 | 1.72 | 2.55 |
| No. of stomachs | 464 | 1035 | 542 | 2320 | 1403 | 3075 | 2749 | 2760 | 2437 |
| Percent empty | 1.7 | 1.8 | 2.2 | 1.3 | 2.1 | 2.6 | 5.9 | 0.9 | 0.9 |
| Length: mean | 55 | 55 | 56 | 58 | 57 | 56 | 53 | 53 | 52 |
| minimum | 21 | 26 | 26 | 17 | 24 | 16 | 14 | 14 | 17 |
| maximum | 112 | 101 | 99 | 126 | 109 | 119 | 113 | 113 | 114 |

Table 4. The food of Atlantic cod (36-71 cm only) off southern Labrador and northeastern Newfoundland in the autumns of 1978 and 1980-85. Values are mean partial fullness indices.

| | 1978 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|
| Invertebrata (misc.) | 0.01 | 0.01 | + | 0.01 | 0.02 | 0.01 | 0.02 |
| Anthozoa | + | 0.01 | 0.01 | 0.01 | + | + | + |
| Ctenophora | + | 0.02 | 0.01 | 0.01 | + | 0.01 | + |
| Gastropoda | 0.01 | 0.01 | + | + | + | + | + |
| Cephalopoda | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| Polychaeta | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 0.01 |
| Ophiuroidea | + | + | + | + | + | + | + |
| Crustacea (total) | 0.54 | 0.45 | 0.43 | 0.33 | 0.45 | 0.58 | 0.63 |
| Hyperiidae | 0.32 | 0.18 | 0.17 | 0.05 | 0.15 | 0.28 | 0.38 |
| Gammaridea | 0.01 | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 | 0.02 |
| Mysidacea | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 |
| Euphausiacea | + | + | + | 0.01 | 0.01 | 0.01 | 0.01 |
| Natantia | | | | | | | |
| *Pandalus borealis* | 0.06 | 0.08 | 0.06 | 0.07 | 0.09 | 0.10 | 0.07 |
| *Pandalus montagui* | 0.02 | 0.01 | 0.02 | 0.01 | 0.04 | 0.03 | 0.02 |
| Others and unid. | 0.09 | 0.09 | 0.07 | 0.08 | 0.10 | 0.08 | 0.09 |
| Reptantia | | | | | | | |
| *Chionoecetes opilio* | 0.01 | 0.04 | 0.04 | 0.06 | 0.03 | 0.04 | 0.02 |
| *Hyas coarctatus* | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | + |
| Others and unid. | + | 0.01 | 0.01 | 0.01 | + | 0.01 | 0.01 |
| Others and unid. | + | + | + | 0.01 | + | + | 0.01 |
| Pisces (total) | 0.20 | 0.45 | 1.03 | 0.62 | 0.65 | 0.90 | 1.83 |
| *Mallotus villosus* | + | 0.08 | 0.76 | 0.30 | 0.41 | 0.61 | 1.02 |
| *Boreogadus saida* | 0.01 | 0.03 | 0.01 | + | + | 0.03 | 0.16 |
| Gadidae (unid.) | + | 0.09 | 0.03 | 0.01 | 0.02 | 0.05 | 0.02 |
| Zoarcidae | 0.04 | + | 0.01 | 0.01 | | + | + |
| *Sebastes* sp. | 0.03 | + | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Pleuronectidae | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 |
| Others | 0.02 | 0.02 | 0.01 | 0.01 | 0.04 | 0.04 | 0.03 |
| Unid. | 0.09 | 0.21 | 0.21 | 0.26 | 0.16 | 0.15 | 0.58 |
| Unidentified and misc. | 0.14 | 0.18 | 0.18 | 0.08 | 0.13 | 0.04 | 0.07 |
| Total | 0.94 | 1.14 | 1.69 | 1.10 | 1.27 | 1.57 | 2.58 |
| No. of stomachs | 827 | 1794 | 948 | 1985 | 1753 | 1672 | 1707 |
| Percent empty | 1.5 | 1.3 | 2.1 | 2.6 | 5.0 | 0.8 | 1.1 |

Table 5. The food of Atlantic cod (36-71 cm only) on Hamilton Bank during the autumns of 1977-85. Values are mean partial fullness indices.

