FEEDING OF PLAICE (*PLEURONECTES PLATESSA* L.) AND COD (*GADUS MORHUA* L.) LARVAE

By

HANS NORDENG AND PER BRATLAND

Institute of Marine Research, Bergen, Norway

Phytoplankton could be a necessary source of nourishment for young cod larvae, since in an initial investigation the guts of 6 out of a sample of 15 Lofoten cod larvae, just beyond the yolk-sac stage, contained *Peridinium pellucidum* and *Coscinodiscus* sp. Because of lack of cultivated phytoplankton, *Chlamydomonas* sp., *Saccharomyces cerevisiae* and trout food were given to plaice and cod larvae by means of *Artemia* nauplii pre-fed on this nutrient. Of the successfully reared plaice, a high proportion (97%) were normally pigmented when given pre-fed nauplii. A few hundred 3 months old surviving cod larvae, measuring about 12 mm died when being separated from *Artemia* nauplii in the tanks.

To avoid harmful cleaning operations, plaice and cod larvae were given freeze-dried food particles (10–200 μ), based on (1) *Calanus finmarchicus*, (2) non-fertilized and (3) 5 days incubated cod eggs. Surplus particles were expected to dissolve and disappear. None of the food types were as clearly visible in water as granules of yolk of hardboiled hen egg, which at initial feeding were taken by 95% of cod larvae in 90 minutes. Types (1) and (2), taken by 40 and 27% of the larvae respectively, formed deposits in the tanks. Type (3), almost invisible in water and possibly not taken regularly, formed no deposits. The stale deposits were eaten by the larvae. This fact could be one reason why no cod larvae survived unfed larvae longer than 24 days.

INTRODUCTION

One of the problems in rearing cod and plaice larvae is to provide the larvae with suitable food. ROLLEFSEN (1939, 1940) introduced nauplii of *Artemia salina* which were suitable for plaice, but mostly too large for newly hatched cod larvae. Until now rearing of cod larvae has failed.

DANNEVIG and DANNEVIG (1950) related the mortality of their one month old *Artemia*-fed cod larvae to an over-inflation of the swimbladder which made the larvae float to the surface. Death might be the result of an unvaried and inadequate diet and to investigate this assumption a series of experiments with selected live and artificial foods were carried out in 1962 and 1965 at the Institute of Marine Research, Bergen.

MATERIALS AND METHODS

The experiments included larvae of coastal cod, Arctic cod and plaice. The eggs were artificially fertilized with the exception of one separate batch of coastal cod eggs which had been spawned naturally in an outdoor basin. These eggs were collected from the surface of the outdoor basin immediately after spawning.

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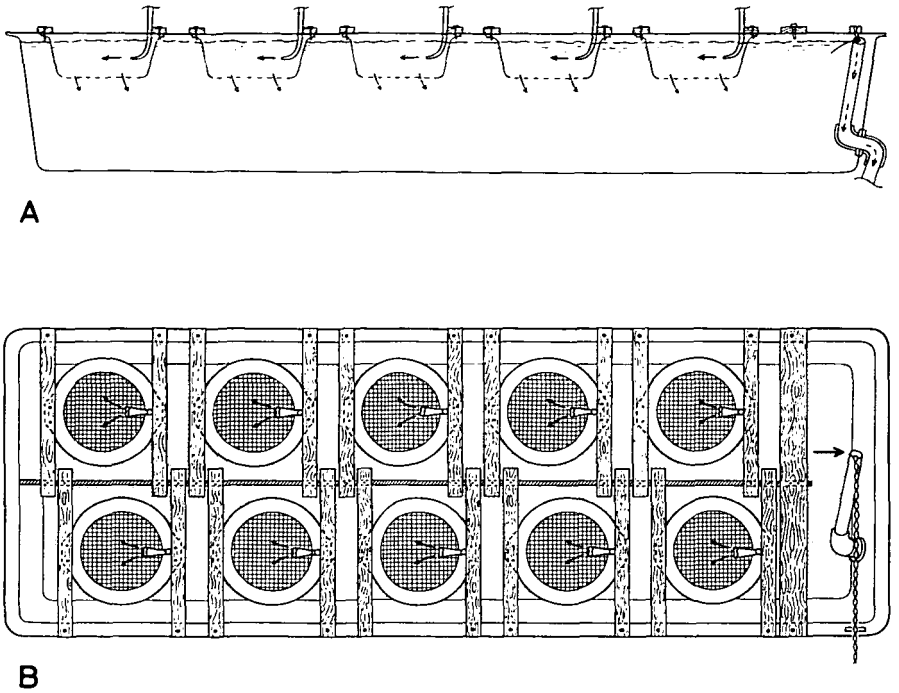

Figure 1. Incubator consisting of a plastic tank (3·1 × 1·1 × 0·5 m) and 10 incubator basins.
A. Diagram of longitudinal section.
B. Incubator seen from above.

