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PREDATION ON HERRING (CLUPEA HARENGUS) EGGS AND YOUNG LARVAE

by

Arne Johannessen

Department of Fisheries Biology, University of Bergen, Norway

ABSTRACT

The study presented here is part of a greater project dealing with recruitment studies of a local herring stock in Lindåspollene north of Bergen.

Fish predators on herring spawn, mainly cod and haddock, were trapped in entangling nets near the spawning ground during 1978, 1979 and 1980. On the basis of stomach contents of these fish species, one has tried to estimate to which degree fish predation on herring spawn influences total egg mortality. During years with moderate and heavy spawning, fish feeding on herring eggs seems to play a minor role in Lindåspollene, but during years with ligh spawn (1978), fish predation was estimated to make up maximum 40-60% of total egg number. These estimates depend closely on fish abundance which is insufficiently known. On the basis of mean stomach contents and values obtained from the literature on food consumption and daily energy requirements, a cod specimen has been calculated to ingest about 15-20 000 eggs daily.

Staging of herring eggs in fish stomachs indicates that the natural mortality of herring eggs is variable, and increases towards the time of hatching.

In situ observations of planktonic invertebrates preying on newly hatched herring larvae, confirm the presumably high predator potential of planktonic invertebrates previously reported (FOSSUM and JOHANNESSEN 1979). *Bolinopsis* sp. and *Sarsia* sp. especially, but also *Pleurobrachia* sp. and other

medusae-species were recorded in situ preying on herring larvae.

INTRODUCTION

Haddock, cod and saithe with their stomachs filled with eggs of benthic spawners have been used for years by fishermen to locate their fishing grounds, and by scientists as an indication to how close they are to the spawning grounds of herring and capelin. HEMPEL and HEMPEL (1971) used haddock feeding on herring eggs as a tool for estimating the relative frequency of dead eggs on a spawning ground.

Several years of study on the recruitment of herring has indicated that fish are among the most important predators on spawn depositions. The present study was conducted in order to obtain an estimate of egg loss from a herring spawning ground due to fish predation. This requires information about rate of ingestion as well as feeding patterns of the predator fishes, and also knowledge about their daily energy requirements.

The study was performed at the spawning grounds of a local herring stock in Lindåspollene north of Bergen (see LIE et al. 1978) during the years 1977-1980.

Predation on fish larvae is assumed to be of great importance in the sea, although very little is known about to which extent it occurs. LEBOUR (1925) observed herring larvae in the guts of several species of medusae, and also in *Pleurobrachia* sp. and *Tomopteris* sp.. STEVENSON (1947, 1962) also reported ctenophores to prey heavily on *Clupea pallasii*-larvae.

A preliminary study on invertebrate predation on fish larvae reported in 1979 (FOSSUM and JOHANNESSEN 1979) revealed that *Bolinopsis* sp. and *Sarsia* sp. are probably important predators on newly hatched herring larvae, but no in situ observations were available for verification. In 1980,however,in situ observations were performed by scuba diver on a herring spawning ground to find support for the hypothesis that several planktonic invertebrates that cooccur with the hatching of herring larvae exert a considerable predator pressure on newly hatched fish larvae.

MATERIAL AND METHODS

Cod and haddock were caught with entangling nets near a herring spawning ground located by scuba divers in Lindåspollene 3 miles north of Bergen. The entangling nets were set in the evening and hauled the next morning.

All fish in a sample were measured for total length and the stomach was dissected off, put into a plastic jar, preserved with 4% seawater formalin and labelled for subsequent examination in the laboratory. Each stomach was determined for volume and a sample of eggs was collected from each of the three regions, anterior-, mid-, and posterior-part. The eggs from each region were sorted into the following groups (according to HEMPEL and HEMPEL (1971)):

- I eggs hyaline with embryo clearly visible;
- II eggs containing an opaque mass in which the embryo is still discernible. These eggs might have been alive at ingestion, but are in a more advanced stage of digestion;
- III eggs containing a more or less homogeneous opaque mass. These eggs resemble those with unsuccessful fertilization.
- IV eggs damaged, parts of the embryo visible
- V eggs damaged, no embryo recognizable;
- VI empty shells. Some of these might have been damaged at ingestion and lost their embryo.