| | 1977[a] | 1978 | 1979[b] | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|
| Invertebrata (misc.) | + | 0.01 | + | + | + | 0.01 | 0.01 | 0.02 | 0.02 |
| Anthozoa | | + | + | + | 0.01 | 0.02 | + | + | |
| Ctenophora | | | | + | 0.01 | + | 0.01 | 0.01 | + |
| Gastropoda | + | + | + | + | + | + | + | + | + |
| Cephalopoda | + | + | + | + | + | + | + | + | 0.01 |
| Polychaeta | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 |
| Ophiuroidea | | + | + | + | + | + | + | + | |
| Crustacea (total) | 0.68 | 0.54 | 0.96 | 0.52 | 0.47 | 0.39 | 0.55 | 0.88 | 0.85 |
| Hyperiidae | 0.39 | 0.25 | 0.78 | 0.26 | 0.17 | 0.04 | 0.27 | 0.54 | 0.63 |
| Gammaridea | 0.02 | 0.03 | 0.01 | 0.05 | 0.03 | 0.04 | 0.03 | 0.03 | 0.02 |
| Mysidacea | + | 0.01 | + | 0.01 | 0.01 | + | + | 0.03 | 0.01 |
| Euphausiacea | + | + | 0.01 | + | + | 0.01 | + | 0.01 | 0.03 |
| Natantia | | | | | | | | | |
| *Pandalus borealis* | 0.15 | 0.08 | 0.08 | 0.05 | 0.02 | 0.06 | 0.08 | 0.09 | 0.04 |
| *Pandalus montagui* | | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 |
| Others and unid. | 0.10 | 0.10 | 0.06 | 0.06 | 0.06 | 0.08 | 0.07 | 0.11 | 0.07 |
| Reptantia | | | | | | | | | |
| *Chionoecetes opilio* | + | | | 0.06 | 0.11 | 0.13 | 0.07 | 0.04 | 0.01 |
| *Hyas coarctatus* | 0.02 | 0.04 | | 0.01 | 0.02 | 0.01 | 0.01 | + | + |
| Others and unid. | | + | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| Others and unid. | + | 0.01 | 0.01 | 0.01 | + | 0.01 | + | 0.01 | 0.01 |
| Pisces (total) | 1.34 | 0.30 | 1.02 | 0.58 | 2.64 | 0.97 | 0.74 | 1.44 | 3.01 |
| *Mallotus villosus* | 0.02 | | 0.02 | 0.19 | 2.21 | 0.55 | 0.55 | 0.98 | 1.74 |
| *Boreogadus saida* | 0.02 | 0.03 | 0.05 | 0.04 | + | + | + | 0.05 | 0.30 |
| Gadidae (unid.) | 0.14 | + | 0.22 | 0.05 | 0.02 | + | 0.01 | 0.08 | 0.03 |
| Zoarcidae | | 0.03 | + | + | | 0.01 | | | + |
| Sebastes sp. | | 0.06 | | | 0.01 | | | | |
| Pleuronectidae | 0.77 | 0.04 | 0.08 | 0.01 | 0.02 | 0.01 | + | 0.02 | 0.01 |
| Others | + | 0.01 | 0.13 | 0.01 | 0.02 | 0.01 | 0.01 | 0.08 | 0.03 |
| Unid. | 0.38 | 0.14 | 0.53 | 0.26 | 0.36 | 0.38 | 0.17 | 0.23 | 0.89 |
| Unidentified and misc. | 0.16 | 0.14 | 0.25 | 0.18 | 0.31 | 0.12 | 0.13 | 0.04 | 0.11 |
| Total | 2.19 | 1.00 | 2.24 | 1.30 | 3.46 | 1.54 | 1.47 | 2.41 | 4.02 |
| No. of stomachs | 85 | 167 | 95 | 392 | 257 | 681 | 545 | 470 | 566 |
| Percent empty | 1.2 | 0.0 | 2.1 | 1.8 | 0.8 | 0.3 | 1.5 | 0.0 | 0.0 |
| Number of tows[c] | 8 | 16 | 11 | 42 | 41 | 72 | 54 | 47 | 58 |

[a]All sets were on the eastern or southeastern part of Hamilton Bank and about 40% of the stomachs came from a single set.

[b]No sets were made in depths <200 m.

[c]Number of tows from which stomachs were collected from at least one cod in the length range 36-71 cm.

