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SEASONAL VARIATIONS IN THE FOOD OF LARVAL HERRING IN COASTAL WATERS OF CENTRAL MAINE

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Observations were made of the food of larval herring Clupea harengus harengus L. as part of a study of the effects of variations in the physical and biological environment on herring recruitment in coastal waters of the Gulf of Maine.

A total of 476 larvae were examined for prey organisms. They were collected in autumn, winter, and spring, 1967-68, and in spring 1965 and 1966, during an investigation of the distribution and abundance of larval herring in coastal waters of central Maine. Larvae were collected in daylight with a Gulf III sampler and a small trawl from the Sheepscot River estuary and the coastal region in the vicinity of Boothbay Harbor. Each larva examined was measured to the nearest half-millimeter (standard length), cleared with lactic acid, and placed on a glass slide, where the alimentary tract was dissected and the contents examined under 25 to 50 magnification. The smallest fragments were stained with methyl blue and examined under high power (up to 600X). Prey organisms were identified to major taxonomic groupings. Copepods were identified when possible to species, and the lengths of intact copepods and other prey were recorded.

Composition of prey by season

The larvae were examined in length groupings to obtain a measure of the seasonal variations in the composition of prey organisms, during their development from post hatching, 7-10 mm long, to prejuvenile stages--11-20, 21-30, 31-40, and 41-50 mm long. The data for spring were combined for all years because of the low numbers of larvae available for examination. Larvae were preying principally on five groups of zooplankters--copepods, crustacean eggs and nauplii, cirriped larvae, and tintinnids. Other organisms present in the alimentary tracts, but in low incidence (in less than one percent of the larvae), were fish eggs, gastropod eggs, isopods, annelid larvae, and phytoplankton. The few phytoplankters observed were partially digested and occurred only with copepod remains, suggesting that they may have been initially ingested by copepods that were subsequently eaten by larval herring. A total of 29 percent of the larvae examined were infested with cestode and trematode parasites.

In early autumn, during the critical stages of development from endogenous to exogenous feeding, the recently hatched larvae (7-10 mm) prey on crustacean nauplii of copepods and decapods. Copepods are the predominant prey in winter among the principal size group of larvae, 21-30 mm long. In spring cirriped larvae (nauplii and cyprids), crustacean eggs, and tintinnids are important prey, but as in other seasons copepods are the predominant food among the major size group (31-40 mm) of larvae (table 1).

The composition of the copepod prey of larvae varies seasonally. In autumn, the newly hatched larvae (7-20 mm) feed principally on copepod nauplii and copepodites. In winter, the larger larvae (21-30 mm) prey on Pseudocalanus minutus and Oithona sp. (O. similis and O. spinirostris), and in spring the principal prey among the predominant size group (31-40 mm) are harpacticoid-cyclopoid species, P. minutus, and Oithona sp. (table 2).

Prey selection

Of the 476 larvae examined, 273 contained food (57 percent). The incidence of feeding and non-feeding larvae is shown in table 3. A chi-square value of 6.12 (2 df) indicated that the differences in the incidence of feeding among the seasons was significantly different ($P < 0.05$); feeding decreased from autumn to winter and increased in spring. Zooplankton volumes obtained from collections made in the region of sampling in 1966[1/] were examined for differences among the seasons with the Kruskal-Wallis analysis of variance. Seasonal differences among the zooplankton volumes (cc per $10m^3$ per tow) were significant ($P < 0.05$); volumes increased from an annual low in winter to a summer high and declined in autumn (fig. 1). Although the standing crop of zooplankton is lowest in winter, the larvae that feed ingest increasing numbers of prey as they grow from hatching in autumn to the late prejuvenile stage in spring (table 4). It is probable that the increase in food intake is a reflection of the increased metabolic demand of the larger larvae. The decrease, however, in the numbers feeding in winter suggests that the low availability of prey may be critical to larval survival in this season.

With the onset of the spring increase in the standing crop of zooplankton, the larvae utilize a wider variety of zooplankton prey including cirriped larvae, crustacean eggs, and tintinnids in addition to the smaller copepod species --Pseudocalanus minutus, Oithona similis, harpacticoid-cyclopoid sp., Acartia sp., and Temora longicornis. The wide variation in the size of prey from autumn to spring is reflected in the large standard deviations among prey in each of the size groups (table 5) and the wide scatter of points in fig. 2, representing the size of prey by size groupings of larvae. Although herring larvae are known to be selective feeders (Blaxter 1965)[2/] our findings suggest that they are also opportunistic, selecting prey organisms within a wide range of sizes as they become available in the plankton. Within the period of our collections, larvae appear selective for prey size only in the earliest stages of development, when relatively large zooplankters (copepods, decapods, brachyuran larvae etc.) may be available, but cannot be eaten because of the limited size of the larvae.

