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REARING OF MARINE FISH FRY IN PONDS ON THE NATURAL FOOD PRODUCTION.

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INTRODUCTION

Experiments in basins and ponds have been carried out for decades in many countries. Probably the most famous are the fish cultivation experiments in Loch Craiglin and Kyle Scotnish during the last world war and the following few years (Gross, 1947; Gross, 1950). In recent years a large basin in Ardtoe, Argyll, has been used for different experiments with flatfish (Milne, 1972). In Norway, Rollefsen (1946) used an artificially constructed basin at the Biologiske Stasjon, Trondheim, for the rearing of metamorphosed flatfish from released yolk sac larvae.

In 1885 an artificial basin was built at the Statens Biologiske Stasjon at Flødevigen, and the following year an experiment on cod fry was carried out. The purpose was to prove the viability of the millions of yolk sac larvae hatched at the station and annually released in fjords in southern Norway. A release of 500 000 yolk sac larvae in the basin resulted in thousands of fry in the autumn (Dannevig, 1886). Later the same basin was used for growth studies on cod (Dannevig, 1925).

A group of scientists from the Institute of Marine Research in Bergen, are researching the problems concerning the first feeding of fish larvae and aspects of the "critical period". Parts of these investigations are carried out in a large basin. The experiments also have the aim of developing a method for mass production of marine 0-group fish. Progress made during the two last years will be presented in this paper together with some suggestions for further experiments.

MATERIALS AND METHODS

An experiment was carried out in a constructed basin at the Statens Biologiske Stasjon at Flødevigen, near Arendal, in southern Norway. The basin had a surface area of about 1,700 m^2, a maximum depth of 4,5 m and a volume of about 4,400 m^3. The shape of the basin and the different bottom types are indicated in Fig. 1.

The basin had been empty for 1½ years when it was filled in January 1975. It was refilled with seawater in September 1975 after the collection of the fish fry. In both years the seawater was taken from a depth of 70 m via a reservoir and the replacement rate was 1-3 % per day.

The transfer program of eggs and larvae to the basin during 1975 and 1976 is summarized in Tables I and II. In 1975 fertilized eggs of cod, plaice, flounder, the hybrid between plaice female and flounder male (later called hybrid) and herring were transferred to the basin. In addition a small number of yolk sac larvae of cod, plaice, flounder and herring was released.

In 1976 only fertilized eggs of flounder were released. Of the other species, cod, plaice, hybrid and herring, yolk sac larvae were transferred from the laboratory and released. The last three species were released twice.

In 1975 a large number of copepods were collected in the coastal waters and transferred to the basin together with adult Littorina littorea and Balanus balanoides (Table III).

The zooplankton and fish eggs were mainly sampled with an electric centrifugal pump with a capacity of 50 l/min. Pump samples were taken in the depths 0m, ½m, 1m, 2m, 3m and at the bottom at several places in the basin, and the water was filtered over gause of 90 µ mesh size.

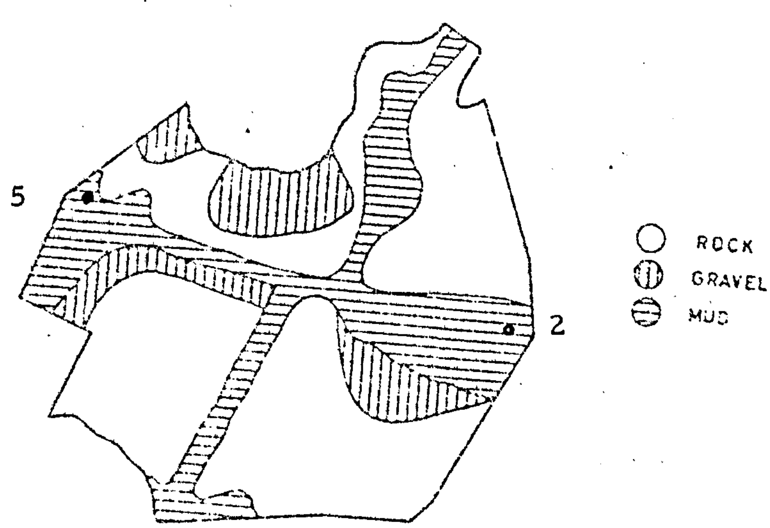

Fig. 1. A plan of the basin indicating the type of bottom substrates, and the locations of stations 2 and 5.

Table I. Groups of eggs and larvae transferred to the basin in 1975.

Species	Date of transfer	Number of eggs	Number of larvae
Cod	February 25-April 14	5 000,000	
	April 23		5,000
Plaice	February 20-April 14	700,000	
	May 14		2,000
Flounder	February 24-April 22	500,000	
	April 29		2,000
Hybrid	February 24-April 14	200,000	
Herring 1	April 8	-	(10,000)+
Herring 2	April 24	-	(20,000)+
	May 22		5,000
Herring 3	May 5	-	(5,000)+

+: an estimate, as an unknown number of herring eggs on PVC-plates were transferred.

Table II. Groups of eggs and larvae transferred to the basin in 1976.

Species	Date of transfer	Number of eggs	Number of larvae
Cod	March 25		200,000
Plaice 1	March 18		3,000
Plaice 2	April 27		3,500
Flounder 1	March 1	100,000	
Flounder 2	April 8	30,000	
Hybrid 1	April 4		5,400
Hybrid 2	April 27		3,000
Herring 1	April 29		3,000
Herring 2	May 25		35,000

The equipment used in 1975 for fish larvae was a Clark-Bumpus sampler drawn horizontally across the basin at different depths. In 1976 a 0.1 m^2 Juday net was used in the subsurface sampling and a Bongo-like net for surface sampling and precision sampling at 1 m and 2 m depths. The fry were caught in a trap.

Water samples from six depths, 0m, ½m, 1m, 2m, 3m and 4m were taken weekly to determine temperature, salinity and oxygen content.

The experiment was concluded in late July both in 1975 and 1976. The basin was drained during one week, and the pelagic fish caught when there was still some water left. The flatfish were collected when the basin was empty. All the fish were preserved in 4%

Table III. Organisms transplanted to the basin in 1975 (numbered in thousands).

Species	February	March	April	May	June	Total
Littorina littorea L.	4	4				8
Balanus balanoides L.			1			1
Harpacticoid copepods	3	3	32	48	8	91
Calanoid and cyclopoid copepods		90	7,070	3,940	2,620	13,720
Copepod nauplii		260	420	260	610	1,550
Evadhe normanni Lovén			10	1,490	2,380	3,880
Cirriped nauplii and cypris		2	140	90	50	282
Bivalve velichonca			90	160	700	950
Spionid nectochaetes		400	2,300	80	120	2,900
Polychaete trochophora		3	20	230	40	293
Oikopleura dioika Follenius				70	860	930
Rotatoria			70	20		90

formalin in 1975, but in 1976 most of the fry were transferred live to the laboratory for further experiments. The parent stock was from the local area, except for some of the herring groups.

Probability paper, as described by Hardy (1949), was used to analyse the trimodal frequency distribution of the herring fry in 1975.

In addition to the experiment in the large basin, another on herring larvae was carried out in a small basin in 1976. This outdoor basin had a volume of 25 m^3 and a depth of 1.3 m. About 400 herring larvae at the end of the yolk sac stage were released into it on April 29.

RESULTS

The temperature and oxygen contents from three depths are presented in Tables IV and V for the experimental period in 1975 and 1976 respectively. The salinity in both years was 33-35 $^{o}/oo$, usually increasing with depth.