Table 6. The food of Atlantic cod (36-71 cm only) on Funk Island Bank during the autumns of 1978-85. Values are mean partial fullness indices.

| | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|
| Invertebrata (misc.) | 0.01 | 0.01 | + | + | 0.01 | + | 0.01 | 0.03 |
| Anthozoa | + | | 0.01 | 0.02 | + | + | 0.01 | |
| Ctenophora | + | | 0.04 | + | + | + | 0.02 | + |
| Gastropoda | 0.01 | 0.01 | 0.02 | 0.01 | + | + | + | + |
| Cephalopoda | 0.01 | 0.21 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| Polychaeta | 0.01 | 0.01 | 0.01 | + | + | + | 0.01 | 0.01 |
| Ophiuroidea | + | + | + | + | + | + | + | + |
| Crustacea (total) | 0.63 | 0.46 | 0.47 | 0.61 | 0.29 | 0.50 | 0.55 | 0.50 |
| Hyperiidae | 0.45 | 0.29 | 0.40 | 0.55 | 0.20 | 0.31 | 0.44 | 0.41 |
| Gammaridea | + | + | + | + | + | 0.02 | 0.01 | + |
| Mysidacea | 0.02 | 0.01 | 0.01 | 0.01 | + | + | 0.01 | 0.01 |
| Euphausiacea | + | + | + | + | + | + | + | + |
| Natantia | | | | | | | | |
| *Pandalus borealis* | 0.06 | 0.04 | 0.02 | 0.03 | 0.06 | 0.11 | 0.04 | 0.03 |
| *Pandalus montagui* | + | 0.01 | | + | + | + | + | + |
| Others and unid. | 0.07 | 0.10 | 0.03 | 0.02 | 0.02 | 0.05 | 0.02 | 0.02 |
| Reptantia | | | | | | | | |
| *Chionoecetes opilio* | 0.01 | + | 0.01 | 0.01 | + | 0.01 | 0.02 | 0.02 |
| *Hyas coarctatus* | + | | | + | | + | + | + |
| Others and unid. | + | + | + | + | + | + | 0.01 | 0.01 |
| Others and unid. | + | 0.01 | + | + | + | + | + | + |
| Pisces (total) | 0.19 | 0.06 | 0.29 | 0.33 | 0.37 | 0.54 | 0.13 | 0.26 |
| *Mallotus villosus* | | | 0.11 | 0.23 | 0.15 | 0.43 | 0.03 | 0.10 |
| *Boreogadus saida* | | | | | | | | |
| Gadidae (unid.) | | | 0.01 | + | | | + | |
| Zoarcidae | 0.08 | | + | + | + | | | + |
| *Sebastes* sp. | 0.04 | | | 0.01 | 0.02 | 0.01 | + | + |
| Pleuronectidae | 0.01 | | | | 0.03 | 0.02 | 0.01 | + |
| Others | 0.02 | 0.06 | 0.02 | 0.01 | 0.01 | 0.02 | 0.03 | + |
| Unid. | 0.05 | + | 0.15 | 0.09 | 0.16 | 0.06 | 0.06 | 0.16 |
| Unidentified and misc. | 0.06 | 0.03 | 0.20 | 0.09 | 0.04 | 0.06 | 0.05 | 0.02 |
| Total | 0.93 | 0.78 | 1.06 | 1.08 | 0.73 | 1.12 | 0.78 | 0.86 |
| No. of stomachs | 178 | 80 | 299 | 172 | 302 | 188 | 280 | 219 |
| Percent empty | 0.6 | 3.8 | 0.7 | 0.6 | 4.3 | 6.9 | 0.0 | 1.8 |
| Number of tows[a] | 15 | 9 | 26 | 18 | 32 | 21 | 29 | 30 |

[a]Number of tows from which stomachs were collected from at least one cod in the length range 36-71 cm.

Table 7. Partial fullness indices for capelin in stomachs of Atlantic cod (36-71 cm), and abundance estimates for capelin, for Division 2J+3K in the autumns of 1978 and 1980-85.

| | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|
| Cod stomach fullness | | | | | | | | |
| $PFI_c$ | 0.000 | - | 0.083 | 0.757 | 0.300 | 0.410 | 0.612 | 1.024 |
| $PFI_c^{*a}$ | 0.000 | - | 0.159 | 0.946 | 0.525 | 0.540 | 0.731 | 1.501 |
| $PFI_c^{**b}$ | 0.086 | - | 0.297 | 0.962 | 0.564 | 0.566 | 0.758 | 1.605 |
| Acoustic abundance estimate ('000's t) | | | | | | | | |
| USSR[c] | 59 | 14 | 20 | - | 611 | 852 | 480 | 1540 |
| Canada[d] | - | - | - | 1794 | - | 223 | 860 | 1255 |

[a] $PFI_c^* = PFI_c + ((PFI_c/(PFI_c + PFI_{of})) \times PFI_{uf})$, where $PFI_{of}$ is PFI for all other identified fish and $PFI_{uf}$ is PFI for unidentified fish.

