INNOVATIONS IN THE NURSERY CULTURE AND MATURATION OF BIVALVES

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ABSTRACT

Innovations in the nursery culture and maturation of bivalves are being worked on at all levels of research and production, but transfer to the development stage must be effected differently in each case. Over the past twenty years, there have been a great many innovations in bivalve rearing, most of which may be described in terms of rearing conditions: higher and lower densities; confined or open environemnt; overflow; upwelling; floating, suspended, raised or ground systems, etc. The quality of an innovation is characterized by its influence on the efficient operation of the specific culture program and by how easily it may be transferred.

key words: innovations, molluscs, bivalves, nursery culture, maturation

RESUME.

Les innovations en matière de prégrossissement et de grossissement de bivalves sont mises au point à tous les niveaux de recherche et de production; selon les cas, le transfert au développement devra s'effectuer de façon différente. Depuis ces vingt dernières années, l'élevage de bivalves a profité de très nombreuses innovations dont les principales sont décrites en fonction des conditions d'élevage à haute et plus faible densité, en milieux confinés, en milieux ouverts , (l'"overflow", l'"upflow", les systèmes flottant, suspendu, surélevé, en sol, etc.) La qualité d'une innovation est caractérisée par son influence sur le bon déroulement de l'élevage considéré et sa capacité à être transférée.

mots clés : innovations , mollusques , bivalves, prégrossissement, grossissement.

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INTRODUCTION

Any innovation should be characterized by its simplicity of implementation and application, and should permit the best possible use of the optimum conditions offered by various natural environments.

New techniques that improve production are quite often also dependent on the climate, geography and, above all, the socioeconomic conditions of the countries where they are implemented, and are thus not always directly application to other countries than that where they originated.

Another observation may be made: in high-yield basins, innovations are rare. Pressure on the part of operators and the routine nature of the work very often run counter to the propagation of new ideas and their application, while in new or low-yield basins, the innovative spirit is much more likely to manifest itself.

Over the past fifteen years, use of plastics has been one of the determining factors in the initiation of new techniques. As well, control of bivalve spat production following work by Loosanoff and Davis (1963) and Walne (1974) has made for considerable progress in nursery culture and even maturation techniques.

I - NURSERY CULTURE, A TRANSITION STAGE

This phase extends from metamorphosis to the intermediate size, from which the bivalve will then be raised at densities close to that necessary to obtain market size. This question was dealt with extensively at the Ghent conference (Nursery Culturing of Bivalve Molluscs, 1981).

The various advanced techniques used depend on the size of spat and rearing density, and may be described as follows:

1 - HIGH DENSITY NURSERY CULTURE

Rearing density: 10^6 to 5.10^4 individuals/m^2

1.1 Hatchery

Metamorphosed spat is matured in the hatchery to a size of approximately 2 mm. This phase requires the addition of food and thus controlled production of single-cell algae. The phytoplankton is transported with the distribution of seawater, and temperature is strictly controlled.

Two techniques are commonly used, depending on the age of spat and the species involved.

- Overflow

  The water current is made to flow downwards. This current is created either by direct inflow or by the use of an "air lift". The water circuit may be either open or closed in order to save energy.

  The rearing unit is made up of frames or cylinders measuring 0.15 m and 0.50 m in height respectively. The spat lies on a screen with a mesh size appropriate to the size of the molluscs being reared. In both cases, the area of the screen is in the order of 0.2 m. Holding tanks are normally made of polyester.

  This technique is used for the three major families of bivalve molluscs *(Ostreidae, Pectinidae* and *Veneridae)*.

- Upwelling

  The water current is made to circulate upwards by "air lift" or using a gravity system. The rearing enclosure is formed by the cylindrical screen. This technique is used for all species with the exception of pectinids.

These two systems are used in both the United States and Europe, with rearing densities in the order of $10^6/m^2$.

1.2 Land bases

Rearing temperature is that of seawater, and food flows in naturally. Rearing densities range from 5.10 to 0,5.10/m^2.

The gravity effect may be obtained by pumping (Bayes, Claus and Leborgne, 1981) or by an engineering arrangement (Bouin* station in France). Where pumping is used, the two techniques used are identical with the above, overflow and upwelling. The rearing enclosures in most cases are screen cylinders 0.5 m high and 0.2 m in diameter. Receiving tanks are concrete or polyester.