Collections of larval herring and zooplankton forage will be continued in each of the seasons through 1970, to obtain an estimate of the affects of annual variations in feeding on survival and recruitment.

1/ Clarke-Bumpus samplers were towed in daylight simultaneously from the surface, 10, 30 and 60 meters depending on bottom topography. The samplers were fitted with nylon netting of 0.36 mm apertures. Tows were made at seven locations from the inner Sheepscot estuary to approximately 28 kilometers off the central Maine coast.

2/ Blaxter, J. H. 1965. The feeding of herring larvae and their ecology in relation to feeding. Calif. Coop. Fish. Inv. Reports 10: 79-88.

Table 1. Seasonal variations in the food of larval herring in central Maine coastal waters.

Season and length group	Number of larvae with food	Number of larval herring with: Cirriped larvae	Copepods[1]	Crustacean eggs	Crustacean[2] nauplii	Tintinnids
Autumn						
7-10	20	---	9	---	12	---
11-20	34	---	34	---	3	---
21-30	1	---	1	---	---	---
	55		44		15	
Percent			80.00		27.27	
Winter						
11-20	4	---	2	---	1	---
21-30	59	---	58	7	3	---
31-40	10	---	10	---	---	---
	73		70	7	4	
Percent			95.89	9.59	5.48	
Spring[3]						
21-30	21	2	18	4	---	---
31-40	108	81	86	34	1	24
41-50	16	14	12	13	---	---
	145	97	116	51	1	24
Percent		66.90	80.00	35.17	<1	16.55
Total	273	97	230	58	20	24
Percent		35.53	84.25	21.25	7.33	8.79

1/ Includes copepodites and copepod remains.

2/ Includes copepod and decapod nauplii.

3/ Present in spring, but in less than one percent of the feeding larvae were fish eggs, gastropod eggs, isopods, annelid larvae, and phytoplankton remains.

Table 2. Seasonal variation in the copepod food of larval herring in central Maine coastal waters.

Season and length group	Number of larvae with copepod prey	Number of larvae with: Copepodites	Copepod remains[1/]	Acartia sp.[2/]	Eurytemora herdmani	Harpacticoid-cyclopoid sp.	Oithona sp.	Metridia lucens	Pseudocalanus minutus	Temora longicornis
Autumn										
7-10	9	8	---	---	---	1	---	---	---	---
11-20	34	34	2	1	---	1	2	---	---	---
21-30	1	---	1	---	---	---	---	---	---	---
Total	44	42	3	1		2	2			
Winter										
11-20	2	---	1	---	---	1	3	---	---	---
21-30	58	5	8	4	4	---	17	---	35	---
31-40	10	2	1	---	---	---	2	1	7	1
Total	70	7	10	4	4	1	22	1	42	1
Spring										
21-30	18	---	3	2	---	1	8	---	13	---
31-40	86	8	34	12	---	40	31	---	41	8
41-50	12	4	2	1	---	13	2	---	2	---
Total	116	12	39	15		54	41		56	8
Total	230	61	52	20	4	57	65	1	78	8
Percent		26.52	22.61	8.69	1.74	24.78	28.26	0.43	33.91	3.48

1/ Copepod fragments from which no species determinations could be made.

2/ Two species were present, Acartia longiremis and A. clausi.

Table 3. Incidence of feeding of larval herring, 1965-68, in coastal waters of central Maine.

	Season			
	Autumn	Winter	Spring	Total
Total number of larvae	96	143	237	476
Number of larvae feeding	55	73	145	273
Number of larvae not feeding	41	70	92	203
Percent of feeding larvae	57.29	51.05	61.18	57.35

Table 4. Mean numbers of prey organisms of larval herring in central Maine coastal waters[1/].

Season and length group (mm)	Number of larvae feeding	Total number of prey organisms	Mean number of prey per larva	Number of larvae with copepod remains	Number of larvae with tintinnid remains
Autumn					
7-10	20	26	1.3	---	---
11-20	34	59	1.7	2(P)[1/]	---
21-30	1	---	---	1(P)	---
Winter					
11-20	4	7	1.8	2(P)	---
21-30	59	201	3.4	7(P)	---
31-40	10	25	2.5	1(P)	---
Spring					
21-30	21	75	3.6	3(P)	---
31-40	108	1319	12.2	27(P)	19(P)
41-50	16	220	13.8	1(P)	---

1/ (P) Prey organisms present as remains but not included in the calculations of mean numbers.

