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Estimates of Consumption of Major Food Objects by Cod in Grand Bank Areas in Spring-Summer 1990

by

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ABSTRACT

Results of cod feeding analysis made in spring-early summer 1990 during the annual bottom fish survey in Grand Bank areas are set forth in the paper. Daily allowance of food was assumed as a basis of quantitative estimate of consumption, frequency of occurrence of food object was taken into account. It is established that intensity of consumption of different objects by cod varies in different areas. To consider potentials for use of stomach fullness indices in further calculation of daily rations the parameters of equation of index of fullness/daily allowance relation are determined.

INTRODUCTION

The importance of capelin as a commercial species and major food object of cod in the Northwest Atlantic specified the principal trend in studying of cod predation (Templeman, 1968; Carscadden, 1983; Lilly, 1987, 1989 and others). It is beyond doubt, however, that study of the value of other organisms being significant in cod feeding is necessary to estimate cod consumption more accurately. This, in its turn, is an indispensable condition for solving the problem of multispecies fishery regulation when a potential yield of cod food objects is to be coordinated with its food requirements.

Lilly (1987) reviews trophic interrelations of cod in the Labrador and Newfoundland areas. Despite the fact that there is much evidence on the subject the author observes a frag-

mentary and contradictory nature of certain data evoked, for instance, by year-to-year and seasonal differences in the distribution of cod and its food items, fluctuations in prey numbers etc. This implies that the data should be yearly updated.

The present paper shows the results of analysis of cod feeding in Grand Bank areas in spring-summer 1990.

MATERIAL AND METHODS

Cod samples were taken for feeding analysis from the bottom trawl catches during a stratified survey in the spring-summer period of 1990. All the stomachs collected in Divs. 3N and 3O were treated at sea while those collected in Divs. 3K and 3L were partially fixed in 10% solution of formalin for further treatment ashore. The analysis involved an identification of stomach contents to different taxa , weighing of separate components of a food bolus. Measuring of organisms digested to a various degree was very important for further definition of reconstructed weight through the size/weight relation.

To analyse feeding the following indices were estimated:

1. Occurrence (%) estimated as a ratio of stomachs with a certain food component to total number of stomachs analysed including empty ones.
2. Mean partial indices of stomach fullness (‰) as a ratio of the weight of a certain food species to the fish weight.
3. Per cent of the weight as a portion of total fullness index (all three indices are listed in Table 1).
4. Daily allowance of food (%) estimated after Bajkov (1935):

$$R = \frac{D}{t} \cdot 24,$$

where D - index of consumption, that is a ratio of reconstructed weight of food to fish weight;
t - time of digestion estimated after Jones (1978):

$$t = \frac{W^{0.54} \cdot L^{-1.4}}{Q \cdot 175 \cdot T^{0.035(T_o - 6^\circ)}},$$

where W - reconstructed weight of food, g;
L - fish length, cm;
T_o - water temperature;
Q - rate of digestion of a certain food species by cod 40 cm long at 6°C, g/h.

For fish Q = 0.15, for shrimp Q = 0.12. These are experimental data borrowed from Jones (1978).

When analysing feeding the cod length frequency series was divided into 9-cm size-groups which allowed to consider size/age characteristics of feeding.

RESULTS AND DISCUSSION

South-eastern and south-western slopes of Grand Bank (Divs. 3NO)

The central part of Grand Bank shoal was affected by near-bottom waters with low (from 0° to -2°) temperatures. This influenced the cod distribution pattern. The fish were rather scattered throughout the whole area surveyed and found in small number, often sporadically, in the catch. These were mainly large mature specimens 90-130 cm long. Sand eel (Ammodytes sp.) was a major prey of cod feeding on the shoal. As follows from the review of long-term observations sand eel is a major food component in cod feeding in this area during various seasons (Popova, 1962; Turuk, 1976; Lilly, 1982, 1987). Popova and Turuk give qualitative and quantitative characteristics of cod feeding, but their estimate of consumption is restricted to definition of fullness indices which though present an intensity of consumption of prey by a predator do not express, none the less, the quantity of the food eaten up.