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*IFREMER Station, Bouin Basin oyster-culture zone.

- Overflow

This system is mainly used for pectinids up to sizes of approximately 10 mm. Cylinder flow is 0.7 m^3/h, and rearing densities vary between 5.10^5 and $0,5.10^5/m^2$. There has been considerable development in the nursery culture of scallops in France at the Le Tinduff farm*).

- Upwelling

Application of this technique is made possible using the hydrodynamic arrangement of reclaimed lands (polders) in Holland and France.

This type of unit may be installed in oyster-rearing basins using the gravity system at moderate capital costs and with no energy costs, as in the polder areas of Holland (e.g. the Ooterschelde) or the Bouin oyster-culture zone in France.

Upwelling is mainly used for nursery culture of *Ostreidae* and *Veneridae*. A very advanced technique using this method is currently under development. This involves drilling operations to use confined groundwater at constant temperatures to heat seawater through a heat exchanger. These waters, if their salinity permits, may also be used directly as a rearing milieu for the production of single-cell algae. This technique was developed chiefly for winter use, for nursery culture of spat. Given the cost of the operation, it now remains to prove that spat red during the winter show better growth potential in the spring than spat raised in the fall using conventional techniques.

This technology was developed in hatcheries in the United States and in France at the SICAMAIR hatchery and in the IFREMER experimental station at Bouin, for use in nursery culturing.

The rearing density that produces the best growth performance varies with size, from 1,25 to $0,5.10^5/m^2$, and the flow per screen cylinder is 3 m^3/h.

This nursery culturing method is mainly being used in the United States and Europe.

2 - LOW DENSITY NURSERY CULTURING

Rearing densities: 3.10^4 to $0,2.10^4/m^2$. Water flow is not forced and food is supplied naturally. This method makes the best use of the outside environment potential.

Nursery culturing may be done out of the ground, on ground or underground.

2.1 Out of ground

- Floating system

The rearing structure is normally made up of a wooden frame 0.03 to 0.10 m high equipped with a screen of appropriate size. The enclo-

*Station working with IFREMER and managed by the local maritime fisheries committee of Brest. The activity is part of the pluriannual scallop program for which spat is produced for recolonization purposes.

sure is made up of two frames placed one on top of the other, with the upper frame being inverted (this technique is extensively used by the AGCM*).

Densities vary from 3.10^4 to $5.10^3/m^2$ for venerids and $3.10^3/m^2$ for pectinids. In the case of scallop spat, the screen in the upper part of the enclosure is replaced by a sheet of black plastic (a technique developed by the SATMAR**).

This type of nursery culture is practised on the coasts of France as well as in marshes in Senegal.

- Suspended system

This technique, which has been used extensively in the Pacific for many years, has become more popular since the availability of nylon and other plastics. A number of innovations have been developed, mainly in Japan (Davy et al., 1982; Ventilla, 1982; Ventilla, 1984).

Nursery culture on strings is practised on *Ostreidae* spat collectors for Japanese oysters or inside collectors for the scallop *Pactinopecten yessoensis* (Ventilla, 1982). Early maturing may be continued in cages or baskets (Pacific scallops and mussels).

The string structure may be replaced by rafts (oysters and mussels in Japan and Portugal, and clams in France).

- Raised system

The technique of rearing on above-ground structures has developed considerably over the past few years with, for instance, the tripod for nursery culture of pearl oysters in the Pacific, the oyster-culture table developed in France in the deep waters of Brest Harbour for early maturing of scallops from 3 mm up to 30 mm (3-15 mm in baskets at $9{,}000/m^2$, 15-30 mm in cages at $1{,}000/m^2$). The oyster-culture table commonly used in open areas holds cultch (Japanese oysters) or plastic mesh bags (hatchery spat). The plastic collection tube permits nursery culturing up to 12 months or even 18 months at the latest. For venerids, the structure developed for the floating system is also used on oyster-culture tables. If cleanliness standards are observed, this type of nursery culture may be practised without stress at densities of 3.10^4 to $10^4/m^2$.

2.2 On-ground and underground

This method basically applied to nursery culture of venerids, from spat up to 3 mm.

