Northwest Atlantic Fisheries Organization

Serial No. N271

NAFO SCR DOC. 81/II/7

SPECIAL MEETING OF SCIENTIFIC COUNCIL - FEBRUARY 1981

Influence of the Labrador Current on Predation by Cod on Capelin and Sand Lance off Eastern Newfoundland

by

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INTRODUCTION

This paper briefly describes the distribution of cod (Gadus morhua) and two of its major prey, capelin (Mallotus villosus) and sand lance (Ammodytes dubius), on the northern and eastern edges of Grand Bank, and shows that the distributions of all three species and hence the patterns of predation are strongly influenced by the Labrador Current. The cold (<0°C) inshore stream of the Labrador Current closely follows the coastline of Labrador and northeastern Newfoundland, and impinges on the bottom to depths of 200 m or more on major headlands and shallow offshore banks. To the north of the Grand Bank the current divides, one branch passing through the Avalon Channel and the other continuing along the northern and eastern slopes of Grand Bank (Smith, Soule and Moseby, 1937). Concentrations of cod may be found in both summer and winter just below the cold core of the current along coastal shelfs and shallow offshore banks (Templeman, 1962a; Templeman and Fleming, 1956, 1963; Templeman and May, 1965). In late spring and early summer the surface waters warm and some of the cod, particularly the smaller individuals, migrate through the cold intermediate layer to warmer shallow waters near the coast, where they feed intensively on capelin (Templeman, 1965). At the same time some cod from north of the Grand Bank move onto the plateau of the bank (Templeman, 1979), and these also feed on capelin (Kovalyov and Kudrin, 1973). These migration patterns and the conspicuous predation by cod on capelin in inshore areas have contributed toward an impression that the cold stream of the Labrador Current is simply a barrier between overwintering areas in the deep water and summer feeding areas in shallower water.

The purpose of this paper is to draw attention to the fact that feeding conditions for cod and other piscivores may also be good both within and immediately below the cold water. Templeman and Handrigan (1949a) reported that in summer of 1948 cod concentrated below the cold water were feeding on capelin on the northern edge of Grand Bank and feeding heavily on sand lance with some capelin on the eastern Grand Bank. Some concentrations on the eastern Grand Bank in 1949 were in cold water (-0.6° to -1.1°C), which prompted Templeman and Handrigan (1949b) to write that "the occurrence of cod in numbers as during 1949 in water below zero centigrade temperature will need further investigation. The explanation may lie in the behaviour of the food fishes launce and caplin the former being common toward the southern and the latter toward the northern part of the bank." The seasonal distribution and inferred behaviour of cod, capelin and sand lance on the eastern Grand Bank will be examined in this paper.

MATERIALS AND METHODS

Data on distributions of cod, capelin and sand lance on the eastern Grand Bank were obtained from selected groundfish surveys in 1965-70 and in 1978. The system of surveying in 1965-70 was the standard line survey, in which fishing stations were generally selected at regular depth intervals on transects perpendicular to the slope (Pinhorn, MS 1971). Seasonal coverage was most extensive on line R at approximately 45°N (Fig. 1), and only information from that line is described. All data came from trips by the A.T. Cameron, which used a 41-5 Yankee otter trawl with 29 mm liner. The survey in 1978 used a random-stratified design (Grosslein, MS 1971; Grosslein and Pinhorn, MS 1971). Only fishing sets near the shelf break or on the slope are discussed. The ship was the Gadus Atlantica, which used an Engel High-Rise otter trawl with 29 mm liner.

RESULTS

The seasonal distributions of cod, capelin and sand lance on line R on the eastern Grand Bank (Fig. 1) are provided in Table 1.

On 12-13 March 1968 cod catches were very poor in the shallower, cooler water of the Labrador Current, but catches from warmer, deeper water were moderate. Neither capelin nor sand lance were caught by the trawl. However, cod from the large catch at 117 m were reported to be feeding heavily on sand lance (unpublished Trip Report, A.T. Cameron 143).

On 30 April 1965 bottom water temperatures were warmer than in March 1968, and large cod catches were taken from depths of 108-229 m. No capelin or sand lance were caught, but the cod were reported to be feeding heavily on sand lance (unpublished Trip Report, A.T. Cameron 102).

