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Food of Atlantic Cod (*Gadus morhua* L.) near Bonavista, Newfoundland in 1983

by

G. R. Lilly

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

and

J. R. Botta

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

ABSTRACT

Atlantic cod (Gadus morhua) caught in the poundnet fishery at Bonavista, Newfoundland, in late June and July, 1983, were feeding intensively and almost exclusively on capelin (Mallotus villosus). Cod caught after July by other gears in shallow water were feeding much less intensively, primarily on benthic invertebrates. Cod caught by gillnet in deep water off Cape Bonavista had a broader prey spectrum than cod caught in shallow water, and had a mean stomach fullness index intermediate between cod caught in poundnets and cod caught by the other shallow-water gears. The appearance of large quantities of sand lance (Ammodytes sp.) in the stomachs of deep water cod in late June and early July cannot yet be explained.

INTRODUCTION

Atlantic cod (Gadus morhua) migrate to the shallow inshore waters of northeastern and eastern Newfoundland in late June and July and feed intensively on capelin (Mallotus villosus) which have approached the coast to spawn. It has been hypothesized that the cod pursue the capelin from offshore over-wintering areas to the coast (Templeman and Fleming, 1962; Templeman, 1966), and that the number of cod coming and remaining inshore, and hence the success of the inshore fishery, depend in part on the strength of the capelin spawning stock (Akenhead, et al., 1982). In addition, the intense feeding by cod on capelin in June-July and the rapid growth of the livers of cod during this period (Thompson, 1943) has led to the hypothesis that capelin provide the major food for cod, and that a reduction in capelin abundance might result in a decline in growth rate of cod (Akenhead, et al., 1982). A detailed description of the seasonal variability in prey spectrum and feeding intensity of cod is required before these hypotheses can be refined and tested.

The inshore fishery for cod off eastern Newfoundland actually comprises two fisheries, one concentrating on cod which migrate into shallow water warmed by the sun and the other exploiting cod which remain in relatively warm deep water. The intermediate cold ($\leq$0.5°C) water of the Labrador Current does not support a fishery (Templeman and Fleming, 1956; Templeman, 1966).

There have been very few studies of the food of cod in inshore areas. Templeman (1965) described the relative importance (as percentage of total volume of stomach contents) of major prey of cod caught in the shallow-water fishery at St. John's from May to November, 1947-51. From mid-June to early August the cod fed almost entirely on capelin, whereas from mid-August to late November they fed mainly on bottom invertebrates, especially crustacea. The fullness of the stomachs was not stated. Lilly and Fleming (1981) reported that capelin represented 99% by weight of the stomach contents of cod from poundnets at St. John's and Bonavista in July 1968-69. The fullness index was high but not higher than observed in cod feeding on capelin and sand lance in some offshore locations. The food of cod caught in the deep-water inshore fishery has not been reported. Templeman and Fleming (1956; p.50) described the junction of the bottom part of the cold intermediate layer and the upper part of the deeper warm layer as an area where cod concentrate and stated that "food is here in good quantity". However, they provided no data on stomach contents.

The present paper provides preliminary analysis of the stomach contents of cod caught by both the shallow-water and the deep water commercial fisheries at Bonavista, Newfoundland, from May to October, 1983. Examination of stomach contents is part of a study of factors affecting the market quality of cod landed by the inshore fishery.

MATERIALS AND METHODS

An attempt was made to collect stomachs from one catch of cod each week from each gear in use in the commercial fishery at Bonavista. Twenty samples from the deep-water gillnet fishery were obtained from the catch of the same vessel between May 11 and October 6 (Table 1). Fewer samples from shorter time periods were obtained from each of five gears in the shallow-water fishery: poundnet (5 samples), baited handline (5), unbaited handline or jig (3), longline (6), and gillnet (1). The seasonal changes in gear usage followed the pattern described by Templeman and Fleming (1956). An attempt was made to obtain up to 32 fish for each sample, with equal numbers across the available length range. Only fish which were alive when brought on board were sampled. Stomachs were removed from the fish shortly after capture and stored in ice until taken ashore later the same day. They were then transferred to a 10% formalin: sea water solution for fixing and storage.

