NOT TO BE CITED WITHOUT
PERMISSION OF AUTHOR

CAFSAC Research Document 79/15

Food and Feeding of the Atlantic Herring (Clupea harengus L.) in the Gulf of St. Lawrence and adjacent waters

by

S. Messieh[1] H. Powles[2] and G. Côté[2]

In order to understand the dynamics of a fish population it is necessary to know its relations with the other organisms in its environment - its prey, predators and competitors. The food supply and length of the feeding season of a fish population largely affect its growth, size at maturation, fecundity and survival. On the other hand, feeding has an important effect on the food supply. The changes in food supply are most marked for pelagic fish showing large fluctuations, such as the Atlantic herring.

Food and feeding of Atlantic herring in the Northeast Atlantic have been studied extensively, e.g., the North Sea herring (Hardy 1924; Savage 1937); Atlanto-Scandian herring (Rudakov 1966); White Sea herring (Ivlev 1961); Baltic herring (Lohmeyer and Hempel 1977). However, the feeding of herring in the Northwest Atlantic has been little studied. Battle et al. (1936) dealt with fatness and food of Passamaquoddy young herring; Sherman and Honey (1970) and Noskov et al (1979) dealt with food of larval herring in the Gulf of Maine and Georges Bank, respectively. For adult herring, Paulmier and Decamps (1973) presented an inventory of stomach contents of herring in the southwest Newfoundland/Banquereau area. Maurer (1976) presented results of a preliminary analysis on inter-specific trophic relationships between herring and mackerel on Georges Bank.

The present paper reports on the food and feeding of the Atlantic herring in various areas of the Northwest Atlantic. Large numbers of samples were examined for stomach indices. Many other samples were examined in detail for qualitative and quantitative estimates of their food content.

[1] Fisheries and Oceans, Marine Fish Division, St. Andrews, N.B.

[2] Fisheries and Oceans, Fisheries Sciences Division, Quéec.

MATERIALS AND METHODS

Two sets of data were available for analysis of herring feeding: 344 samples (34,420 fish) for stomach index analysis and 44 samples (1120 fish) with identified stomach contents (Table 1).

All samples were collected from commercial catches over the period 1970-1973, thus the distribution of samples by area, gear and month reflects the pattern of commercial fisheries. Stomach index (range 0-4) was noted, 0 representing empty, 1 representing one-quarter full, 4 representing full. Stomachs for food content identification were removed at landing ports and preserved in 10% formalin; data on fish weight were taken at the same time. Food items were identified to major taxa in all samples and to genus or species when condition of the material permitted.

The degree of feeding on a particular food item was expressed by three indices: (a) stomach fullness $\frac{\text{weight of a food item}}{\text{weight of fish}} \times 10^4$;

(b) frequency of occurrence $\frac{\text{number of stomachs containing food item}}{\text{number of stomachs in a sample}} \times 100$;

(c) significance index, which is the geometric mean of stomach fullness and frequency of occurrence (i.e. $\sqrt{a \times b}$).

RESULTS AND DISCUSSION

Feeding Intensity

Between-gear comparison

Four major gear types were compared for stomach index: purse seine, trawl, gill-net and fixed gear (traps and weirs) (Fig. 1). Full or nearly full stomachs were rare in fish from all gears; stomach indices of 3 (three-quarters full) or more were found in less than 10% of herring from all areas (except for 200 fish from trawl samples in the Bay of Fundy (Fig. 1)).

In all areas, stomach index was highest in trawl-caught fish, followed by purse seine, fixed gear and gill-nets. In the Gulf of St. Lawrence (Fig .1), there was a clear separation between herring from the offshore fishery (trawls and purse seines) and from the inshore fishery (gill-nets and fixed gear), with a substantially lower proportion of index 0 and 1 stomachs in the offshore catches. Off eastern Nova Scotia (Fig. 1), there was little difference in stomach index between gear types. Stomach indices for Bay of Fundy herring from purse seines, gill-nets and fixed gear were similar, but substantially higher proportions of fish from trawl samples had stomach indices of 2-4; in fact, trawl-caught Fundy herring had the highest proportion of these heavily feeding fish of any group studied. For the Gulf of Maine (Fig. 1), only purse seine and trawl-caught fish were available; percentage of empty stomachs was similar in both but feeding purse seine fish had fuller stomachs on average than feeding, trawl-caught fish.

