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A study on survival and growth of fish larvae in a large basin, related to feeding conditions. A preliminary study on herring larvae (Clupea harengus L.) and fry

by

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INTRODUCTION

Field studies on survival and growth of fish larvae are complicated by a number of factors. Among them are the long spawning period in natural populations. Most serious, however, are the dispersion as a result of active movement and of current transport. Different velocities in depths and the diurnal migration of the fish larvae make the study of a particular larval patch very difficult. Even a method of the type described by Dragesund and Nakken (1973) will meet with great problems.

Studies on growth and survival of fish larvae in the laboratory are possible, but the results have limited value in the interpretation of what happens in nature.

What we ideally want is to study survival and growth of fish larvae correlated with feeding conditions in a system
- with limited dispersion of the larvae
- where the larvae are offered the food they normally eat

- where the food are produced within the system
- where the larvae and the other organisms have the possibility to react normally on the environmental factors.
- without predators on and competitors to the larvae.

This system will consist of only two main components: the fish larvae and their prey animals. Known numbers of larvae are released in the system at fixed times, and sampling in the system gives us information about feeding conditions. This procedure opens the opportunity to study

1 the critical period aspect
2 density dependent growth and mortality and
3 density independent growth and mortality.

An experiment was performed this year to investigate whether the necessary requirements were fullfilled to permit such studies (1-3) in a large basin.

MATERIAL AND METHODS

The experiment was carried out in an artificial basin at Statens Biologiske Stasjon Flødevigen, Arendal, Southern Norway. The basin had a surface area of about 1700 m^2, a maximum depth of 4.5 m and a volume of about 4400 m^3. Further informations concerning the basin are given in ELLERTSEN et. al 1975.

A great number of mature benthic and planktonic animals were transplanted to the basin in order to establish an ecosystem (table 1).

In the experiment we used larvae of cod, plaice, flounder, the hybrid between plaice female and flounder male and herring. In this publication we will only include the results with herring.

Table 1. Organisms transplanted to the basin. Numbers in thousand.

Month	February	March	April	May	June	Total
Species						
Littorina littorea	4	4				8
Balanus balanoides			1			1
Harpacticoid copepods	3	3	32	48	8	91
Calanoid copepods		90	7070	3940	2620	13720
Copepod nauplii		260	420	260	610	1550
Evadne normanni			10	1490	2380	3880
Cirriped nauplii & cypris		2	140	90	50	282
Bivalve velichonca			90	160	700	950
Spionid nectochaeta		400	2300	80	120	2900
Polychaet trochophora		3	20	230	40	293
Oikopleura dioika				70	860	930
Rotatoria			70	20		90

Table 2 summarizes the data for the transferred herring eggs and larvae. The eggs in the first and third batch were from a local herring stock in Lindåspollene (LH1 and LH2) outside Bergen. This stock of herring is the subject of an ICES-recommended study (ANON 1969). The rest of the eggs came from spring spawning Skagerak herring (SH).

Table 2. Transferred herring eggs and larvae to the basin

Herring eggs from	date of fertilization	date of transfer to the basin	transfered as	date of hatching	maximum estimated number of yolksac larvae
Lindås, Bergen (LH1)	3/4	8/4	eggs	23/4	10 000
Skagerak, Arendal (SH)	23/4	7/5 22/5	eggs larvae	12/5 15/5 §	20 000 5 000
Lindås, Bergen (LH2)	2/5	20/5	eggs	24/5	5 000

§ Hatched in the laboratory at a lower temperature than in the basin.

The sampling of zooplankton was performed mainly by an electric centrifugal pump with a capacity of 50 l/min. Samples were taken at six stations in the depths 0 m, $\frac{1}{2}$ m, 1 m, 2 m, 3 m, and 4 m at least twice a month with a total of 29 samples each time.

Estimates of standing stock of zooplankton was made from the results of the plankton pump samples, according to the following procedure: the basin was divided in six subareas, one for each station and a particular depth range was assigned to each pump depth. At day-time the zooplankton tended to accumulate near the bottom and surface layer and accordingly these pump stations have only been assigned a 10 cm layer. The rest of the water column have been divided according to pump depth. By multiplying surface with depth range the volume in m^3 of seawater which each pump depth represented was calculated.

Temperature was measured automatically with a temperature profile recorder. Salinity and oxygen was calculated from water samples.

The experiment was finished in late July. The basin was drained and all fishes collected. The fishes were conserved in freshwater with 4% formalin.

Total length was measured from a large subsample. A part of fishes were wet-weighed after being dried off on filter paper.

Probability paper, described by Harding (1949), was used in the analysis of the threemodal frequency distribution of the herring fry.

RESULTS

Temperature, oxygen and salinity

The temperature conditions in the basin are shown in table 3, and the oxygen content in ml/l in table 4.

Table 3. Temperatures, °C, from three depths in the basin, March-July.

Month	March		April		May		June	July
Date	10.	25.	10.	25.	10.	25.	10.	25.
Depth								
0 m	3.7	5.4	6.2	13.2	12.2	17.4	19.0	-
1 m	3.0	3.4	5.6	8.6	12.6	13.2	17.5	18.5
4 m	3.0	3.6	4.4	7.1	9.5	11.8	12.3	15.4

Table 4. Oxygen contents, ml/l, from three depths in the basin, March-July.

Month	March		April		May		July
Date	10.	25.	10.	25.	10.	25.	25.
Depth							
0 m	9	9	8	8	8	7	-
1 m	12	10	9	8	8	7	7
4 m	12	9	9	8	-	6	1

During the experiment the salinity in the basin was about 33 °/oo from the bottom to the surface. After heavy rainfalls the upper centimeters were brackish for a few days.