RESULTS AND DISCUSSION

During April 1978 (one week after herring spawning), May 1979 (shortly before hatching of herring eggs) and May 1980 (one week after main spawning and also close to time of hatching), 34 cod (31-78 cm, mean 42,3 cm) and 20 haddock (35-60 cm, mean 48.0 cm) were examined for stomach contents. Mainly herring spawn, but also small fractions of algae and other bottom substrates had been ingested. Cod greater than about 50 cm was observed to have ingested adult herring only or in addition to herring spawn. In 1980 a cod of 55 cm was recorded with 5 adult herring and no spawn, and another 49 cm cod with one adult herring and 28 000 herring eggs. The feeding incidence of cod and haddock with herring spawn seemed to be very high close to the spawning grounds of herring during all the three years (Table 1).

The number of herring eggs per stomach, mean 15 110 (0-207 220) for cod and mean 3 666 (468-16 420) for haddock, indicates that there is a great variability in the number of eggs recorded in the stomachs of cod and haddock at any particular point of time

(Table 1). Feeding intensity tends to be higher in 1980 than in previous years, which probably can be explained by the far greater spawn density in 1980.

The correlation between egg number per stomach with standard length of cod was significant at 5%-level (r^2=0.50).

In the subsequent calculations on predation rates of fish feeding on herring spawn, only data from cod has been used.

Relative frequency of dead eggs

The majority of eggs was recorded from the mid and the posterior regions of the stomach, indicating that ingestion had taken place some time prior to time of catching and gear handling. According to HEMPEL and HEMPEL (1971), eggs in the stages of digestion I, II and IV were alive at ingestion, while III and V were supposed to be dead.

From Fig. 1, 2 and 3 it is apparent that stage I - eggs in general predominated in the anterior region of the stomach of both cod and haddock. Due to progressive digestion when passing posteriorly, the percentage of dead eggs in the posterior regions are presumably overestimated, as was pointed out by HEMPEL and HEMPEL (1971). Consequently, sampling of eggs for the estimation of mortality should be done from the anterior region only. The percentage of living eggs in this region was 75.8% in average for the three years, ranging from 0-100%. The great range in mortality may be due to heterogeneity in bottom substrates and differences in sampling time relative to stage of egg development. Mortality estimates of demersal eggs based on passive gear sampling with an extended fishing time are also adhered with several errors, of which time from the fish being trapped till being released and the stomach contents fixed may be the most important. Other kinds of active gear would be more appropriate for this aim.

Fish feeding on herring eggs

TYLER (1970) in his study of gastric emptying in young cod in relation to temperature and meal size, presented some information necessary for feeding rate estimates. He observed a curvilinear relation between rate of gastric emptying and quantity of food in the stomach. On the average, rate of gastric emptying will equal rate of ingestion. This led TYLER (1970) to assume that daily rations for fish could be estimated by obtaining data on quantity of food in the stomach. Mean rate of depletion that the cod can achieve may thus be calculated by applying the mean quantity of food that the fish can hold in its stomach. In this study the mean number of eggs per stomach of any cod irrespective of size is used, presuming that the mean value observed closely corresponds to the average of the fish length groups present on the spawning ground. Use of mean number of eggs per stomach would probably tend to underestimate the food consumption of fish caught with nets, because the stomach content will have been processed to various degrees depending on time lapse from a fish was trapped and feeding ceased, till the entangling nets were hauled.