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 0.1g. The relative quantity of food in the stomachs and the relative importance of individual prey types was assessed using stomach fullness indices. The mean total fullness index (TFI) =

$$\frac{1}{n} \sum_{f=1}^{n} \frac{\text{weight of stomach contents of fish}_f}{(\text{length of fish}_f)^3} \times 10^4$$

where n is the number of stomachs examined.

Mean partial fullness index of prey_p (PFI_p) =

$$\frac{1}{n} \sum_{f=1}^{n} \frac{\text{weight of prey}_p \text{ in fish}_f}{(\text{length of fish}_f)^3} \times 10^4$$

The stomach fullness index method is not strongly influenced by the frequent occurrence of small prey which contribute little to total weight, as is the occurrence method, and is not strongly weighted by the infrequent occurrence of large prey in large predators, as is the gravimetric method.

The length frequency of cod sampled from each gear did not closely reflect the catch because of the attempt to have all sizes in the catch equally represented in the sample. There was a difference in size among gears, with poundnet and handline fish being smallest and deepwater gillnet fish being largest.

	N	Length (cm) Median	Minimum	Maximum
Poundnet	132	53	40	79
Handline	110	54	40	76
Jig	38	59	46	81
Linetrawl	166	59	43	80
Gillnet (shallow)	15	64	60	68
Gillnet (deep)	411	67	47	115

Because the prey spectrum and stomach fullness index may vary with cod length (see, for example, Lilly and Fleming (1981)), only cod in the length range 45-79 cm were included in calculations of stomach fullness indices. This excluded 15 (3.3%) small fish and 2 (0.4%) large fish from the shallow-water examples and 45 (11.0%) large fish from the deep water gillnet samples.

RESULTS

The total fullness index (TFI) was high (5.5) in cod from poundnets, low (≤0.8) in cod from the other shallow-water gears, and intermediate (1.7) in cod from deepwater gillnets (Table 2). The high TFI in cod from poundnet was due to intense feeding on capelin. There was also some predation on sand lance (Ammodytes sp.), but no other prey were important. The TFI varied considerably among samples but remained high through the short poundnet season from late June to late July (Table 1, Fig. 1). Capelin were also the most important prey of handline cod (Table 2), but they were present only during the capelin spawning season (Table 1, Fig. 1). Samples collected in September contained no capelin and TFI values were very low. No other prey were important. The jig and linetrawl samples were obtained after the capelin spawning season and contained only small quantities of capelin (Table 1, Fig. 1). Major prey in the jig samples were toad crab (Hyas araneus) and unidentified fish. Major prey in the linetrawl samples were toad crabs (H. araneus and H. coarctatus), brittle stars (Ophiuroidea) and cephalopods (both squid and octopods) (Table 2).

Cod from deepwater gillnets had a greater variety of prey than cod from shallow water. Sand lance and capelin were most important, but there were also shrimp (primarily Pandalus borealis and P. montagui), crabs (mainly snow crab, Chionocoetes opilio), hyperiid amphipods, gastropods and bivalves (Table 2). The TFI tended to be low (<1.0) throughout the fishing season, but a dramatic increase occurred from late June to early July (Table 1, Fig. 2). Capelin increased in importance in one sample (June 22) and sand lance appeared for five consecutive samples (June 22-July 21), with high PFI values on June 27 and July 5.

DISCUSSION

The samples from cod caught in shallow water (<70 m) confirm previous reports (Templeman, 1965; Lilly and Fleming, 1981) that during the capelin spawning season (late June to late July) cod feed intensively on capelin, but that after July cod feed much less intensively, primarily on benthic invertebrates. Total fullness indices (TFI) of cod caught in poundnets during June-July tend to be about ten times higher than TFI values of cod caught later on baited and unbaited hooks. As suggested by Templeman and Fleming (1956), it appears that there is not much food for cod in the shallow inshore area after the capelin die or move offshore following spawning. It must be noted, however, that the abundance of squid (Illex illecebrosus) was very low in 1983, and that in years of higher squid abundance cod do prey on squid during late summer and autumn (G.L., unpublished data).

Total fullness indices of cod caught in deep water gillnets tended to fluctuate at relatively low levels throughout most of the fishing season (May to October). Fluctuations in TFI and prey spectrum may reflect in part changes in precise location of fishing. The appearance of sand lance in the samples from June 22 to July 21, with high PFI values on June 21 and July 5, is surprising, for sand lance have not previously been found in cod stomachs collected from deep water off Cape Bonavista (G.L. unpublished data). The fishing vessel whose catches were sampled did not change its fishing location significantly during this period. Sand lance may have migrated into the area and become available to the cod, or the cod might have recently moved quickly into the area from some other place where they had been feeding on sand lance.

