International Council for Exploration of the Sea

C.M. 1985/F:63/Ref. G
Mariculture Committee

Mass production of juvenile Atlantic cod (Gadus morhua L.) in a pond: results and new approaches in 1985.

by

A. Folkvord [1], P.G. Kvenseth [1], T. Pedersen [2] and V. Øiestad [3]

[1]Austevoll Aquaculture Station, N-5392 Storebø, Norway

[2]Institute of Fishery Biology, University of Bergen
N-5011 Nordnes Bergen, Norway

[3]Institute of Marine Research, N-5011 Nordnes Bergen, Norway

ABSTRACT

Large scale production of juvenile Atlantic cod has been carried out since 1980. A break-through was obtained in 1983 with high survival rates of cod larvae to metamorphosis. This year we have tried to solve two remaining problems: the high rates of cannibalism post metamorphosis and the development of a rational harvesting method of juvenile cod in large pond systems.

Five days old cod larvae in a number of about 2 million were released in the pond in mid-March. Those surviving beyond metamorphosis were offered dry pellets from day 40 onwards. The pellets were distributed by five propellers that set up five current fields in which juvenile cod formed large schools grazing on the pellets. An underwater loudspeaker was set to give sound pulses just before each time food was offered, and within few days the juvenile cod were conditioned

to the sound signals. Their distribution and behaviour were studied by use of echosounders and underwater television. From mid-July dry pellets were released inside a fish trap while giving sound signals the cod juveniles were conditioned to. This procedure secured a convenient capture of the juvenile cod and a computer-controlled fish pump transported the fish into vaccination baths and grading grids. The automatic fish-capturing devices gradually emptied the pond for fish, and the vaccinated and graded cod were distributed to fish farmers or were used in a coastal ranching program. All processes involved in large-scale commercial production of juvenile cod in pond systems are now at hand in Norway.

INTRODUCTION

Large-scale production of juvenile Atlantic cod had a breakthrough in Norway in 1983 (Øiestad et al. 1985). In 1984 and particularly this year, the method has been further refined. This year we seem to have solved most of the remaining problems: the cannibalism post metamorphosis and the harvesting of juveniles in large pond systems. This report will mainly describe these new approaches, but will also give a review of the production method and general results.

MATERIALS AND METHODS

Location and sampling

The experiments were carried out in an enclosed pond (Hyltropollen) in western Norway. The pond has a surface area of 22.000 m^3, a volume of 60.000 m and the maximum depth is 5-6 m. Hydrographic features, phytoplankton, zooplankton and fish larvae were sampled at 0, 1, 2, 3, 4 and

5 m depth. For more details see Kvenseth and Øiestad (1984). The brood stock of local coastal cod was kept in a plastic pen where it spawned naturally. The fertilized eggs were collected in a system described by Huse and Jensen (1983).

General management

The pond was treated with rotenone (1,0 ppm) during December 1984 (Table 1), after the harvest of that year's production of about 75.000 juvenile Atlantic cod. Rotenone treatment was repeated in late February with a concentration of 0,4 ppm. A propeller was started in the basin to secure proper mixing, and from mid-March fertilizers were added to the pond.

Release of cod larvae started March 15 (see Table 1 for further details). At April 12 the pump was started (3 m^3 /min), exchanging the water in the pond with seawater from 40 m depth. When the first group of cod larvae passed an age of 40 days after hatching, they were observed in schools in the surface layer and could then be sampled with a dipnet.

As a large number of cod larvae metamorphosed in late April, they grazed down the zooplankton in the pond. It was therefore necessary to replace part of the dam with metal gratings (3 m^2 with 1 mm circular perforatings) to secure additional zooplankton supply from outside the pond. Additional feeding with dry pellets started simultaneously with the mounting of the gratings in the first week of May. Coarser gratings were mounted in the dam in June to further increase the water exchange and water quality and to allow larger zooplankton organisms to enter the pond from the fjord outside.

Growth and cannibalism studies in the laboratory

The purpose of this year's laboratory studies was to obtain comparative data on growth and survival between fish in the laboratory and fish in the pond. These experiments were conducted with juveniles captured in the pond to ensure a homogenous experimental material.

