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REARING OF SCALLOPS (*Pecten maximus*) IN FRANCE, FROM HATCHERY TO INTERMEDIATE CULTURE, RESULTS OF A 10 YEAR PROGRAMME (1983-1993)

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ABSTRACT

A stock enhancement programme for scallop was initiated in France in 1983. As the natural spat collection on the French fishing grounds as well on Irish and Scottish waters was unsuccessful, artificial reproduction was attempted in order to produce regularly one million spat per year for a restocking experiment. In 1988 the target was increased to 3 million juveniles ready for seeding through a concerted action in the bays of St Brieuc and Brest, aimed at coordinating fishermen, administrators and researchers. One of the new objectives was to control artificial reproduction in order to produce year round.
Results of production and research in the hatchery as well as effects on intermediate culture are discussed.

INTRODUCTION

The scallop R&D programme was drawn up between 1980 and 1982, through concerted meetings between researchers, the industry (fishermen associations) and the administrators. It was focussed on two experimental sites in Britany: the bays of Brest and Saint-Brieuc, and based on the results obtained from the initial mariculture results on *P. maximus* (Buestel and Dao, 1979). A technical pathway (Fig. 1) was selected with the objective of enhancing stocks in depleted ground in the bay of Brest. The focus of this project was to develop natural spat collection in France.

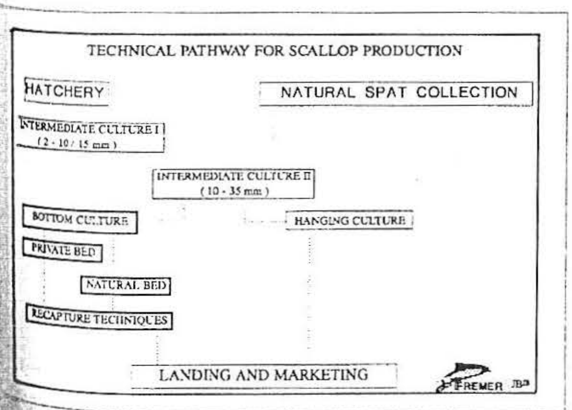


Fig. 1: Technical pathway for scallop (*Pecten maximus*) culture and production in France

As an alternative to natural spat collection in Brittany, juveniles were imported from Ireland and Scotland. However this proved unsuccessfull despite promising trials (Dao, 1985) and it was decided to develop hatchery/nursery techniques. After the first 5 years of the programme, the objective was revised and changed from restocking to aquaculture: it was assumed that the technical results were conclusive to propose a second step with an economical goal, i.e., sea bed cultivation, although a low final yield was expected. Work was carried out by IFREMER and fishermen associations from each of the two bays (Fig. 2).

HATCHERY/NURSERY

The first experiments in France were conducted at IFREMER (Buestel et *al.*, 1982) and the basic results are still being applied: scallops were maintained in the hatchery, then placed after metamorphosis under nursery conditions with natural sea water and transferred to sea when they reached a size of 2 mm.

Biological mechanisms

The hatchery/nursery coordinates all operations corresponding to the biological cycle, of which the physiological mechanisms are still poorly understood. These operations are summarized in Fig. 3. Activities included water stocking, filtration, heating/cooling, filling the tanks in a limited time, flow control, maintenance of broodstock, microalgal production and distribution, larval and postlarval rearing, and quarantaine. Examples shown in Fig. 4 and 5 correspond to the small experimental facilities of IFREMER in Argenton near Brest.

a) broodstock. Wild animals are known to be in an unpredictable physiological condition and they have to be brought to the right state of maturation before spawning. The first attempts showed large seasonal variation in larval yields after rearing the animals with microalgae for 2 months thus obtaining appa rently ripe gonads (Fig. 6). One basic reference to check for the ripe gonads is the natural reproduction cycle which varies between populations (Fig. 7), but also the status of the reserve tissues as glycogen content in the adductor muscle (Fig. 8). Internal factors which can be managed on the long term include origin of population or strains and selection. Monitoring of broodstock must involve control of physical factors such as temperature, quantity of food (Fig. 9), and photoperiod (Fig. 10). Quality of food is reflected in gonad condition but has not yet been proved to induce changes in larval rearing. Conditioning effects are summarized in the Fig. 11.