EXPERIMENTAL CONDITIONS

The fertilized eggs were incubated in plastic basins 35 cm in diameter and 15 cm deep. The bottom of the incubator basin was made of perlon gauze with mesh opening 0·45 mm. Ten incubator basins were mounted in a large plastic tank (Fig. 1) with the inside coated with a two component black plastic paint. Each basin was supplied with 0·8 l water per minute. The water entered the basin peripherally and left through the sieve bottom. The water flow was regulated to be approximately parallel with the bottom of the basins and the desired slow stirring of the eggs was achieved by giving the outlet of the plastic pipes a compressed profile, causing the water flow to divide into two currents, one to the right and the other to the left.

The water used for the experiments was taken from a sea water system where surplus gas had been removed by stirring in special tanks. Throughout the experiment the water salinity was 33–34‰. The water temperature was adjusted continually in accordance with the mean temperature of the surface layer at Eggum in Lofoten, *i.e.* during the incubation period from 5° to 6°C and during feeding from 6° to 13°C. Rearing was undertaken in black tanks consisting of two feeding compartments separated by the water intake chambers (Fig. 2). The bottom of the feeding compartments consisted of fine perlon gauze placed 10 cm above the bottom of the tank. From a cylindrical sieve in the intake chambers a water supply of about 3 l per minute flowed into the feeding com-

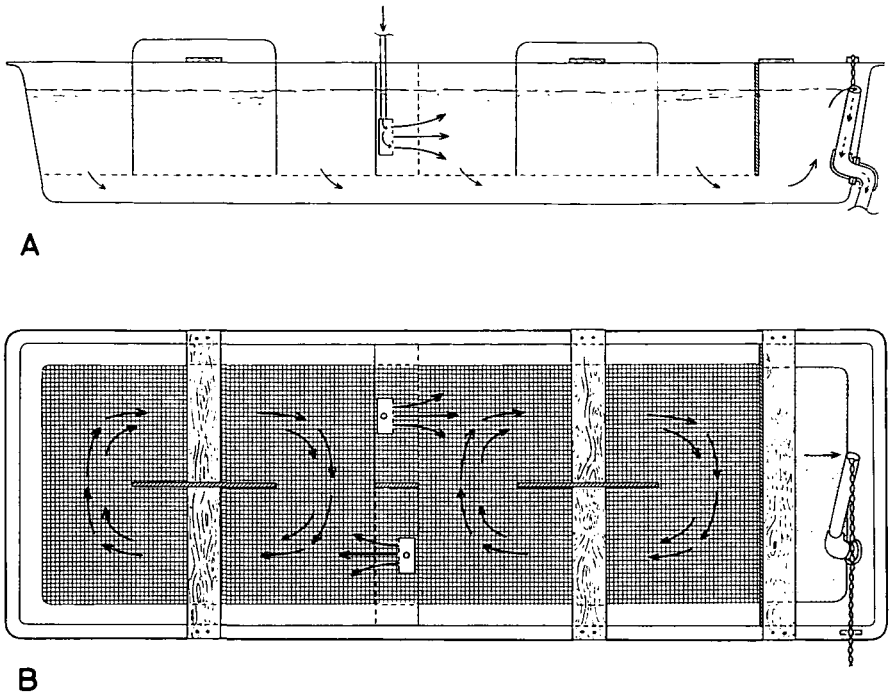

Figure 2. Rearing tank (3·1 × 1·1 × 0·5 m) consisting of two rearing compartments divided by two water intake chambers.
A. Diagram of longitudinal section.
B. The rearing tank seen from above.

partments, causing a slight circular current. At no point in the feeding compartments were the larvae exposed to excessive current.

A wall of laminated wood 50 cm long was placed in the middle of each feeding compartment to prevent larvae and particles being trapped in the centre of the swirl. Water entering the feeding compartments passed through the sieve bottom and left via the tank's discharge pipe.