In the subsequent calculations a mean egg number per stomach of about 15 000 for cod will be used. An egg dry weight of about 0.180 mg/egg (Table 2) gives thus a dry weight of about 2.7 grams per mean filling of stomach for cod. The calorific value of eggs was taken as 5 kcal/gram dry weight without chorion, as this constituent was regarded as indigestible. The same calorific value was also used for fish larvae (LAURENCE 1977). Conversion from wet to dry weight was taken as 5:1. Chorion makes up about 25% (17-25%) of the egg dry weight (BLAXTER and HEMPEL 1963), the remaining 75% is mainly digestible protein and fat.

By inserting the mean values observed into the equation of rate of depletion

$$\frac{dW}{dt} = -bW \quad \text{(TYLER 1970)}$$

where W = dry weight of stomach content (mg)
b = coefficient for instantaneous rate of depletion, calculated by TYLER (1970) to be 0.063 at $5^{\circ}C$ (0.14 at $10^{\circ}C$) for thawed shrimps as food, gives

$$\frac{dW}{dt} = -0.063 \cdot 2.7 = -0.17 \text{ gr. dry weight per hour,}$$

which may be interpreted as mean rate of depletion at $5^{\circ}C$. The rate of depletion is proportional to the initial meal size, whether the depletion is rectilinear or curvilinear with time (TYLER 1979). If this rate could be maintained for 24 hours, the fish would pass from its stomach 4 grams dry weight per day, which equals about 22 000 eggs/day. This means that the stomach has to be filled about 1.5 times per day in average.

Another way to calculate the effect of fish predation is to use estimates of daily energy requirements. JONES (1974) arrived at about 10 kcal/day for a cod weighing about 500 grams on the basis of stomach content weights. For haddock the estimates were about half of those for cod due to different growth rates. Similarly DAAN (1973) estimated daily ration of North Sea cod (40 cm length, 666 gr. weight) to be 8.5 grams (equals 1.7 gr. dry weight). If one converts these data into number of herring eggs, it is apparent that the data on daily energy requirements and daily ration of cod obtained from the literature are in close agreement. The figures are also comparable with the mean number of herring eggs recorded in the stomach (Table 2). This may be interpreted like the mean stomach content suffices the daily energy requirements of cod. The estimates agree also well with time of digestion presented by other authors who presume 1-6 days to be appropriate for cod, depending on temperature, size and kinds of food items (DAAN 1973, KARPEVICH and BOKOVA 1937, TARVERDIEVA 1962 and TYLER 1970).

As long as spawn is present on the spawning grounds, the predator fishes are assumed to eat it. During the incubation period of herring eggs (about 20 days at 5-6^{o}C), each cod will therefore have a predator potential of about 440 000 herring eggs based on stomach depletion rate and about 300 000 eggs based on energy requirements and daily ration estimates. In nature the consumption of herring spawn by cod will probably lie between the two estimates obtained. When food (spawn) is plentiful and easily available, predator fish will probably consume more food than just what is necessary to satisfy their daily energy requirements.

Few observations have been made that can give a reliable estimate of number of fish in the area, but based on visual observations a maximum number of about 200 fish has been suggested. This means that based on depletion rate estimates, about 60% and 12% of the total egg production recorded in Lindåspollene in 1978 and 1979 were vulnerable to fish predation (JOHANNESSEN 1978, 1979). Based on the other method, comparable estimates would be 40% and 8% respectively.

Invertebrate predation on herring larvae

At the time of hatching of herring in 1980, April 30-May 12, planktonic invertebrate species predominated by Bolinopsis and Sarsia occurred in increasing numbers. No effort was put into the estimation of density of these species, but seemed to be rather high especially in the semi-enclosed area represented by the spawning ground (LIE et al. 1978).

The spawning ground was located in a bay (Syslakvågen) from 0.5 to about 4 meters' depth. When the sea was calm, the newly hatched larvae were distributed with greatest abundance in the upper 1.5 m, and significantly smaller density below. This was also the case with the majority of planktonic animals recorded. It was not difficult to observe Bolinopsis sp. and Sarsia sp. with herring larvae in their guts. One random selected Bolinopsis-specimen was recorded with 3 herring larvae under digestion, while a small medusa, probably Rathkea sp. (4-5 mm clock-diameter) was recorded with a herring larva under ingestion with the caudal end first entering the mouth tube. Pleurobrachia was also observed with herring larvae in the gut, although less frequently.