b) larval rearing. This stage is usually considered as the main activity of a hatchery. It combines the development of the larvae and the culture of the microalgae as food (Fig. 3). The initial results showed large variability among various larval rearing attempts (Fig. 12) which can be explained through different factors: the choice of the spawners (Fig. 13), the quantity but also the quality of the food as shown by the

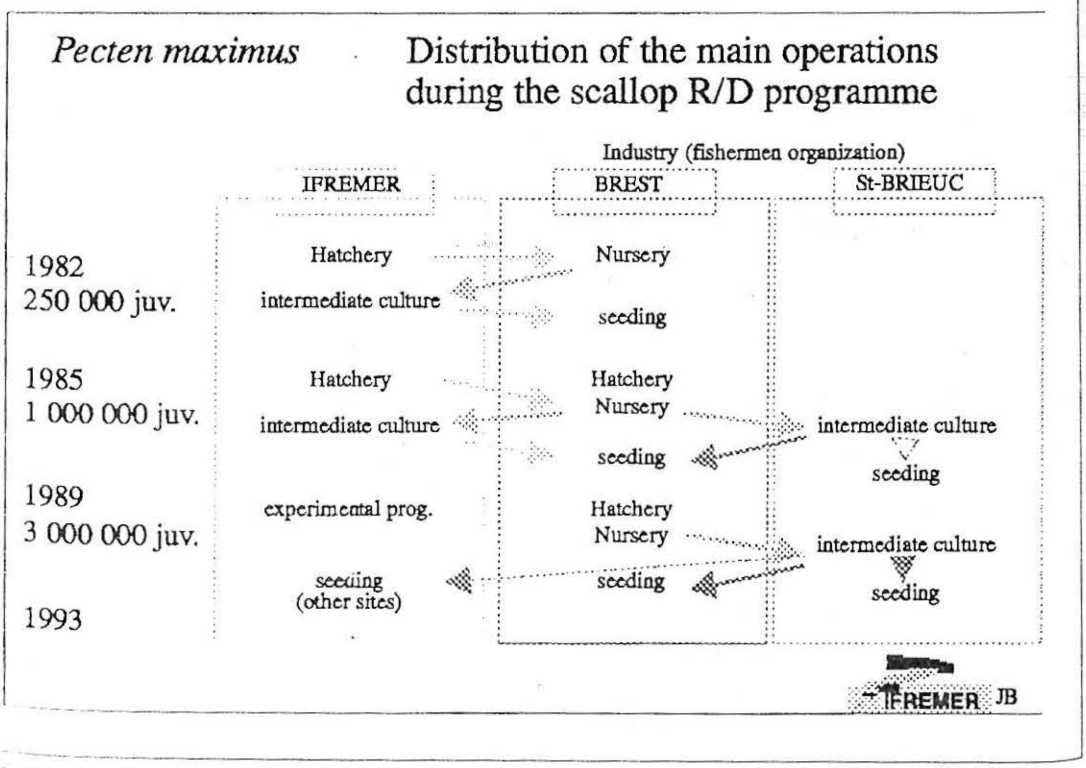


Fig. 2: Distribution of the main operations of the French programme between the research institute and the fishermen organization for scallop production

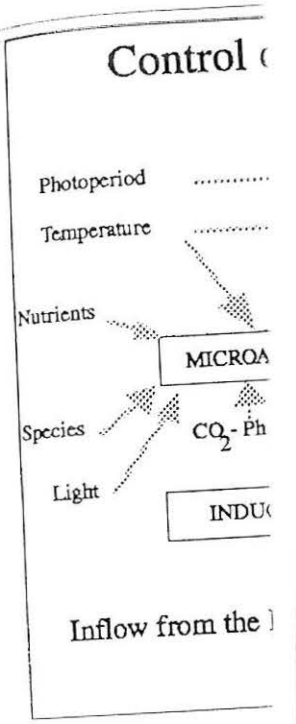
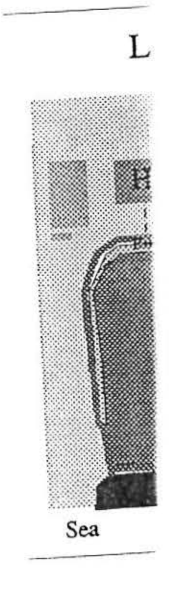