The experiments were carried out in natural light supplemented by fluorescent tubes above each feeding compartment during the day. The fluorescent tubes were turned off each evening at dusk. During inspection of the water system each night the light was turned on for brief periods.

Cleaning of the gauze bottom of the feeding compartment was carried out from underneath with some difficulty by means of a special brush with a hollow flexible handle. The T-shaped core of the brush was perforated so that water and particles could be siphoned out through the handle. The insides of the compartments were cleaned once every four days with a plastic sponge fastened to a wooden rod.

FOOD AND FEEDING

In 6 out of a sample of 15 Lofoten cod larvae just beyond the yolk-sac stage, the guts contained the phytoplankton species *Peridinium pellucidum* and

Coscinodiscus sp., alone or together with a single crustacean nauplius. It was assumed that phytoplankton could be a necessary source of nourishment of which the laboratory larvae were deprived when fed with *Artemia* nauplii only.

In 1962, a plan to feed the larvae with cultivated phytoplankton in addition to *Artemia* nauplii could not be carried out because the culture could not be prepared in time. Instead, the larvae were given additional nutrient by means of *Artemia* nauplii which had been pre-fed for 24 hours with:

A. Marine *Chlamydomonas* sp
B. Yeast (*Saccharomyces cerevisiae*)
C. Trout food

respectively.

The trout food (C), which had proved satisfactorily nutritious for salmonid larvae, consisted of one part heart and three parts liver from cattle, with 1% kelp meal, 0·5% B-vitamin concentrate, 0·5% cod liver oil and 4% alginate added as binding agent. However, it proved impossible to remove large *Artemia* from the feeding compartment without damaging the larvae.

In 1965 artificial food particles were used, based on the following freeze-dried foodstuffs, bound with gelatine or alginate:

1. Paste of *Calanus finmarchicus*
2. Contents of non-fertilized cod eggs
3. Contents of 5 days incubated cod eggs

Regarding the contents of incubated cod eggs (3), it was assumed that enzymes from the germical disc had to some extent converted the yolk into a more adequate nutrient for the larvae. Each category of basic foodstuff (1–3) was ground in a cooled mixmaster and then strained or pressed through very fine gauze. The finished portions, containing 4% alginate or gelatine, were formed into bars 0·5 cm thick and afterwards freeze-dried.

Prior to feeding, pieces of these bars were pulverised. The powder was mixed with sea water, strained, and then given to the fish larvae by means of a pipette. The particles spread evenly in the water. The size of the particles was about 40 μ, ranging from 10 to 200 μ, like the granules of yolk of hardboiled hen egg, which were taken eagerly by the larvae in a secondary experiment in 1962.

In both experiments feeding took place daily at 0900, 1300, and 1700 hr. For comparison, in 1965 one lot of coastal cod larvae was fed only with granules of egg yolk, and another lot which was not fed at all, was used for control.

RESULTS

LIVE FOOD

In order to ensure that the larvae received varied food, they were all given all three groups of pre-fed nauplii alternately (Group A–C).

1. The plaice larvae took the nauplii satisfactorily. The larval metamorphosis commenced 35 to 50 days after hatching and the post-larval pigmentation after 40 to 70 days. The pigmentation developed first along the dorsal and ventral fins, starting either from the foremost part of the body or the rear. Only 3% of the specimens remained unpigmented or were partly pigmented. The expe-

riment was concluded 4 months after hatching with the young plaice, making approximately 45% of the original population, in excellent condition, measuring 20 to 30 mm.

2. Comparatively few cod larvae succeeded in taking the pre-fed *Artemia* nauplii. After 3 months a few hundred surviving larvae measured about 12 mm. To free these larvae from the repeated and lasting procedure of removing large nauplii from the feeding compartment, the larvae were transferred to clean compartments. During 3 transfers in the course of 5 days the death rate increased considerably, and within 8 days the last larvae were dead.

ARTIFICIAL FOOD

During the incubation period some of the eggs from coastal and Arctic cod sank to the bottom of the incubating basins, whether the egg lots originated from various parents or a single pair of parents. The eggs in the surface and those on the bottom hatched normally. Each of the artificial food types (1–3) were given to three separate lots of plaice and cod larvae. The food particles were almost as good in size, distribution and buoyancy, as granules of hen egg yolk, but they were less visible in water, especially the gelatine bound particles. Gelatine and alginate bound particles of each food type were given alternately.