Stomach indices of herring in the Bay of Fundy from gill-net samples were compared with those from purse seine samples during the period May-July. These series of samples were the best data for offshore and inshore fishing gear available for comparison. Excluding a single purse seine sample which was composed mainly of fish with stomach index 4, the proportion of empty stomachs in purse seine-caught fish was insignificantly different from that for gill-net fish ($X^2 \simeq 0.11$, $p > 0.5$). Similar results were obtained comparing proportions of fish with stomach index 0-1 with proportions of fish of stomach index 2-4.

Between-gear differences in stomach index may be due either to different lengths of time spent in the net prior to collection of fish, resulting in differences in digestion rates, or to sampling of fish at different life stages (and thus in different feeding conditions) by the different types of gear. Herring caught by purse seines and trawls spend relatively short periods in the net prior to being boated (several hours) while fish caught in gill-nets and fixed gear may spend long periods in the nets (up to 24 hours). On the other hand, gill-nets and traps frequently are fished on spawning grounds and thus may sample non-feeding fish, while purse seines and trawls are fished on feeding and overwintering grounds and thus sample various maturity stages.

Comparison of gill-net and purse seine-caught fish in the Bay of Fundy during May-July suggested that the difference due to direct gear effects may be relatively small; probably the fact that the herring spend some time in the boat prior to being sampled at dockside, during which digestion may be proceeding, tends to even out the difference in time spent in the gear prior to being boated. Thus, much of the observed differences between gears, particularly pronounced in Gulf of St. Lawrence samples, may be due to the differences in biological characteristics of fish collected in inshore and offshore fisheries.

Seasonal variations

Monthly distributions of stomach index values from the four major sampling areas and four major gear types were examined for evidence of seasonal cycles in feeding intensity (Fig. 2).

Gulf of St. Lawrence herring (Fig. 2) appear to feed most intensely during the summer months (July-September); proportion of fish with stomach index 2-4 was high in purse seine- and trawl-caught fish during those months. However, high proportions of heavily feeding fish were also observed in purse seine samples in March and May. The porportion of fish with empty stomachs generally declined during the year and there was a concurrent increase in fish with stomach index 1 late in the year (October-November). The proportion of feeding fish was low in samples from gill-nets and fixed gear.

Off eastern Nova Scotia (Fig. 2), the feeding cycle appears similar to that of the Gulf of St. Lawrence; proportion of heavily feeding herring (stomach index 2-4) was high in spring and summer (April-September) in samples from all gears for which data were available. As in the Gulf, instances of heavy feeding occasionally occurred early in the year (February, trawl-caught fish). In contrast to the Gulf, the proportion of empty stomachs increased during fall to highs in October-December. Although proportions of empty stomachs were generally higher, and proportions of heavily feeding fish lower, in inshore gear than in offshore gear samples, the general cycle of feeding intensity appeared to be similar in both gear types.

Off southern Nova Scotia and in the Bay of Fundy (Fig. 2) the feeding cycle appears to be different than further north. There was a decline in feeding intensity (an increase in proportion of empty stomachs and a decrease in fish with stomach index 2-4) from April (earliest samples available) to July of August in samples from all gears available. The decline continued in gill-net-caught fish until September, but feeding intensity increased in August in trawl-caught fish and in September-November in purse seine-caught fish. All fish available in December samples had empty stomachs. Thus, the general picture is of two periods of feeding - spring and fall - separated by a summer period of relatively lower feeding intensity.

The feeding cycle in the Gulf of Maine (Fig. 2) appears similar to that off southwest Nova Scotia and the Bay of Fundy, although the summer decline in feeding continues somewhat longer. The proportion of fish with stomach index 2-4 declined from April to September, and increased markedly in October. In general, the proportion of fish with empty stomachs was somewhat lower here, throughout the period for which samples were available, than in other areas, and the proportion of fish with stomach index 1 was higher.

A somewhat similar seasonal pattern in feeding intensity was shown by comparison of the average index of fullness available for 21 samples (Fig. 3). The samples were subdivided into two general areas, Gulf of St. Lawrence and eastern Nova Scotia/Gulf of Maine, for this comparison. In the Gulf of St. Lawrence, the index of fullness varied widely throughout the period sampled; low indices were found in May and September for spawning fish, while high indices were found from May through September for non-spawning fish. Variability in samples from eastern Nova Scotia/Gulf of Maine was considerably less; samples in April and August had higher mean indices of fullness than those in September and October.