Fig. 3: Factors affecting la



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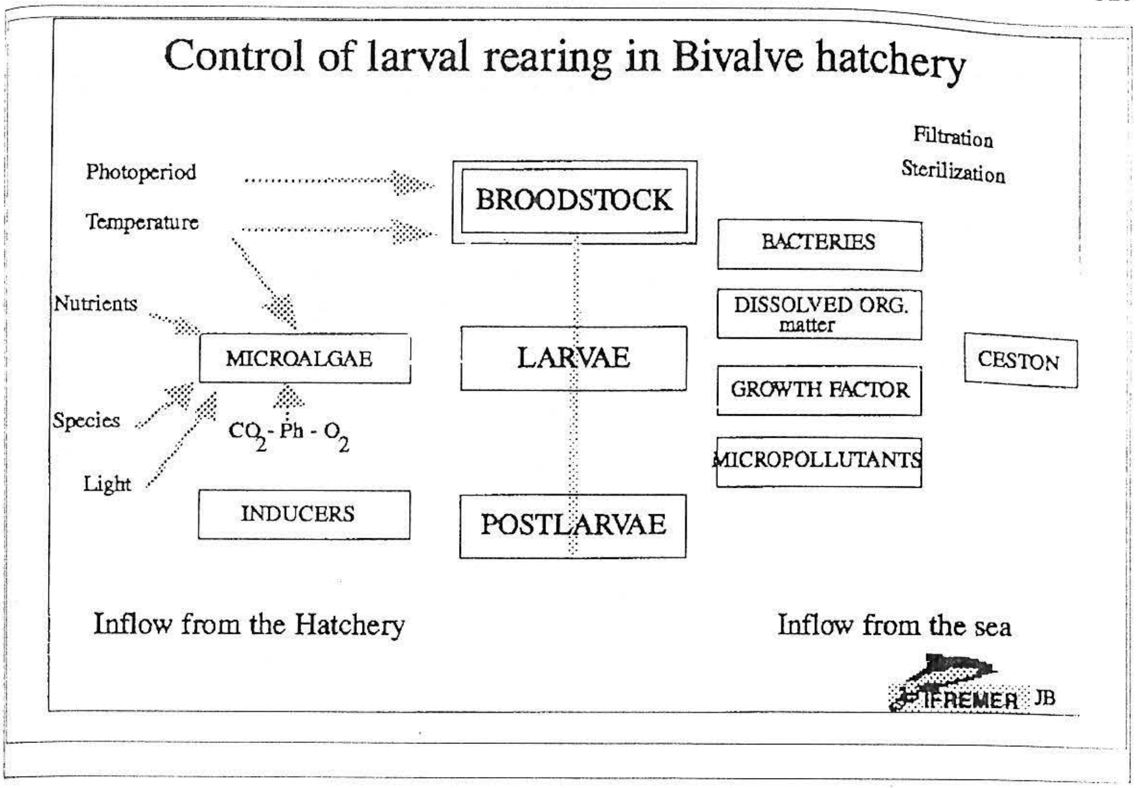


