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Size Relationships in Predation by Atlantic Cod, *Gadus morhua*, on Capelin, *Mallotus villosus*, and Sand Lance, *Ammodytes dubius*, in the Newfoundland Area

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Abstract

The minimum length of cod which can prey on adult capelin and sand lance is about 35 cm, but cod as small as 20 cm in length can prey on juveniles of both species. The length range of cod which prey intensively on adult capelin and sand lance is approximately 40-70 cm, the upper limit being imprecise. Intensity of predation is highly variable.

Introduction

Capelin, *Mallotus villosus* (Müller), is a major prey of Atlantic cod, *Gadus morhua* (L.), throughout the Labrador and Newfoundland areas exclusive of the Flemish Cap, and sand lance, *Ammodytes dubius* Reinhardt, is particularly important as food on Grand Bank and St. Pierre Bank (Thompson, 1943; Popova, 1962). Capelin stocks in Subareas 2 and 3 have recently declined significantly (ICNAF, 1979), whereas sand lance on the Grand Bank appears to have increased in abundance (G. H. Winters, pers. comm.). Examination of the effects of these changes on feeding behaviour, growth and reproduction of cod requires knowledge of the size range of cod likely to be affected. Size-relationships in the predation by Atlantic cod on capelin and sand lance are examined in this paper.

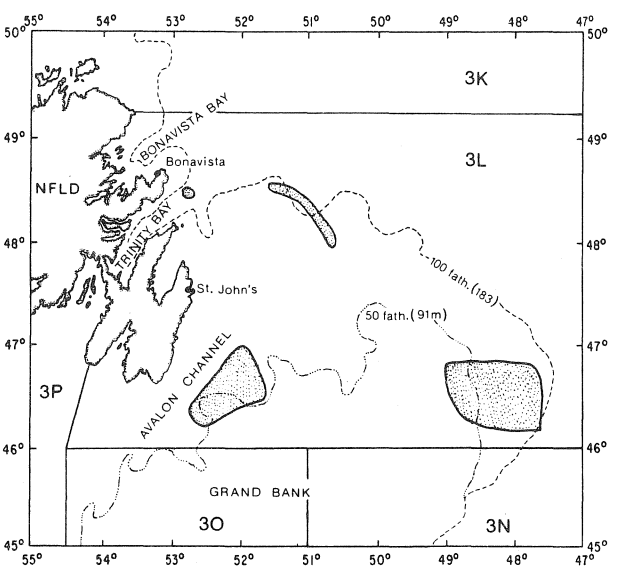

Fig. 1. Sampling locations and place names mentioned in the text.

Materials and Methods

Cod were sampled from poundnet and gillnet catches in inshore areas and from research otter trawl catches in offshore areas of Division 3L during 1966-71 (Fig. 1), and a supplementary sample was obtained from the southern Grand Bank (Div. 3N0) in June 1978. Fork lengths of cod were recorded to the nearest cm. Stomachs were excised and preserved in 10% formalin.

Stomach examination involved separating food items into taxonomic categories, the level of identification varying with the relative importance and state of digestion of the food. Items in each taxon were placed briefly on absorbent paper to remove excess liquid and then weighed to the nearest 0.1 g. In some samples, if digestion was not too far advanced, the capelin and sand lance were measured (total length) to the nearest mm. No correction was applied for any shrinkage that may have occurred.

To examine the relationship between prey length and predator length, all available measurements of capelin and sand lance from cod stomachs taken in Div. 3L were combined and supplemented with 41 sand lance measurements from 22 cod stomachs taken in Div. 3N0. For detailed examination of the effect of cod size on the intensity of predation, samples were selected from several areas where cod were feeding predominantly on capelin or sand lance (Table 1). Each sample consists of the combined data from several fishing sets. The importance of capelin or sand lance as prey in each sample was assessed as percentage occurrence and percentage contribution to the total weight of the stomach contents.

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TABLE 1. Summary results of analysis of cod stomachs relevant to predation on capelin and sand lance in the Newfoundland area, 1966–68.

Location	Date	Gear	No. of sets	No. of stomachs	Percent frequency[a]	Percent by weight[b]	PSFI
			Capelin				
Avalon Channel	May 1968	Otter trawl	5	134	51	47	1.52
Bonavista and Trinity Bays	May 1967	Gillnet	3	146	33	50	1.02
Bonavista and St. John's	Jul 1968–69	Poundnet	—	149	88	99	4.50
Off Cape Bonavista	Mar 1967	Otter trawl	2	117	85	96	5.82
North Grand Bank	Jul 1966	Otter trawl	3	80	45	74	1.01
			Sand lance				
East Grand Bank (46°–47°N)	Jul–Aug 1966	Otter trawl	6	103	58	83	2.45
East Grand Bank (46°20'N)	Jun 1967	Otter trawl	5	63	57	89	4.71

[a]Number of occurrences/total number of stomachs.
[b]Weight of designated prey/total weight of contents of all stomachs.