Zooplankton

L. littorea started to spawn in the beginning of March, (fig. 1). The first veliger was recorded in the beginning of April. The figure indicate two spawning maxima and two maxima of veliger. Calanoid copepods, mainly Temora longicornis, Acartia spp, Pseudocalanus elongatus and Oithona similis, started to spawn in the beginning of May. This spawning lasted till the beginning of June. At this time the adult populations of calanoid copepods suddenly collapsed (fig. 2). Only few nauplii developed into copepodites.

The harpacticoid copepods were much more numerous than the transplantation should indicate. They started spawning in the middle of April. The eggs were too small to be recorded in the samples. Until early June most of the harpacticoid copepods carried egg sacs. From the middle of June an increasing part of them were without egg sacs and in the end of July only 1-2% had egg sacs.

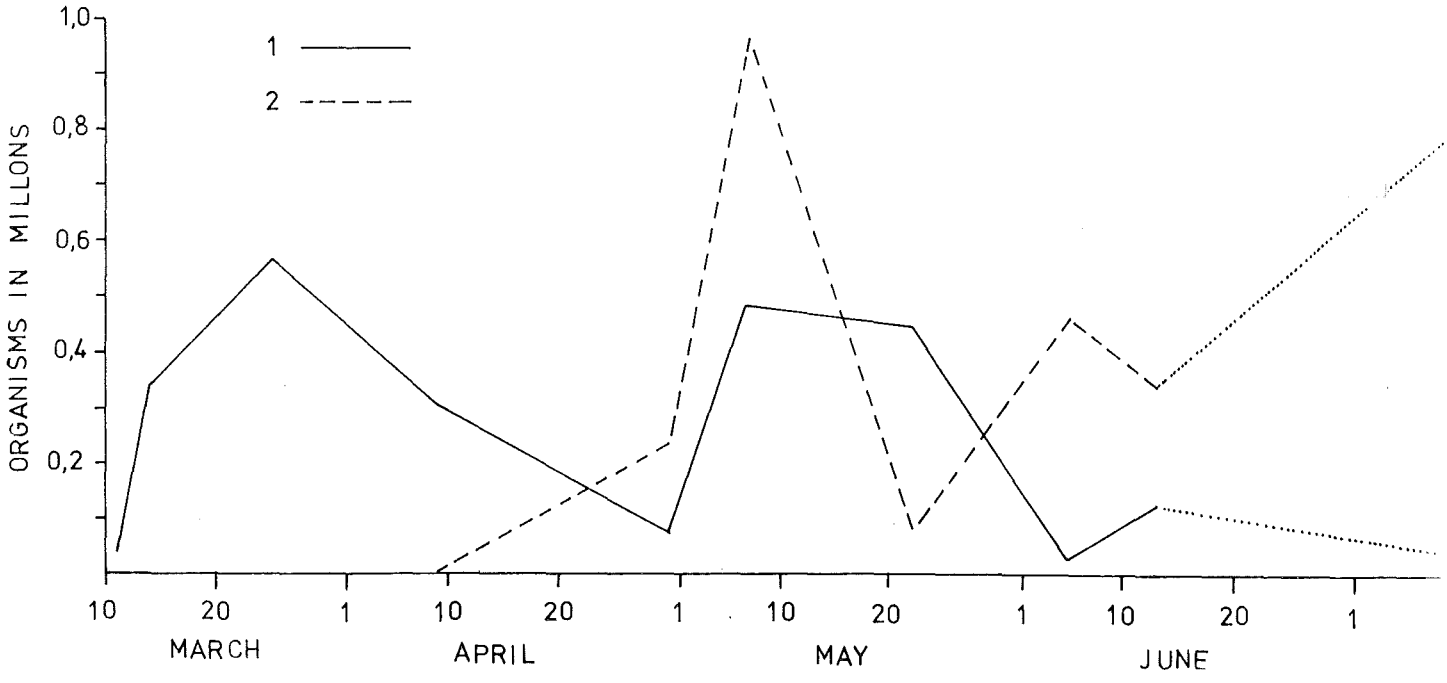

Fig. 1. Variation in number of organisms with time:
1) L. littorea eggs and 2) L. littorea veliger.