Two sets of feeding experiments were conducted in tanks of 200 litres, one with live zooplankton (mainly calanoid copepods) and another with dry pellets as food. A description of the tanks and water supply is given by Braaten et al. (1983). The average water temperature during the experiments was 8,5 °C and a 16 hour light-cycle/day was used.

The first experiment (I) was conducted with juveniles with an average wet weight of 0,09 grams and lasted for 23 days. Two groups were fed live zooplankton and two groups were fed dry pellets. In the second experiment (II) two groups were fed live zooplankton, and the start weight of these fish were 0,3 grams. This experiment was terminated after 21 days. The stocking density of fish was 200 fish/tank in both experiments. Cannibalism was calculated as the difference between numbers at start and numbers at the end of the experiment after the number of dead and removed ones had been accounted for.

Green gut experiments

First feeding of marine fish larvae in pond and basins have been characterized by larval guts filled with a mushy mass that could vary in colour, from green to yellow and brown (Kvenseth and Øiestad 1984). A special program was run in the Hyltropond this year to find out the importance and origin of this mushy mass present in the guts during the first days of external feeding. Larvae were sampled alive and fixed in chloroform and methanol (2:1) and they were stored in a

freezer at 25 °C for fatty acid analysis. Both whole and gutted larvae were fixed from hatching until they were 50 days old. Larvae from the same egg group were also fed different live diets in the laboratory. Groups feeding on rotifers with and without addition of algae and starvation groups were included in the study.

In order to evaluate larval growth, cod larvae from both the laboratory and the pond have been examined to find out the ratio between RNA and DNA. The larvae were frozen and kept in liquid N_2 until examination could be done. The RNA/DNA ratio gives an indication of larval protein synthesis. It is therefore used as an index of growth rate (Buckley 1979).

If it could be possible to show that this mushy mass is advantageous or even necessary for growth and survival of marine fish larvae, improvements in rearing techniques of marine fish larvae would be possible.

RESULTS

Hydrography

The temperature rose from 6 °C in early March to 10 °C in late April and 14-15 °C in late June (Fig. 1a). The salinity at 4 m depth varied between 31,5 and 32,5 permille and the oxygen saturation varied between 90-130% (Fig. 1b).

Phytoplankton

The phytoplankton community at onset of feeding of the cod larvae was dominated by diatoms, especially Skeletonema costatum (Fig. 2) which reached densities above 12.000.000 cells/l at 5 m depth March 19. Flagellates and dinoflagellates became numerous later in the season with densities above

1.300.000 and 600.000 cells/l respectively (April 12, dinoflagellates with highest abundance at 0 m).

Zooplankton and feeding conditions

During the first feeding period for first group (cohort I) and second group (cohort II) the density of potential prey organisms in the depth with highest densities of cod larvae were between 7.9/l and 0.6/l for rotifers and copepod nauplii respectively (Fig. 3). As the larvae grew older they grazed down the stocks of copepods in late April (densities of copepods, medusae and decapod larvae given in Fig. 4). The densities of hydromedusae peaked in April at 330/m followed by a sharp decline.

Cod larvae

The first group metamorphosed around 20 April at an age of about 40 days, the second group at the end of April at an age of almost 35 days. About 500-600.000 cod larvae reached metamorphosis from the first group (Fig. 5). Growth values for the first group (cohort 1) to day 30 post-hatching, when standard length was 9.1 mm, is given in Table 2.

Feeding of juvenile cod in the pond

Cod larvae and metamorphosed cod have been observed to stem the stream and feed on zooplankton coming through the screens in the dam. This behaviour could make it possible to organize the juvenile cod in the currents from propellers in the pond and to feed them there. Five propellers were placed inside bended pipelines (Fig. 6). Dry pellets which were supplied from a common automatic feeder, entered at the opening of the bended pipelines. The pellets did not become desintegrated before they were eaten by the cod in the streams.

The pellets were made of fish meal (47 %), shrimp meal (20 %), wheat (16 %), fat (9 %), binder (7 %) and vitamins (1 %). Only the first two tons of pellets given to the cod contained shrimp meal, which was replaced by fish meal from mid-June.