The few observations reported here are single ones, but the feeding incidence of the above mentioned species seemed to be surprisingly high over the spawning ground during the hatching period. Their immense number and also their relatively high capacity of digestion (FOSSUM and JOHANNESSEN 1979) make them therefore highly relevant as predators on fish larvae.

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Table 1 Data from each fish specimen, cod or haddock trapped with entangling nets on the spawning grounds of a local herring stock in Lindåspollene in 1978-1980. Under the heading SP, the species and sex are given (10=cod, sex not determined, 11=cod male, 12=cod female, 20=haddock, sex not determined, 21=haddock male, 22=haddock female). Total length (TL) is given in cm. No eggs per stomach (No. egg), sample size from the anterior (NF), mid (NM) and posterior stomach region (NP), and composition (%) relative to stage of egg condition (I-V) in each region, is also given.

	Date	SP	TL	No. Egg	FI	FII	FIII	FIV	FV	NF	MI	MII	MIII	MIV	MV	NM	PI	PII	PIII	PIV	PV	NP
1.	790508	21	40	207	11	36	25	21	7	28	4	27	17	37	15	162	8	21	25	22	25	77
2.	790508	22	46	117	0	0	0	0	0	0	23	26	5	10	36	39	14	18	21	10	37	78
3.	790508	22	35	601	32	27	8	11	22	276	29	28	4	22	17	194	14	25	4	24	34	191
4.	790508	20	52	831	20	24	30	30	4	142	24	28	21	23	4	488	18	22	17	28	14	201
5.	790508	22	48	1599	4	12	38	5	42	242	0	2	51	12	35	83	1	5	50	6	39	334
6.	790508	20	52	5030	27	31	10	12	20	142	33	28	18	7	14	2688	35	30	11	10	13	2198
7.	790508	22	47	1276	28	11	11	22	28	18	21	22	15	19	23	579	19	22	17	19	24	679
8.	790508	21	46	605	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.	790508	21	52	934	0	0	0	0	0	0	2	15	44	21	18	300	2	10	22	35	31	634
10.	790503	10	41	6193	32	26	13	16	13	310	23	36	8	26	7	2236	18	34	11	32	5	3647
11.	790508	10	0	556	12	35	53	29	12	17	0	6	11	72	11	18	23	11	5	31	30	521
12.	790508	10	0	8236	50	12	14	16	8	1506	17	16	26	35	6	3300	17	19	21	38	5	3430
13.	790508	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14.	790508	10	0	9	0	0	0	0	0	0	50	33	0	17	0	6	99	1	0	0	0	3
15.	790508	10	0	105	0	0	0	0	0	0	7	13	0	40	40	15	1	9	36	38	17	90
16.	790508	10	0	10430	67	7	0	19	8	600	56	13	3	19	9	2700	32	18	5	38	7	7120
17.	790508	10	0	5035	43	12	12	21	12	268	38	12	20	22	8	1577	22	16	23	29	11	3190
18.	790508	10	0	2548	0	0	0	0	0	0	4	5	14	32	45	828	1	9	13	39	37	1720
19.	790508	10	0	2170	50	50	0	0	0	4	39	12	8	28	13	162	35	13	13	29	9	2004
20.	790503	10	44	17924	58	13	11	11	8	1504	48	14	10	22	5	7230	29	16	11	37	6	9190
21.	790503	10	58	10013	63	12	1	18	6	1003	43	19	1	32	6	2800	41	18	3	33	5	6210
22.	790503	10	42	4469	30	38	1	22	9	259	42	22	3	24	9	1730	35	30	4	23	7	2480
23.	790503	10	37	5952	43	14	43	0	0	7	14	14	33	33	7	2604	23	15	17	41	3	3341
24.	790503	10	41	14190	35	26	8	26	6	2469	30	28	11	25	7	5833	29	28	5	30	8	5888