Zooplankton

The standing stock of different groups of zooplankton during 1975 and 1976 is illustrated in Figs. 2 and 3, and in Table VI are given the numbers of some other organisms for the two years. The list is not complete, as some unimportant animals are excluded.

In 1975 the production of copepod nauplii started at the end of April (Fig. 2). In 1976 there was a hatching at the end of March and another peak in the last part of April, lasting for some weeks.

In 1976 the vertical distribution of copepod nauplii was rather constant and they formed a strata between 2 and 3 metres depth with a density greater than that observed above and below, as shown in Fig. 4. This distribution was characteristic for the period March-June.

Table IV. Temperature (° C) and oxygen content (ml/l) at three depths during March - July 1975.

Date	0 m Temp.	0 m Oxygen	1 m t	1 m 0_2	4 m t	4 m 0_2
March 10	4.2	9.1	3.6	12.9	3.2	11.9
March 24	5.5	9.3	3.5	9.6	4.0	9.0
April 7	5.2	8.4	4.4	8.6	3.9	8.5
April 21	7.3	8.2	7.3	8.3	6.4	8.2
May 12	12.5	7.5	12.6	7.5	9.5	-
May 22	15.4	7.4	13.6	7.1	10.9	6.2
July 25	-	-	18.5	6.8	15.4	1.2

Table V. Temperature (° C) and oxygen content (ml/l) at three depths during March - July 1976.

Date	0 m t	0 m 0_2	1 m t	1 m 0_2	4 m t	4 m 0_2
March 10	0.3	9.0	1.3	9.2	1.7	9.0
March 24	2.7	8.2	2.8	8.1	4.9	-
April 7	6.1	6.2	6.0	6.0	6.6	5.5
April 21	8.3	6.4	8.4	6.7	8.9	6.3
May 12	12.4	4.4	12.4	3.7	8.4	4.3
May 26	15.6	6.5	15.1	6.7	9.9	7.1
June 9	15.9	7.2	15.3	7.5	9.6	7.7
June 23	17.0	6.4	16.1	7.2	10.7	6.6
July 7	21.8	7.1	20.6	7.4	12.7	7.7
July 27	20.0	-	19.4	-	13.6	-

Table VI. Standing stock of some evertebrate animals in 1975 and 1976 at maximum occurrance.

Species or group	1975 Time of max. occ.	1975 Standing stock (x 1 000)	1976 Time of max. occ.	1976 Standing stock (x 1 000)
Spionidae nectochaeta	early May	550	early June	380,000
Amphipoda adult	-	+	late March	200
Aurelia aurita ephyra	-	few	early April	10
Sarsia sp.		few	May	10
Tunicata	late July	2	late July	5

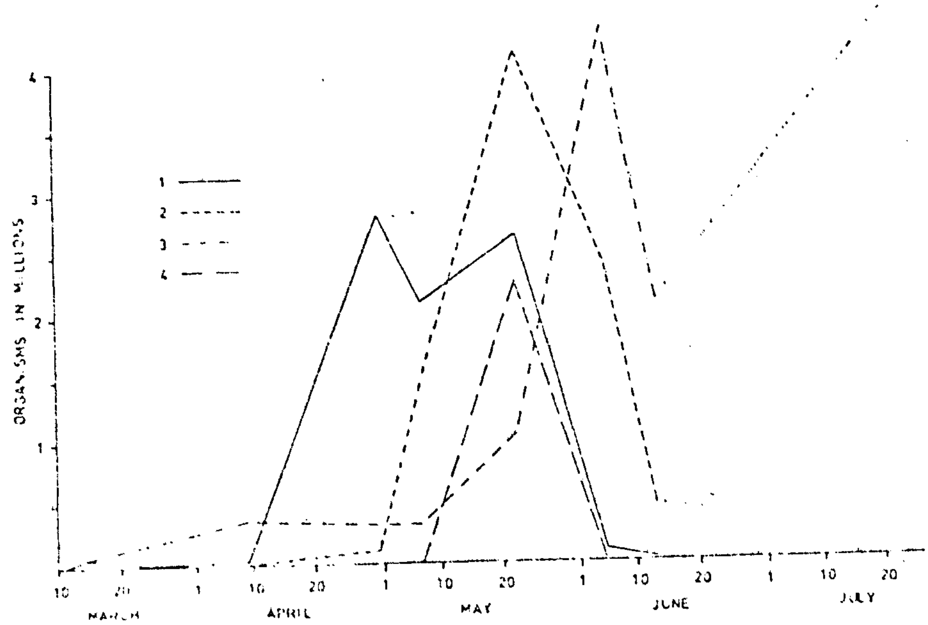

Fig. 2. Estimated standing stock in 1975 of 1: calanoid and cyclopoid copepods, 2: copepod nauplii, 3: harpacticoid copepods, and 4: copepod eggs during the experiment. The dotted lines connect the estimates of June 13 and July 21.

Predators

A few hundred fish larvae (which comprised few flatfish) were in 1975 transplanted together with the zooplankton. Some of the larvae survived and were captured after draining the basin (Table VII). Seaweed, mainly *Laminaria hyperborea*, was transplanted to the basin in April, unfortunately accompanied by some lumpsuckers (*Cyclopterus lumpus* L.) and probably by gobies (*Pomatoschistus minutus* (Pallas)) and father lashers (*Myoxocephalus scorpius* (L.)). The lumpsuckers grew quickly, 15 were captured between early June and the end of July. One of them had 33 herring fry in its gut.

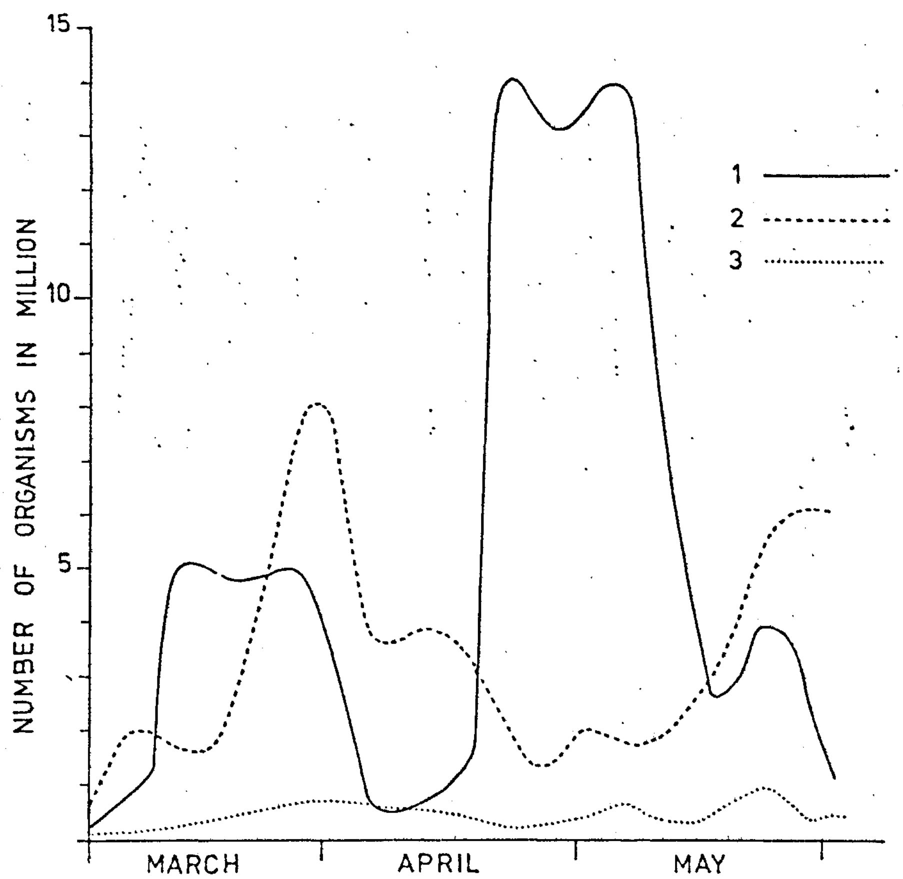

Fig. 3. Estimated standing stock in 1976 of 1: calanoid copepods, 2: copepod nauplii and 3: semipelagic copepods.