Table 5. Mean length, variance and standard deviation of larval prey for each size group of larval herring, autumn, winter, and spring, 1967-68.

	Season								
	Autumn		Winter			Spring			
Length group of larvae (mm)	7-10	11-20	11-20	21-30	31-40	21-30	31-40	41-50
Mean length of prey	0.421	0.514	0.629	0.638	1.048	0.697	0.578	0.495
Variance	0.130	0.495	0.197	0.940	0.240	0.509	3.189	0.460
Standard deviation	0.360	0.704	0.444	0.969	0.489	0.714	1.786	0.678

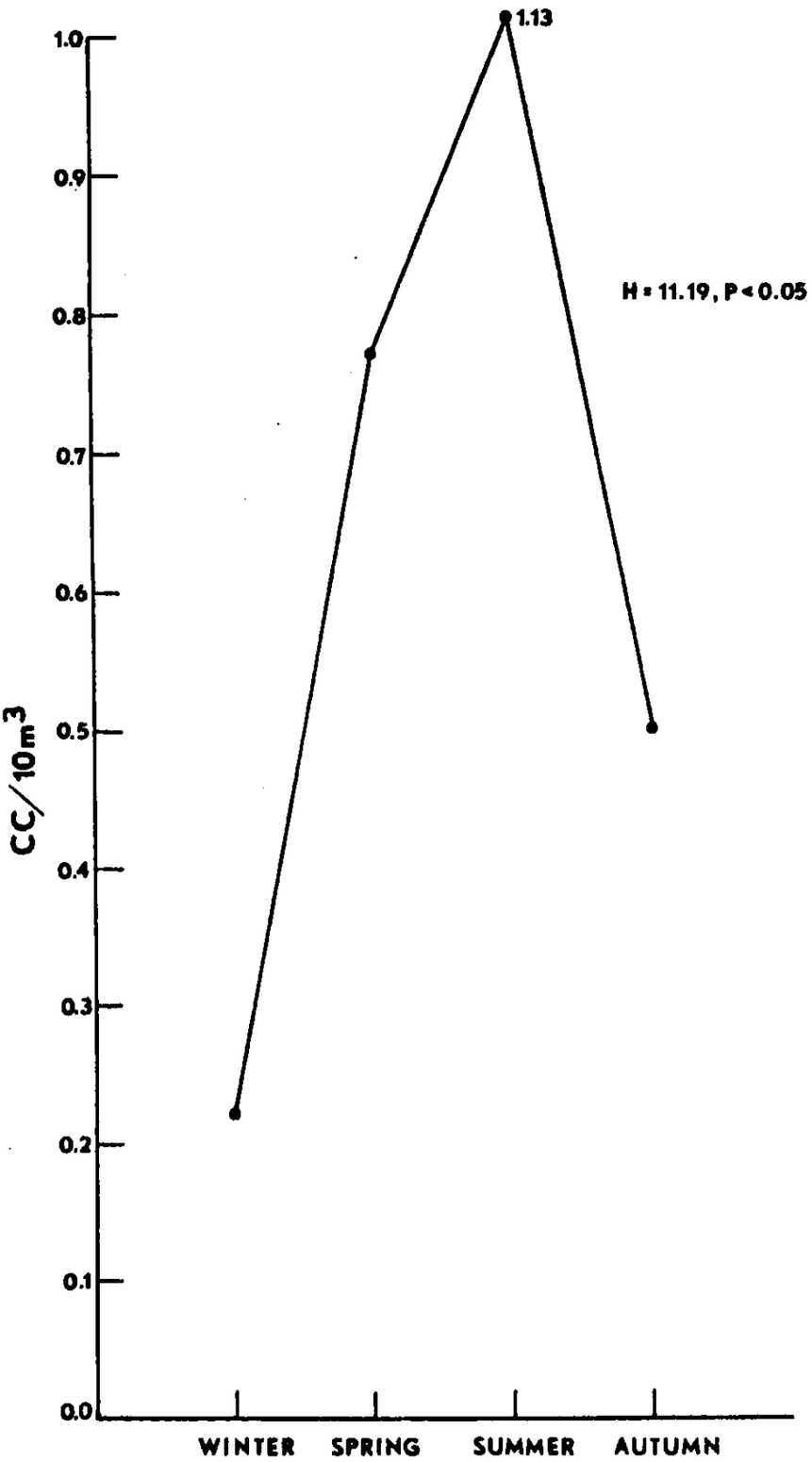

Fig. 1. Mean seasonal volumes of zooplankton in coastal waters of central Maine in 1966. Kruskal-Wallis H value is given for the among season comparisons.