Turuk reported data on daily allowance estimated after Romanova (1958). The average value is given to be 7-17% of fish body weight. However, these data should be regarded as overestimated for the population on the whole since they are computed for persistently feeding fish. In the case under review consumption is proportional to the weight of food in the stomach and is, probably, an upper limit of potential intensity of consumption.

Our samples comprised only cod above 50 cm. Mean partial indices of stomach fullness varied in relation to sand eel from 128 to 658‰, 326.7‰ on the average, for different cod size groups. Estimated daily allowance was 0.8-1.8% of fish body weight. An attempt was made thereupon to determine the relation between the partial fullness index (PFI) averaged for size groups (n=9) and the daily allowance (R). The regression equation is written as:

$$R = \frac{67.9+0.138\ PFI}{100},$$

where R - food allowance, %;
PFI - partial index of stomach fullness, °/₀₀.
The correlation coefficient K=0.84.

Using stomach fullness indices given by Turuk for December 1964 and Popova for July 1960 we estimated food allowance values for above periods (Table 2). As is seen from the Table daily intake of cod when feeding on sand eel during various seasons did not show essential distinctions and was, on the average, 0.88-1.15% of cod body weight.

Analysis of size preference of cod in relation to sand eel showed that fish 9-23 cm long were prey of cod above 50 cm, ratio of prey length (l) to predator length (L) varied from 25% in average cod to 13% in large (above 70 cm) one. Popova (1962) observes that young cod feed on young sand eel 5-12 cm long. The number of swallowed organisms varied from some specimens to some dozens. The maximal number - 78 specimens 15-22 cm long - was found in cod 102 cm long. Various digestion rate for separate food fractions was distinctly marked in fish which was indicative of periodicity of food capture as it was evacuated from the stomach. This was particularly pronounced in fish with a high stomach fullness degree.

During the survey capelin was found in feeding of small and average cod, concentrated in the southernmost part of the Bank shoal. Feeding intensity was low: occurrence frequency was about 17%, mean partial index was 356.7°/₀₀. Due to insignificant number of specimens analysed the food allowance value was estimated to be 2.2 and 1.3% for young cod 21-29 and 30-38 cm long respectively. Mean length of capelin consumed by these cod size groups was 11 cm. Cod fed also on redfish, flatfishes and own juveniles.

Among other food the importance of benthic invertebrates should be noted, of which crabs, molluscs and prevailing in feeding of young cod amphipods are most significant.

Saint John's area (Div. 3L)

In analysing the level of cod predation in relation to capelin during the spring-summer period the study of trophic interactions of these fishes in Div. 3L is of particular concern: capelin numbers are very high in this period and they are most intensively preyed by cod (Templeman, 1965; Minet and Perodon, 1978; Akenhead et al., 1982; Lilly and Rice, 1983).

In April 1990 capelin were found in the stomachs of cod forming aggregations in frontal waters of the eastern and western Bank slopes. Cod fed most persistently in the north-western areas where large capelin concentrations were observed with predominant specimens of the 1988 yearclass (mean length L=11.9 cm) and 1987 yearclass (L=14.3 cm). Capelin occurrence in cod stomachs was 19.4% throughout the whole area. The value varied from 2% in cod 21-30 cm long to 25% in cod above 50 cm. Cod size preference in relation to capelin from different length groups is shown in Fig. 1. Length range of capelin consumed by small, average and large cod is rather wide. The l/L ratio varies from 16 to 38%. Preference for larger prey is pronounced in cod as the fish grow: the mean capelin length in the stomachs of cod $<$ 50 cm was 10-10.5 cm, l/L=38 - 30%; in larger cod - 14-15 cm, l/L=16 - 30%. Daily food allowance for different cod size groups estimated on the basis of mean partial indices of capelin consumption were within 1.7-0.9%. The relation between average partial indices of stomach fullness and daily food allowance was derived from the equation:

$$R = \frac{73.47 + 0.2PFI}{100} \quad K=0.93, \quad n=8 \quad \text{(Fig. 2)}.$$

Consumption of other fish by cod was low. In particular, the occurrence of sand eel being preyed by cod just in the southern and slightly in the central parts of the area was 1.2%. Single speciments of young halibut, haddock, American plaice, Agonidae were encountered in cod stomachs.