Partial stomach fullness indices (PSFI) were calculated to permit comparison of quantities of prey in stomachs of cod of various sizes. The PSFI of prey category P_i in fish F_j is

$$PSFI_{ij} = \frac{\text{weight of } P_i}{(\text{length of } F_j)^3} \times 10^4$$

and the average PSFI of prey category P_i in a sample is

$$\frac{1}{n} \sum_{j=1}^{n} PSFI_{ij}$$

where n is the number of cod stomachs examined. In calculating PSFI values, length was used in preference to weight as a measure of predator size, because length is not influenced by changes in the weight of liver, gonads and stomach contents. For examination of trends in PSFI with predator size, cod sizes were combined into 10-cm length groups. Any group with less than four cod was excluded from the analysis.

Results

Prey length and predator length

If the length at maturity is about 14 cm in female capelin (Carscadden, 1978) and about 18 cm in sand lance (Scott, 1968; G. H. Winters, pers. comm.), the minimum length at which cod can feed on adult capelin is about 35 cm (Fig. 2A) and the minimum length for predation on adult sand lance is between 30 and 35 cm (Fig. 2B). Smaller cod can ingest smaller individuals of both prey species, but there are insufficient data to define accurately for either prey species the maximum value of the ratio of prey length to cod length.

Stomach fullness and predator length

A changing prey spectrum with increasing body size of predator is illustrated in the cod sample from the

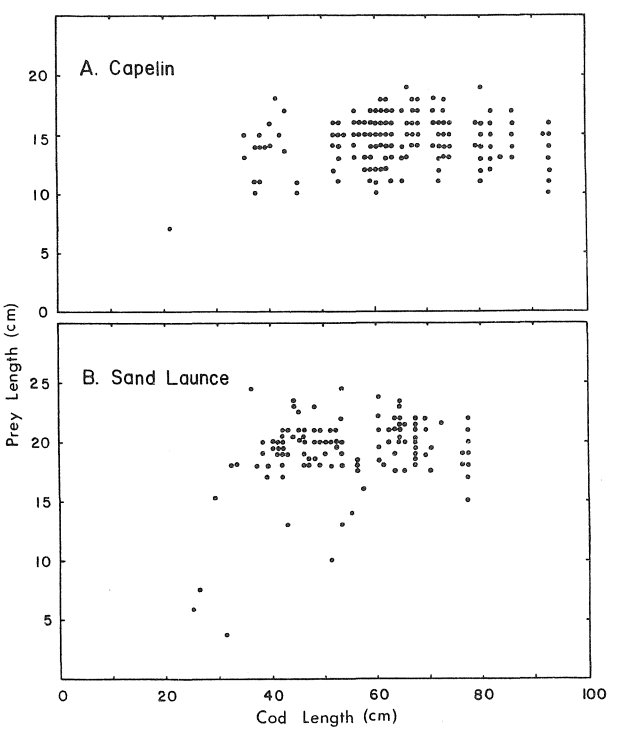

Fig. 2. Relationships between size of cod and size of capelin and sand lance. Capelin data from northern Grand Bank (Div. 3L), and sand lance data from eastern Grand Bank (Div. 3L) supplemented by 41 length measurements from southern Grand Bank (Div. 3N0).

Avalon Channel in May 1968. Cod have been reported to feed heavily on capelin in this area in the spring (Seliverstov and Kovalev, MS 1976), but, as shown in Fig. 3A, capelin was the major prey of cod only in the length range from 35 to about 90 cm. Cod smaller than 35 cm in length preyed primarily on euphausiids, and cod larger than 90 cm in length preyed primarily on crabs, which occurred as a minor component in smaller fish. This pattern of change in prey spectrum and stomach fullness with increasing size of predator (Fig. 3A) typifies the patterns seen in the limited data