Index of stomach fullness is apparently less dependent on season per se than on maturity stages of herring (Fig. 3); fish in spawning or immediately pre-spawning condition had lower indices of fullness than pre- and post-spawning fish. This was more clearly demonstrated when variations in index of stomach fullness were plotted for fish in different maturity stages (Fig. 4). This figure shows that stomachs in general are relatively empty at maturity stages 5-6 and relatively full at stages 2-4 and 8.

Composition of the Diet

Overall composition

Throughout the sampling period, calanoids had the highest percentage of occurrence followed by euphausiids (Fig.5). Amphipods and fish eggs were present in 12% and 11%, respectively, of the herring examined while all other groups of prey were present in proportions of less than 10%.

Calanoids and euphausiids ranked first and second in their importance (significance index) for all samples for which this index could be calculated (Table 4). Chaetognaths, amphipods and pteropods were important, but their occurrence was occasional. Other prey items were much less important (Table 4).

Considering the importance of the calanoids and the euphausiids in the herring diet, we decided to concentrate our analysis on these two groups. A list is given of the calanoid and euphausiid species which were identified during this study for all the areas of sampling (Table 2).

Seasonal variations

The relative importance of calanoids and euphausiids in the herring diet throughout the fishing season was analysed for samples taken in the Gaspé/Chaleur Bay area; the lack of samples from other areas did not allow us to make such an analysis elsewhere. Seasonal variation in the percentage of occurrence and the number of organisms per fish was established (Fig. 6). Calanoids were the most frequent and abundant in July, while euphausiids were most important in May and June, declined in July and August and had a second, but smaller peak in September and October. For this area, only 4 species of calanoids and 2 species of euphausiids were identified (Table 2). Of the 579 fish examined, only 159 had contents identifiable to species. Amongst calanoids, Calanus hyperboreus , Calanus finmarchicus and Temora longicornis occured equally frequently when we considered the whole sampling period (Table 3), Calanus hyperboreus being the most frequent in May and June while Calanus finmarchicus and Temora longicornis were very frequent in May and August. The number of calanoids per fish followed the same trends (Fig. 6). Amongst euphausiids, Meganyctiphanes norvegica occured more frequently (Table 3) but Thysanoessa raschii was the more abundant. Considering the fact that Meganyctiphanes norvegica is from 2 to 3 times bigger than Thysanoessa raschii, it can be hypothesised than the former may be more important, quantitatively, than the latter in the herring diet for the area and the period under study.

The above results show that herring depend largely on holoplanktonic organisms for their food supply. Meroplanktonic organisms, although frequently occurring , are much less significant. Epibenthic organisms occasionally occur in the herring diet and could constitute an alternate, significant food source under certain conditions, e.g., when the prey organisms are moving in swarms, associated with a particular water mass or a sharp thermocline. The study of the physical and biological characteristics of the different water masses associated with herring feeding should lead to a better understanding of the pattern of herring feeding migration.

References

Battle, H., A.G. Huntsman, A.M. Jeffers, G.W. Jeffers, W.H. Johnson, and N.A. McNair. 1936. Fatness, digestion and food of Passamaquoddy young herring. J. Biol. Bd. Can. 2(4): 401-429.

Hardy, A.C. 1924. The herring in relation to its animate environment. Part 1. The food and feeding habits of the herring with special reference to the east coast of England. Fish. Invest., Lond. (2), 7, No. 3, 1-53.

Ivlev, V.S. 1961. On the utilization of food by plankton-eating fishes. (In Russian) Tr. Sevastop. Biol. Stn. 14 (Fish. Res. Bd. Can., Transl. Ser. No. 447).

Lohmeyer, U., and G. Hempel. 1977. Winter food of the Baltic herring (Clupea harengus L.). ICES C.M. Ref. P: 7, 13 p. (mimeo).

Maurer, R. 1976. A preliminary analysis of inter-specific trophic relationships between the sea herring, Clupea harengus L.and the Atlantic mackerel, scomber scomber L. ICNAF Res. Doc. 76/VI/121, 22 p.