Fig. 3: Factors affecting larval rearing in a bivalve hatchery

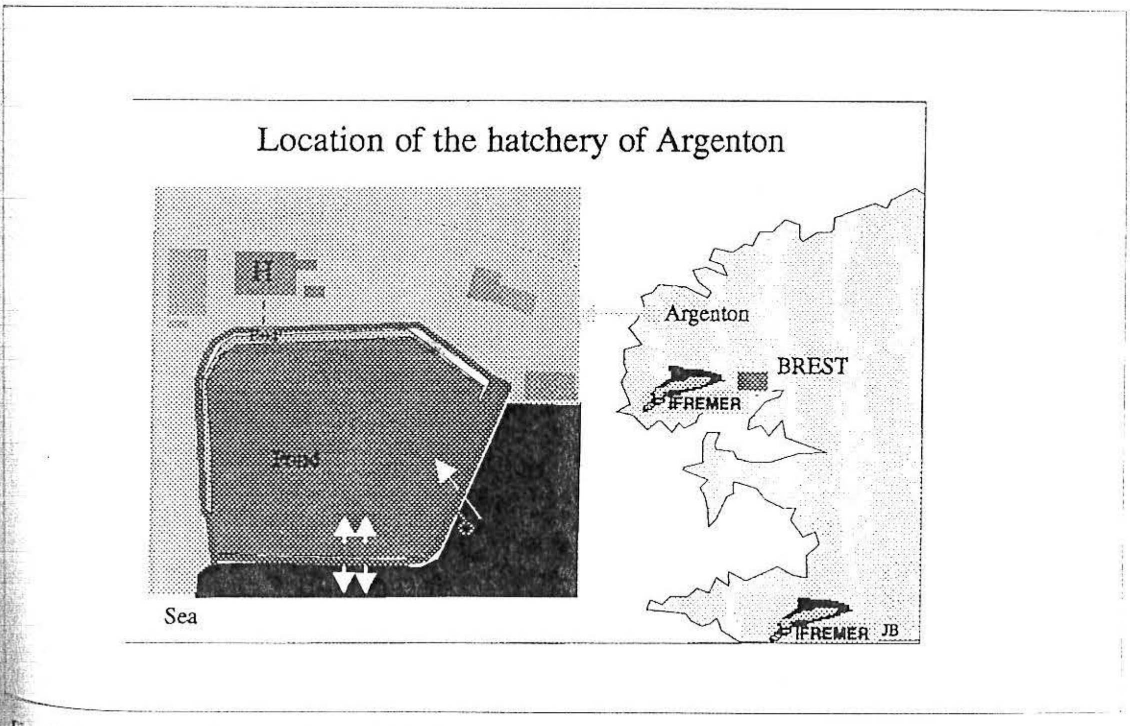


Fig. 4: Location of the experimental bivalve hatchery of Argenton

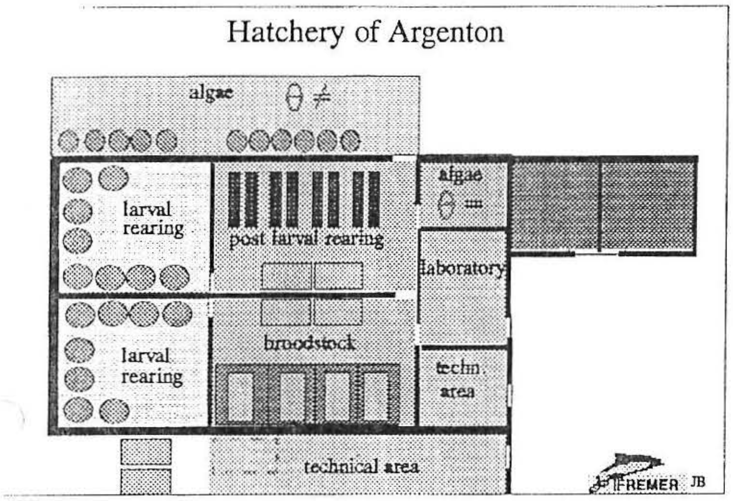


Fig. 5: Organization of the bivalve hatchery of Argenton

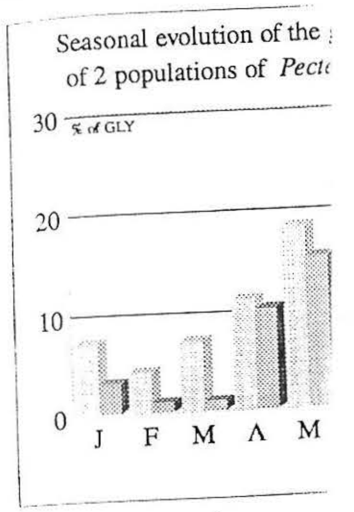


Fig. 6: Variation of the larval rearing as a function of season of broodstock conditioning for Pecte*n maximus*