The juveniles were fed every 6 min from May 6 to June 30 and from early July the juveniles were fed every 10 min. The total daily ration was gradually increased (20 kg in May, 70 kg in June, 100 kg in July and 60 kg in August, lower values in August due to harvesting). A loudspeaker was programmed to give sound pulses at 150 Hz and the sound started 30 sec before feeding and lasted 60 sec after the pellets entered the propellers. Within few days the juvenile responded to the sound by swimming in the direction of the feeding points or towards the loudspeaker that was placed close to one of the feeding sites.

The behaviour of juvenile cod was studied by underwater-television. By changing the depth and position of the TV-recorder it was possible to study their reaction to the sound used for conditioning to pellets in the streams and to disturbances from birds, boats etc. From mid-June a number of echosounders were installed to study the vertical and horizontal distribution of juvenile cod in the streams and outside the streams. Most of the cod were distributed from 2 1/2 m to the bottom (5-6 m), while during nighttime they were distributed throughout the water column. In the daytime some fish were in the surface and these were preyed upon by terns.

Feeding activity was highest at dusk and dawn. During midday they were feeding with lesser appetite and some pellets might have dropped to the bottom. A large number of juvenile plaice could have prevented this from being a problem by eating those pellets.

A number of cod with suspiciously large stomachs were from time to time examined for detecting cannibalism, but from early June cannibalism was only observed once among those inspected. The stomachs were at most occasions very filled up and the fraction of zooplankton in the stomachs of the fishes was negligible after mid-June.

By starving cod for some hours, the reaction towards food was sharply amplified, but aggressiveness was not observed. From early July the feeding regime changed from a 18 h feeding cycle (from 3 a.m. to 12 p.m.) in the five propellers to a 12 a.m. to 3 p.m. feeding cycle at the propellers combined with a 9 a.m to 12 a.m. feeding at a position close to the fishtrap.

Harvesting of juvenile cod

The fish trap is a chamber with two entrances, each of which can be closed by Venetian blinds (Fig. 7). Feeding takes place in the chamber and the other feeding sites are temporarily shut off forcing the juveniles to enter the trap to obtain food. The closure of the entrances is followed by pumping out the fish. A flashing light from the roof of the chamber scares the fish to the bottom of the trap where they are caught in the water stream set up by the fish pump and they are pumped into a vaccination tank (Fig. 7). The process can be repeated until a suitable number of juveniles are collected in the tank, and they are then exposed for one hour to a vaccination solution against vibriosis. Finally the fish enter a high capacity sorting tank where they are graded in three size-groups and drained to their respective net pens or to a transportation unit.

Growth and cannibalism studies

In the tank studies the fish had better growth when fed live zooplankton and also less losses due to cannibalism was

observed than in groups fed dry pellets (Table 3). The difference in growth rate between the juveniles in the laboratory and the juveniles in the pond (6% versus 9%) can be explained by the difference in temperature in the two systems (8.5 °C in the laboratory versus 12,5 °C in the pond).

Natural mortality in the tanks was generally low in the experiments. With one exception the daily natural mortality rate was 0,001 or less. In one of the groups fed dry pellets the daily natural mortality was 0,011 (Z). The overall mortality in the lab groups fed live zooplankton was lower than calculated values for similar stages in previous pond experiments (Øiestad et al. 1985). The overall mortality from this year's season will not be known until late autumn when all the juveniles have been removed from the pond.

DISCUSSION

All major processes in the production of juvenile cod have finally been investigated and an acceptable solution which can make fullscale commercial production of cod possible, is now developed:

The brood stock produce large quantities of high quality eggs; the incubation of cod eggs and the transportation of hatched larvae have been a large-scale operation in a number of countries since the 1880-ties (Shelbourne 1964); in the pond the larvae have a very high survival rate when released at the right time relative to the occurence of hydromedusae and food organisms.

Juvenile cod feed on natural zooplankton until they reach a size of about 5 cm (1.5 gram wet weight); when the natural zooplankton is insufficient to supply their daily ration, they form large schools feeding on dry pellets in the

artificial streams generated by the propellers.