The spat may be placed in 0.1 m plastic mesh bags of a new type. These bags are placed right on the ground. This technique makes it possible to use protected areas (ponds, claires, marshes). Nursery culture may also be carried out between two layers of netting, either on the foreshore or in protected areas. Size after early maturing varies and may be up to 25 mm (5 g). Optimum rearing density is $2\ 10^3/m^2$.

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Nursery culture is an indispensable stage which, depending on the culture techniques used, will have major repercussions on the animal's later life.

II - MATURATION

Maturing takes place in the last stage of the animal's life, up to the time it reaches marketable size. During this phase density may vary, but should not change by any more than a factor of 2.

In many cases, the techniques used are comparable to those used for preculturing.

1 - OUT OF GROUND

1.1 Suspended rearing

- Strings and rafts

These two systems, although of different structure, generally use the same rearing units and are based on the biological advantage of rearing right in the water.

In the Pacific, and particularly in Japan, these technical and biotechnical innovations (Ventilla, 1982) have been responsible for a major increase over the past fifteen years in production of cultured scallops, which rose from 10,000 tonnes in 1971 to 60,000 in 1981 (official statistics from the Japanese fisheries authorities).

The same is true for the pearl oyster *(Pinctada fucata)*, where pearl production was kept stable (42 T in 1981) through application of new techniques to these species, with aquaculture completely replacing harvesting of wild oysters.

Mussels have also been farmed extensively on rafts, both in the Pacific (India, Japan) (Davy, F.B. et al., 1982), and on the Atlantic coast (Spain and Portugal).

Suspended rearing from frames fixed in the ground has developed considerably in areas with low tidal amplitudes for farming of flat oysters and mussels (Etangs Méditerranéens farms in France). The shellfish are attached with cement or polyster glue on bars or strings hanging vertically down from frames.

1.2 Raised culture

A major part of French oyster production comes from rearing on tables using plastic bags. This innovation permits standardization of culture (better manpower organization, better control over biological parameters) provided norms are respected for culture densities, management of structures, etc.

The seed placed in the bags may be of natural origin, once it has been removed from cultch, or come from hatcheries. In this connection, a new phenomenon has been observed in France: the use by certain professionals of hatchery product alone, even where natural supplies are available. For the past four years, the SATMAR company has been supplying four oyster farmers in Brittany and Normandy with $26x10^6$ spat separated from one another by 6-8 mm. The spat is placed in mesh bags at the beginning of the year at densities of 500/bag, or $1500/m^2$. At the end of the year, average weight is approximately 30 g, or 13 kg/bag. The animals are then planted right in the ground and reach a weight of 60 g by the end of the following year. Survival is in the order of 85%, and annual tonnage is 1,300 tonnes. In this case, natural growth potential is perfectly duplicated, and the growth curve for cultured oysters is quite close to the optimum natural curve while respecting the profitability standards of the operation.

2 - UNDERGROUND

This technique is used for commercial species of *Veneridae*, such as hard clams in the United States and cockles and hard clams in the Pacific and in Europe.

It is in the United States, for hard clams, and especially in France, for carpet-shells, that the techniques under development are most strongly inspired by marshland cultural practices.

The basic obstacle to this type of culture is the problem of predators, with the main predators being crabs and, in some cases, fish.

Protective measures tailored to the habits of the main predators involved are of two types: horizontal protection and vertical protection.

2.1 Horizontal protection

In this type, the facility may be covered by a grill or a layer of netting. The main problem with this method is the difficulty of precise monitoring, since access to the culture is particularly difficult.

Two adaptations have been applied to the rearing of the clam *(Ruditapes philippinarum)*: rearing in buried cages or under nets.

The cage has a grill on its lower side, which is filled with sediment and then covered with a screen once the seed is in place. The surface is 0.3 m, density is $700/m^2$, and the rearing cycle is from 24 to 28 months. The cages are tied into strings that may be raised at high tide. Harvesting in this case is greatly simplified. The structures are lifted onto the deck of the boat and then washed with a hose. The openings in the grill on the underside allow the sediment to flow out and hold the clams in. This technique, although somewhat cumbersome, is used in France by several clam-farmers (France, Gulf of Morbihan, 10 to 12 T/year).