Cod caught by handline during the capelin spawning season contained much less capelin than did cod caught in poundnets (Table 1). The extent to which the stomach contents of fish caught in each gear is representative of the natural population is not known, but is a major concern when consumption rates are to be calculated from stomach contents. Cod contained for some time within a poundnet might have no access to food and therefore have low stomach fullness indices compared with unrestricted cod. It is also possible, however, that if a school of capelin entered the poundnet the cod might feed intensively on them and therefore, have inflated stomach fullness indices compared with cod outside. A fishery with baited and unbaited hooks depends on cod approaching and usually biting the hook and might therefore be selectively sampling hungry fish. Fish caught with baited hooks might contain bait which might be erroneously identified as natural prey. Line trawls have the further disadvantage that the cod remain in the water for some time after being hooked and therefore might have reduced fullness indices. Cod caught in gillnets might be more representative of the population than cod caught on hooks, but again fullness indices might be reduced if fish are not landed soon after being netted. Gillnets set for a maximum duration of a few hours might provide the least biased sample, but this has yet to be studied.

The sampling at Bonavista is continuing in 1984.

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Table 1. Summary results of analysis of stomachs of cod (45-79 cm only) caught by various gears in the commercial inshore fishery near Bonavista, Newfoundland, in 1983.

Gear	Date	Depth (M)	Number of Stomachs	Fullness Index		
				Capelin	Sand lance	Total
Poundnet	June 23	-	29	5.01	0.12	5.21
	29	-	30	4.20	0.12	4.42
	July 06	27	20	10.24		10.28
	14	27	23	2.81		3.65
	25	27	20	4.62		5.02
Handline	June 20	26	29	1.49		1.69
	July 28	27	24	0.81		1.20
	Sept 09	46	16			0.14
	14	37	22			0.11
	19	42	17			0.25
Jig	Aug 12	46	11			0.21
	24	22	9			0.40
	Sept 26	42	17	0.02		0.18
Longline	Aug 26	64	25			0.40
	Sept 01	55	24	0.03		0.67
	09	55	29			0.31
	14	37	31	0.01		0.31
	19	42	29			0.44
	26	42	24			0.29
Gillnet-shallow	July 28	27	15	0.36		0.87
Gillnet-deep	May 11	302	20	0.57		0.96
	17	302	25	0.06		0.31
	27	329	21	0.80		0.91
	June 01	293	17			0.13
	10	293	13	0.31		1.14
	22	293	19	2.06	0.18	3.18
	27	293	25	0.55	7.29	9.34
	July 05	311	23		3.81	4.68
	12	311	18		0.90	1.39
	21	329	23	0.01	0.24	0.84
	26	320	21	0.06		0.51
	Aug 01	348	16	0.02		0.75
	09	348	22	0.81		1.56
	16	348	14	0.04		0.74
	23	348	13	0.03		0.77
	30	348	14	0.03		0.43
	Sept 06	348	17	0.05		0.75
	13	348	13	0.12		0.53
	21	348	15	0.01		0.68
	Oct 06	348	17	0.29		0.87

Table 2. The food of cod (45-79 cm only) caught by five commercial gears near Bonavista in 1983. Values are mean partial fullness indices.

	Gill[1] Net	Pound Net	Hand Line	Jig	Line Trawl
Invertebrata (misc.)	.01		.01	.01	.01
Gastropoda	.02	+	+		+
Bivalvia	.01		+		+
Cephalopoda	+		+		.06
Ophiuroidea	+	+	.01	.01	.08
Crustacea					
Hyperiidae	.03		+	+	+
Natantia					
Pandalus borealis	.02			+	+
Pandalus montagui	.03		+	+	+
Others and unid.	.04	+	+	+	.02
Reptantia					
Chionocoetes opilio	.03	+			+
Hyas araneus	+	+	+	.03	.02
Hyas coarctatus	+	+	+		.03
Others and unid.	+	+	+	+	.01
Others	+		+	+	+
Pisces					
Mallotus villosus	.31	5.19	.58	.01	.01
Ammodytes sp.	.81	.06			
Others	.03	.01	+	+	+
Unidentified	.35	.26	.11	.09	.02
Fish eggs	+		.02		+
Bait					.02
Unidentified	.07	+	.05	.08	.10
TOTAL	1.74	5.52	.80	.24	.40
No. of stomachs	366	122	108	37	162
No. of samples	20	5	5	3	6

+Indicates presence but partial fullness index <0.005.