In 1976 eleven flatfish from the 1975 experiment were collected from the basin. They had reached a mean length of 25 cm. In addition there were a few gobies and one father lasher.

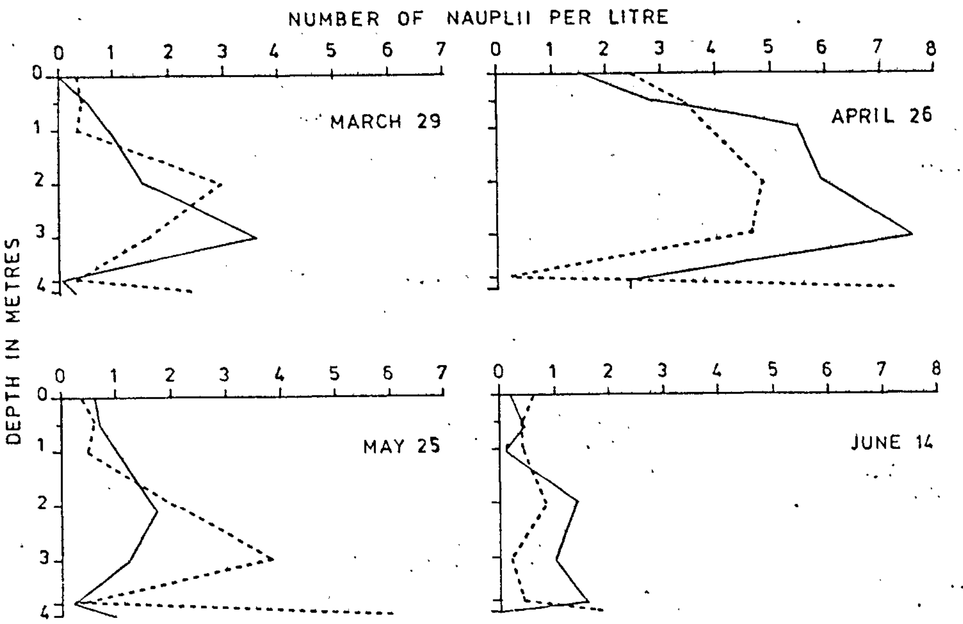

Fig. 4. Vertical distribution of copepod nauplii at stations 2 and and 5.

Table VII. Numbers and average lengths of other fish species in the basin in 1975.

Species	Month of capture	Number	Average length (mm)
Cyclopterus lumpus L.	June	11	73
	July	4	74
Liparis montagui (Donovan)	July	2	21
Gobius flavescens Fabricius	July	1	45
Pomatoschistus minutus (Pallas)	July	19	39
Myoxocephalus scorpius (L.)	July	13	42
Agonus cataphractus L.	July	1	40

Cod

Although about 5 million fertilized cod eggs were released in the basin in 1975, only about 1 $^{o}/oo$ of them hatched and the yolk sac larvae observed were deformed or irregular and inactive.

The yolk sac larvae transferred from the laboratory to the basin in 1975 were released when the food supply was increasing, as shown in Fig. 5. None of them were caught during the sampling programme, but at the end of the experiment 147 cod fry were collected. The mean length was 7.0 cm and the length-frequency

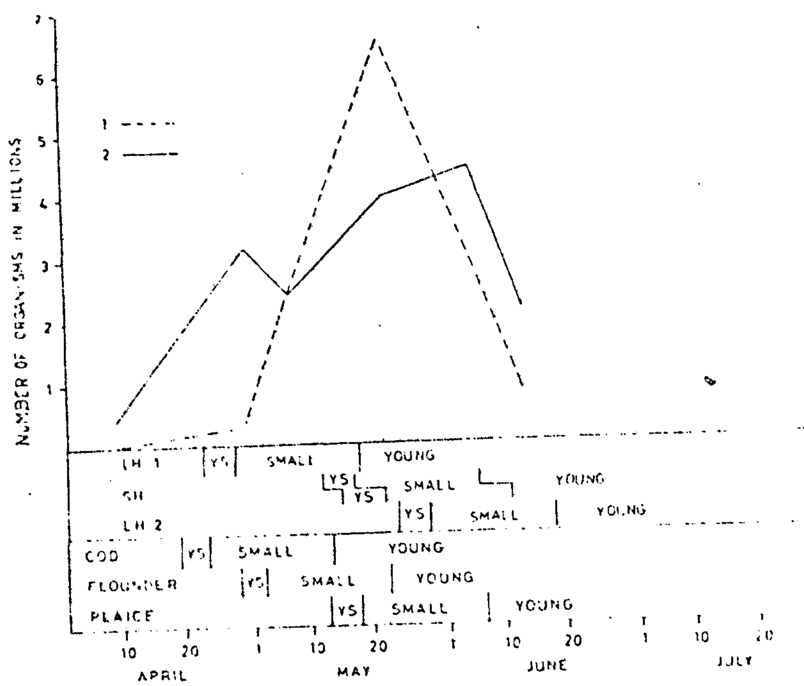

Fig. 5. Numbers of suitable food organisms in 1975 for the youngest fish larvae (SMALL) consisting of copepod eggs and nauplii and gastropod veligers (1) and for the elder larvae (YOUNG) consisting of calanoid cyclopoid and harpacticoid copepods (2). YS: yolk sac larvae.

distribution is given in Fig.6a. In 1976, 200 000 cod larvae were released at the end of the first production period of nauplii (Fig. 7). About 5 000 cod larvae and fry were caught from this group while the experiment was going on. Most of them were caught during the first 50 days after release.

The cod larvae started to eat 6 days after hatching and their diet consisted of copepod nauplii. Usually 80-90% of the larvae had some food in the gut, and the mean daily ration was about 10 nauplii for the first 20 days after hatching. One month later the daily ration had increased to about 130 organisms.

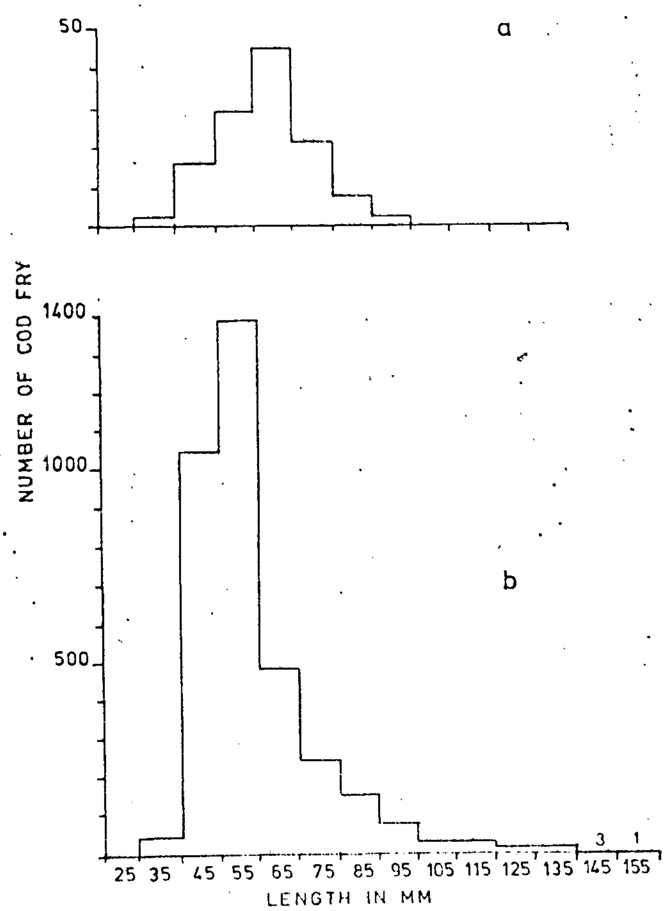

Fig. 6. Length-frequency distribution of cod fry at the end of the basin experiment, (a) in 1975, and (b) 1976.