On 21 May 1969 cod catches from the core of the current were fairly small, but again better catches were recorded from warmer waters below. Both capelin and sand lance were caught in the cold water. The main food of the cod was sand lance (unpublished Trip Report, A.T. Cameron 160).

On 8 June 1967 and 18 June 1970 bottom water temperatures were considerably below those recorded on transects earlier in the year. Catches of cod were greater in the warm water than in the cold, whereas capelin and sand lance were taken only from the cold water. There were no reports on cod stomach contents, but cod taken at similar depths at 46°20'N during the 1967 trip were feeding intensively on sand lance (Lilly and Fleming, MS 1980).

On 4-5 October 1968 and 16-17 October 1970 bottom water temperatures were again cold. Catches of cod were small, with most cod being taken from the deeper, warmer water. Capelin and sand lance were again taken only from the cold water. In 1968 stomachs were collected from 52 cod caught in sets at 148, 185 and 223 m. Although no sand lance were taken in these sets, sand lance was the major prey of the cod, occurring in 27% of the stomachs and constituting 64% of the total stomach contents by weight. A further 32% of the food was unidentifiable fish, and much of this may have been sand lance, for no other fish was identified in the stomachs.

The distribution of cod and its potential prey with respect to temperature and depth during the July 1978 survey is less readily described because fishing sets were not on transects. To illustrate that the patterns found at 45°N (line R) occurred all along the eastern slope within Div. 3N during this survey, all sets except those near canyons have been grouped by latitude and arranged by depth within each grouping (Table 2). Cod were caught in numbers only in the deeper, warmer water, whereas sand lance were caught only in the shoaler, cold water. No capelin were taken. Detailed cod stomach examinations at sea revealed that the major prey of the cod was sand lance.

DISCUSSION

Certain trends in the seasonal pattern of water temperatures and the distributions of cod, capelin and sand lance on the eastern Grand Bank are apparent in Tables 1 and 2. Examination of bottom temperatures reported here and temperature-depth profiles (unpublished A.T. Cameron Trip Reports) reveals a seasonal pattern similar to the average conditions observed at Station 27 in the Avalon Channel (Templeman, 1966). In March, April and May temperatures near the shelf break were generally greater than 0°C. There was only a small volume of colder (<0°C) water, which impinged on the bottom in March and May sections to depths no greater 100 m. By June the volume of cold (<0°C) water was much greater, reaching a depth of about 160 m in both years of observation. Water less than -1°C was now present, and impinged on the bottom at the shelf break in 1967 but not in 1970. In October the volume of cold (<)°C) water was still large, extending to about 210 m in 1968 and about 150 m in 1970. Very cold (<-1°C) water impinged on the bottom in both years. Thus, the core of the current is colder and greater in volume in June and October than in March to May, and annual variation is apparent.

The seasonal pattern of catches of cod, capelin, and sand lance could be biased by annual changes in abundance and diel changes in availability to the trawl. Nevertheless, it is apparent that cod catches tended to be largest in winter and spring. Many of the cod presumably migrated onto the shelf in summer and remained there in autumn (Templeman 1974). Capelin were neither caught in the trawl nor found in cod stomachs before late May, which is approximate time of their arrival on the southeastern Grand Bank in preparation for spawning (Kovalyov and Kudrin, 1973). Sand lance were not caught at the time of warm temperatures in March and April, but were found in cod stomachs in both months. Some large catches of sand lance were taken from cold water in May, June and October. This apparent seasonal difference in catches could reflect a migration into the area in May-June or low availability to the trawl in March and April when the core of the Labrador Current was relatively warm.

The July 1978 catches were unusual compared with those of 1965-70. No capelin were caught, and the catches of sand lance were very high. The absence of capelin corresponds with the failure of

capelin to spawn in numbers on the southern Grand Bank in 1978 (Carscadden and Miller, MS 1979; Ulltang and Sangolt, MS 1979). The high catches of sand lance are consistent with an apparent recent increase in abundance of sand lance on Grand Bank (G.H. Winters, pers. comm.), but could also be related to seasonal distribution shifts or higher susceptibility to capture by the high-lift trawl used in 1978.