[b] $PFI_c^{**} = PFI_c + PFI_{uf}$.

[c] Bakanev (MS 1983); Bakanev and Mamylov (MS 1986).

[d] Carscadden, et al. (MS 1985); estimate for 1985 from J. Carscadden (pers. comm.).

Table 8. Quantities of capelin in stomachs of Atlantic cod population in NAFO Div. 2J, 3K at time of sampling in autumn 1982.

| Length group (cm) | Number of stomachs | Capelin in stomachs PFI | av.wt.(g) | Cod abundance (X $10^{-3}$) | Total capelin in stomachs(t) |
|---|---|---|---|---|---|
| Div.2J | | | | | |
| 9-17 | 11 | 0.00 | 0.00 | 466 | 0.0 |
| 18-26 | 77 | 0.06 | 0.09 | 2,077 | 0.2 |
| 27-35 | 168 | 0.61 | 2.03 | 9,249 | 18.8 |
| 36-44 | 308 | 0.64 | 4.03 | 26,786 | 108.0 |
| 43-53 | 216 | 0.33 | 3.84 | 12,143 | 46.6 |
| 54-62 | 310 | 0.25 | 5.28 | 30,783 | 162.5 |
| 63-71 | 284 | 0.30 | 9.12 | 26,908 | 245.4 |
| 72-80 | 188 | 0.22 | 9.53 | 6,456 | 61.5 |
| 81-89 | 83 | 0.20 | 12.05 | 1,433 | 17.3 |
| 90-98 | 41 | 0.25 | 23.00 | 632 | 14.5 |
| 98 | 21 | 0.00 | 0.48 | 355 | 0.2 |
| Total | 1707 | | | 117,288 | 675.0 |
| Div. 3K | | | | | |
| 9-17 | | | | | |
| 18-26 | 43 | 0.07 | 0.12 | 1,165 | 0.1 |
| 27-35 | 160 | 0.02 | 0.06 | 3,214 | 0.2 |
| 36-44 | 130 | 0.16 | 0.92 | 3,898 | 3.6 |
| 45-53 | 239 | 0.21 | 2.45 | 11,912 | 29.2 |
| 54-62 | 253 | 0.16 | 2.89 | 17,145 | 49.5 |
| 63-71 | 245 | 0.21 | 6.90 | 16,319 | 112.6 |
| 72-80 | 187 | 0.12 | 4.90 | 5,509 | 27.0 |
| 81-89 | 81 | 0.36 | 20.33 | 1,544 | 31.4 |
| 90-98 | 25 | 0.68 | 53.45 | 677 | 36.2 |
| 98 | 5 | 0.00 | 0.00 | 408 | 0.0 |
| Total | 1,368 | | | 61,791 | 265.5 |

Table 9. Quantities of capelin (tons) estimated to be present in stomachs of predator populations in Div. 2J,3K at time of sampling in autumn.

| Predator | Division | 1981 | 1982 | 1983 |
|---|---|---|---|---|
| Cod[a] | 2J | 2209 | 675 | 1215 |
| | 3K | 269 | 266 | 420 |
| | Total | 2478 | 941 | 1635 |
| Greenland halibut [b] | 2J | 1016 | 1098 | |
| | 3K | 261 | 275 | |
| | Total | 1277 | 1373 | |
| GRAND TOTAL | | 3755 | 2314 | |

[a]Estimated as in Table 8.

[b]From Bowering and Lilly, 1985.