The feeding success according to larval length revealed that the biggest larvae had the greatest gut contents at any time and that they increased their gut contents considerably while the smallest larvae stagnated, as shown in Fig. 8.

Mortality was high, particularly 10-20 days after hatching, with a reduction in number of larvae from 200 000 to 40 000, (Fig. 9). One month later 20 000 larvae were still alive and had reached a mean length of 12mm.

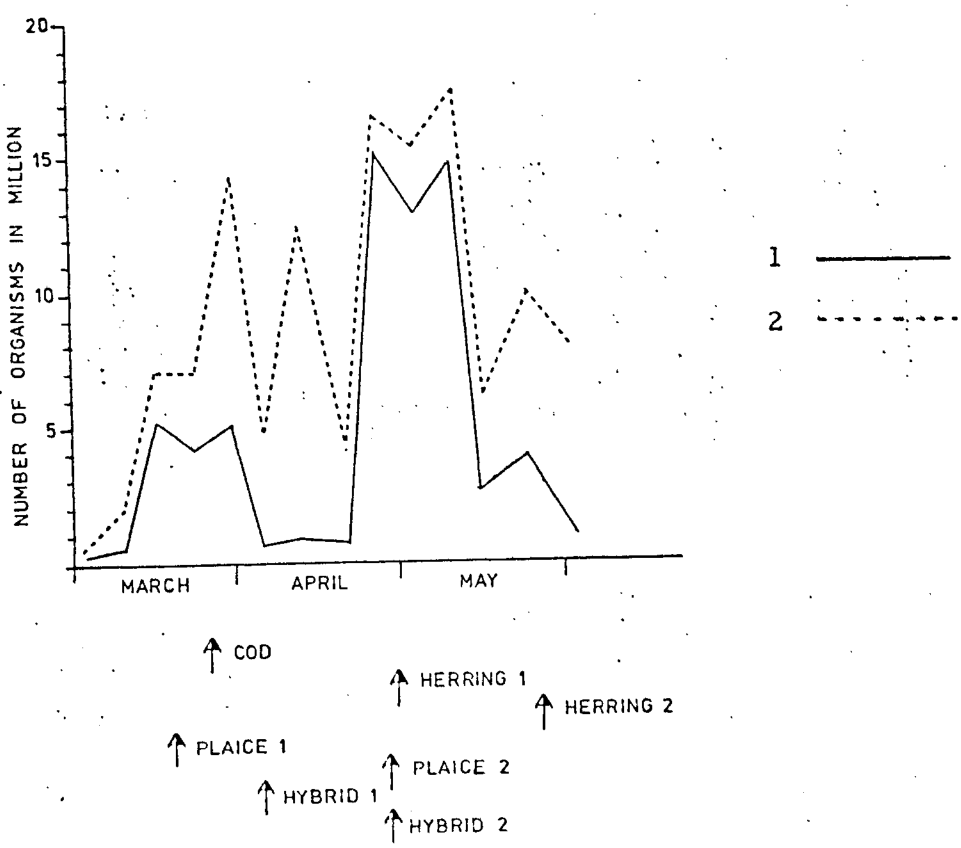

Fig. 7. 1: Number of suitable food organisms for the youngest fish larvae in 1976, (copepod nauplii), and 2: for elder larvae (copepod nauplii, calanoid copepod and semi-pelagic copepod).

The size difference between the smallest and largest larvae increased from about 1 mm 10 days after hatching to 1 cm at an age of 50 days, and to 12 cm at the end of the experiment, as illustrated in Fig. 10.

The diet changed at an age of 15 days to a larger prey animal, Cyclopina gracilis, and at an age of 60 days the main diet had changed to even larger prey animals, mainly juvenile amphipods and harpacticoid copepods, as shown in Table VIII.

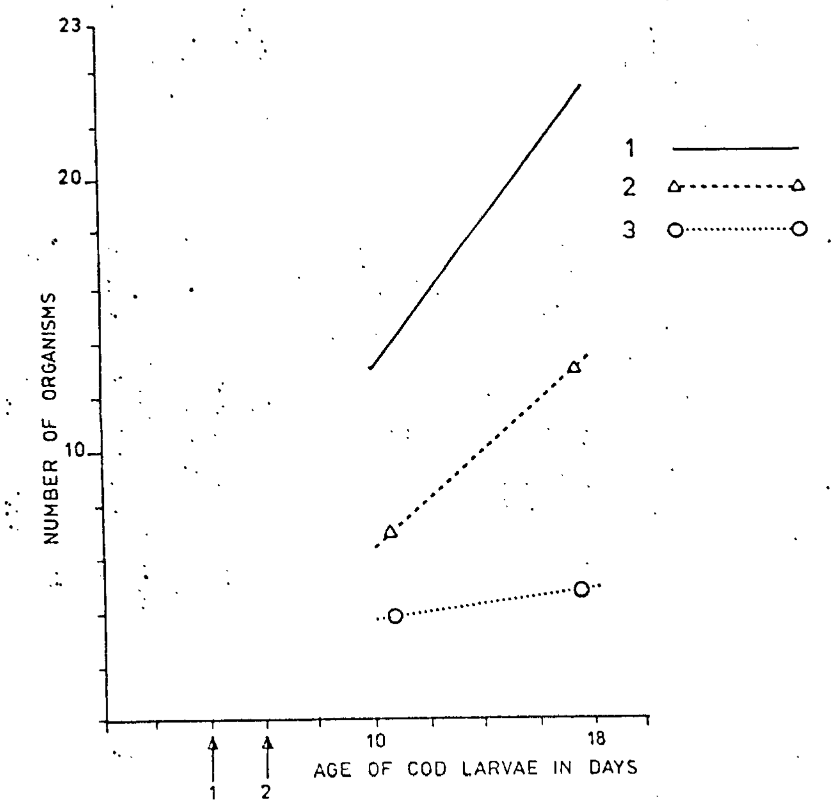

Fig. 8. Daily ration according to larval length. The population has been divided into thirds according to length - the top line shows the largest larvae, the lower line indicates the smallest, and the middle line represents those of inbetween sizes. The arrows 1 and 2 indicate the times of transfer and of first feeding respectively.

These continued to be the diet until the end of the experiment. In addition there were a number of observations of cannibalism among the cod fry. About 4 000 fry survived to the end of the experiment, giving a survival of 2%. The length-frequency distribution is given in Fig. 6b, the mean length being 6.5 cm.