Noskov, A.S., V.I. Vingradov, and L.G. Ptitsina. 1979. Feeding of larval herring, Clupea harengus, in the Georges Bank area, 1965-75. ICNAF Selected Papers No. 5: 43-48.

Paulmier, G., and Ph. Decamps. 1973. Studies on the food of herring (Clupea harengus) in ICNAF Divisions 3P, 4R, 4T and 4V. ICNAF Res. Doc. 73/51, 8 p.

Rudakov, V.A. 1966. Conditions and basic regularities in the feeding of the Atlanto-Scandian herring (Clupea harengus L.) in the Norwegian Sea (1951-52). Trudy PINRO, vyp. 17: 5-53(translated).

Savage, R.E. 1937. The food of North Sea herring 1930-1934. Fish. Invest., Lond. (2), 15, No. 5, 1-57.

Sherman, K., and K.A. Honey. 1970. Seasonal variations in the food of larval herring in coastal waters of central Maine. Cons. Perm. Int. Explor. Mer, Rapp. R.-v. Réun. 160: 121-124.

Table 1. Numbers of herring stomach examined for feeding study.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Gulf of St. Lawrence												
a.			199	296	2675	971	899	1180	1838	649	142	
b.					246	35	154	126	172	78		
Eastern Nova Scotia												
a.	1286	1386	895	346	52	1437	625	834	549	200	690	947
b.					50			20	50			
Bay of Fundy												
a.				200	1830	3340	2727	2873	2033	708	200	89
b.								100		50		
Gulf of Maine												
a.				319	99	291	375	522	399	315		
b.				40								

a = sampled for stomach index

b = sampled for detailed stomach analysis

Table 2. List of calanoid and euphausiid species identified during the sampling period in the Gulf of St. Lawrence, Nova Scotia and Gulf of Maine.

Calanoids	Euphausiids
Calanus hyperboreus	*Meganyctiphanes norvegica*
C. finmarchicus	*Thysanoessa raschii*
Temora longicornis	*T. inermis*
Metridia longa	*T. longicaudata*
Pseudocalanus minutus	
Tortanus discaudatus	
Eurytemora herdmani	

Table 3. Frequency occurrence (%) of calanoids and euphausiids in herring stomach samples during the sampling season in the Gaspé/Chaleur Bay area.

Species	Month					
	May	June	July	Aug.	Sept.	Oct.
Calanoids						
Calanus hyperboreus	24	38				10
C. finmarchicus	20	8		24		12
Temora longicornis	20	8		56		
Metridia longa	8	16				
Euphausiids						
Meganyctiphanes norvegica	36	15	100	84		16
Thysanoessa raschii	20	54		4		19

Table 4. Significance index of food items in herring diet.

		Food Item										
	ICNAF											
Month	Subarea	CA	EU	AM	HA	ME	CH	DL	IE	PT	FL	HY
April	515	0	0	0	0	0	0	0	0	31	0	0
May	414	120	18	0	0	0	9	5	0	0	0	3
May	438	0	31	0	7	3	6	0	12	0	0	0
July	435	115	32	0	0	0	0	0	0	0	0	0
Aug.	467	47	50	0	0	0	0	0	0	0	0	0
Sept.	431	85	110	35	0	0	0	0	0	0	0	0
Sept.	436	55	91	40	0	0	129	0	0	0	7	0
Sept.	438	13	53	18	0	0	0	0	0	0	0	0

