The food of Arctic cod, Boreogadus saida (Lepechin), off Labrador in autumn, 1978

by

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INTRODUCTION

The food of Arctic cod, Boreogadus saida (Lepechin), has been studied at several sites in the Arctic, including the following areas in northern Canada: Amundsen Gulf (J. Hunter, pers. comm.), Dease Strait (Tyler, 1979), Cornwallis Island (Bain and Sekerak, 1978), northern Baffin Island (Bohn and McElroy, 1976) and Hudson Strait (Vladykov, 1933). The major purpose of the present investigation was to determine the food of Arctic cod of a wide size range in a previously unstudied area, the cold waters of the Labrador Current off Labrador. A second purpose was to compare the food of Arctic cod with that of another prominent but more southern pelagic species, the capelin (Mallotus villosus).

MATERIALS AND METHODS

Stomachs were examined from 42 Arctic cod collected during cruises of the R.V. Gadus Atlantica off Labrador during autumn of 1978. Twenty-two specimens of large (16.4-25.8 cm FL) Arctic cod were randomly selected from an ottertrawl catch on September 28 in NAFO Subdivision 2G ($58^{o}37'N$, $62^{o}35'W$). Seven small specimens (4.2-5.6 cm) and 13 intermediate-sized (7.7-11.5 cm) specimens were selected from a midwater trawl catch in

October in NAFO Subdivision 2J. Small specimens predominated in the latter catch. The fish were frozen whole onboard ship and examined after thawing in the laboratory.

Examination of the smaller fish (4-12 cm) involved subjective estimation of the degree of stomach fullness and identification of the stomach contents. The results are given as frequency of occurrence, defined as the number of stomachs in which a given prey category was recorded expressed as a percentage of the total number of stomachs.

Examination of the larger fish (16-26 cm) involved sorting the stomach contents into major taxonomic groupings, and weighing each group to the nearest 0.1 g wet weight. The relative importance of the various groupings was assessed using 3 indices: frequency of occurrence, percentage of total wet weight, and partial stomach fullness index (PSFI). The PSFI of prey category P_i in fish F_j is -

$$PSFI_{ij} = \left(\frac{\text{weight of } P_i}{(\text{length of } F_j)^3} \right) \times 10^5$$

and the average partial stomach fullness index of prey category P_i is

$$\frac{1}{n} \left[\sum_{j=1}^{n} PSFI_{ij} \right]$$

where n is the number of fish. The total stomach fullness index (SFI) of fish F_j is

$$\sum_{i=1}^{m} PSFI_{ij}$$

where m is the number of prey categories.

All intact prey items were measured.

RESULTS

Small and intermediate-size Arctic cod

Stomachs of all small (4.2-5.6 cm) Arctic cod were judged to be at least 2/3 full. Copepods were the major prey in all stomachs (Table 1). Hyperiid amphipods occurred as minor items in 3 stomachs. The copepods were 2-3 mm in total length (TL) and the hyperiids were about 2 mm TL.

Stomachs of intermediate-size (7.7-11.5cm) Arctic cod varied from 1/4 to 3/4 full. Copepods were the major prey (Table 1), but hyperiids and other crustaceans (probably euphausiids) were important in some stomachs. The copepods were up to 5 mm TL, and the few measureable hyperiids were about 10-11 mm TL.

One Arctic cod was identified from otoliths found in an intermediate-size (10.7 cm) Arctic cod. From the size of the otoliths, the prey was estimated to be about 4.0 cm FL, or about 37% of the length of the predator. Seven intermediate-size Arctic cod in addition to the 13 described above were examined. No further incidence of piscivory was discovered.

Large Arctic cod

The major prey of large Arctic cod were hyperiid amphipods (Table 2). Copepods and chaetognaths were of lesser importance. The quantities of hyperiids and copepods in the stomachs, expressed relative to body size of the fish (PSFI), decreased with increasing body size. Most hyperiids were well digested. Those sufficiently intact to be measured were 10-14 mm TL.