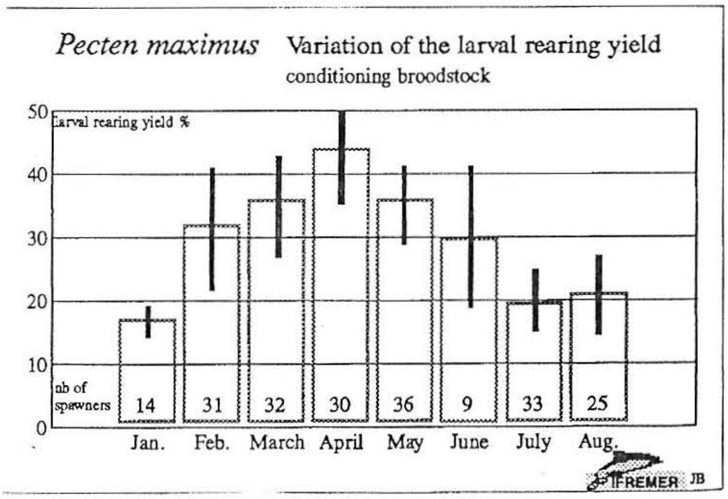


Fig. 9: Effect of quantity of food during conditioning on spawning efficiency on *Pecten maximus*

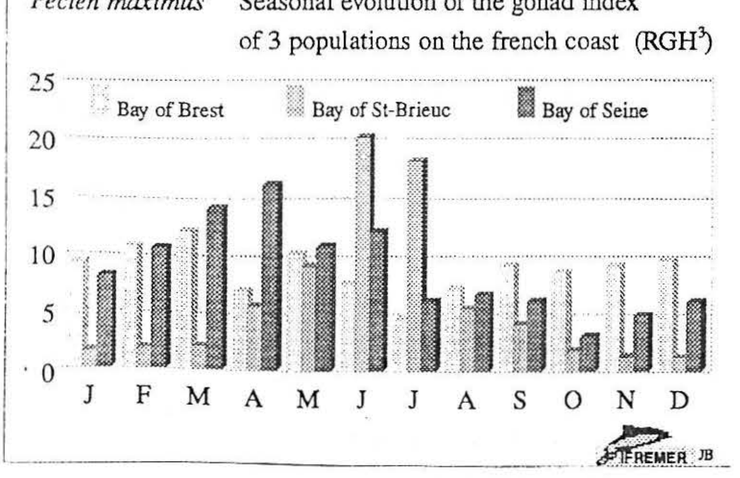
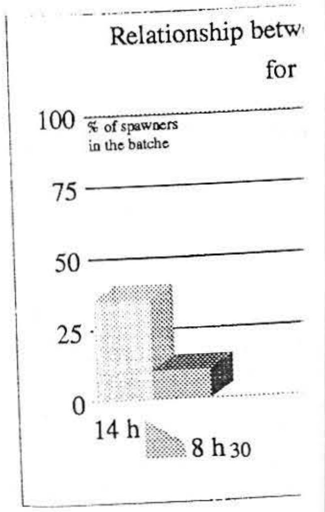


Fig. 7: Evolution of the gonad of 3 distinct populations of scallop (*Pecten maximus*) showing different reproductive stategies



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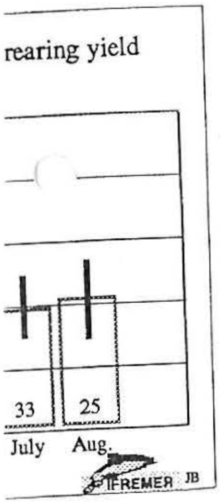

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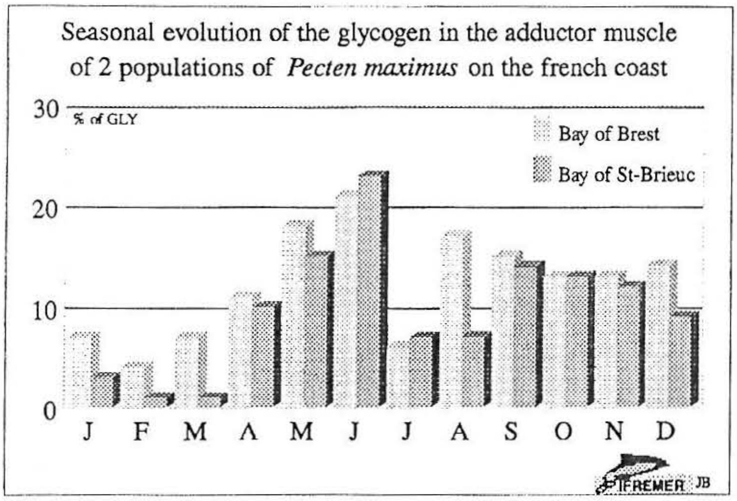