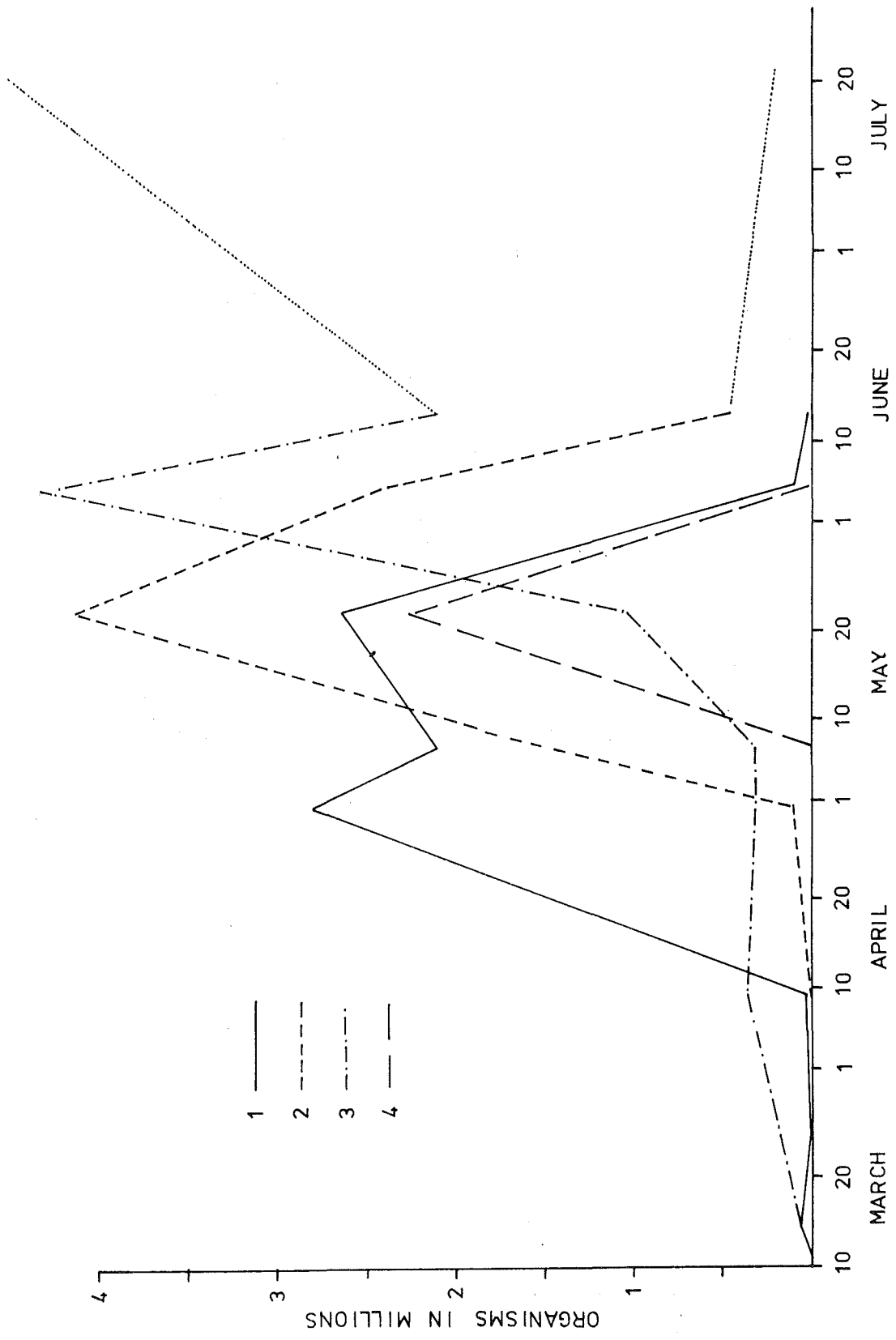

Fig. 2. Estimated standing stock of 1) calanoid copepods, 2) copepod nauplii, 3) harpacticoid copepods and 4) copepod eggs during the experiment. The dotted lines connect the estimates of 13. June and 20. July.