25.	780418	10	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26.	780418	10	34	2823	80	10	10	0	0	350	40	40	20	0	0	800	20	20	60	0	0	1000
27.	780418	10	34	2150	80	20	0	0	0	0	60	20	20	0	0	0	40	20	0	40	0	0
28.	780418	10	34	3293	70	20	10	0	0	700	80	0	20	0	0	100	80	0	10	10	0	1500
29.	780418	10	35	3040	99	1	0	0	0	200	55	40	0	5	0	600	75	20	0	0	5	250
30.	780417	10	40	789	0	0	63	19	18	60	2	0	56	32	10	120	0	0	80	20	0	180
31.	780417	10	40	5089	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32.	780417	10	45	3192	99	1	0	0	0	600	80	20	0	0	0	1300	99	1	0	0	0	1100
33.	780417	10	53	15000	60	20	0	10	10	4000	40	55	0	5	0	5200	40	20	0	20	20	5400
34.	780417	20	54	5400	67	0	33	0	0	200	45	0	50	5	0	2600	40	0	20	20	20	2200
35.	780417	20	46	3280	40	40	20	0	0	580	20	60	20	0	0	1330	33	17	17	17	17	933
36.	780418	20	49	8044	50	33	17	0	0	560	50	50	0	0	0	4090	25	25	25	25	0	3056
37.	780417	20	49	1560	0	0	60	0	40	300	0	0	60	0	40	260	0	0	60	0	40	600
38.	780418	20	53	5013	50	50	0	0	0	1000	33	33	33	0	0	1300	60	0	20	0	20	2620
39.	780418	20	53	2668	60	20	20	0	0	500	60	20	20	0	0	800	20	20	60	0	0	1100
40.	780419	20	44	468	75	0	25	0	0	100	60	20	20	0	0	270	40	20	0	20	20	150
41.	780417	20	60	11812	60	20	20	0	0	2300	20	60	20	0	0	3700	50	17	0	17	17	5200
42.	780418	20	47	3111	33	0	67	0	0	970	33	0	67	0	0	1180	33	33	33	0	0	900
43.	780417	20	47	3014	60	40	0	0	0	850	40	40	20	0	0	1050	40	0	20	20	20	993
44.	800418	10	43	10450	84	0	13	3	0	360	39	0	23	20	19	128	31	0	18	35	17	180
45.	800418	10	31	21180	54	0	36	6	4	262	28	18	43	8	4	105	51	0	33	8	7	150
46.	800418	10	36	29790	58	0	22	15	4	259	50	24	21	6	0	173	22	53	5	4	15	73
47.	800418	10	42	28440	86	0	5	6	3	232	80	0	12	5	3	169	63	0	25	9	3	130
48.	800418	10	49	28080	92	0	2	6	0	228	0	0	0	0	0	0	0	0	0	0	0	0
49.	800418	10	37	33070	61	0	11	23	5	187	64	0	26	5	5	173	17	28	43	8	5	144
50.	800418	10	55	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51.	800418	10	40	44210	77	0	10	12	1	168	51	0	24	22	3	147	56	0	22	17	5	155
52.	800430	10	78	207220	88	0	1	10	0	137	48	0	38	11	3	79	29	0	42	10	19	107
53.	800430	10	37	3180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54.	800430	20	39	16420	64	0	9	16	11	114	56	0	9	25	10	100	62	0	18	12	8	134

Table 2. Daily ration estimates obtained from the literature, compared with estimates on daily rates of stomach depletion and mean number of herring eggs recorded in cod stomachs obtained from the spawning grounds of herring in Lindåspollene during 1978-1980.

Author	Daily ration Dry weight	Energy requirements Kcal/day	Herring eggs[2] number recorded in the stomach of cod, or converted from dry weight or kcal	Rate of depletion[3] of herring eggs per day (at 5°C)
-	-	-	15 000 (0-207 000)	22 000
DAAN (1973)	1.7 gr (8.5 gr.wet weight)		13 000	
JONES (1974)	-	10[1]	15 000	
Predator potential/fish			300 000	440 000

(1) Energy requirements of 4 000 kcal/year for North Sea cod and
3 000 " " " Faroe cod.