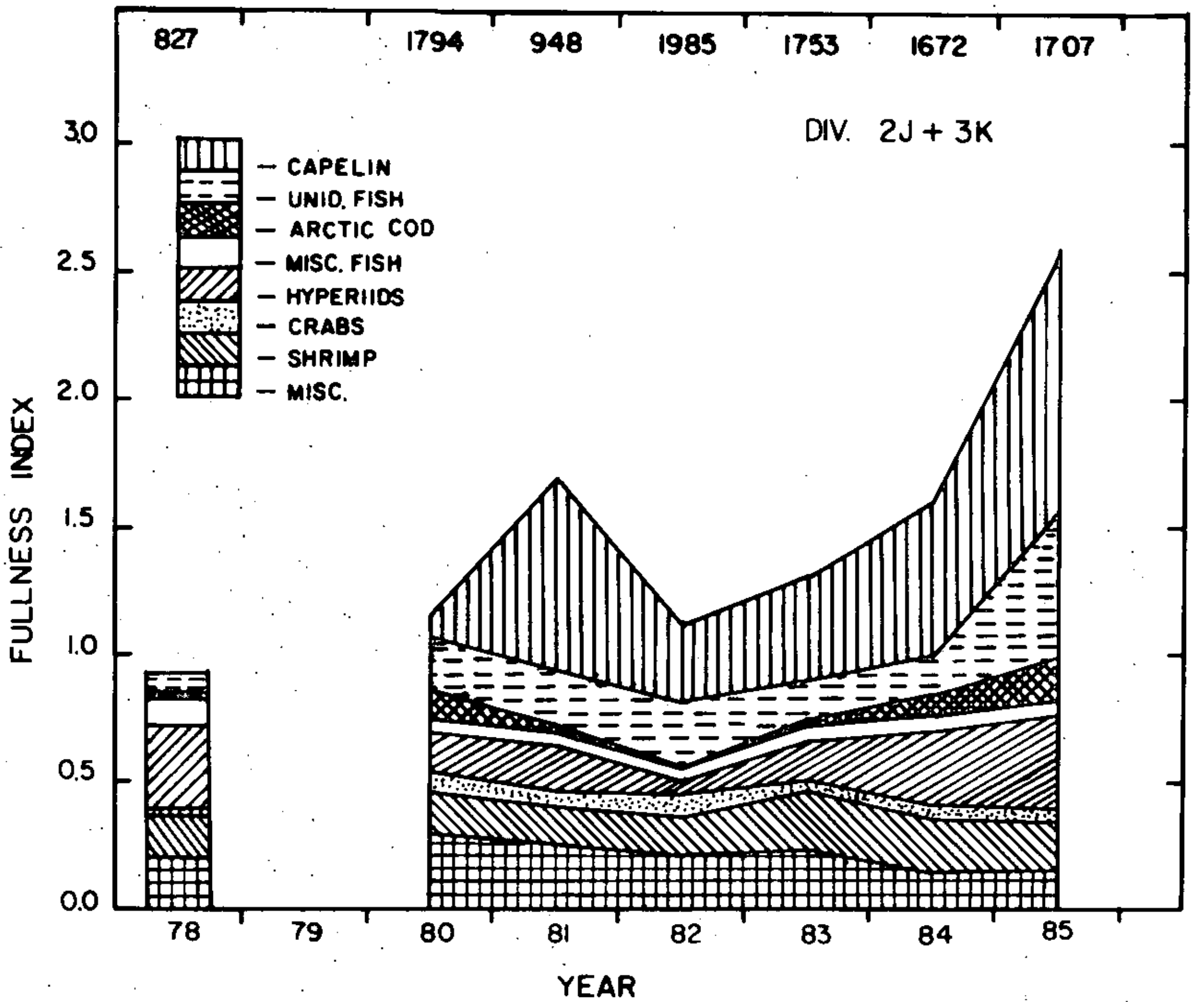


Fig. 1. The prey composition (expressed as fullness index) of Atlantic cod (36-71 cm only) in NAFO Div. 2J+3K in the autumns of 1978 and 1980-85. Arctic cod includes Gadidae. The number of stomachs examined each year is given at the top.