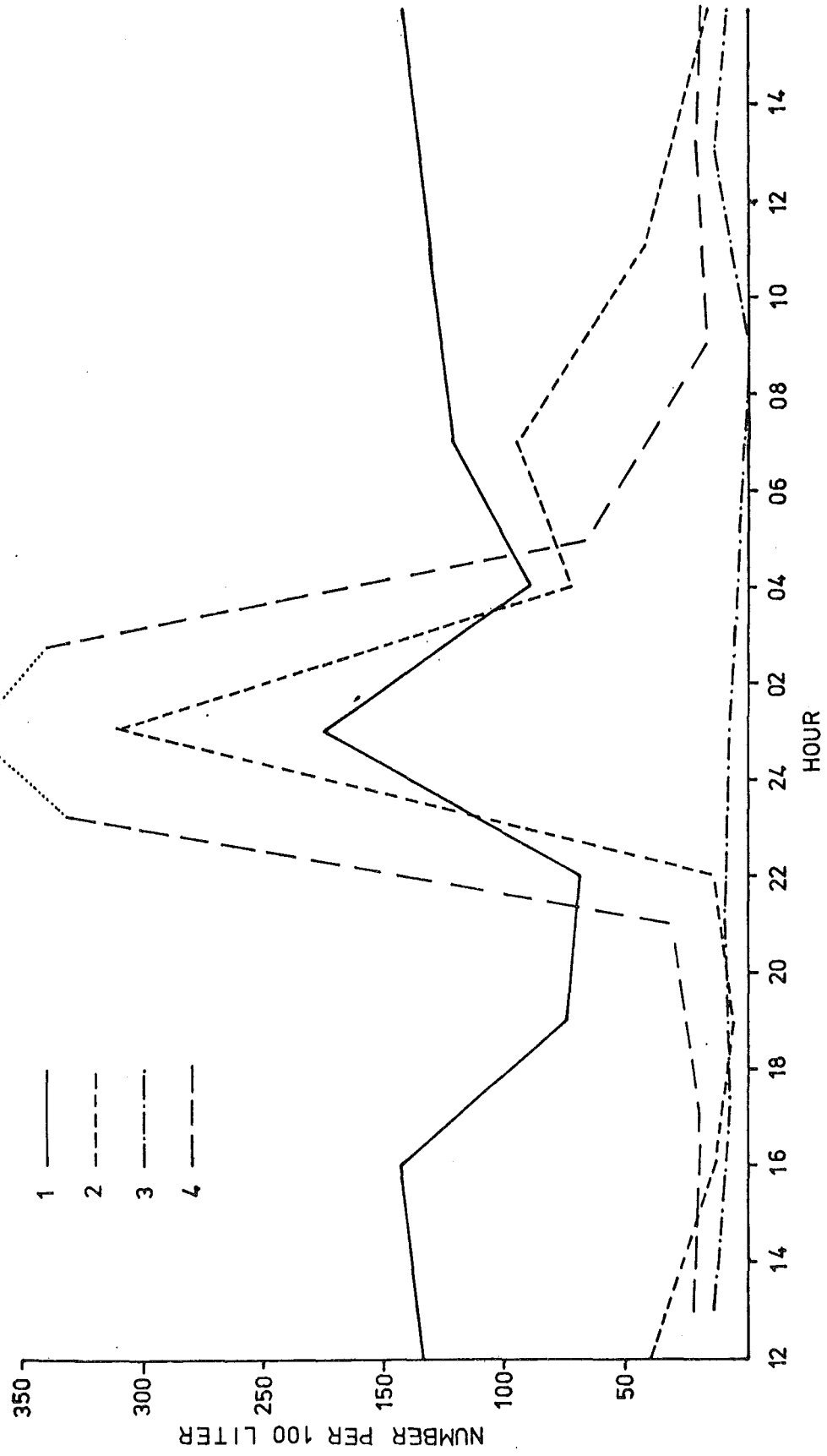

Fig. 3. Number of organisms per 100 l, during two 24-hour cycles.
1)- copepod nauplii, 2)- harpacticoid copepods, 26.-27. May
3)- copepod nauplii, 4)- harpacticoid copepods, 13.-14. June

Day and night sampling in late May and in the middle of June revealed clear indication of a higher activity of harpacticoid copepods and copepod nauplii during night time than day time (fig. 3).

The uneven distribution of the harpacticoids are summarized in table 5.

Table 5. Number per 100 l of harpacticoid copepods at day time, 5. June.

Depth in m	0	$\frac{1}{2}$	1	2	3	4
Station						
1	288	116	152	64	-	-
2	280	166	54	38	40	56
3	70	324	180	62	1664	-
4	246	106	74	74	-	-
5	240	252	178	62	42	128
6	198	114	52	400	-	-

Herring

The length distribution of the herring at the end of the experiment are given in fig. 4. Identifications of the three groups with probability paper are shown as dotted lines superimposed on the histogram.

The increases in length with age of each herring group are shown in fig. 5, and the condition (W/L^3) in fig. 6.

In fig. 7 the changing number of food organisms are put together with different stages of herring larvae. Suitable food for the youngest larvae (copepod eggs and nauplii and gastroped veliger) and for older larvae and fry (copepods) are given separately.

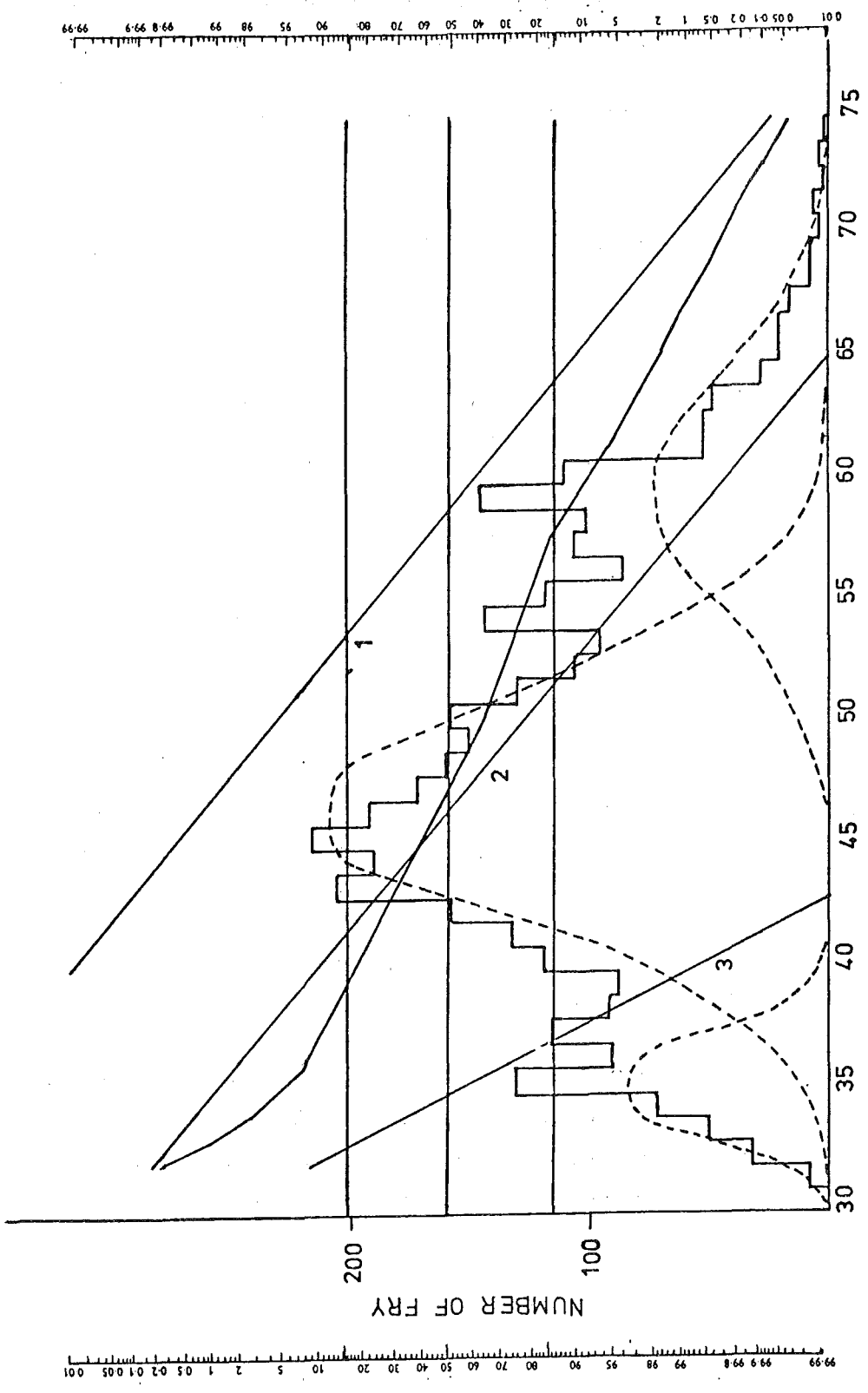

Fig. 4. Length distribution of 3940 herring fry caught 29. July. The three dotted length distributions are based on the probability paper method (HARDING 1949). These distributions represent: LH2 (left), SH (middle) and LH1 (right).