Rearing under nets, which has been experimented in the United States in Puget Sound on *Ruditapes philippinarum* (Anderson et al., 1982) has not yet produced significant amounts of product. In France, this technique is spreading, but is still in the development stages. It offers the advantage, on hard ground, of allowing the use of machines for planting and installing nets. The main interest of this method is that it offers no resistance to bad weather and currents. A negative net effect has nevertheless been observed on growth, due to the inevitable silting over of surfaces even with intensive brushing operations. Weights of 20 g are reached in 26 months.

2.2 Vertical protection

This technique, which is more difficult to implement in areas that are exposed and have very strong currents, nevertheless has the advantage of not placing any stress on the crop which, provided optimum densities are respected, develops naturally in enclosures where access and monitoring are extremely simple.

The enclosure method was developed in the United States on the Virginia coast (Castagna and Craeuter, 1981) for hard clams. Since tidal amplitude is fairly slight in this region (3 m), the enclosure in this case is high enough to prevent entry by a swimming crab, the blue crab *Callinectes sapidus*, and the eagle ray *Rhinoptera binasus*. The effectiveness of this protection is increased by adding fine gravel (Kraeuter and Castagna, 1980).

This technique is being developed intensively, mainly on the Atlantic coast of France in the intertidal zone, between 2 and 2.50 m above hydrographic zero, for culture of the clam *R. Philippinarum*. Here, the main predator is the green crab *Carcinus maenas*, which is a climber rather than a swimmer. Culture is carried out in enclosures. The effectiveness of the barrier (45 to 50 cm) is increased by attaching to it a plastic element (plastic sheeting folded over into a teardrop shape) which, when well maintained, is certain to prevent the predator from getting through. Protection effectiveness is also increased by adding fine gravel, which limits predation when young crabs develop inside the structure. This additional protection is also effective against attack by fish (bream and flatfish).

If the maturation period at the beginning of the year is respected, the culture cycle is 20 months (for an average weight of 20 g) for rearing densities of 250 clams/m^2.

CONCLUSION

This list of innovations in the field of preculturing and culturing of bivalve molluscs is not exhaustive, since there exist a great many variants of these methods.

We have not mentioned scientific and technical research that has not led to any applications for technical or economic reasons.

An innovation may thus be one element of a given research or production activity, or it may itself constitute the whole research project.

Depending on the case, transfer of this innovation will be carried out in various ways. For example, the upflow technique, used in nurseries and described in great detail in reports and other publications, may be put into application quite rapidly by producers. Conversely, an innovative culture method such as that of *P. yessoensis* in Japan or *R. philippinarum* in France cannot be transferred using the same methods, since these types of culture are broken down into small stages which, while simple and original, are occasionally still evolving, thus making it both difficult and dangerous to use publications or manuals that have been written up too hastily. In such cases, research should accompany the innovation, insofar as possible, up to the point where a definite culture procedure is developed. This participation of research in development work should be done very cautiously and evaluated according to the individual case and species.

Any innovation, however, if it is to be usable, must not be too disturbing to the biological results; it should make the best possible use of natural growth potential. As well, experiments should not be confined to unnecessarily short periods in the bivalve life cycle.

A decline in biological yields, that is, a flattening of the growth curve and mortality, may occur for three main causes:

1) negative effect of the technique on the harmonious development of the species involved,
2) deterioration of the environment,
3) degeneration of the population being reared.

In most cases, the first cause is, in the short or long term, the trigger for the other two. Deterioration of product quality is then very rapidly observed, as is the increasing frequency of diseases capable of destroying the entire crop in a very short time.

It is therefore wise to devote some preliminary work to standardizing biotechniques as development progresses, rather than trying to solve problems after the fact, since at that point in time, the measures that must be taken are liable to be extremely costly.

This is why it is essential to establish simple zootechnical references, in close cooperation with the professionals involved. These could include "pilot curves" on an international scale for species being raised in different geographic areas, and then on a national level for each site and for the various techniques used. Operators must be able to compare their own observations to standards which they can easily obtain from local sources (co-op headquarters, regional offices, etc.).

It might also be proposed that studies be carried out, for several reference species, on the effect of nursery culturing techniques on eventual growth in order that spat quality categories may be developed. To do this, it would be well to have reference curves prepared in advance that could be adapted to take into account individual and annual variations. This would presuppose standardized techniques and very close communication among laboratories in the various countries involved.

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