The wellfed juvenile cod do not seem to prey on each other although the size difference within the population is rather substantial. The juvenile cod are totally dependent upon the pellets for their food supply. Therefore they are easily captured in the fishtrap and can be pumped out of the pond system for vaccination and grading. If the pond system is able to produce 5 juveniles/m^3, this will enable commercial application of the production method as the construction and managing of the system most likely can be paid by taking a mean price of 2 Nkr (0,25 $) per fish. The actual production /m^3 in the Hyltro pond will be known in October this year.

USE OF JUVENILE COD

The cod produced in the pond will be used for three different purposes:

1. Coastal ranching

This program started in 1982 and results from this restocking experiment have been reported (Svåsand 1985, Svåsand and Kristiansen 1985). From the 1983 release of 20.000 tagged juveniles of 15-20 cm, the tag return has been about 10%. In 1985 this program will be further scaled up by a planned release of 30.000 tagged juvenile cod.

2. Ranching of sound-conditioned juvenile cod

From a size of 3 cm onward, the juvenile cod have been given sound pulses before feeding and they have established a conditioned behaviour. This autumn 20-30.000 juvenile cod are planned to be released in a small fjord outside the pond and fed in conjunction with the sound from the loudspeaker used for conditioning the cod. The purpose is to see if it is

possible to keep the fish in the area until harvest can take place two or three years later and further to see if the slow winter-growth can be enhanced by feeding them. We will be able to compare this production method with the net-pen production method.

3a. Intensive farming in net-pens at ambient temperature

Most of the juvenile cod will be used in intensive net-pen farming. Experience from such ongrowing studies has been reported by Kvenseth (1985).

3b. Intensive farming of cod in cooling water from a gas terminal

Some thousand cod will be fed in tanks on land at their optimal temperature for growth. This is possible by using the cooling water from the gas terminal at Kårstø, Norway.

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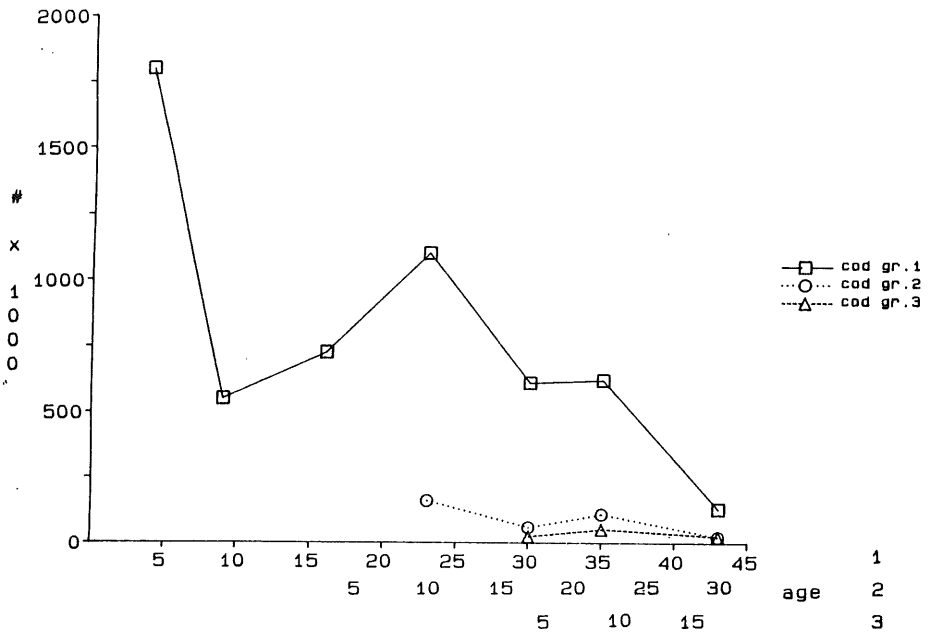

Figure 5. Population estimates of three cohorts of cod larvae in Hyltro 1985. (values are not corrected for avoidance). Values are numbers x 1000.