DISCUSSION

The Arctic cod is a pelagic or semi-pelagic species (Hognestad, 1968),

and the prey found in its stomach (Table 3) generally reflect a pelagic mode of feeding. Even those specimens taken by bottom trawl in the present study were feeding on copepods (predominantly calanoids), hyperiids and chaetognaths, all of which are generally found in the water column. The Arctic cod is often associated with nearshore environments (Nikolsky and Radakov, 1968; Ponomarenko, 1968), and here its prey include harpacticoid copepods, epibenthic amphipods, and other epibenthic crustaceans (Andriyashev, 1954;Bain and Sekerak, 1978). However, even most of these prey are capable of swimming off the bottom to some extent, or are sometimes associated with the undersurface of sea-ice (Bain and Sekerak, 1978). That Arctic cod very seldom feed directly off the bottom is further supported by the very low incidence of polychaetes in their stomachs (Bain and Sekerak, 1978), and the absence from their stomachs of echinoderms and benthic molluscs.

As in other predaceous fish, the prey spectrum of Arctic cod changes with size. During its first year of life, as it grows through larval stages to fry, the Arctic cod feeds primarily on eggs, nauplii and the copepodite stages of copepods but also consumes the larvae or young of a variety of invertebrates (Table 3). As the cod continues to grow, copepods become less important, being replaced primarily by amphipods (Bohn and McElroy, 1976; Bain and Sekerak, 1978; present study). As shown in the present study, the maximum size of a particular type of prey increases with fish size. Thus, in the sample from the midwater trawl the smaller Arctic cod (4.2-5.6 cm) had consumed hyperiids about 2 mm TL, whereas larger cod (7.7-11.5 cm) had consumed hyperiids up to 11 mm TL. Much larger hyperiids (25-30 mm TL) had been taken in the trawl, and an hyperiid 17 mm TL had been found in a 7.6 cm Greenland

halibut (Reinhardtius hippoglossoides), but none of the Arctic cod had consumed these larger hyperiids.

Another aspect of feeding strongly influenced by body size is cannibalism. Cannibalism in Arctic cod was mentioned by Ponomarenko (1968), and described in more detail by Bain and Sekerak (1978), who reported that young-of-the-year (2.0-3.0 cm) were eaten by much larger fish (14.1-20.0 cm). The single incidence of cannibalism found in the present investigation also involved a young-of-the-year (about 4.0 cm), but the predator was a 1-year-old, only 10.7 cm long. The sample containing this cod had consisted primarily of young-of-the-year, with a relatively small number of 1-year-olds. The prey had been near the bottom of the size range. Perhaps the low incidence of cannibalism reflects the large size of the young-of-the-year relative to the size of the 1-year-olds. If one-year-olds had been associated with the school of fry earlier in the summer, when the fry would have been relatively smaller, there may have been more extensive cannibalism. None of the large Arctic cod taken in the bottom trawl had been feeding on smaller Arctic cod.

The Arctic cod is generally considered an Arctic species and the capelin, Mallotus villosus, a Boreo-Arctic species (Nikolsky and Radakov, 1968), but their distributions do overlap off Labrador and eastern Newfoundland, especially off southern Labrador (Jangaard, 1974; Lear, 1979). In this area the prey spectrum of Arctic cod (Table 1) is very similar to that of capelin. The food of capelin collected from southern Labrador in autumn 1973 was mainly calanoid copepods and hyperiid amphipods, with euphausiids of less importance and fish larvae, thecosomes, mysids, ostracods and chaetognaths occurring infrequently (Chan and Carscadden, 1976). Studies of capelin food elsewhere

have revealed a similar prey spectrum, with the larger prey being euphausiids rather than hyperiid amphipods (Corlett, 1968; Panasenko, 1968; Prokhorov, 1968; Kovalyov and Kudrin, 1973; Vesin, 1979). To the author's knowledge, there are no reports of prey size relative to body size for capelin, but undoubtedly there will be considerable overlap between prey sizes taken by capelin and Arctic cod.

In view of the overlap in distribution and the similarity in diet between these two species, it may be important to consider niche overlap and possible competition between them. Prokhorov (1968) is of the opinion that there is no marked competition between capelin and Arctic cod in the Barents Sea because their main areas of distribution are different. The Arctic cod feeds in colder water than does the capelin. In the area of overlap in the northwest Atlantic the detailed seasonal distribution by temperature and depth and the seasonal prey spectrum by species and size for both Arctic cod and capelin remain to be elucidated.