During initial feeding 95% of densely populated cod larvae filled themselves with the clearly visible granules of hen egg yolk in 90 minutes. The less visible particles of *Calanus* (1) and non-fertilized cod eggs (2) were taken by 40% and 27% of the larvae respectively, whereas particles of incubated cod eggs (3) nearly invisible in water, were taken by only 7% of the cod larvae. In this early stage cod larvae also took pulverised aquarium food, *Artemia* eggs and shell of *Artemia* eggs.

With the exception of the particles of incubated cod eggs (3), which dissolved completely, remains of the other types of foods adhered to the walls and bottoms of the feeding compartments.

It appeared that the larvae fed from the coating of stale food which had gradually formed on the walls of the feeding compartments. In order to examine this phenomenon more closely, a new batch of cod larvae was hatched and placed in a feeding compartment with stale *Calanus* particles on its walls and within 24 hours some of the larvae had eaten this food.

During feeding the larvae of both Arctic and coastal cod descended towards the bottom of the feeding compartments. About 21 days after hatching nearly all the larvae were at the bottom of the compartments where there were accumulations of stale food. The larvae were very active and most of them had food in their stomachs. In order to investigate if the larvae went to the bottom of the compartments for the food deposits or to compensate for increasing pressure within the swimbladder, some larvae were transferred to a clean feeding compartment. The larvae immediately dispersed evenly in the new compartment displaying normal feeding behaviour, suggesting that the larvae gathering on the bottom had, in fact, sought out the deposits of food.

At the start of the feeding experiment larvae with hen egg yolk in their stomachs in the evening were transparent the following morning. After a period of about 6 days the digestion time gradually increased. Finally, the larvae did not become transparent and died with their stomachs filled with yolk granules.

All the plaice larvae were dead 47 days after hatching. The control cod larvae, not fed, died 31 days after hatching. The cod larvae given particles of incubated cod eggs (3), non-fertilized cod eggs (2), granules of hen egg yolk and *Calanus* particles (1), survived the control larvae by 4, 9, 16 and 24 days respectively.

DISCUSSION

Inflation of the swimbladder of the cod larvae as mentioned by DANNEVIG and DANNEVIG (1950) was not observed in our experiments. According to DANNEVIG (1960) cod larvae are exceedingly sensitive to changes of pressure and to excessive light. Light from a torch used during attempts to count the larvae, or transfer of larvae from one compartment to another in a white ladle caused instantaneous death. Transfer by means of a black ladle was apparently successful, except when the larvae were collected from the deepest part (30–40 cm) of the tanks.

DANNEVIG and DANNEVIG (1950) are of the opinion that cod larvae need a pressure corresponding to a depth of at least 10 m in order to develop normally. Admittedly, the larvae in our experiment descended towards the bottom during the feeding period, but after transfer to feeding compartments without stale food deposits at the bottom they again spread evenly in the water. DANNEVIG (1960) relates the distribution of the cod larvae in their natural environment at a depth of 10 to 30 m to the pressures within the swimbladder. The distribution might also be determined by the density and vertical distribution of the food organisms.

We do not know if mortality was due to the pressure conditions in the feeding compartments gradually becoming unsatisfactory to the larvae. Contributary causes of death might have been disturbance during cleaning of the feeding compartments, the switching on of laboratory lights during nigh inspection of the water system, and the fact that the larvae consumed stale food deposits on the walls and the bottoms of the feeding compartments.

The comparatively high rate (97·0%) of completely pigmented young plaice in our experiment may possibly be connected with the additional nutrient (A–C) conveyed to the larvae via the *Artemia* nauplii, since only 55·8% of larvae fed with nauplii which had not been pre-fed were completely pigmented. (VON UBISH 1950). The artificial food types (1) and (2) were visible in water, but formed deposits in the feeding compartments, whilst type (3) which did not leave any deposits was almost invisible in water.

Artificial wholesome food particles, 10–150 μ, clearly visible in water and not leaving deposits could be suitable even for cod larvae.

An unexpected feature of the otherwise sensitive cod larvae was their voracity when fed on *Calanus* particles (1) and yolk granules of high particle density. The size of the particles, 10 to 200 μ, is similar to the size of individual cells and cell colonies in the microplankton during vernal blooming. If, in the sea, newly hatched larvae are so voracious as to take any particle in sight – spined phytoplankton included – such plankton may become fastened in the throat or oral cavity with fatal results. If so, the relative quantity of spined phytoplankton may affect the year-class strength.

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