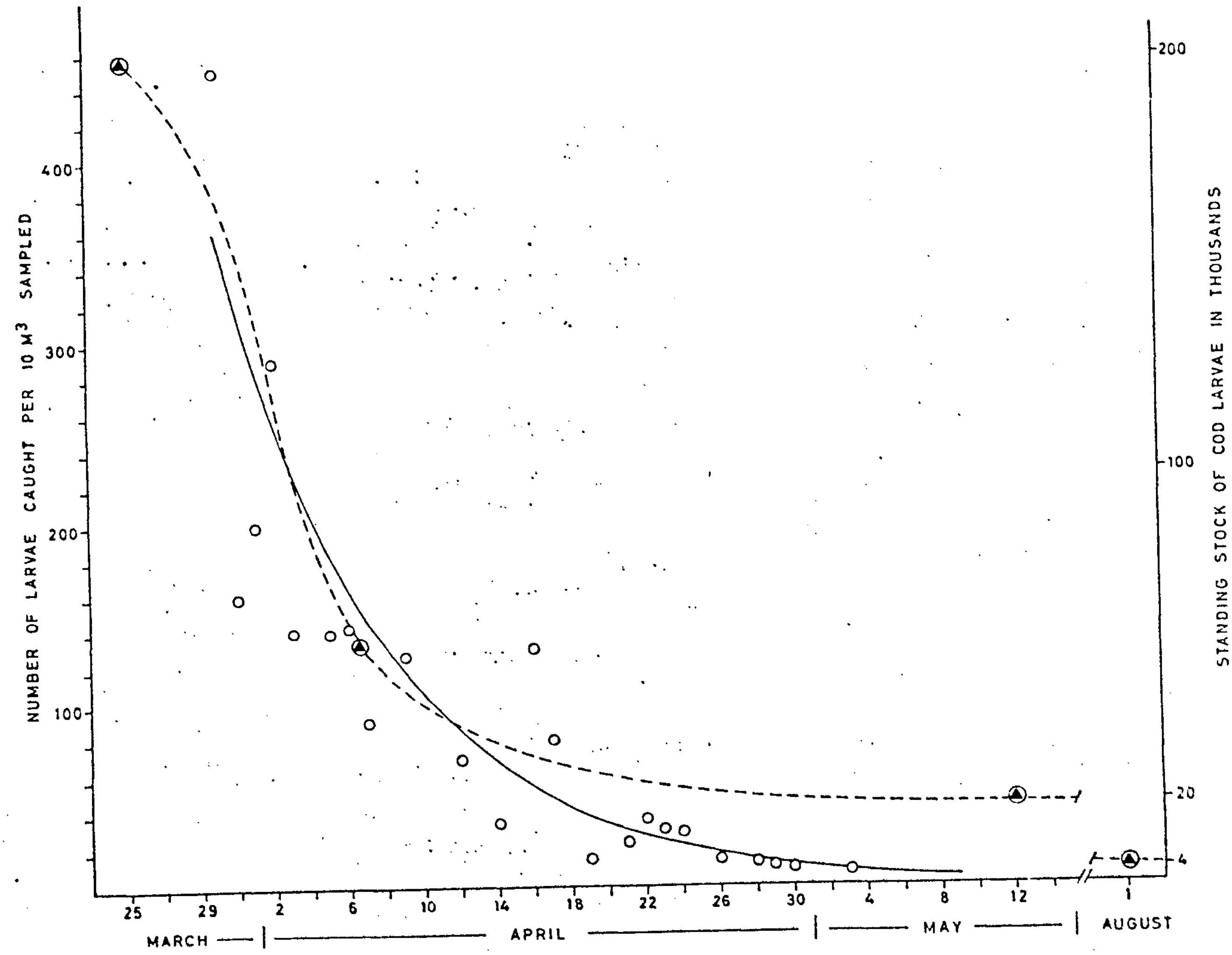

Fig. 9. Catches of cod larvae at 0900 hrs. from March 30 until May 3. (o) with a regression curve. The dashed curve is drawn through the best estimates, symbolised by ⊕.

March 25.	Initial population
April 5	Diurnal sampling station
May 12	Diurnal sampling station
August 1	Collection of fry after draining the basin.

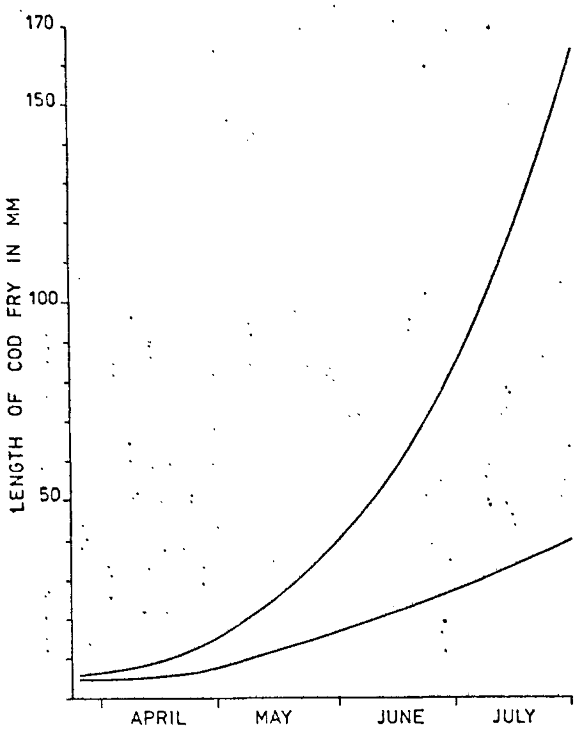

Fig. 10. Length of the longest and shortest larvae observed in the basin in 1976.

Herring

The herring larvae in 1975 originated mainly from eggs hatched in the basin. The three groups of larvae met with different feeding conditions, as shown in Fig. 5. The growth rate of the first herring group was faster than for the other two (Fig. 11), but the survival was about 10% for all groups.

The diet until a size of 20 mm is unknown, but after that length it consisted mainly of pelagic polychaete larvae (spionids) and semipelagic copepods (C. gracilis and harpacticoid copepods). During the summer the fry ate also by night. About 4000 herring fry survived to the end of July and the mean length of each group was 5.9 cm, 4.6 cm and 3.6 cm respectively. Their length-frequency distribution is given in Fig. 12.

Tabell VIII. Percentages of the different prey organisms found in cod larva stomachs in the basin experiment of 1976. Results from samples taken at 0900 and 1900 are combined.

Prey organism		Copepod nauplii	Cyclopina gracilis	Calanoid copepods	Harpacticoid copepods	Amphipod juveniles
Size in mm		0.1-0.3	0.3-0.5	0.3-1.8	0.8-1.4	1.5-15
Date	Age					
31.3	10	96		4		
2.4	12	96	1	3		
5.4	15	89	6	5		
9.4	19	46	50	4		
12.4	22	27	69	4		
16.4	26	41	54	4		
19.4	29	27	68	5		
21.4	31	43	55	2		
28.4	38	59	40	1		
1.5	41	35	64	+	+	
7.5	47	58	41	1	+	
10.5	50	45	35	4	16	+
11.5	51	38	44	+	13	5

Only three herring fry survived from the first group transferred to the basin in 1976, while no fry survived from the second. In the parallel experiment in the small basin, where 400 yolk sac larvae from the first group were released the same day as in the large basin, the survival was about 50% after 54 days. Feeding conditions in the small basin were poor and the growth rate slow compared with that observed in the large basin, as seen in Fig. 11.