Fig. 8: Evolution of the adductor muscle of 2 distinct populations of scallop (*Pecten maximus*) showing seasonal changes in reserve tissues.

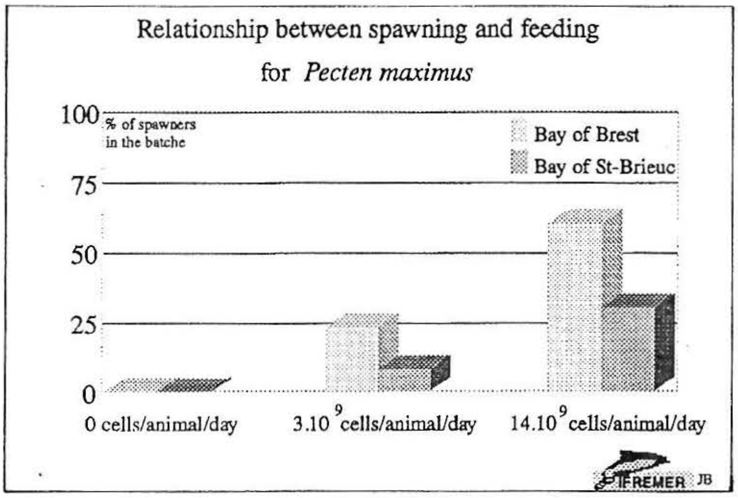

Fig. 9: Effect of quantity of food during conditioning on spawning efficiency on *Pecten maximus*

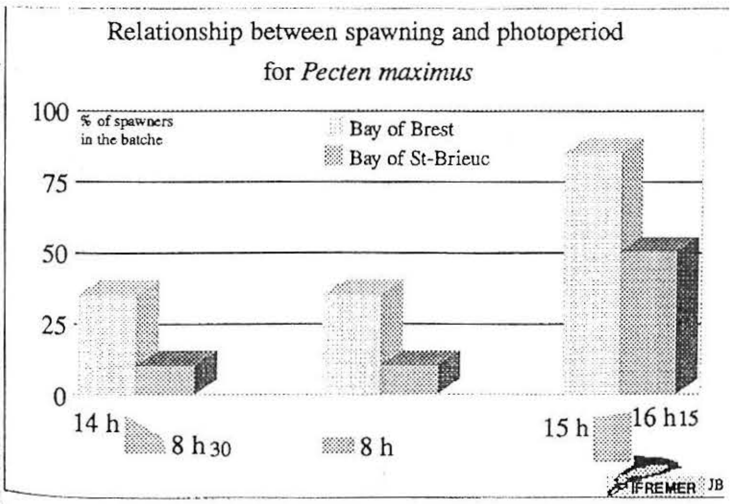

Fig. 10: Effect of 3 photoperiods (decreasing, low photoperiod, increasing to high photoperiod) during conditioning on spawning efficiency on *Pecten maximus*.

Effects of some internal and external factors on the reproductive activity of *Pecten maximus*

	Internal factors		External factors		
	GEOGRAPHIC ORIGIN	FOOD RATIO	PHOTOPERIOD ▼ ▲	TEMPERATURE	CONDITIONING DURATION
GAMETOGENESIS	+	+	− +	+	+
FECUNDITY	+	+	− +	+	+

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Fig. 11: Sumary of the effect of internal and external factors on the reproductive activity of *Pecten maximus*