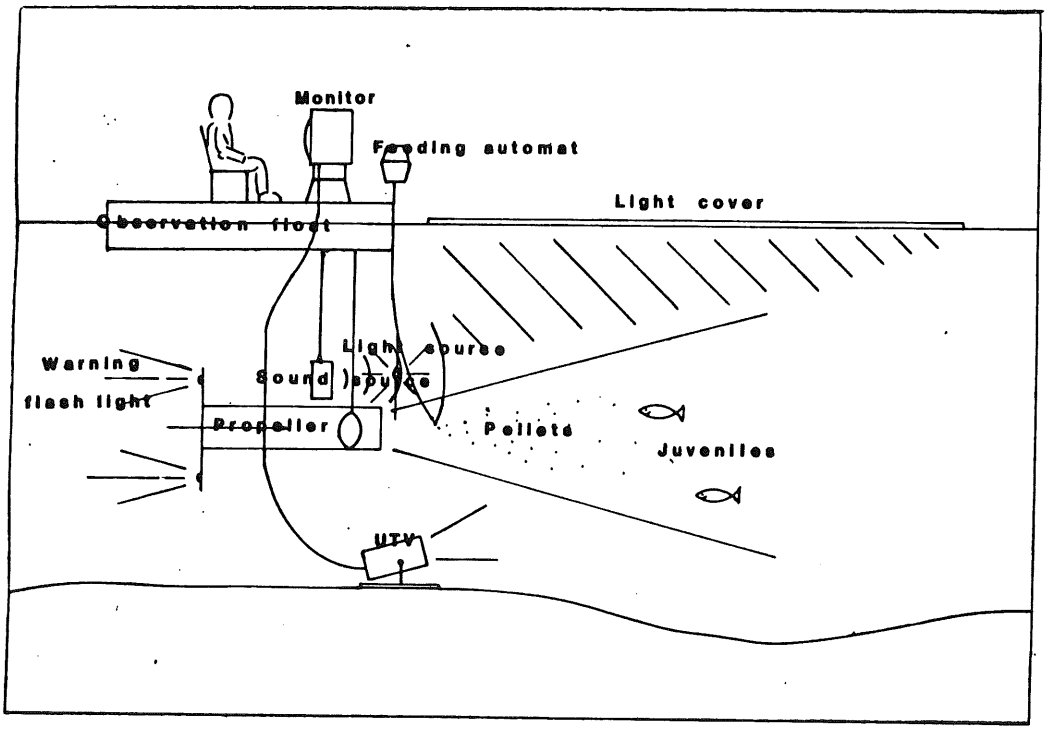

Figure 6. Feeding system used during conditioning of juvenile cod.