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Table 1. The occurrence of prey in stomachs of Arctic cod caught by midwater trawl in October in NAFO Subdivision 2J.

	Occurrence	
A. Small cod (4.2-5.6 cm) N=7	Actual	P.C.
Copepoda	7	100
Hyperiidea	3	43
B. Intermediate size cod (7.7-11.5 cm) N=13		
Copepoda	13	100
Hyperiidea	6	46
Euphausiacea(?)	6	46
Chaetognatha	1	8
Boreogadus saida	1	8

Table 2. The food of 3 arbitrary size-groupings of Arctic cod taken by bottom trawl on September 28 in NAFO Subdivision 2G, expressed as percentage occurrence, percentage total wet weight (g) and average stomach fullness index.

	OCCURRENCE		GRAVIMETRIC		AVERAGE STOMACH
	N	P.C.	Wt.	P.C.	FULLNESS INDEX
A. Length: 16.4-18.9 cm N=6 Empty = 0					
Hyperiidea	6	100	2.5	89	0.81
Copepoda	4	67	0.3	11	0.10
Chaetognatha	2	33	+		+
TOTAL			2.8		0.91
B. Length: 19.0-21.9 cm. N=11 Empty=0					
Hyperiidea	10	91	3.4	92	0.37
Copepoda	6	55	0.2	5	0.02
Chaetognatha	4	36	0.1	3	0.01
TOTAL			3.7		0.40
C. Length: 22.0-25.8 cm N=5 Empty=0					
Hyperiidea	4	80	0.15	17	0.03
Copepoda	1	20	0.05	6	0.01
Chaetognatha	1	20	+		+
Unidentified			0.70	78	0.09
TOTAL			0.90		0.13

+ Unsufficient mass to be weighed

Table 3. The food of Arctic cod, *Boreogadus saida*, at various locations in the Arctic and northern Atlantic. The size or age of the fish is given whenever reported.

LOCATION	SIZE OR AGE	FOOD	AUTHORITY
Northeast Greenland	5-15 cm	mainly mysids; also copepods (*Calanus*) and an amphipod	Johansen (1912).
Barents Sea		Euphausiidae and Calanidae (*C. finmarchicus*); also amphipods, Crangonidae, small fish.	Thielemann (1922), quoted by Svetovidov (1948).
Barents Sea	adult	mainly *Calanus finmarchicus*; also Larvacea (Appendicularia) and Hyperiidae.	Hognestad (1968)
Barents Sea, Kara Sea	larvae and fry	mainly eggs, nauplii and copepodites of Copepoda; also larval or young Pteropoda, Bivalvia, Larvacea, Euphausiacea, Decapoda (Crustacea), Amphipoda	Ponomarenko (1967)
Laptev Sea		Copepoda, various species of fish	Nikolsky & Radakov (1968)
Amundsen Gulf	larvae and 0-group	Calanoida, Larvacea, Cyclopoida, invertebrate eggs, Chaetognatha, Hyperiidae, Euphausiidae, Cirripedia	J.G. Hunter (pers. comm.).
Dease Strait		Amphipoda, Calanoida, Mysidacea, larval fish	Tyler (1979)
Cornwallis Island nearshore ice cracks	1-5 year-olds	Harpacticoida, epibenthic Amphipoda; also Calanoida, Hyperiidae, Mysidacea	Bain and Sekerak (1978)
open water and under ice		Hyperiidae, Calanoida; also epibenthic Amphipoda, Pteropoda, Pisces, Mysidacea. (In both areas, cod < 10 cm ate mainly copepods; those greater than 10 cm ate mainly amphipods and the other largely organisms).	
Northern Baffin Island		Copepoda, pelagic Amphipoda (Lysianassidae) Decapoda (Crustacea) (Copepods more prevalent in fish less than 10 cm).	Bohn & McElroy (1976)
Hudson Strait	28-31 cm	Amphipoda, Mysidacea, Euphausiacea	Vladykov (1933)
Labrador	4-26 cm	Copepoda, Hyperiidea; also Euphausiacea Chaetognatha, 0-group *B. saida*. (Copepods more prevalent in small fish; hyperiids more prevalent in larger fish).	present study
Unspecified		phytoplankton, zooplankton, bottom crustaceans eggs of fish and shrimp, fish fry.	Andriyashev (1954)