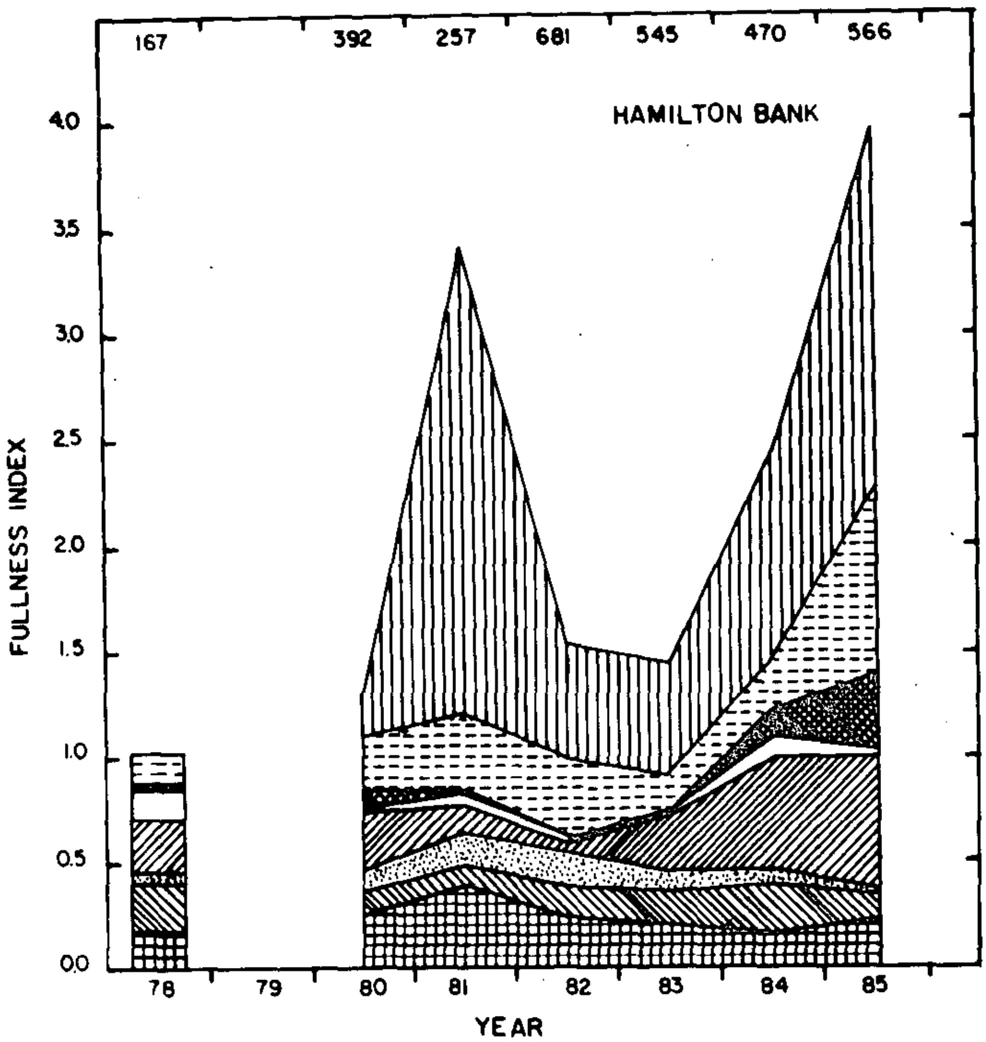


Fig. 2. The prey composition (expressed as fullness index) of Atlantic cod (36-71 cm only) on Hamilton Bank in the autumns of 1978 and 1980-85. Symbols as in Fig. 1.