As stated above, the large catches of capelin and sand lance were taken only where the cold water impinged upon the bottom. It is possible that both species are also pelagic within the cold water over greater depths. The cod could then prey upon the capelin and sand lance either by moving along the bottom to shoaler depths or by migrating vertically.

A similar stratification of predator and prey appears to exist on the northern Grand Bank. Templeman (MS 1962b; 1965) described a transect in March 1961 in which sets were made from 185 m to 666 m (Fig. 1). Cod were abundant at 185 m (1.2°C) and 230 m (2.0°C), but decreased in numbers in warmer, deeper water. The cod in these two shallowest sets were feeding well on adult and young (10-12 cm) capelin. Templeman's (1979) interpretation of both the catch and the echo-sounder records was that both cod and capelin live just below the overlying cold layer. Two sets off Trinity Bay in March 1967 (Fig. 1) in 228-278 m (0.7° and 1.4°C) yielded good catches of cod which had been feeding intensively on capelin, but no capelin were taken in the trawl (Lilly and Fleming, MS 1980). These results in both 1961 and 1967 may be interpreted in light of the observation that in nearby Trinity Bay concentrations of capelin overwinter in the cold midwater layer (Winters, MS 1968, MS 1969) which is continuous with the cold core of the Labrador Current (Bailey, 1958). It seems probable that the concentrations of capelin on the northern Grand Bank are primarily in the cold (< 0°C) water, and are preyed upon by cod migrating vertically from the warmer water below.

A similar situation may exist in more northern areas (Div. 2J and 3K) in summer and fall. On the offshore part of the Labrador Shelf in late July-early August the largest concentrations of cod were in the shallower, cold water and feeding heavily on capelin (Templeman, 1965). Presumably many cod move into the cold water in pursuit of the capelin. During the fall, capelin concentrations are found in low temperatures in the vicinity of the edge of the coastal shelf in Div. 2J and 3K and on the Hamilton Inlet Bank (Letaconnoux, 1966). Cod along the shelf and on the bank have been reported to feed on capelin at this time (Rojo, 1958; Templeman and May, 1965) and surveys in the area in 1979 and 1980 have shown Atlantic cod feeding on both capelin and Arctic cod.

It appears from the limited data available that capelin are associated with the cold stream of the Labrador Current for much of the year, and that much of the predation by cod on capelin occurs within or along the edge of this cold water. An obvious exception occurs when cod prey on capelin in warmer water both inshore and offshore during the capelin spawning season (Templeman, 1965).

The availability of capelin to cod on the northern Grand Bank in winter may in part explain why the growth rate of cod in Div. 3L exceeds that in Div. 2J. This difference in growth rate (Fleming, 1960) has been attributed to differences in temperature (May et al., 1965), there being a trend from north to south of increasing surface temperatures and decreasing volume of cold Labrador Current water. However, in both 2J and 3L the cod overwinter in warmer deeper water and in spring and summer either remain in the deep water or move to shallower warm water above the intermediate cold layer. As pointed out by Templeman (1979), cod overwintering in the deep slope waters off Labrador appear to have little food available. Presumably, most capelin are in cold water much nearer the coast and to the southwest. In contrast, cod on the northern Grand Bank can prey on capelin in winter, and cod on the northwestern Grand Bank and Avalon Channel can prey on capelin in cold water during the spring (Seliverstov and Kovalev, MS 1976; Lilly and Fleming, MS 1980). Cod on the northeastern and eastern slopes have access to sand lance in winter and spring. Thus, the period of availability of food, particularly capelin, appears to be longer in 3L than in 2J, and this might result in greater annual food consumption and thus explain the higher growth rate in 3L.

The presumed concentration of capelin and sand lance within the cold core of the Labrador Current also has implications for the feeding behaviour of other piscivores, particularly American plaice (Hippoglossoides platessoides) and Greenland halibut (Reinhardtius hippoglossoides). American plaice are most abundant within cold water (Templeman, 1966) and presumably can prey on capelin and sand lance without extensive migration. Pitt (1973) found that sand lance was the major prey (by weight) of American plaice in Div. 3N, and sand lance and capelin were the major prey in Div. 3L. Greenland halibut are most abundant in the warmer water below the cold Labrador Current, but the importance of capelin in their diet suggests that they migrate vertically in pursuit of the capelin (Lear, MS 1970). It is of interest that predation by Greenland halibut on capelin in Trinity Bay was most intensive in winter (Lear, MS 1970), when capelin were concentrated in deep, cold water, as described above.