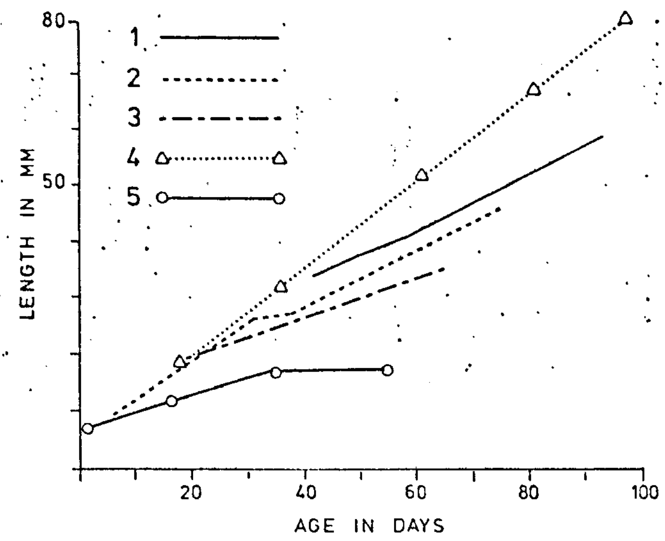

Fig. 11. Growth of the three herring groups in 1975 (1-3), and growth of the herring in the basin experiment of 1976 (4), and of the herring in the small basin experiment of 1976 (5).

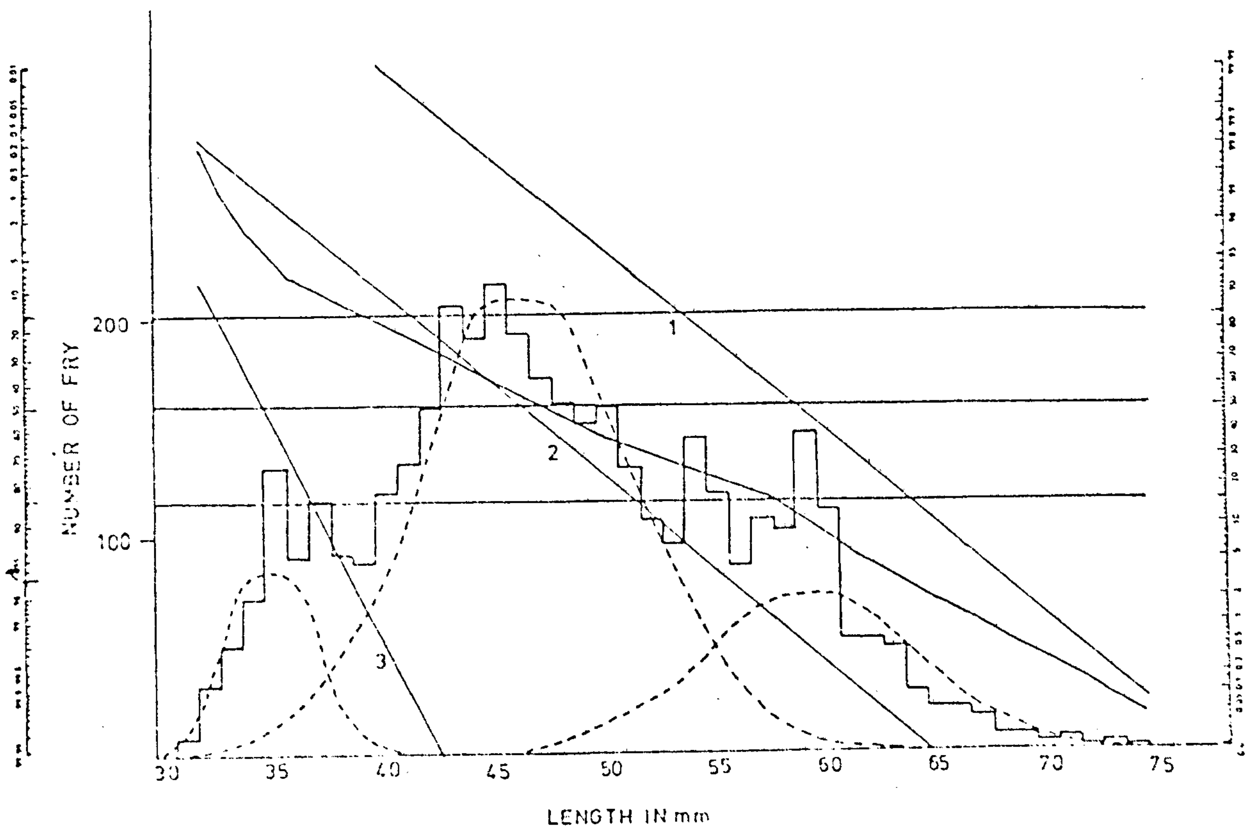

Fig. 12. Length-frequency distribution histogram of 3,940 herring fry caught at the end of July 1975. The three dotted curves are based on the probability paper method (Harding, 1949). These distributions represent Herring-3 (left) Herring-2 (middle) and Herring-1 (right). The corresponding assumed normal distribtuions are given by the lines 3, 2 and 1.

Flatfish

The high number of fertilized eggs of plaice, flounder and hybrid released in the basin in 1975 (Table I) resulted in very few yolk sac larvae and apparently no viable post larvae. The yolk sac larvae of plaice and flounder were released in the basin when the food supply was increasing (Fig.1). No larvae were caught in the subsequent sampling programme.

No hybrid fry survived, while the numbers of surviving plaice and flounder were 135 and 460, giving a survival of 7% and 23% respectively. Their length-frequency distribution is given in Figs 13 and 14. The mean length was 6.3 cm for both species.

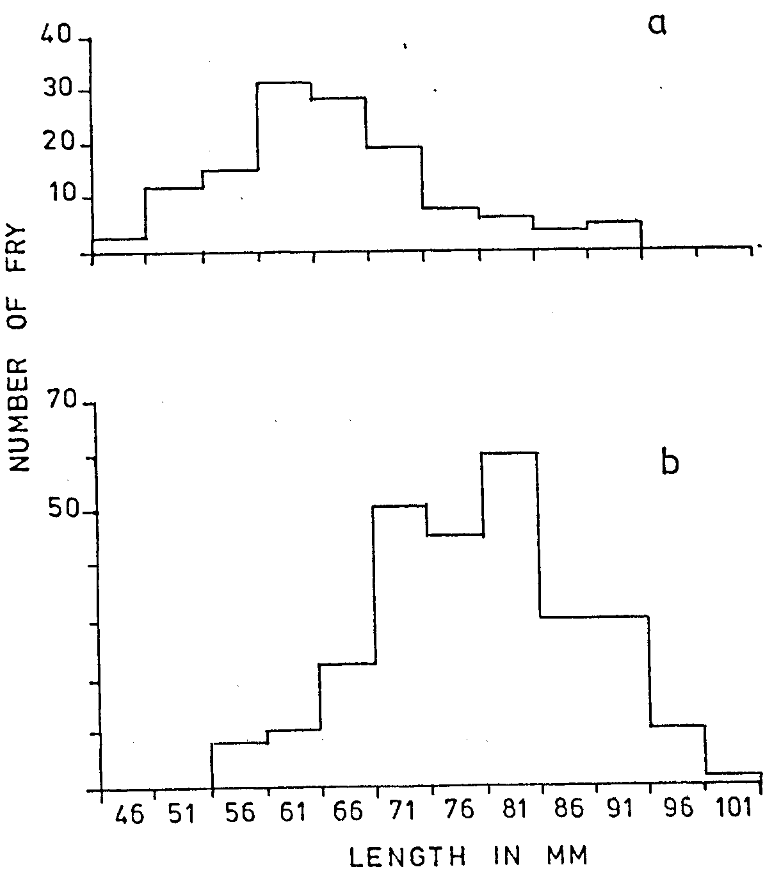

Fig. 13. Length-frequency distribution of plaice fry at the end of the basin experiment in (a) 1975 and (b) 1976.