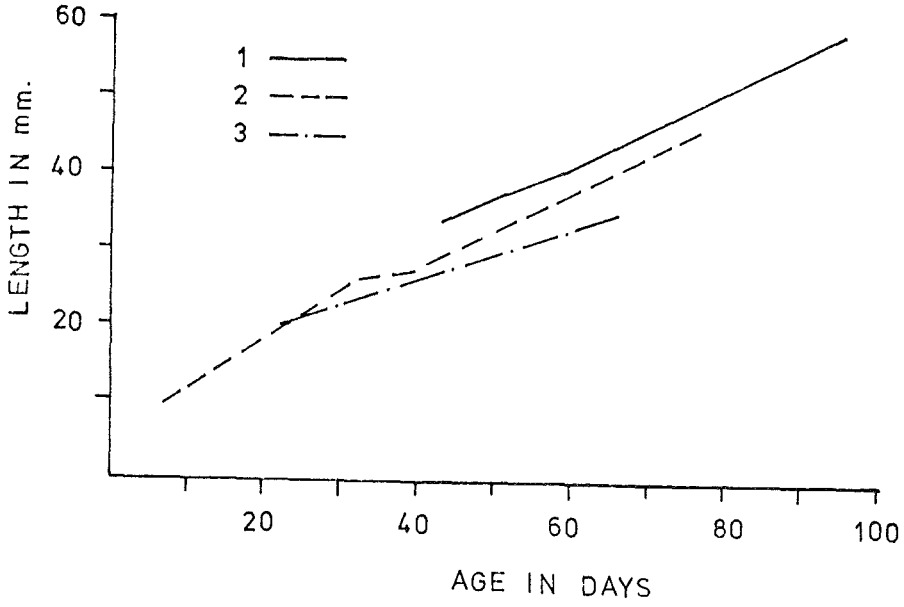

Fig. 5. Growth of the herring groups 1) LH1, 2) SH and 3) LH2

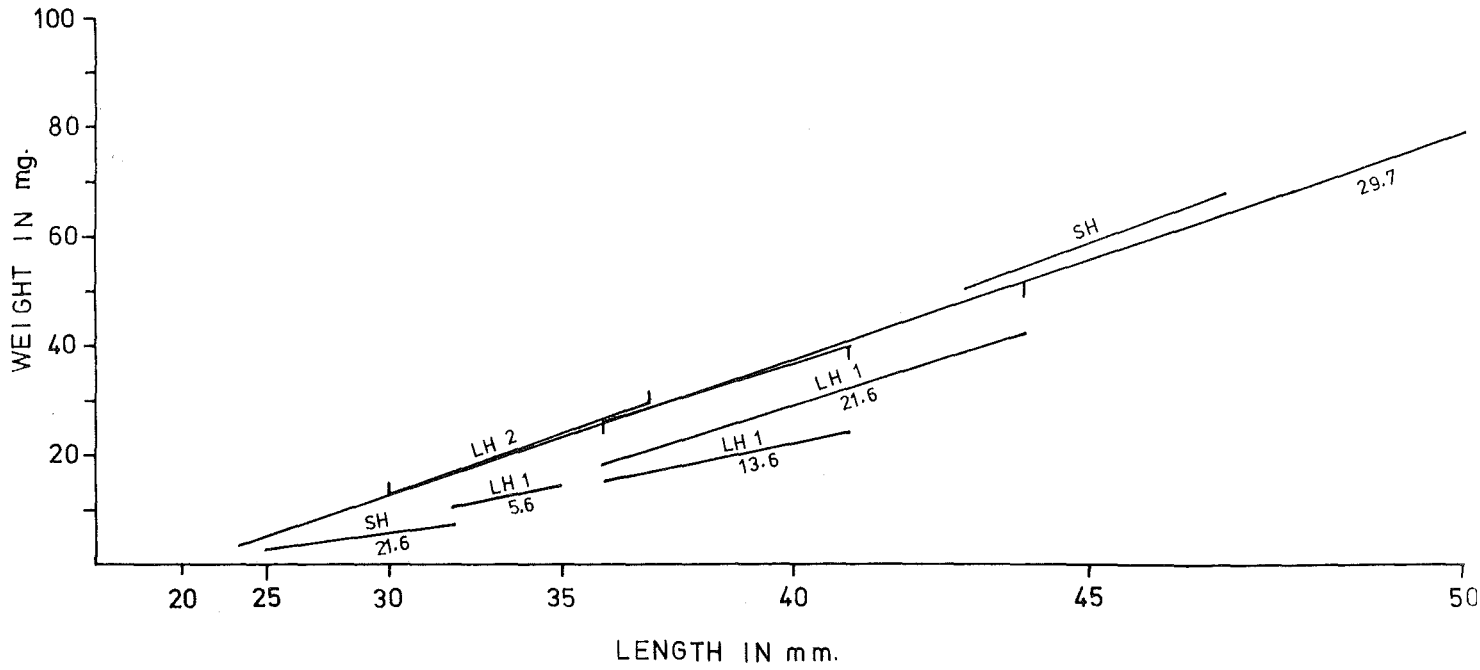

Fig. 6. Calculated relationship between W and L^3. The line marked 29.7 (29. July) represents the total material at the end of the experiment. Calculations on SH and LH2 have been given separately. Earlier sampling, SH 21.6; LH1 5.6; LH1 13.6 and LH1 21.6 are indicated. The LH1 group from 29. July falls outside the length range of the figure.