The most important crustacean prey were crabs (Chionoecetes opilio and Hyas araneus) and shrimp (Pandalus sp.). Crab occurrence increased on the average from 8 to 40% in cod $>$ 50 cm with the increase of cod size.

The occurrence in the area as a whole was 20.2%, crabs being found in cod stomachs througout the whole Division. The highest stomach fullness indices (to 900%) were observed in the north-western parts of the Bank.

Feeding on shrimp was mainly registered in cod 40-60 cm long on the western Bank slope. The occurrence value varied from 7 to 15%. Partial indices of stomach fullness were 272‰ in small cod and 27‰ in fish above 65 cm. Daily food allowance varied, accordingly, from 0.9 to 0.3%. The regression equation showing the stomach fullness/daily food allowance relation was:

$$R = \frac{33.22 + 0.25PFI}{100} \quad (K=0.87, \quad n=6).$$

Euphausiids, amphipods and polychaetes, in addition, were predominant in the diet of small cod.

Northern Grand Bank (Div. 3K)

Systematization of data on cod feeding in Div. 3K was not so complete compared with that for other areas, a more detailed study of seasonal characteristics of feeding is needed since the results of investigations for various years show a high among-year variability (Popova, 1962; Turuk, 1978; Minet and Perodon, 1978; Lilly and Rice, 1983; Lilly, 1990). In 1990 the survey was carried out in the first half of June. Cod were widespread and scattered throughout the whole Bank area though cod aggregations were only observed in the south-eastern part of Division.

The intensity of cod feeding on capelin was low everywhere excluding northernmost parts and parts off continental slope where capelin was not found in cod stomachs. Capelin occurrence in fishes from various size groups varied within 2.2-7.4% and was 4.7% for the area as a whole. Partial indices of stomach fullness were 23.5-840‰, 224.4‰ on the average.

Shrimp (Pandalus borealis) was a major food prey of cod in Div. 3K in early June. Cod from various size groups fed persistently on shrimp, the shrimp occurrence varied from 35.5 to 62.5% and was 49.3% for the area as a whole. Partial indices of stomach fullness made up 113.1-319.9‰, 224.4‰ on the average. Weight percentage was 72.1. Mean length (SL) of shrimp consumed was 6.6-9.2 cm. No shrimp size selection was registered in cod from various size groups , the l/L ratio varied from 21% in cod 30-31 cm long to 11-14% in cod above 60 cm. The daily food intake was estimated, its value did not differ much in cod from various size groups and varied from 1.1 to 1.6% of fish body weight. The regression equation of the stomach fullness/daily food intake was in the form:

$$R = \frac{84.52 + 0.175\ PFI}{100} \quad (K=0.85,\ n=5).$$

Crabs were another important prey of cod feeding. Their occurrence in cod stomachs was 15.8% for the area as a whole, the value increases from 6.7 to 29% in cod as they grow. The mean stomach fullness index is 76.8‰, weight percentage - 5.3. Crabs were found in cod feeding throughout the whole Bank area, as a matter of fact.

Amphipods have been earlier mentioned to be of no small importance in cod feeding in this area in spring (Popova, 1962; Minet and Perodon, 1978), though in no case was the amphipod consumption reported during our survey. Polar cod, flounders, halibut, grenadiers, redfish, sculpins of the genus Triglops, goby were occasional in cod feeding. In addition to shrimp, amphipods, mainly P. gaudichaudi, were appreciable in the diet of cod below 40 cm.