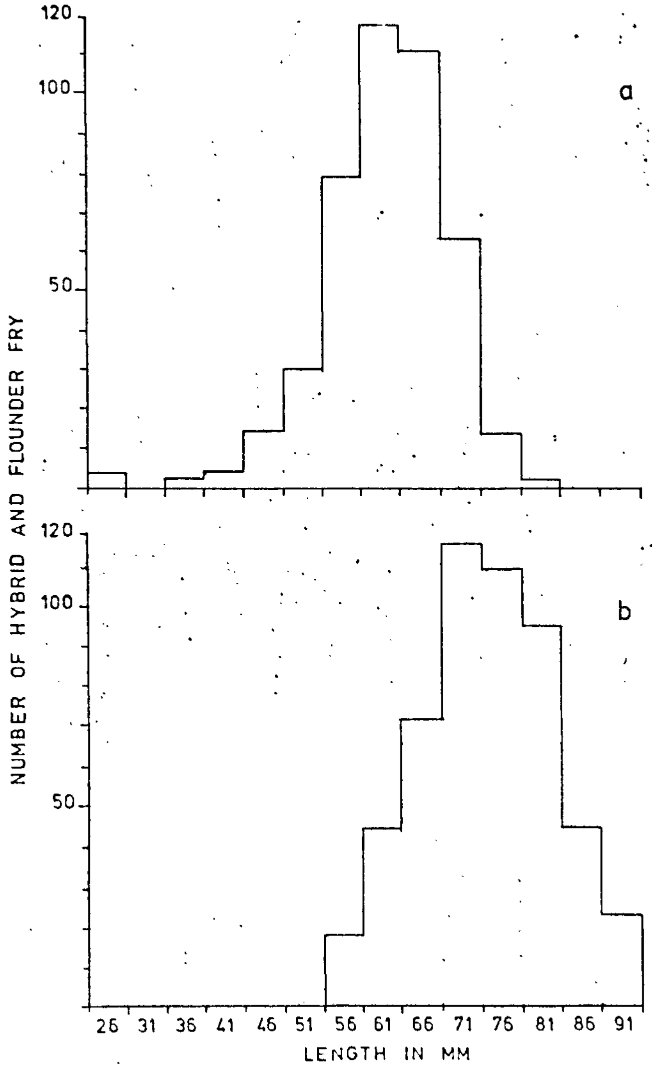

Fig. 14. Length-frequency distribution of (a) flounder fry and (b) hybrid at the end of the basin experiment in 1975 and 1976 respectively.

The diet of the pelagic larvae is unknown, but the fry diet consisted mainly of benthic polychaetes, while amphipods and chironomid larvae were of some importance. Pigment deficiencies (5%) as well as inverse fry (25%) occurred only among the flounder.

In 1976 no flounder fry survived from the released eggs. Larvae from the first released groups of plaice and hybrid were frequently caught during the sampling programme, until they reached the stage before metamorphosis. The diet of these pelagic flatfish larvae consisted mainly of C. gracilis, but pelagic polychaete larvae were also of some importance in the diet. The second group of plaice and hybrid larvae disappeared within 10 days after release, despite the fact that conditions for first feeding at that time were unusual good (Fig. 7).

Table IX. Growth period, initial length, mean length at end of experiment, daily growth rate, number of fry at end of experiment and survival percentage for each larval group for 1975 and 1976.

Species and year of experiment	Growth period	Initial length (mm)	Mean length August 1 (mm)	Daily growth rate (mm)	Number surviving until August 1	Survival percentage
Cod 1975	100	3.5	70.0	0.67	147	2.9
Cod 1976	130	3.5	64.7	0.47	4,000	2
Plaice 1975	77	5.5	63.0	0.75	135	7
Plaice-1 1976	140	5.5	80.0	0.53	260	9
Flounder 1975	95	3.0	63.0	0.63	460	23
Hybrid-1 1976	122	5.0	76.0	0.58	560	10
Herring-1 1975	97	7.5	59.0	0.53	980	10
Herring-2 1975	77	7.5	46.0	0.50	2,825	11
Herring-3 1975	66	7.5	35.0	0.42	495	10
Herring-1 1976	100	7.5	81.0	0.74	3	0.1
Herring-1 1976+	54	7.5	17.5++	0.19	140++	44+++

\+ the herring larvae transferred to the small basin

++ experiment ended on June 15

+++ of the 400 transferred, 80 larvae were sampled during the experiment and those are subtracted when calculating the survival percentage.

Their length-frequency distribution is given in Figs. 13 and 14; the mean length was 8.0 cm for the plaice and 7.6 cm for the hybrid. A total of 800 flatfish survived, with 240 plaice and 540 hybrids, giving a survival of 9% and 10% respectively. No fry had pigment deficiencies or were inverse.

The growth rate of the different species, as well as their survival percentages, are given in Table IX. The standing stock of fry at the end of the experiment was about 5 300 in 1975 (1.2 fry/m^3) and 4 800 in 1976, with 1.1 fry/m^3.

DISCUSSION

Release of fertilized pelagic eggs in ponds or basins seems not to be a suitable incubation method. This was clearly demonstrated by the high mortality rate during incubation and the otherwise amazing fact that no hybrids survived in 1975 and no flounder in 1976. The flatfish release programme in 1976 was planned solely to demonstrate that even the best surviving species in 1975 would give no fry when only eggs were released. The reason for this high mortality and the seeming inviability of the few hatched larvae is not known, but it might be a sunlight affect as the eggs are lying in the near surface layers.

The main purpose of these experiments was to evaluate the affect of feeding conditions on the daily food intake of the larvae. Food intake determines the growth rate and survival of the larvae and fry.

In 1975 the feeding conditions were at their best during the first feeding period for all the released groups except the third herring group, (Fig. 5). In 1976 the feeding conditions for the first released plaice and hybrid group were comparatively poor (Fig. 7), but nevertheless the survival was high. This was probably due to the low temperature at that time (Table V) giving the larvae a longer life span and a reduced food demand for survival. The large cod larval population released in 1976 reduced the population of copepod nauplii, as illustrated in Fig. 15, and only the larvae with the highest ability to catch food survived this period (Fig. 8) and were then able to change their diet to C. gracilis. The herring larvae in the small basin were to a high degree able to survive under marginal feeding conditions.