[1]Deep-water gillnet only.

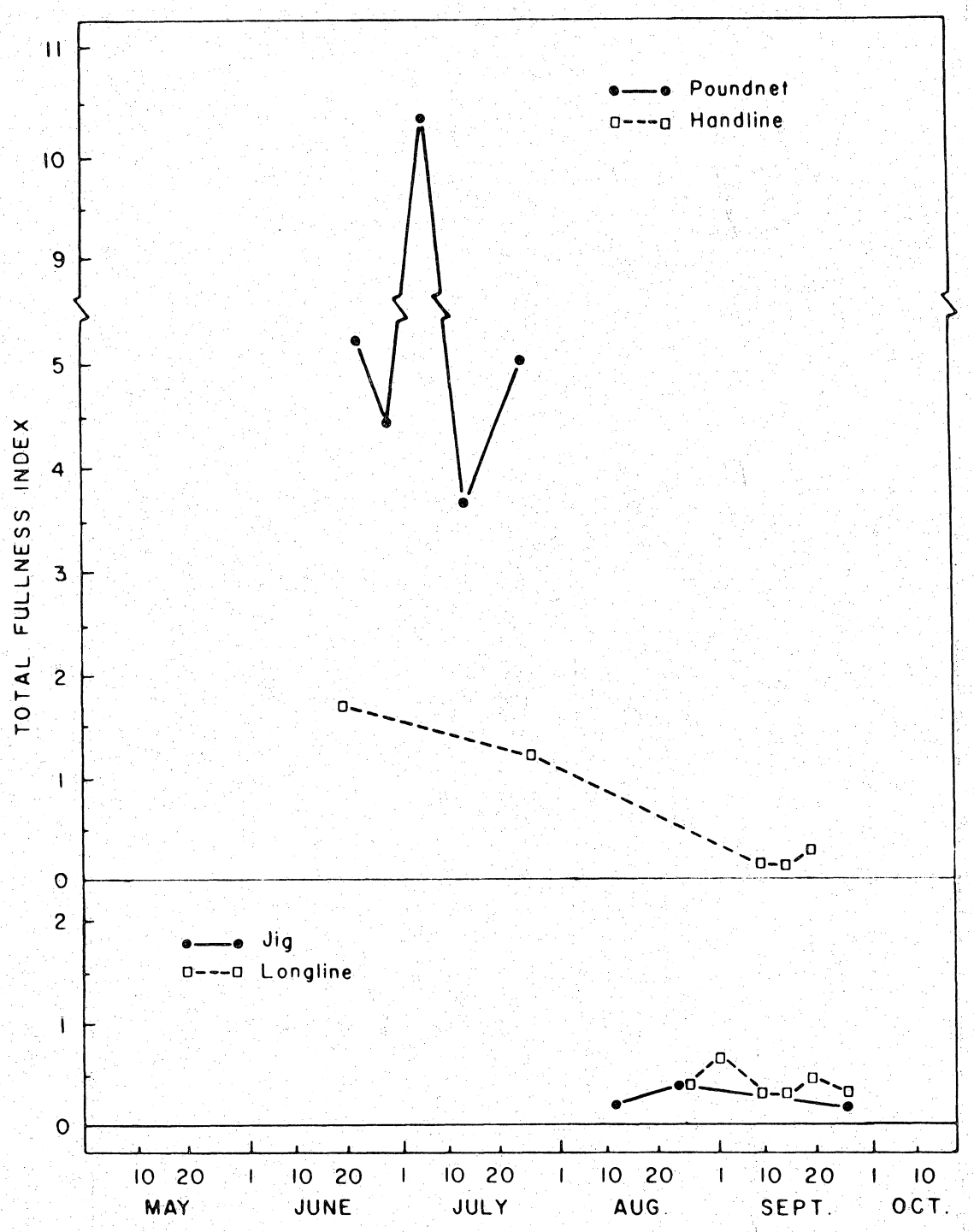

Fig. 1. Weekly changes in total stomach fullness indices in cod caught by various shallow-water gears at Bonavista in 1983.