CONCLUSIONS

Estimates of cod daily food allowance may serve the different purposes. First, they are used when determining optimum food requirements of the population as a whole. At the same time the values can be basis of natural mortality correction when estimating the stocks of prey species. It is true for both capelin, an important food item of cod and commercial species, and other organisms suffering from a high pressure of cod predation.

A close relation between the food allowance estimated and stomach fullness indices showed high correlation coefficients. The obtained parameters of regression equation illustrating a level of connection between these indices allow to have tentative estimates of food consumption with the use of factual data on stomach contents.

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Table 1. Cod feeding intensity in April, June 1990

Food component	3NO, April			3L, April			3K, June		
	mean PFI, °/oo	% by weight	occurrence, %	mean PFI, °/oo	% by weight	occurrence, %	mean PFI, °/oo	% by weight	occurrence, %
Fish									
capelin	356.7	19.8	17.4	323.9	45.6	19.4	224.4	6.2	4.5
sand eel	326.7	48.6	28.3	479.9	10.0	1.2	-	-	-
cod	383.0	5.7	1.6	135.2	0.4	0.3	733.1	5.1	0.1
halibut	-	-	-	134.6	0.2	0.1	71.1	0.3	0.1
polar cod	-	-	-	-	-	-	581.5	4.0	0.3
redfish	275.8	2.1	0.3	-	-	0.1	350.0	2.4	0.2
flounders	255.6	7.6	2.3	113.9	0.8	0.9	279.7	1.0	0.2
haddock	-	-	-	125.9	0.2	0.1	-	-	-
grenadiers	-	-	-	-	-	-	98.3	0.3	0.2
others	-	-	-	103.7	1.8	-	59.2	0.1	0.1
Crustaceans									
shrimp	42.0	0.3	0.6	91.5	8.5	11.9	250.2	74.8	41.8
crabs	72.8	6.5	9.9	198.9	22.7	20.2	76.8	5.3	13.5
hermit crab	-	-	-	318.1	0.5	0.8	-	-	-
euphausiids	-	-	-	130.0	1.3	1.5	-	-	0.6
amphipods	138.0	7.1	4.6	51.8	2.8	20.2	18.1	0.2	5.4
Molluscs	44.6	2.5	5.6	203.5	2.6	5.2	128.6	0.3	0.3
Ctenophora	-	-	-	35.2	0.2	0.1	-	-	-
Ophiura	-	-	-	-	-	0.1	11.3	0.1	0.6
Polychaeta	-	-	-	66.9	2.6	7.7	18.0	0.1	3.2
No.of stomachs analysed, spec.	89		304	230		1219	117		678
No.of empty stomachs,%	-		35.9	-		20.0	-		29.9

Table 2. Intensity of cod feeding on sand eel on southern slopes of Grand Bank (Div.3NO) in different seasons

Year (month)	Fish length, cm	Mean index of stomach fullness, °/oo	Daily food allowance,%
1960 (July)	Small (< 50)	148.0*	0,88
	Average	217.5*	0.98
	Large (> 70)	302.0*	1.10
1964 (December)	Small (< 50)	263.4**	1.04
	Average	342.6**	1.15
	Large (> 70)	285.0**	1.07
1990 (April)	Small (< 50)	-	-
	Average	221.4	0.98
	Large (> 70)	298.5	1.09

*Data borrowed from Popova (1962)

