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FEEDING PROBLEMS AND THE TECHNOLOGY OF REARING MARINE FISH LARVAE

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ABSTRACT

—The production of marine fish fry is presently based on the use of live food organisms, at least during the first few weeks after hatching. As outdoor pond techniques, with natural production of live food organisms, could never be very successfully applied to marine larvae, the food organisms used are either cultured or bought at a high price on a specialized market.

Cutting down the cost of the production of fry implies cheaper live food organisms and early weaning techniques, but the most promising solution for the future would undoubtedly be the use of artificial diets straight from first feeding. It has been demonstrated on some species that the larvae can survive on such diets, but important technological problems still have to be overcome before they can prevail over live food. —

RÉSUMÉ

—La production des juvéniles, chez les poissons marins, se fait actuellement avec des proies vivantes, au moins pendant les premières semaines de l'élevage. Dans la mesure où il n'a jamais été possible d'appliquer efficacement à ces animaux des techniques d'élevage en bassins de grandes dimensions, avec des productions planctoniques naturelles, les proies employées doivent être produites en écloserie, ou achetées sur un marché spécialisé.

Le coût de production des juvéniles pourrait être réduit en faisant baisser le prix de ces proies, et en réalisant un sevrage précoce des larves. Mais la solution la plus prometteuse pour l'avenir est sans aucun doute l'emploi d'aliments composés dès le début de l'élevage. Il a été démontré chez quelques espèces que les larves peuvent survivre avec de tels aliments. Mais de sérieux problèmes technologiques restent à résoudre avant qu'ils ne puissent prendre la place des proies vivantes. —

1. INTRODUCTION

Since May (1971) published a bibliography of the attempts to rear the larvae of marine fish in the laboratory, many more experimental papers became available. However, one has to agree with Nash (1977) that marine fish culture did not progress for the last decade as rapidly as freshwater fish culture or shrimp culture except on the very few species whose juveniles could be caught from the wild in large quantities. The mass production of fry was pointed out as the main problem to be solved.

The marine fish that are worth culturing most generally have smaller larvae than the freshwater species that are cultured on a large scale. There is no doubt that this difference accounts very much for the present situation (Nash, 1977; Girin, in press). Such larvae not only had to be cultured on live food organisms, but the outdoor pond technique, based on natural production of zooplankton, which is widely used for the production of cyprinid fry (Tamas and Horvath, 1976) could not be successfully applied to marine larvae (Ellertsen et al., 1977). The experimentalist had to go into the complicated process of feeding them on cultured live animals, at least during the first month after hatching (Girin and Person-Le Ruyet, 1977).

2. FOOD CHAINS AND PRODUCTION COSTS

The commercial production of post-larvae of penaeid shrimps is based on similar food chains, but the quantities that are requested are much smaller. The post-larvae of *Penaeus japonicus* are currently weaned to inert diets at a weight of a few milligrams (Laubier-Bonichon et al., 1977). In large scale production of the European sea bass *(Dicentrarchus labrax)*, weaning takes place at the much larger weight of 50 mg (Girin and Person-Le Ruyet, 1977). Considering that the food organisms used cost at least 170 U.S. dollars/kg in dry weight (Girin, in press), such a difference is important and one could be tempted to conclude, with Barnabe (1976), that the future of marine fish fry production is based on feeding the larvae on artificial diets straight from first feeding.

There is little doubt that this conclusion is right for the long-term future. But the required diets and techniques are still far from being available presently, and some much simpler solutions like cutting down the price of live food, or developing early weaning techniques may still prevail for the coming decade.

The price of live food can be reduced rather easily, at least for the two most important organisms, *Brachionus* and *Artemia.* Most of the production cost of *Brachionus* is due to the production of the live planktonic algae which they are usually fed (Girin, in press), but it has been demonstrated that they can be cultured on algae powders which are lower in cost (Person-Le Ruyet, 1976; Hirayama and Nakamura, 1976). A shortage of *Artemia* cysts from the San Francisco Bay during the years 1974–1977 produced a great increase in market prices (Sorgeloos, 1976), but new sources were developed and the shortage is not only over but hatcheries can now choose their supplier according to price and quality of cysts offered.