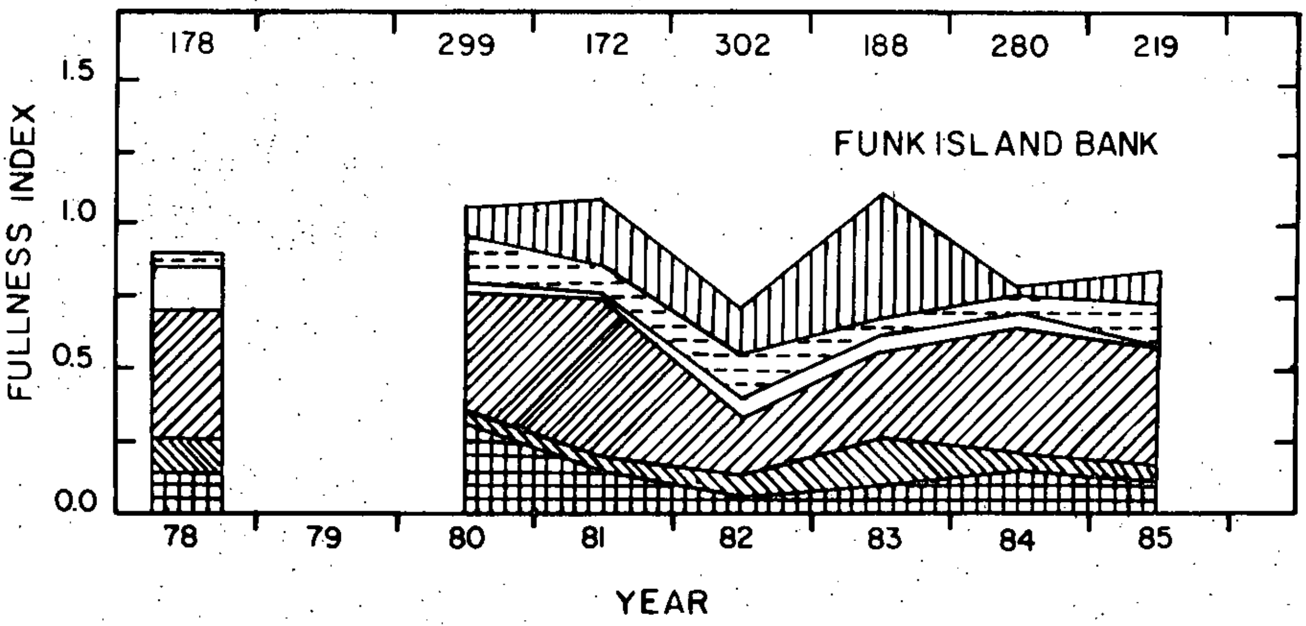


Fig. 3. The prey composition (expressed as fullness index) of Atlantic cod (36-71 cm only) on Funk Island Bank in the autumns of 1978 and 1980-85. Symbols as in Fig. 1.