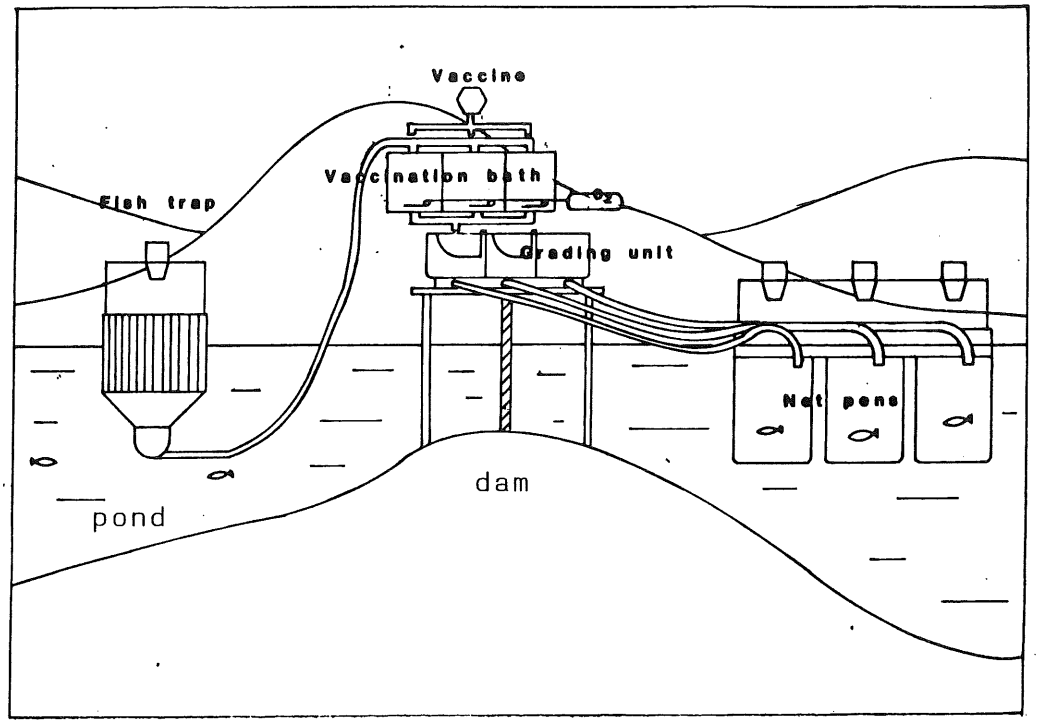

Figure 7. Automatic harvesting, vaccination and grading system.

Table 1. Hyltropond events 1985

Date	Events
dec -84	Rotenone treatment of the pond, 1,0 ppm.
21 jan -85	Opening of the dam by installation of gratings
13 feb.	Start the deepwater pump ($3m^3$/min)
20 feb	Rotenone treatment of the pond, 0,4 ppm.
	Stop of the deepwater pump
	Start of a propeller to mix water masses
25 feb	Start of the deepwater pump again
13 mar	Stop of the deepwater pump
	Closure of the dam
15 mar	Release of cod gr.1 (1.800.000)
28 mar	Release of cod gr.2 (160.000)
30 mar	Starvation group from gr.1 died out
10 apr	Release of cod gr.3 (225.000)
12 apr	Start of the pump again
20 apr	Observed large amounts of post metamorphosed cod
	Started feeding dry pellets
	Caught 100 cod fry with dipnet
01 may	Start of the propellers
03 may	Installation of fine gratings in the dam
23 may	Installation of coarse gratings in the dam
01 jun	First use of echosounders for distribution survey
23 jul	Start of harvesting cod juveniles with harvesting unit
31 jul	Start of vaccinating cod juveniles
	Start of transport of juveniles to fish farms

Table 3. Data from laboratory experiments.

Exp. no.	Food	Size (gram) start	Size (gram) end	Growth rate (in %) ind.	Growth rate (in %) pop.	Cannibalism z	Nat. mort. z
I	pellet	0.068	0.320	6.7	4.7	0.018	0.001
I	pellet	0.123	0.431	5.5	1.6	0.019	0.011
I	zoopl.	0.075	0.572	8.8	8.6	<0.001	0.001
I	zoopl.	0.079	0.516	8.2	8.0	0.001	<0.001
II	zoopl.	0.307	1.233	6.6	6.4	0.002	0
II	zoopl.	0.307	0.984	5.6	5.6	0	0

Table 2. Growth of larval cod (Cohort 1) in 1985 pond study.

Date		length in mm	myotome heigth in mm	age	weight in µg gutted	weight in µg ungutted
15-3	n	44	44	4	20	21
	X	4.5	0.23		48.8	50.9
	sd	0.2	0.01		7.5	6.4
15-3	n	44	44	4	22	22
	X	4.0	0.26		41.3	46.3
	sd	0.3	0.02		7.4	5.8
16-3	n	42	42	5	20	20
	X	4.2	0.27		42.8	51.9
	sd	0.2	0.02		6.4	8.5
17-3	n	44	44	6	22	21
	X	4.4	0.27		44.9	51.5
	sd	0.3	0.02		6.5	7.8
18-3	n	44	44	7	20	22
	X	4.2	0.27		44.3	54.8
	sd	0.2	0.02		4.8	9.3
19-3	n	44	44	8	20	20
	X	4.3	0.28		52.9	55.7
	sd	0.3	0.02		7.8	7.8
21-3	n	22	22	10		20
	X	4.8	0.30			56.2
	sd	0.4	0.03			10.9
22-3	n	44	44	11	19	21
	X	4.6	0.31		67.7	73.7
	sd	0.2	0.02		8.9	9.2
26-3	n	44	44	15	21	22
	X	5.0	0.37		97.9	105.9
	sd	0.4	0.03		22.1	19.2
29-3	n	22	22	18		22
	X	5.7	0.41			168.4
	sd	1.5	0.03			24.6
31-3	n	44	44	20	22	21
	X	6.1	0.46		202.2	212.2
	sd	0.5	0.04		39.1	43.3
02-4	n	22	22	22		22
	X	5.7	0.50			269.7
	sd	0.5	0.07			67.1
05-4	n	22	22			21
	X	6.8	0.67			398.0
	sd	0.6	0.06			52.8
10-4	n	22	22	30		22
	X	9.1	0.86			807.5
	sd	0.9	0.15			300.0