**Data borrowed from Turuk (1976)

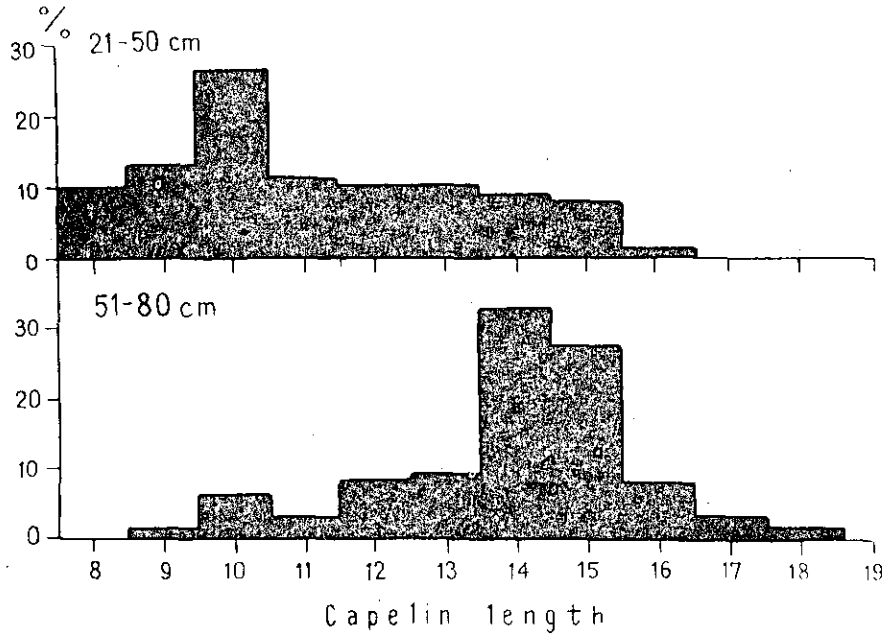

Fig. 1 Capelin length from the stomachs of cod 21-50 and 51-80 cm long caught in Div. 3L (April 1990)

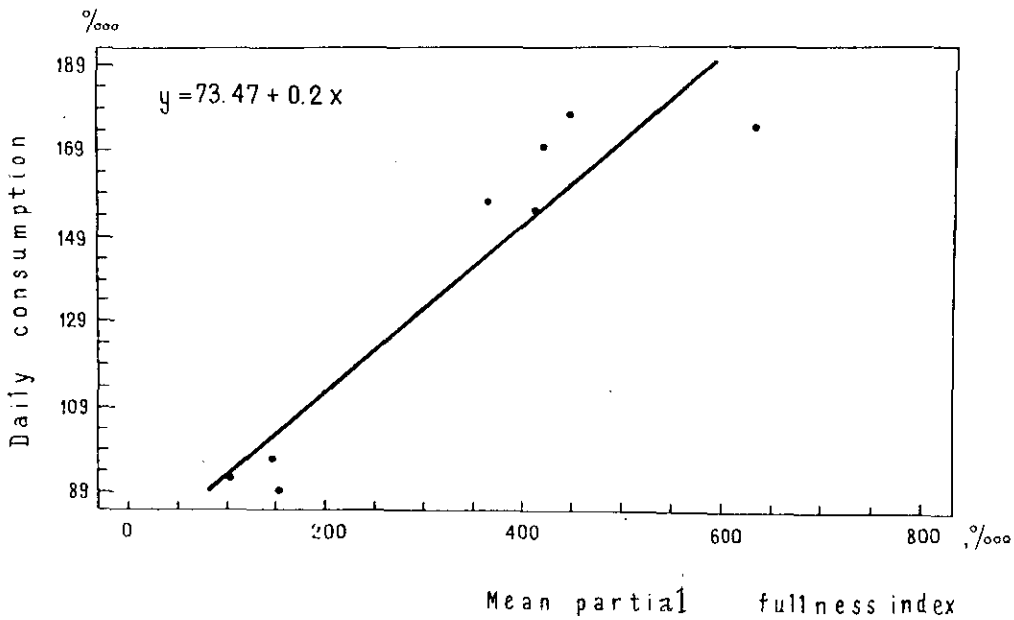

Fig. 2 Relation between mean partial fullness index and daily capelin consumption for cod from Div. 3L (April 1990)