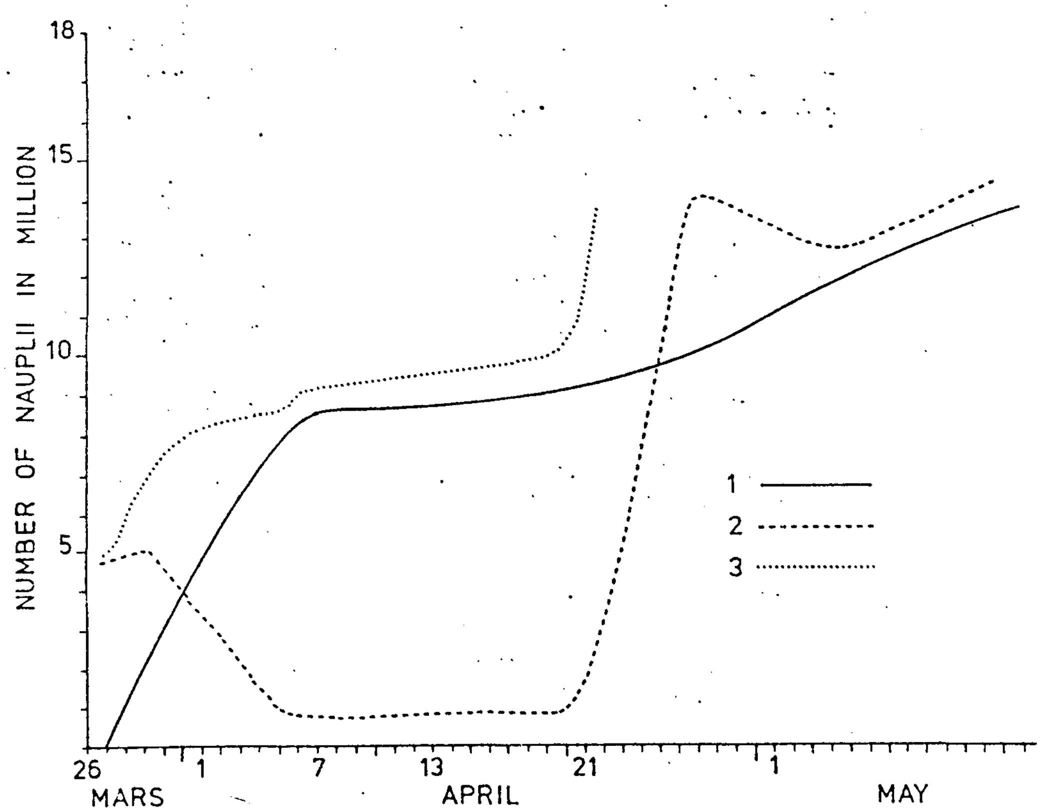

Fig. 15. Standing stock of copepod nauplii in the basin during the spring 1976 (dashed line), the accumulated number of nauplii consumes by the cod larval population (solid line) and the hypothetical standing stock of nauplii without predation, (dotted line).

All those cases seem to indicate a struggle for life and a survival of the fittest. Survival during the first 50 days might be as high as 50%, but seems more often to be about 10%, as was the case with the cod. Nevertheless, this is a large survival rate compared to the assumed survival in nature. There seem to be at least two explanations for this high survival. The food in the basin is concentrated in a stratum (Fig. 4) giving a high density of food, although the mean food concentration is low. This stratum is stable and larvae have a short distance to swim if they loose contact with it.

The second important point is the lack of predators. Although this ecosystem included some potential predators (Tables VI and VII), their density was low and food organisms other than larvae might have been more suitable for them. However, the effect of predation was certainly illustrated. As already stated, in 1976 cod larvae were the dominant larval group in the basin. Larval groups released in the basin when the cod larvae had reached a size of 10-15 mm did not survive although feeding conditions were unusually good (Fig. 7), while the larval groups of the same species released at the same time in 1975 into worse feeding conditions (Fig. 8) had a high survival (Table IX). It seems obvious that the cod larvae preyed upon the second release group of plaice and hybrids until extinction, and on both the herring groups, giving only three surviving fry from the first group. The high survival of the herring in the parallel experiment in the small basin, where the feeding conditions were marginal, is further support of this assumption.

The cod did not only prey upon other species, but also on slow growing individuals of their own species. The length-frequency distribution of cod fry, Fig. 6b, might indicate that at least 200 cod fry had other fry as an important part of their diet. Assuming a consumption of one cod fry per day for 60 days, a total of 12 000 fry were eaten. This might explain the reduction in number from 20 000 well established cod larvae at an age of 50 days to 4 000 fry 80 days later.

The diet of the pelagic larvae seems to have been rather similar among all the species indicating competition, although the polychaete larvae were of some importance to the flatfish larvae in contrast to the cod larvae.

After metamorphosis, however, when the consumption in biomass became more important, the main diet was varied for the different species. The herring fry preyed upon pelagic animals, while the cod fry had a combined diet of holo- and semipelagic animals. The flatfish preferred benthic animals and to a small degree semipelagic organisms.

The carrying capacity of the basin seems to have been fully exploited in both years. The dominant stock in 1975, herring, had a daily growth rate far below that of herring in 1976, when only three herring fry exploited that niche.

The dominant species in 1976, cod, had a growth rate below that of cod in 1975, when the number was far smaller and consequently the niche less exploited. The growth rate of the flatfish was somewhat lower in 1976, which might be explained by the stock being 25% larger, or by the bad feeding conditions during the first months of their life.

The very poor growth rate in the small basin might be explained by the high density of larvae giving a high feeding pressure on the stock of prey animals.

The most critical period in the life history of fish seems to be the period following resorption of the yolk sac. If production of suitable fry is required, it would be desirable to create a strong selection pressure at that time, allowing only the fittest larvae to survive. In the laboratory the concentration of food can be extremely high and for some species it is possible to bring more than 50% through metamorphosis. Consequently, selection is weak and might not necessarily sort out the fittest fraction of larvae. In addition, the price per fry would be high.
Rearing of larvae based upon natural production in a pond would be cheaper, and in addition, this seems to be the only possible method for rearing cod fry.

Of great importance is the fact that selection pressure will be high and probably only permit the survival of the best hunters.

If desirable, production of some types of nauplii and mature female copepods can easily be carried out. Probably the most suitable are semipelagic copepods of harpacticoids or cyclopoids.

The choice of food seems to be similar for all the types of pelagic larvae used in the present experiment, and competition might therefore occur. After metamorphosis the interspecies competition seems to be of lesser importance. A multiculture would result in an exploitation of a wider range of food organisms in the system and consequently be more favourable.

Inclusion of cod in the system will, in addition, help to remove the weakest and most slow-growing fry of at least the pelagic species. Of even more importance would be the fact that the cod fry could teach the other species fear of enemies. Blaxter (1976) stressed the importance of this aspect, and he called the laboratory reared fry naïve, as they will not try to escape from predators if released in the sea. This is one of the main objection against mass-rearing of fry at the laboratory for later release in coastal waters. Pond rearing on a natural diet might also solve this problem. To test this aspect it is necessary to carry out tagging experiments with pond fry against coastal fry.

The density of fry in the basin experiment could be increased by supplementary feeding, starting when the larvae have reached a size of 1-2 cm and the selection pressure has had its effect. The heavy cannibalism among the cod might be reduced in this way, which is desirable.

Along the coast of Norway there are a high number of land-locked ponds which might be suitable for mass productions of commercial fry. Still, these locations have not been tried, but the basin experiment may have indicated that the force that ordinarily reduces huge numbers of larvae to a few fry can, in a pond, be weakend, and give the opportunity to strengthen local stocks of fish.

Literature cited

BLAXTER, J.H.S. 1976. Reared and wild fish - how do they compare? In "10th European Symposium on Marine Biology", edited by G. Persoone and E. Jaspers, Vol. 1, pp 11 - 26.

DANNEVIG, A. 1925. On the growth of the cod and the formation of annual zones in the scales. FiskDir. Skr., Ser, Havunders. 3(6). 23 p.

DANNEVIG, G.M. 1886. Aarsberetning for Arendal og Omegns Filial. Årsberetn. Selsk. norske Fisk. Frem.: 37 - 44.

GROSS, F. 1947. An experiment in marine fish cultivation I. Introduction. Proc. R. Soc. Edinb. B 62(1): 1 - 2.

GROSS, F. 1950. A fish cultivation experiment in an arm of a sea-loch. I. Introduction. Proc. R. Soc. Edinb. B 64(1): 1 - 4.

HARDING, J.P. 1949. The use of probability paper for the graphical analysis of polymodal frequency distributions. J. mar. biol. Ass. U.K. 28: 141 - 153.

MILNE, P.H. 1972. Fish and shellfish farming in coastal waters. Fishing News (Books) Ltd, London. 208 p.

ROLLEFSEN, G. 1946. Kunstig oppdrett av flyndreyngel. p. 91 - 113. In: Forskning og framsteg. Godske, C.L. (Ed.) J.W. Eides Forlag, Bergen. 189 p.