(2) Mean egg dry weight 0.180 mg, chorion (25% of weight) assumed indigestible.

(3) $\frac{dW}{dt} = -bW$ (after TYLER 1970) under the assumption of the same rate of depletion during 24 hours.

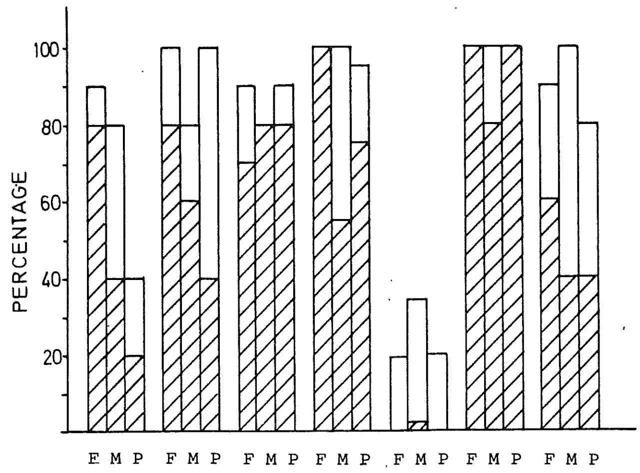

Fig. 1.1 Percentage of herring eggs alive at ingestion from anterior (F), mid (M) and posterior (P) parts of the stomach of cod sampled from a herring spawning ground in Lindåspollene on April 17-18, 1978. (Stage I-eggs -- hatched).

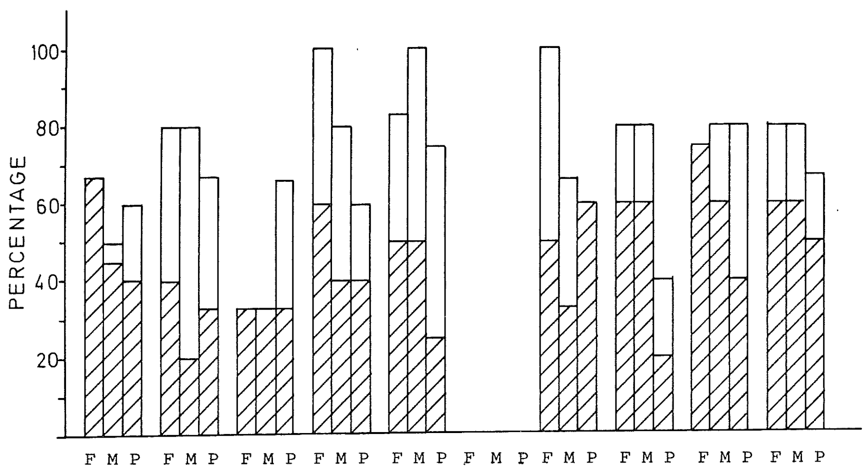

Fig. 1.2 Same as Fig. 1.1, sampled from haddock on April 17-18, 1978.