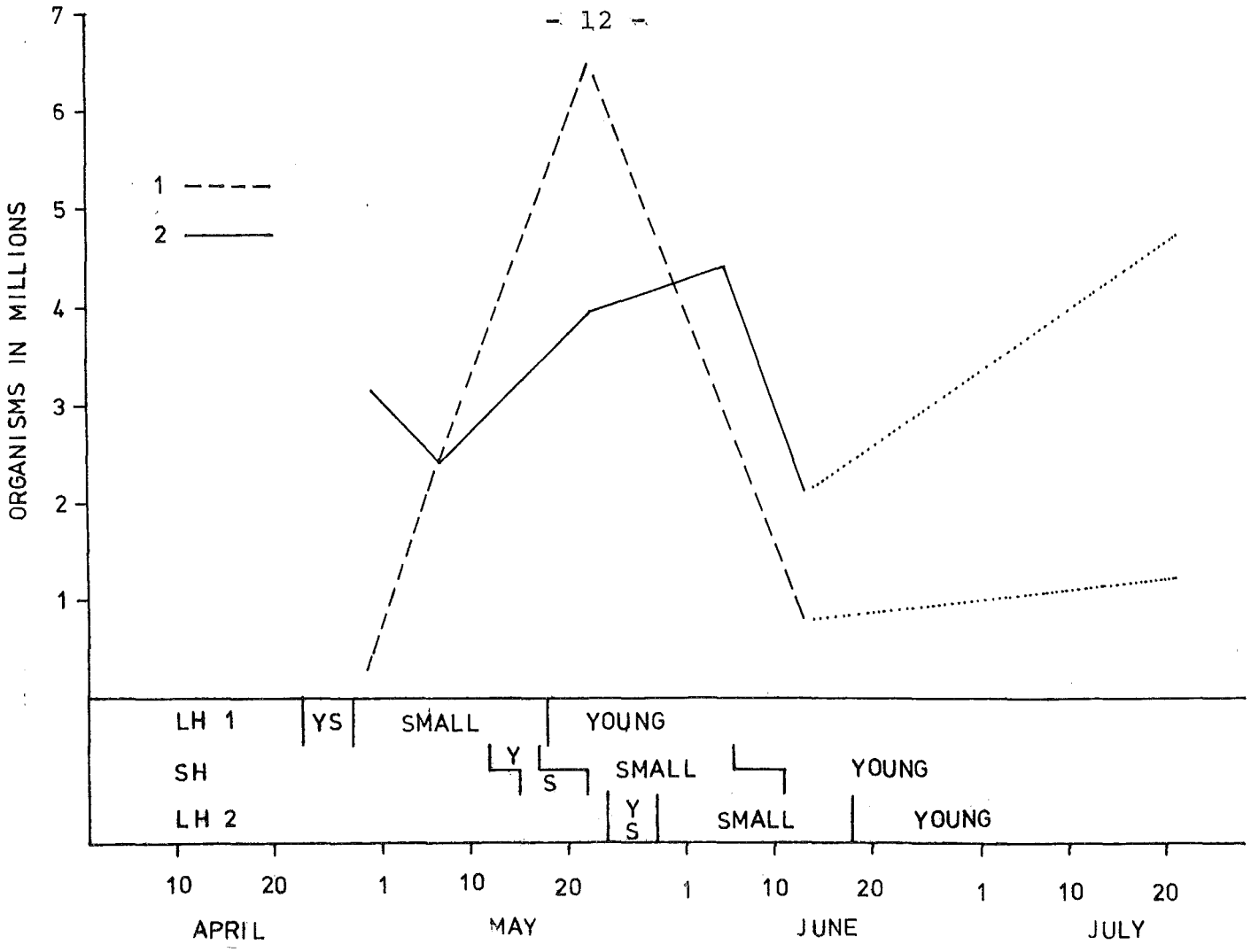

Fig. 7. Number of suitable food organisms for the youngest herring larvae (SMALL) consisting of copepod eggs and nauplii and gastropod veliger (1) and for the older larvae (YOUNG) consisting of calanoid and harpacticoid copepods (2). YS: yolksac stage.

The small number of yolksac larvae (table 2) did not permit estimations of the survival during the first stages. Schooling behaviour was first observed when the herring fry was about 30 mm. In late July the three groups were schooling together. Herring fry were captured 5., 13. and 21. June.

4300 herring fry survived till the end of the experiment. According to the probability paper method the herring fry was split in three groups, table 6. On the basis on the maximum estimated number of yolksac larvae (table 2), survival percentages were calculated for each group (table 6).

Table 6. Number and mean length of herring fry at the end of the experiment and survival percentages from yolksac stage.

	Number of yolksac larvae	Number of surviving fry	Survival in percentage	Mean length in mm
LH1	10 000	980	10	35
SH	25 000	2 825	11	46
LH2	5 000	495	10	59

Table 7 shows the content of the digestive system as number of food organisms per fry. Harpacticoids are dominant both in June and July. Spionid nectochaets, a group of larval polychaets, which played an important role in June, disappeared in July. Chironomid larvae are of some importance in both June and July. Calanoid copepods, which are rather numerous in June, disappeared in July.

Table 7. The number per herring fry of different animals in the digestive system.