CA: Calanoids

EU: Euphausiids

AM: Gammarid Amphipods

HA: Harpacticoids

ME: Medusae

CH: Chaetognaths

DL: Decapod larvae

IE: Invertebrate eggs

PT: Pteropods

FL: Fish Larvae

HY: Hyperiid amphipods

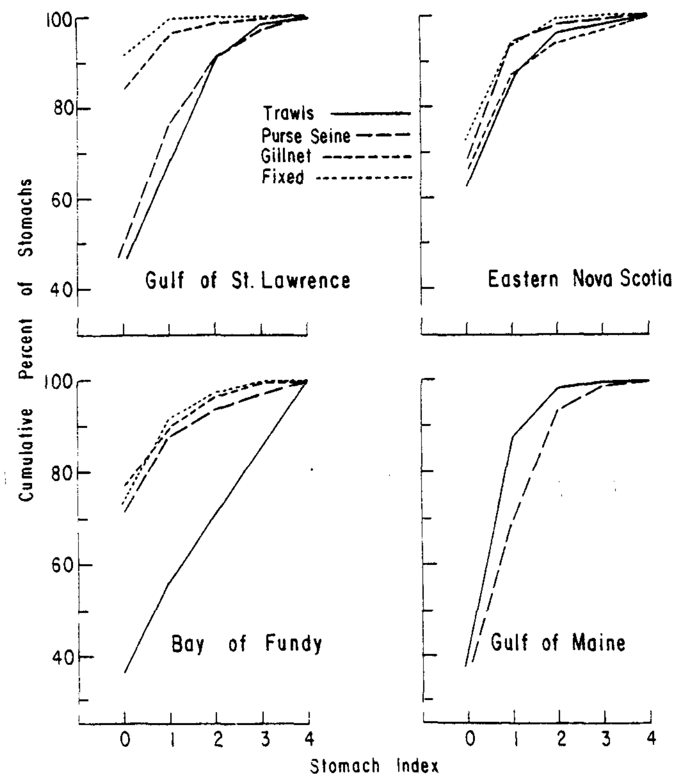

Fig. 1. Stomach indices (cumulative percent) for the four types of fishing gear from which samples were collected.