Early fry weaning techniques, saving large quantities of *Artemia*, are progressing rapidly for some species. The average weight for successful weaning of sea bass in laboratory experiments recently dropped down from 50 mg to 10 mg (Barahona-Fernandes and Girin, 1976) cutting down by 4 the total amount of *Artemia* required for the production of each juvenile. The technique has already been applied successfully in the production of more than 50 000 juveniles. In Japan the same objective was reached with the red sea bream *(Chrysophrys major)* by an early transfer into sea cages, where the newly metamorphosed fry are fed on natural plankton and minced fish flesh (Kittaka, 1977).

At present, there is no clear demonstration that a commercial hatchery for marine fish using a succession of live organisms and artificial diets could be financially profitable, but the present multiplication of pilot-scale ones at least demonstrates that such hatcheries can now be built and operated at a reasonable expense. The lack of a proper method for rearing the larvae on an artificial diet straight from first-feeding may therefore not be presently the main limiting factor for large scale production of fry.

3. THE TECHNOLOGY OF REARING MARINE FISH LARVAE AND THE USE OF ARTIFICIAL DIETS

It has already been demonstrated on sea bass (Barnabe, 1976; Gatesoupe et al., 1977), sole (Gatesoupe et al., 1977), and plaice (Adron et al., 1974, 1977) that rearing marine fish larvae on artificial diets straight from first feeding is not an impossible goal. Larvae at the first feeding stage do not necessarily require a living, self-moving, food particle, but the relatively low survival and growth rates obtained also demonstrated that many problems will have to be solved before efficient methods become available.

The larvae at the first feeding stage are found in all areas of the rearing tank and do not concentrate where the food is distributed. To be efficiently consumed, the food should be permanently available in the water column. It should not only be attractive, taste good, and be tender enough to be ingested, but also keep these qualities for hours in agitated water. Such requirements take us very far from the much simpler problem of feeding juvenile salmonids which swallow the food as soon as it is distributed to them.

One could think that a step by step procedure would be the easiest way to solve the different problems included in these requirements. A possible first step might be an adequate technology for the use of *Rotifers* and *Artemia* in a frozen or freeze-dried form. Frozen food organisms can be considered as natural, moist capsules whose taste and nutritional qualities undoubtedly fulfill the requirements of the fish. Correct tank design and agitation of the water should keep the food in suspension. A continuous distribution would maintain the variations of food density and availability in the tanks at a reasonable rate. A convenient water quality could be obtained from an increased exchange rate.

The technology developed in the 1960's for mass production of marine fish fry, mainly in Japan, was based on large tanks with flat bottoms and low exchange rates of the water. Such methods would be inadequate for the use of dry diets, but it looked like smaller volumes, more suitable for the use of such diets, would hardly provide an environment stable enough for the larvae (Nash and Kuo, 1975).

However, more recent technologies, combining the smaller volumes used by Shelbourne (1968) in his first demonstrations of large scale production of plaice and sole, and the round tanks with conical bottoms now popular for shrimp production (L'Herroux et al., 1977) could more easily be adapted to the use of dry diets. Only a few trials have been performed so far, and their results are quite poor (Gatesoupe et al., 1977), possibly because the researchers did not attempt to use strong water currents in the rearing containers, a necessity to keep frozen organisms in suspension. Some fish larvae can withstand high flow rates perfectly well (Barahona-Fernandes, in press).

4. ELABORATE ARTIFICIAL DIETS FOR FISH LARVAE

Artificial diets indeed have several advantages: the feedstuffs they are made from can be stored, and their size and composition can be adjusted to the exact requirements of the fish, provided that they are known. The various types of artificial diets that were experimented with for the last decade have recently been reviewed by Métailler and Alliot (in press), who distinguished dry, moist, and encapsulated ones.