The data presented in this paper and the review of other studies suggest that the Labrador Current tends to produce vertical habitat stratificiation in the major commercial groundfish and their prey. This stratification may be particularly important to the trophic interaction between cod and capelin. More detailed studies are required to determine if capelin and particularly sand lance are indeed concentrated pelagically in the cold water where it extends over the warmer, more saline water below,

and if cod concentrated in this warmer water do prey on the capelin and sand lance by migrating vertically. In addition, the intensity and seasonality of this feeding pattern should be investigated to determine its contribution to the annual food consumption by the cod stocks and to the mortality imposed upon the capelin and sand lance stocks.

ACKNOWLEDGMENTS

I wish to acknowledge the helpful comments of J. T. Anderson, J. Carscadden, and R. Wells, and to thank A. T. Pinhorn and S. A. Akenhead for permission to report unpublished information on cod stomach contents. G. Kean, T. K. Pitt, and R. Wells were in charge of the A. T. Cameron trips. C. Mullins aided in the literature search and H. Mullet drafted the figure.

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Table 1. Seasonal distribution of cod, capelin and sand lance on line R (approximately 45°N) on the eastern edge of Grand Bank, 1965-1970.

Depth (m)	Bottom temp. (°C)	Capelin (kg)	Sand lance (kg)	Cod	
				No.	kg.
March 12-13, 1968 (A.T. Cameron - 143)					
64	1.0	0	0	4	47
66	0.9	0	0	2	38
71	0.0	0	0	0	0
91	0.2	0	0	1	18
117	0.3	0	0	1620	1755
146	0.4	0	0	368	465
187	0.6	0	0	166	210
230	1.0	0	0	388	546
271	1.6	0	0	746	802
318	2.4	0	0	826	605
April 30, 1965 (A.T. Cameron - 102)					
73	0.6	0	0	454	179
108	1.0	0	0	4910	5479
185	0.9	0	0	4220	3384
192	-	0	0	1414	1158
229	1.3	0	0	4250	4200
309	-	0	0	-	8
May 21, 1969 (A.T. Cameron - 160)					
64	-0.1	0	0	13	15
93	-0.1	3	10	208	161
146	0.3	0	0	334	321
185	0.7	+	0	1082	1095
230	0.9	0	0	1447	1754
274	-	0	0	122	210
June 8, 1967 (A.T. Cameron - 133)					
68	0.1	0	0	25	51
64	-0.1	0	0	35	22
73	-0.7	136	0	76	117
112	-1.2	23	0	214	226
143	-0.2	0	0	1228	1144
183	0.2	0	0	646	472
227	2.0	0	0	656	572
June 18, 1970 (A.T. Cameron - 174)					
66	-0.9	1	1	0	0
104	-0.6	7	54	13	10
148	-0.1	0	0	26	43
187	0.4	0	0	18	11
229	2.4	0	0	486	346

Table 1. (Cont'd).

Depth (m)	Bottom temp. (°C)	Capelin (kg)	Sand lance (kg)	Cod No.	Cod kg.
October 4-5, 1968 (A.T. Cameron - 152)					
73	-1.2	0	113	1	18
113	-0.2	1	1	1	1
130	-0.5	0	1	5	9
148	-0.4	0	0	19	24
168	-0.6	0	0	67	91
185	-0.2	0	0	67	79
223	1.0	0	0	106	99
October 16-17, 1970 (A.T. Cameron - 178)					
66	-0.8	2	0	4	1
110	-0.6	7	+	31	6
144	-0.3	0	0	-	9
172	0.4	0	0	39	16
225	1.2	+	0	216	76
282	1.4	0	0	252	107

Table 2. Distribution of cod, capelin and sand lance on the eastern edge of Grand Bank in Division 3N, July 9-12, 1978.