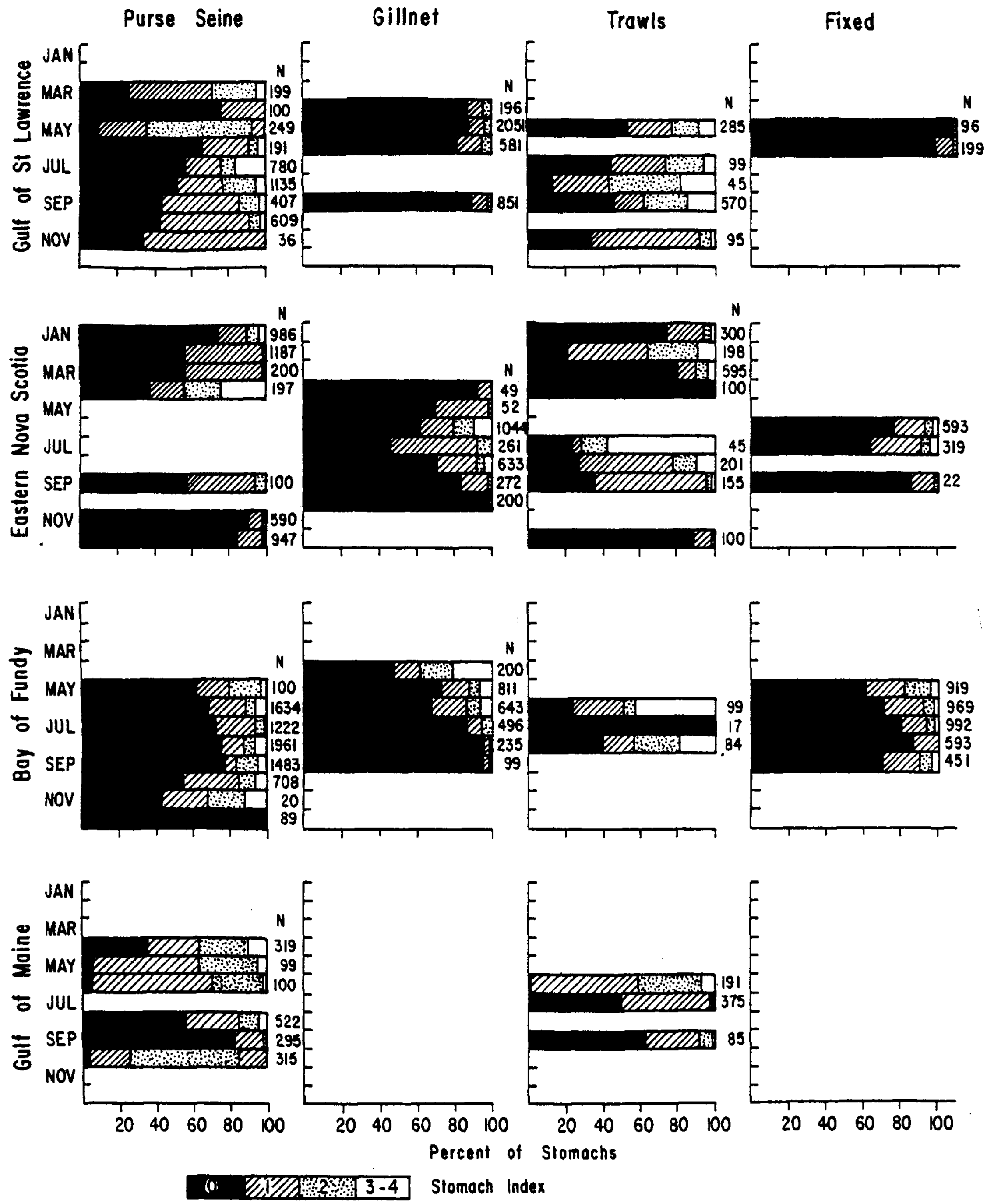

Fig. 2. Seasonal variations in stomach indices of herring samples from four areas in the Northwest Atlantic.

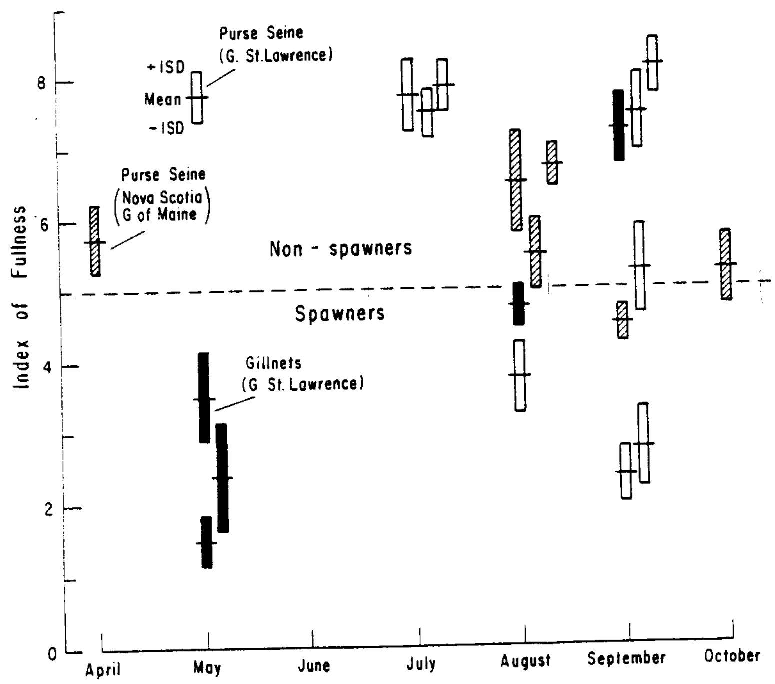

Fig. 3. Seasonal variations in indices of fullness of herring in spawning and and non-spawning condition.

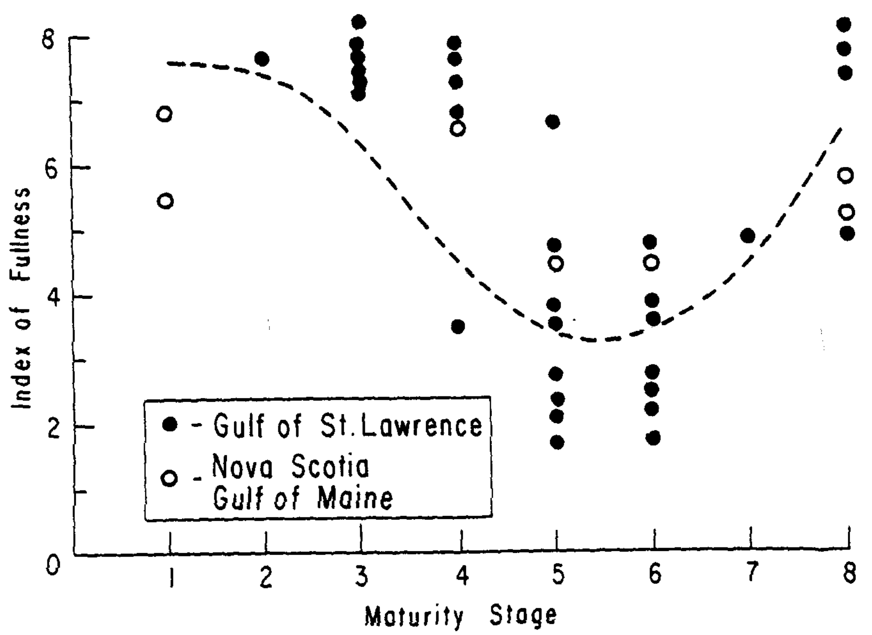

Fig. 4. Variations of indices of fullness with maturity stages.