The moist diets are the closest to the food organisms. Most usually they are made from fish flesh and a binder, possibly with oils or vitamins added (Alessio et al., 1976; Kittaka, 1977; Bromley, 1977). The fish flesh is sometimes replaced by egg yolk (Villani, 1976). Like the frozen food organisms, they give quite good results when used for large fry (i. e. over 10 mg), but poor results when fed straight from first feeding. The reasons are still the same: the technical problems of continuous distribution and tank hygiene with moist diets have not yet been effectively solved.

Dry diets are more easily stored and distributed, but they may not be as easily ingested by the fish. They can be pelleted or flaked, made with more or less elaborate techniques. Much attention has been paid to the binder, in order to obtain a high stability in agitated water (Gatesoupe and Luquet, 1977). Using dry diets in pelleted form, Barnabe (1976) obtained 4% survival at the age of 3 1/2 months with the European sea bass *(Dicentrarchus labrax)*, but under the same conditions the fish grew twice as fast with a survival rate six times higher when they were fed on live food for the first 2 months. Adran at al. (1974), with plaice *(Pleuronectes platessa)*, obtained 17.5% survival at the age of 7 weeks, nearly half the survival rate of the control fish which were fed live food. They didn't mention the comparative growth rate of the two populations.

From a theoretical point of view, microencapsulated diets are the most promising ones: they can combine the tenderness of moist diets and the high stability of the best dry pellets. After Meyers et al. (1971) recommended their use for larval feeding, very much was expected from the technique. Indeed, in 1973, at the first International Symposium on the Early Life History of Fish, Lasker announced that several larvae of Anchovy *(Engraulis mordax)* had been reared past metamorphosis on an encapsulated diet, but further experiments on shrimps (Jones et al., 1976) or fish (Adron et al., 1977) did not bring highly convincing results. Obtaining the right palatability, density, nutritional value, and stability proved difficult.

5. HYGIENE

There is, particularly from the results obtained with dry pellets, a real potential for the use of artificial diets straight from first feeding, but all researchers have pointed out tank hygiene as the main difficulty they faced.

Whatever method is used for the elaboration of the diet, it looks like the only solution to maintain the food density high enough to rear marine larvae on artificial diets is to distribute a tremendous excess of food. Gatesoupe and Luquet (1977) observed that the main reason for the failure of many experiments was the pollution due to the uningested food accumulating on the bottom and sides of the tanks. Métailler and Alliot (in press), in their review on the subject, concluded that the present technology of larval rearing is totally inadequate for dry diets. They considered that the comparative efficiency of different artificial diets could not be assessed properly as long as several technical problems remained unsolved. They suggested that more attention should be paid to techniques of food distribution, tank design, agitation and flow rate of the water.

In larval rearing techniques based on the use of live food, most of the attention was focused on producing the right daily supply of food organisms, as the fish could do well in a wide range of conditions, provided that they had plenty of live food available (Girin, in press). With artificial diets, a completely new technology may have to be established.

It may be a long time before larvae are reared on artificial food alone, and there may be for some time much interest in intermediate methods, like the alternative use of live and artificial food. That method is already applied in freshwater for large-scale productions of the post-larvae of the prawn *Macrobrachium rosenbergii* (Aquacop, 1977). On a small scale, it has been applied successfully on the larvae of the Atlantic silverside, *Menidia menidia*, using live *Artemia* one day, and a dry pellet the alternate day. Bentson et al. (in press) obtained the same growth and survival as in the control fish, fed on live food only. It simulteneously reduced the amount of live food required, and maintained the pollution due to the artificial diet at an acceptable level. Unfortunately, the authors give no information on the exact amount of live food they could save that way.

Assessing now which artificial diets will replace live food in the early life history of cultured marine fish larvae, and when they will do it, is quite impossible, but there are undoubtedly several clues on the best ways to reach that goal. In any case, even before it would be reached, the production of fry, at least of some species, should no longer remain the limiting factor of marine fish culture in the coming decade.

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