Depth (m)	Bottom temp. (°C)	Capelin (kg)	Sand lance (kg)	Cod No.	Cod kg.
North of Carson Canyon (45°30'N-46°00'N)					
91	0.1	0	5	4	5
100	0.0	0	583	0	0
170	1.2	0	0	57	55
322	2.1	0	0	347	314
330	2.5	0	0	40	53
Lilly Canyon to Carson Canyon (44°55'N-45°30'N)					
88	-0.4	0	0	0	0
103	-0.8	0	432	0	0
318	2.1	0	0	155	159
Kettle Canyon to Lilly Canyon (44°05'N-44°55'N)					
54	-0.1	0	0	9	5
62	-0.9	0	0	0	0
South of Kettle Canyon (43°30'N-44°05'N)					
72	-0.6	0	335	1	4
99	-0.3	0	223	0	0
98	0.7	0	0	136	211

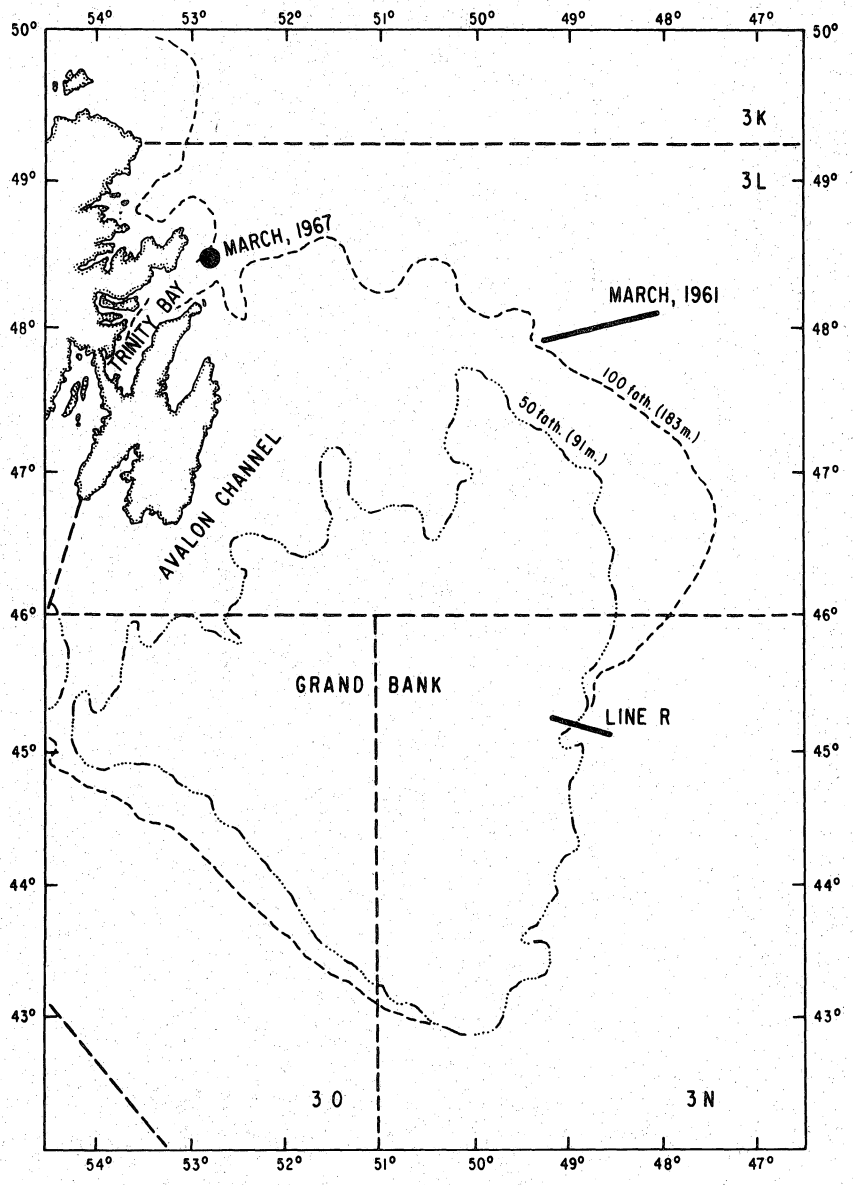

Fig. 1. Sampling positions and other localities mentioned in the text.