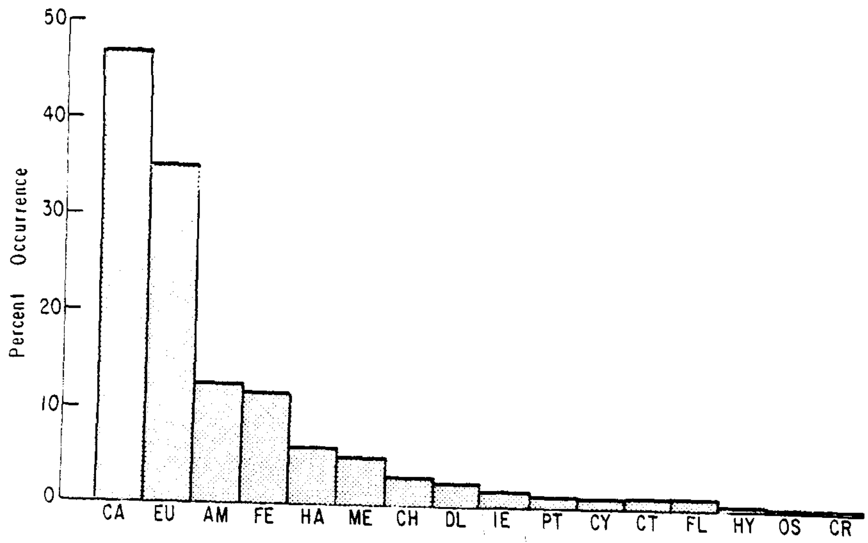

Fig. 5. Percent occurrence of different food organisms in herring stomachs.

CA	Calanoids	IE	Invertebrate eggs
EU	Euphausiids	PT	Pteropods
AM	Amphipods	CY	Cyclopoids
FE	Fish eggs	CT	Ctenophores
HA	Harpacticoids	FL	Fish larvae
ME	Medusae	HY	Hyperiids
CH	Chaetognaths	OS	Ostracods
DL	Decapod larvae	CR	Crustacea, non-identified

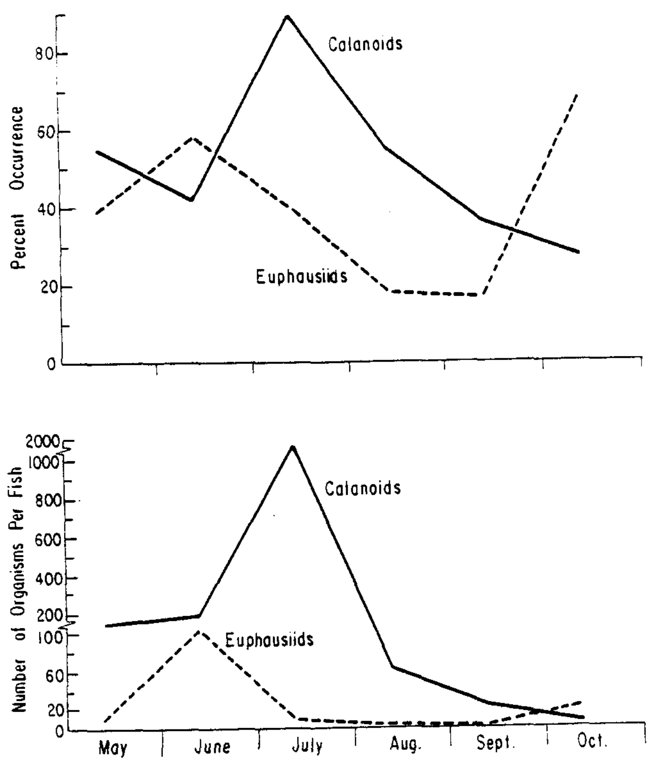

Fig. 6. Seasonal variations of frequency of occurrence and numbers of calanoids and euphausiids in herring stomachs in the Gaspé/Chaleur Bay area.