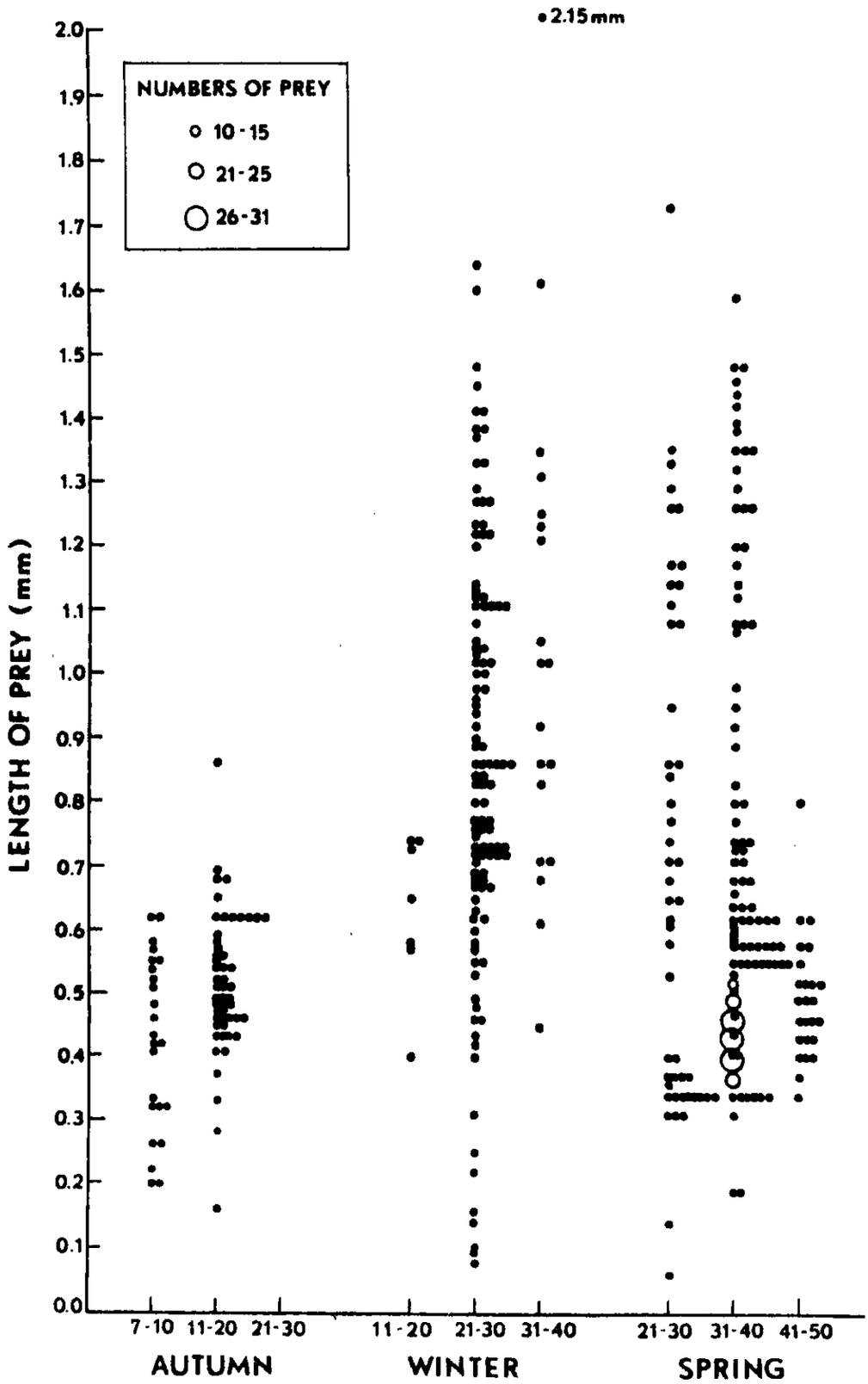

Fig. 2. Size of prey by size groupings of larvae collected from central Maine coastal waters, 1967-68. Each dot represents a single prey organism. The symbols represent numbers of prey organisms in groupings of 10-15, 21-25, and 26-31.