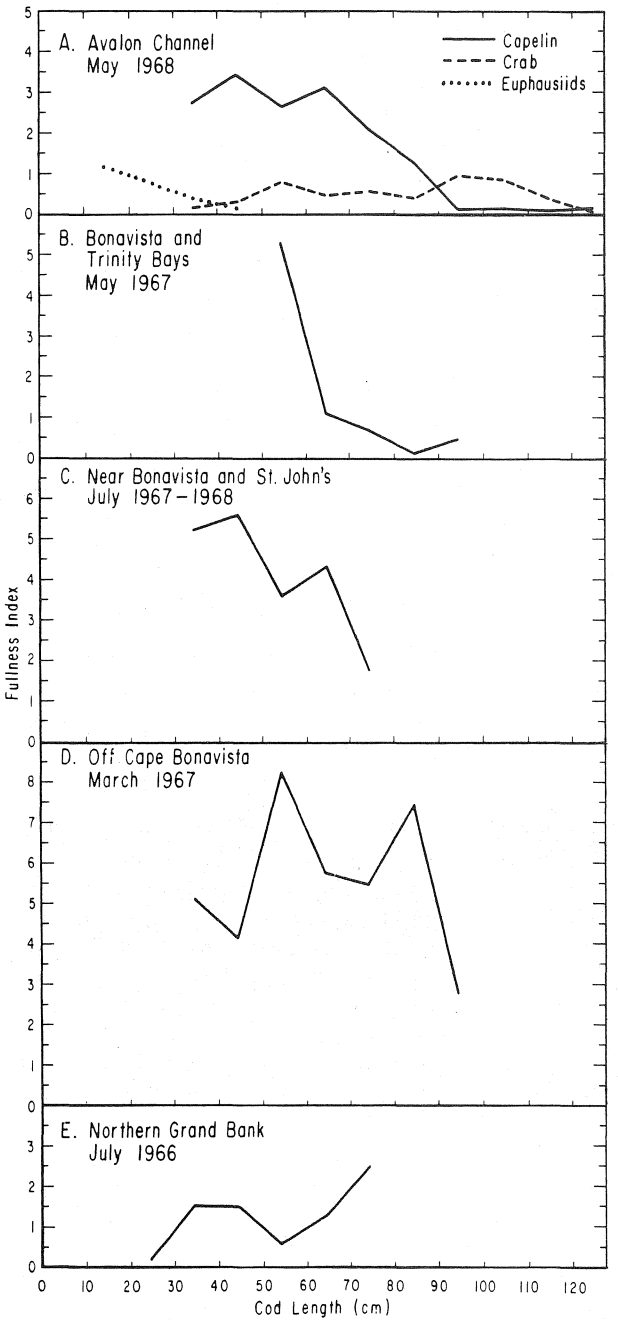

Fig. 3. Relationships between size of cod and partial stomach fullness indices for samples in which capelin was the dominant prey.

available for other areas, but considerable variation has been observed. In a sample of large cod taken by gillnet in Bonavista and Trinity Bays in May 1967 (Fig. 3B), the larger cod were not feeding intensively on capelin, which was, however, the dominant prey of the smallest size-group (50–59 cm) of cod. Crabs and shrimp were the other important prey. In a combined sample of smaller cod from the inshore trap fishery at Bonavista and St. John's (Fig. 3C), the PSFI was high (almost 6) in the smaller cod and decreased with increasing size of predator. Templeman (1965) reported that the relatively small cod taken in the inshore fishery in late spring and summer feed almost exclusively on capelin.

In a sample taken by bottom otter trawl off Cape Bonavista in March 1967, cod of a broad size range were preying intensively and almost exclusively on capelin (Fig. 3D). Even the large cod (80–89 cm) were preying heavily on capelin (PSFI about 7.5), and the stomach fullness index was higher than that recorded for the inshore cod sample (Fig. 3C). The cod were caught at depths of 228–278 m where bottom temperatures were 0.7° to 1.4° C, but no capelin were taken in the small-meshed research trawl. It is possible that the capelin were located in the colder (<0° C) overlying water of the Labrador Current, for large concentrations of capelin have been reported overwintering in the cold midwater layer in nearby Trinity Bay (Winters, MS 1968, MS 1969). Some of the capelin in the cod stomachs were only 10–11 cm in length. The other major food item was shrimp.

In a sample taken by bottom otter trawl on the northern Grand Bank in July 1966 (Fig. 3E), the pattern of predation was similar to that of the previous sample (Fig. 3D), except that the intensity of feeding was much lower. Even cod of 20–29 cm in length were feeding on capelin, presumably selecting small capelin (10–11 cm) which were also found in some of the larger cod. The other major prey were amphipods and shrimp.

Sand lance was the major prey of cod caught by bottom otter trawl on the eastern Grand Bank in July 1966 and June 1967 (Fig. 4). Cod of 20–29 cm in length fed primarily on amphipods, but some sand lance were found in the stomachs. With increasing size of cod, predation on sand lance became more intense, attaining a maximum in cod of 50–69 cm. For this size group of cod, stomach fullness in the 1967 sample was almost twice as high as in the 1966 sample. Although the reason for this is not readily apparent, the difference presumably reflects varying availability of sand lance. Changes in availability could result from seasonal variability in distribution, the July 1966 sample having been taken about 50 days later in the year than the June 1967 sample, or from variation in the degree of concentration of sand lance due to the effect of the Labrador Current, the volume of cold water being greater and water temperatures in the area being considerably lower in 1967 than in 1966 (Templeman, 1975).