Date	5/6	13/6	21/6	21/6	26/7
Length ranges in mm	32-35	36-41	25-32	36-44	48-83
Number of fry investigated	4	8	10	12	15
Harpacticoid copepods	16.3	160	10.1	15.2	230
Calanoid copopods	0	0.1	17.7	12.2	0
Copepod nauplii	11.3	0.1	1.4	0	0
Spionid nectochaets	13.3	0	1.9	140	0
Chironomid larvae	0.5	5.6	0.2	2.0	4.6
Other organisms	6.3	0.1	9.3	13.6 §)	0
Total of organisms per fry	47.7	165.9	40.6	195.0	234.6

§) 7 out of 12 fry had an egg string from gastropods in the digestiv system

Fig. 8 gives a rough indication of the feeding activity throughout day and night. Stomach filling seems to take place mainly before 9 a.m. and 10 p.m.

The rate of digestion from 10 p.m. and onwards are given in fig. 9. The fry were kept at 16°C in a barrel, and each second hour a subsample of 10 fishes were investigated.

The two last figures indicate filling of the stomach at least two times diurnally. This gives a total of about 1.7 million organisms eaten per day by the herring fry in late July.

DISCUSSION

The transplantation of calanoid copepods (table 1) was not particularly successful (fig. 2). The abrupt collaps in late May included all the calanoid species transplanted. In fact none of the species established in the basin, probably due to a combined effect of predation from fish larvae and lack of niches. Calanoids are probably more vulnerable to predation due to their holopelagic behaviour, in contrast to the substratedwelling harpacticoids.

The production of copepod eggs and nauplii in May (fig. 2) may have formed the main food supply for the fish larvae (fig. 7). Also for the smallest fry the copepod nauplii have been of some importance as food (table 7).

The population of harpacticoid copepods increased steadily from March till the beginning of June (fig. 2). Despite of a heavy predation estimated to 60 million animals in the period from 13. June to 29. July, the population seems to increase till late July (fig. 2).

The estimation of standing stock (fig. 2) are based on daytime sampling. Fig. 3 indicates underestimation, particularly of the substrate-dwelling harpacticoids. By night a much larger part of the harpacticoid population is pelagic.

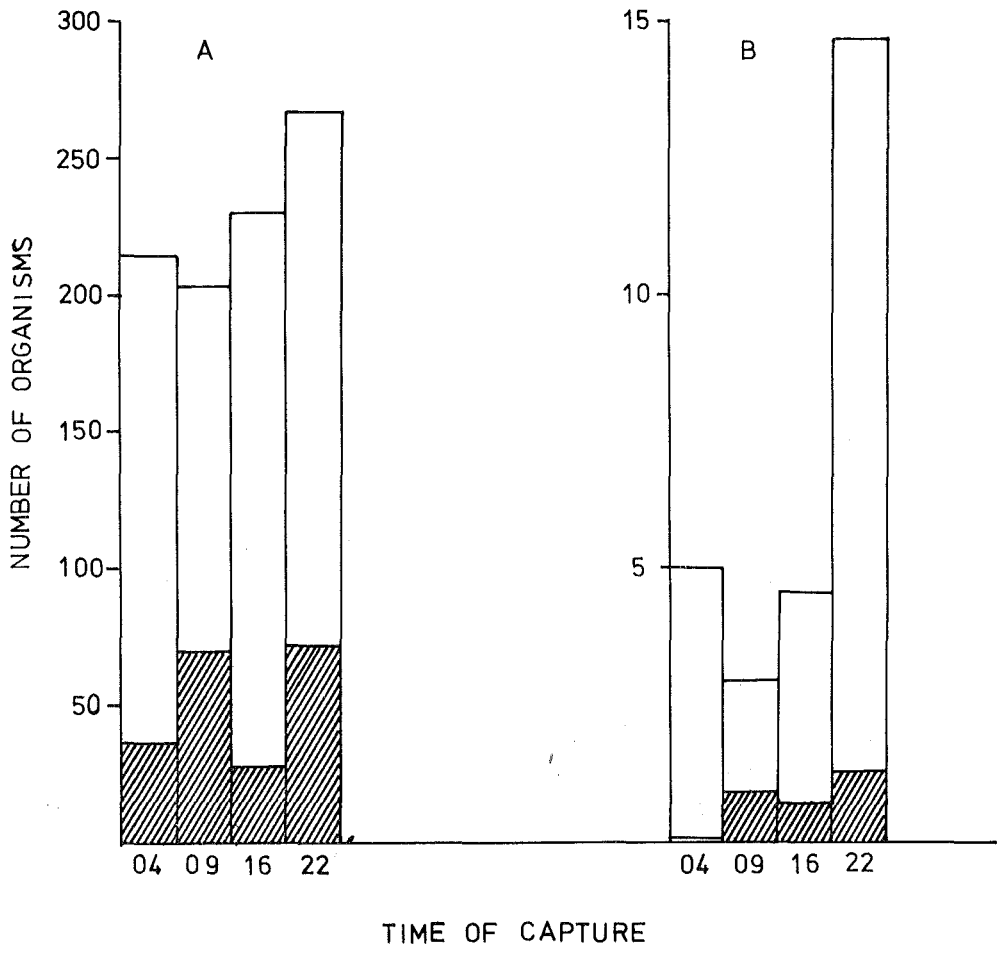

Fig. 8. Number of organisms in stomach (hatched) and intestine per herring fry at different hour of capture, 25.-26. July. Each column represents the average number of food organisms from 15 fry. Length range 40-83 mm. A) harpacticoid copepods, B) chironomid larvae.