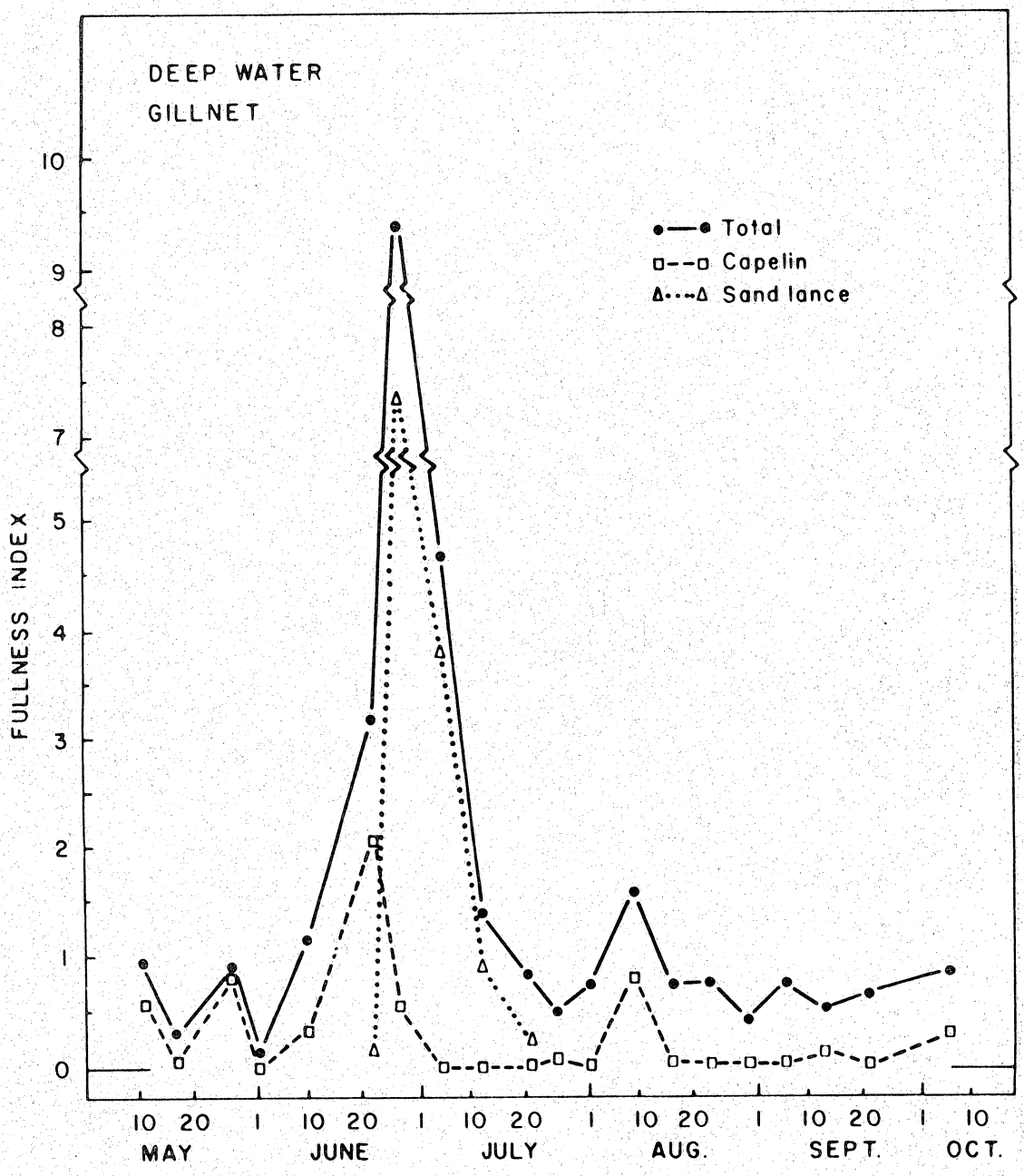

Fig. 2. Weekly changes in stomach fullness indices in cod caught by deep-water gillnets off Cape Bonavista in 1983.