Discussion

The data presented above were selected to show that the intensity of cod predation on capelin and sand lance varies with predator size and with geographic

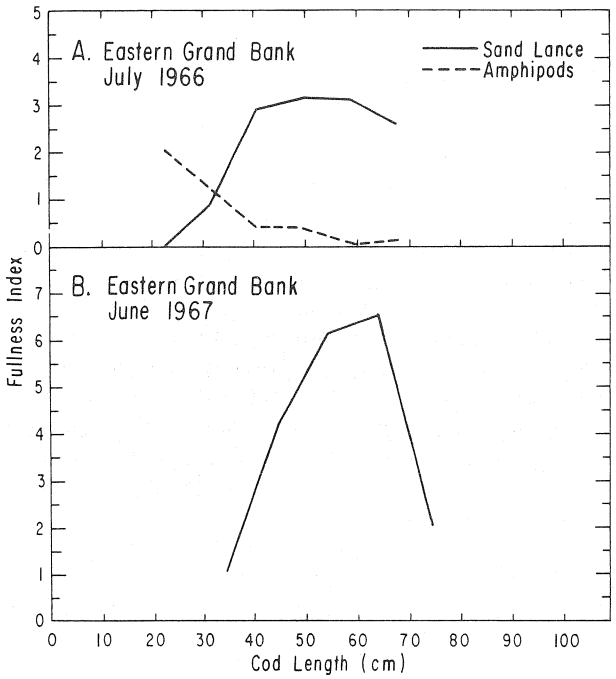

Fig. 4. Relationships between size of cod and partial stomach fullness indices for samples in which sand lance was the dominant prey.

location. Geographical and temporal comparisons of feeding behavior are often based on frequency of occurrence of a given prey as food or the percentage contribution of the prey by weight or volume to the total stomach contents. These data can be misleading indicators of feeding intensity. For example, in the two samples of cod preying on sand lance on eastern Grand Bank, the frequency of occurrence and the percentage by weight were similar in the 2 years (Table 1), but the stomach fullness index was much higher in 1967 than in 1966 (Fig. 4).

The changes in prey spectrum with increasing size of cod (Fig. 3 and 4) are in general agreement with observations by other investigators (Powles, 1958; Rae, 1967; Daan, 1973; Minet and Perodou, 1978). Small cod tend to feed on small crustaceans, such as mysids, euphausiids, amphipods and small shrimp; medium-sized cod feed on larger crustaceans and small fish; and large cod feed on crabs and medium-sized fish, such as pleuronectids. These changes in prey spectrum with increasing predator size are a consequence of an energetic requirement for larger prey (Kerr, 1971; Wankowski and Thorpe, 1979) and a morphological limitation on maximum prey size (Wankowski, 1979).

The size range of cod that prey on capelin is not easily defined. The present study indicates that cod must be about 35 cm in length to feed on adult capelin but that cod as small as 20 cm can feed on juvenile capelin (Fig. 1 and 3). A similar observation was reported by Powles (1958). Cod with the highest PSFI for capelin were approximately 40–70 cm in length, but there appears to be no precise upper limit, as cod of 100 cm or more may prey on capelin under some circumstances. Such predation by large cod may be related to high abundance and availability of capelin. The size range of cod which feed on capelin has previously been reported as 30–60 cm by Popova (1962), 35–70 cm by Turuk (1968), and 30–60 cm by Stanek (MS 1975).

Cod are presumed to feed primarily on adult capelin, but there is some evidence of predation on 10–12 cm capelin (probably age 2) off eastern Newfoundland in the northern part of Div. 3L in March (Templeman, 1965) and on the offshore banks in Div. 3K and 3L in summer (Popova, 1962) (Fig. 3). There is also one report of cod feeding on age 1 capelin (7–10 cm) in inshore waters of Div. 3K in August (Templeman, 1948). Cod at West Greenland have been reported feeding on age 2 (10–14 cm) and age 1 (3.5–6 cm) capelin (Hansen, 1949).

The intense predation by cod on capelin during capelin-spawning in inshore Newfoundland waters (Fig. 3C) is well known (Thompson, 1943; Templeman, 1965), but such predation may be intense at other times as well (Minet and Perodou, 1978). Large numbers of capelin appear to be available as food for cod which concentrate just below the very cold (<0° C) Labrador Current water at temperatures of 0.5° to 1.5° C, such as in the Cape Bonavista area in March 1967 (Fig. 3D) and on the northern Grand Bank in March 1961 (Templeman, 1965). These capelin presumably overwinter in or near the lower boundary of Labrador Current water and are accessible to vertically migrating cod.

The size range of cod which feed on sand lance appears to correspond closely to the size range of those which feed on capelin, with respect to both the overall size range involved and the sizes showing the highest stomach fullness indices. In this respect, capelin and sand lance appear to occupy very similar roles in the diet of cod.

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