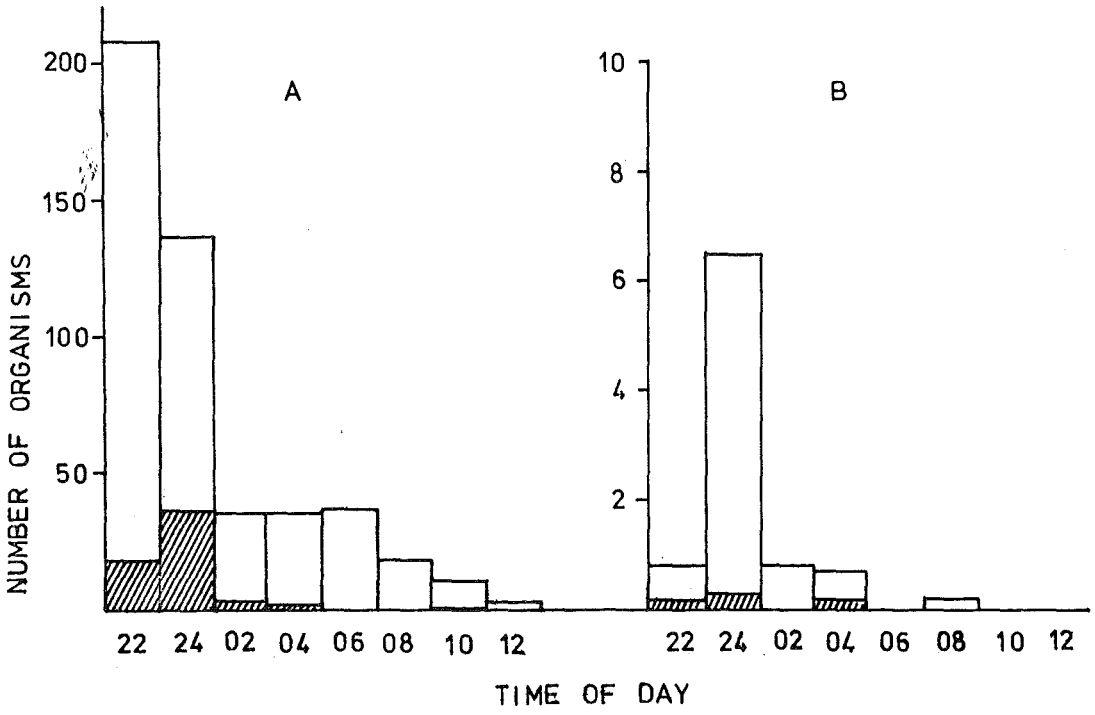

Fig. 9. Number of organisms in stomach (hatched) and intestine per herring fry. The herring fry, captured 26. July, were kept in captivity from 10 p.m. and subsampled each second hour. Each column represent the average number of food organisms from 10 fry. Length range 40-70 mm. A) harpacticoids, B) chironomid larvae.

The spawning of L. littorea seems to change in intensity during the springtime (fig. 1). A steady increase in the number of L. littorea veliger during the same period might have been expected. The recorded reduction during May may be a grazing effect from the fish larvae. We emphasize that at this time large populations of pelagic flatfish and cod larvae also were grazing . From the middle of June till the end of July another encrease in the number of veliger occured. No veliger, however, was observed in the herring stomach in late July.

Feeding activity occurs both day and night with maximum stomach content at 09 a. m. and 10 p. m. (fig. 8). This is in agreement with the observation of BAINBRIDGE AND FORSYTH (1971) on herring larvae in the Clyde.

A better growth for LH1 than for SH and LH2 is indicated on fig. 5. Fig. 7 might explain this phenomenon in terms of different feeding conditions. First feeding of LH1 shows good syncronization with the mass production of eggs, nauplii and veliger from different species and the larvae grew up together with an increasing prey population. The importance of this synchronization for growth and mortality has been stressed by JONES (1973). In contrast SH and LH2 passed through the first stage (SMALL) with a decreasing number of prey organisms.

A similar pattern is shown for the three groups of young herring fry. The reduction in copepods are mainly due to the disappearance of calanoids (see fig. 2). Consequently the LH1-group was offered a more varied diet.

The feeding conditions during late summer seem to have improved, mainly because of an increase in the harpacticoid copepod population. However, the effect of the different growth rates in the first month after hatching prevails. In the calculation of W/L^3 in fig. 6 there is an indicat ion of good feeding condition during late summer for all groups. Separate calculations of W/L^3 for each herring group do not give any deviation from the straight line of the total material from 29. July. Due to practical reasons the LH1 group could not be presented in the figure. The linear regression for the total material is $W_{tot} = 0,680\ L^3 - 6,38$ and for LH1 $W_{LH1} = 0,686\ L^3 - 7,75$. The condition in July is better than in June for the same length ranges. The improved condition of LH1 from 13. June via 21. June till 29. July is significant. The long period of good food supply during late June and July might be the explanation of the improved condition (fig. 2 and table 7).

The survival of the herring in the basin has been rather high compared to the usually reported survival in nature (Dragesund and Nakken 1973). This is probably caused by a combined effect of sufficient food and insignificant predation.

CONCLUSIONS

The aim of the present study was to investigate the possibility to perform, in a large basin, the studies mentioned in the introduction (1-3). The large basin proved suitable because:

1 - a large number of herring fry was produced

2 - growth and survival was satisfactorily, behaviour normal and identification of the different herring groups possible.

3 - the predominant part of the food was produced within the basin and these food animals behaved normally

4 - predation on the fish larvae was insignificant

5 - the physical environment was within the tolerance range of both fish larvae, fry and their food organisms

6 - the interaction between fish larval population, the food organisms and the physical environment could be described continuously.

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