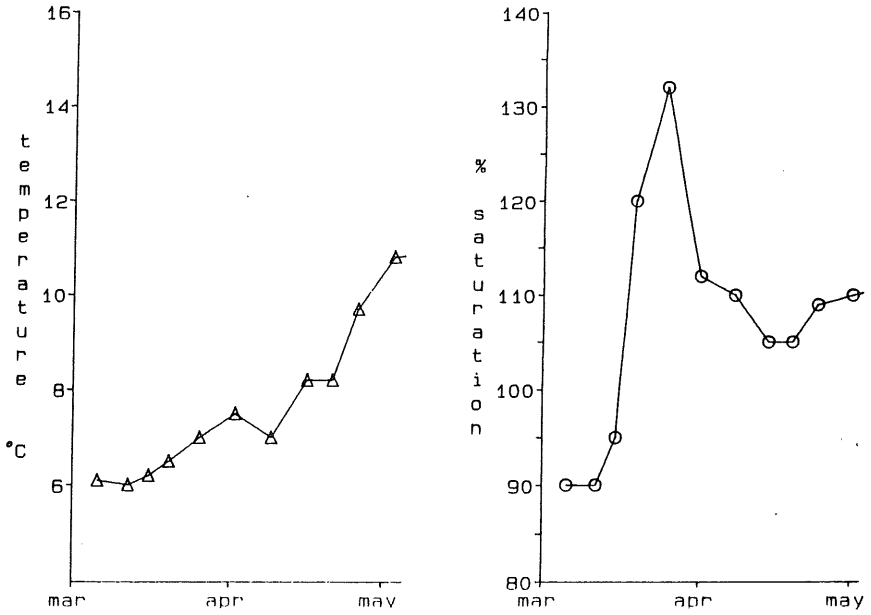

Figure 1. a) Temperature in Hyltro 1985 (2 m).
b) % O_2 saturation in Hyltro (2 m).

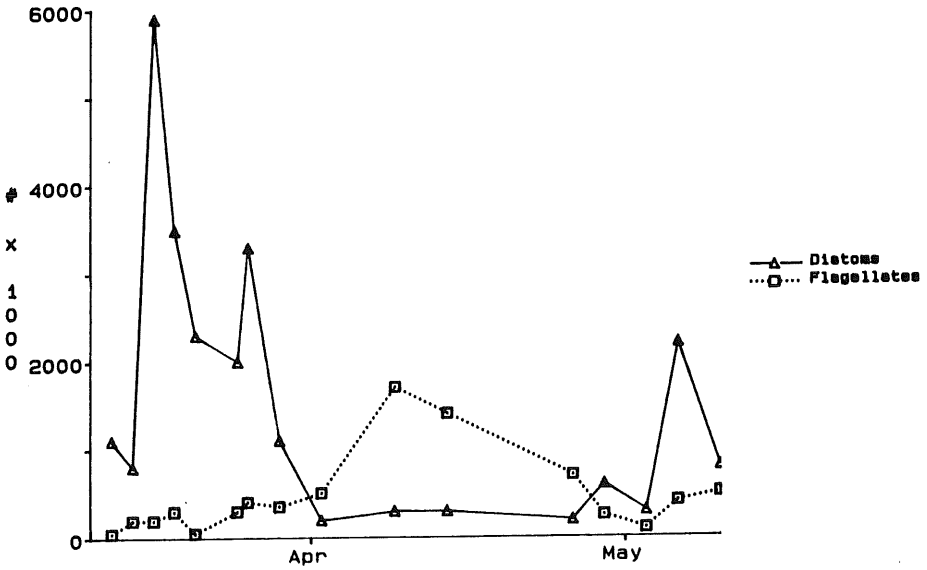

Figure 2. Phytoplankton densities at 2 m in Hyltro 1985. Dinoflagellates were present only at densities below 100.000 cells/litre. (values given are numbers x 1000 cells/litre).