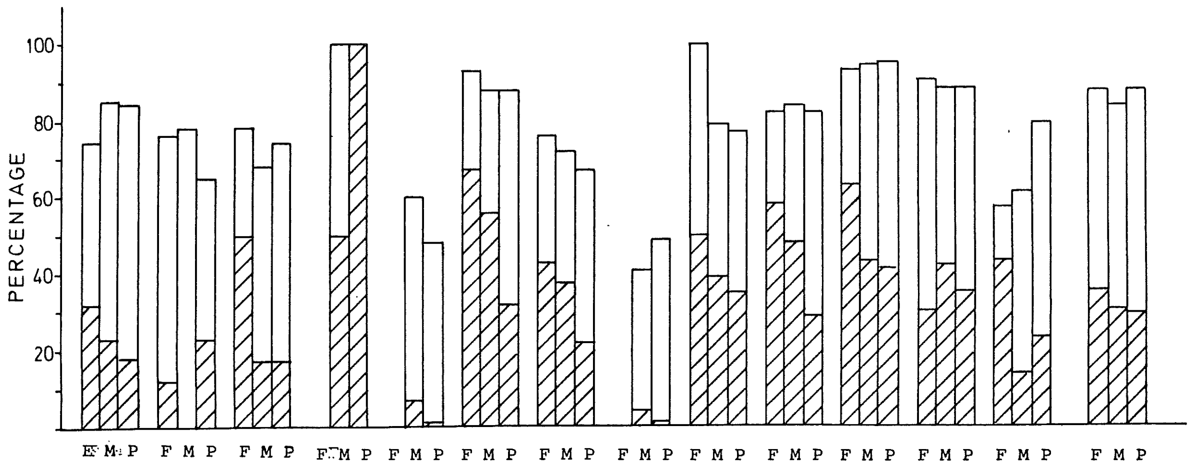

Fig. 2.1 Same as Fig. 1.1, sampled from cod on May 2-8, 1979.

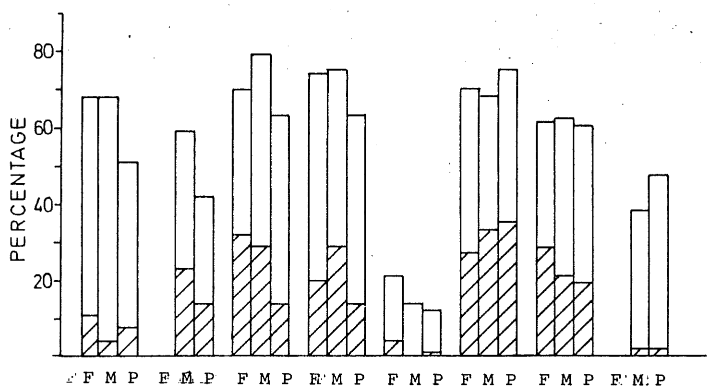

Fig. 2.2 Same as Fig. 1.1, sampled from haddock on May 8, 1979.

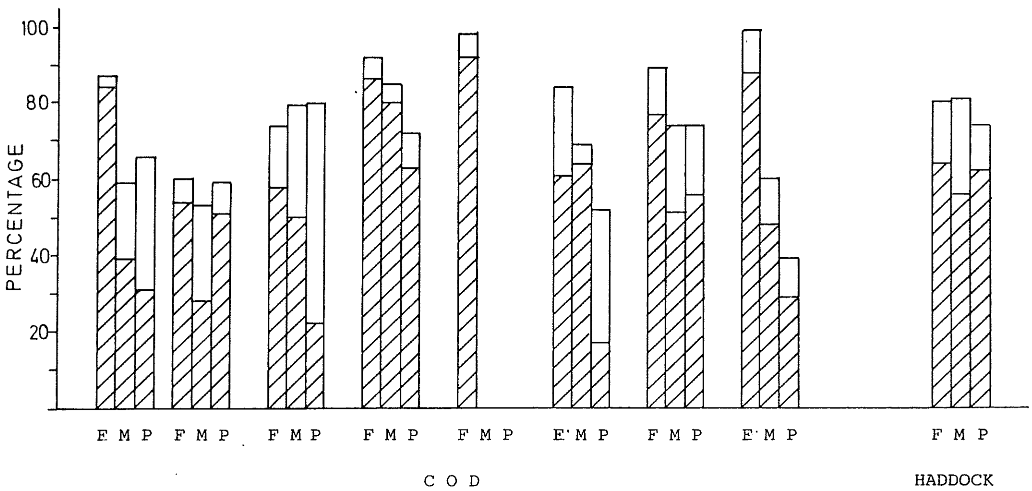

Fig. 3.1 Same as Fig. 1.1, sampled from cod and haddock on April 18-30, 1980.