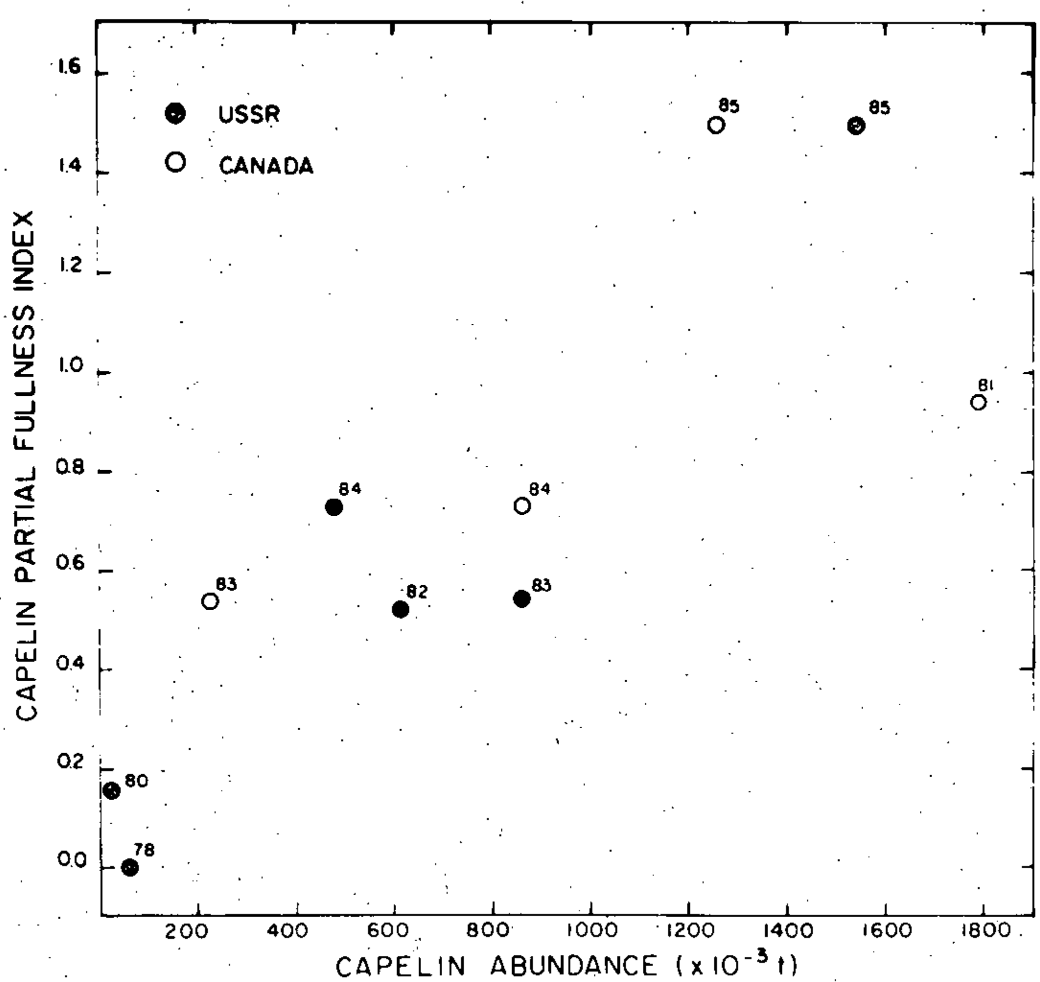


Fig. 4. The relationship between the partial fullness index for capelin ($PFI^*_c$) in stomachs of Atlantic cod (36-71 cm only) and estimate of capelin abundance, in Div. 2J+3K in autumn.

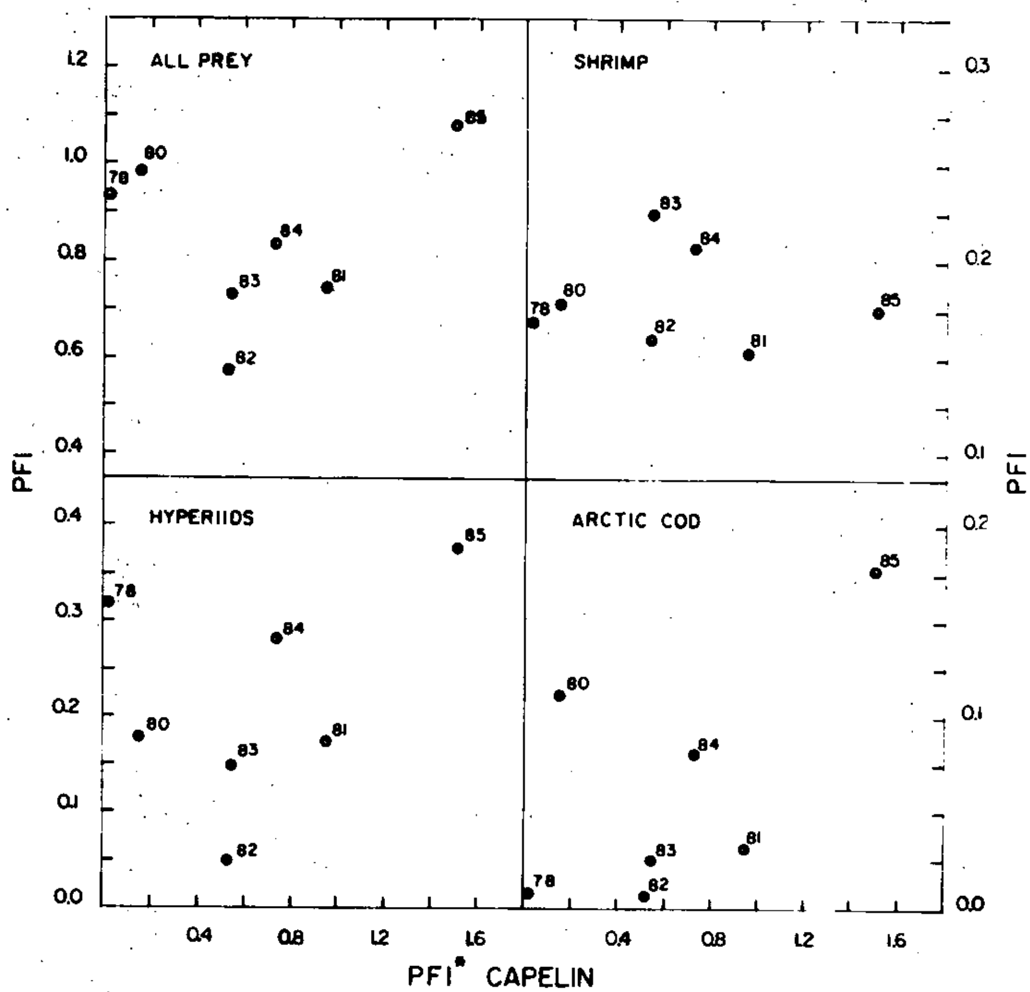


Fig. 5. The relationship between the partial fullness indices of various prey categories, including all prey other than capelin combined, and the partial fullness index for capelin ($PFI^*_c$), for Atlantic cod in Div. 2J+3K in autumn.