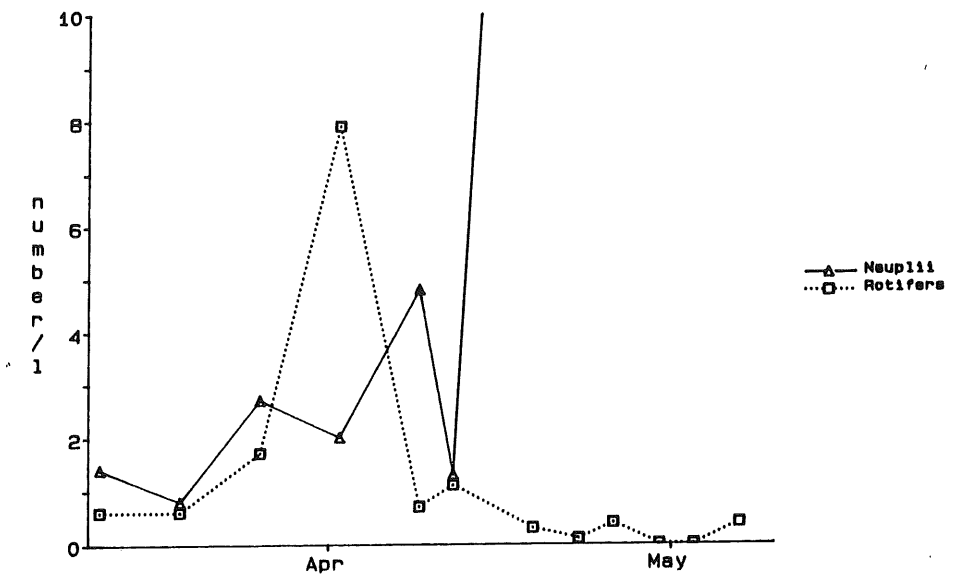

Figure 3. Micro zooplankton densities at 3 m in Hyltro 1985. (values are numbers/litre). Nauplii densities were above 25/litre after April 19.

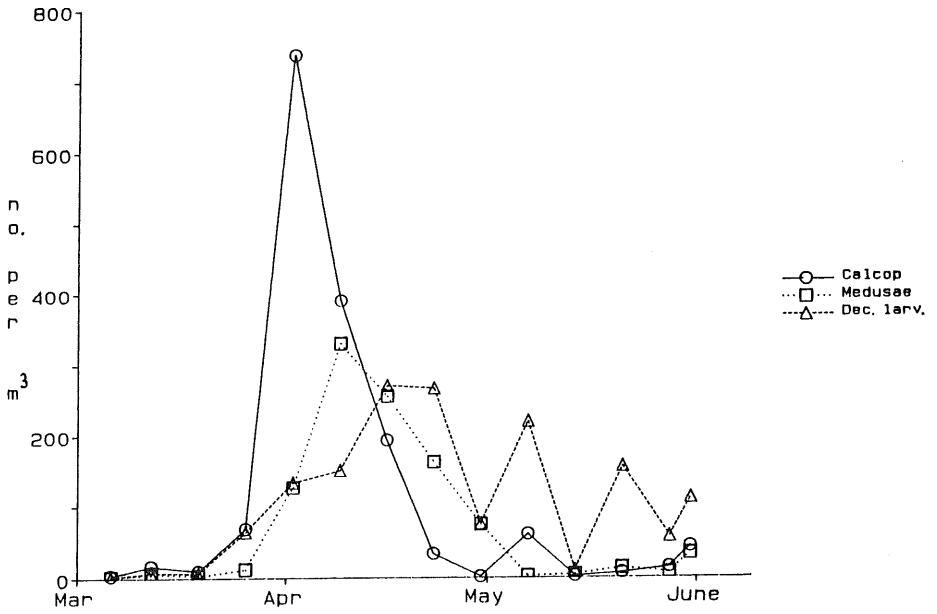

Figure 4. Macro zooplankton densities at 2 m in Hyltro 1985. (values are numbers/m^3).