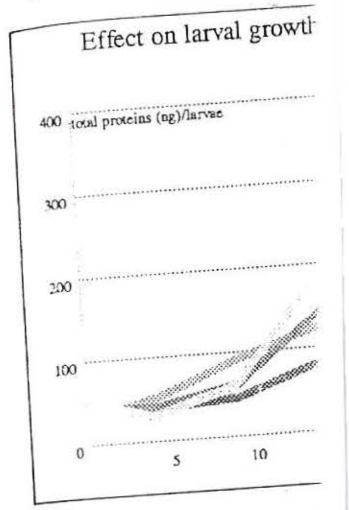


Fig. 12: Growth variability among various larval rearing of scallop (*Pecten maximus*) during 1987-1988 in Argenton

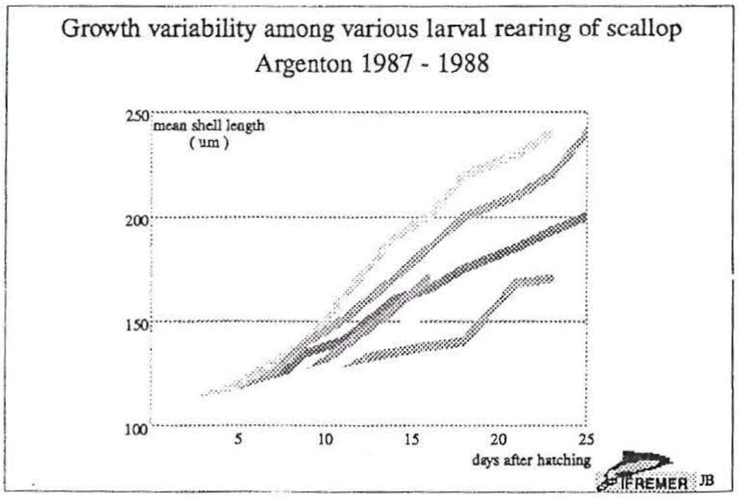


Fig. 15: Effect of different filtered waters on larval growth showing a selected «growth factor» of particles of size between 0.2 and 1 μm in the pond water in Argenton of scallop (*Pecten maximus*)

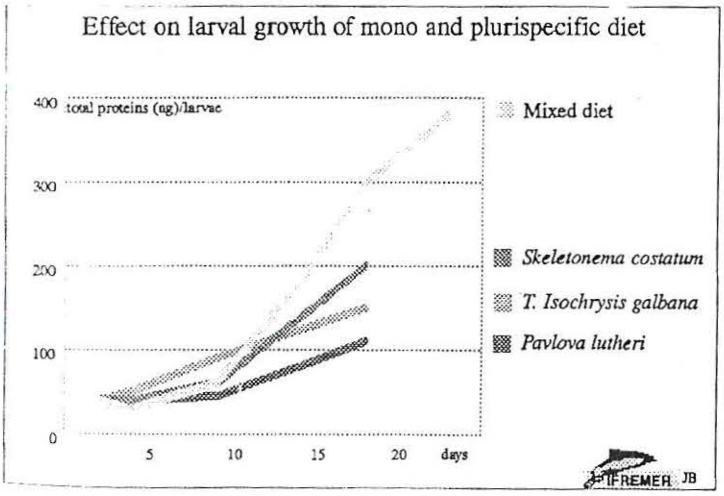
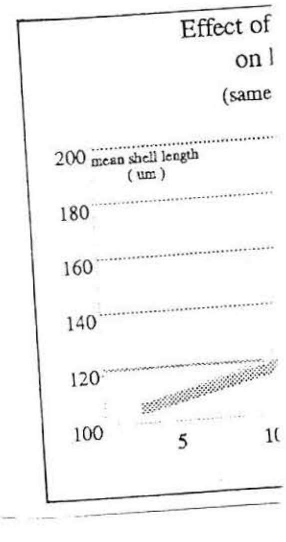


Fig. 13: Effect of individual spawner on gowth variability of larval rearing of scallop (*Pecten maximus*)



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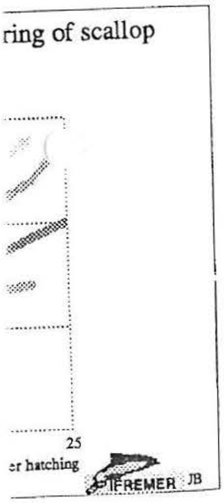

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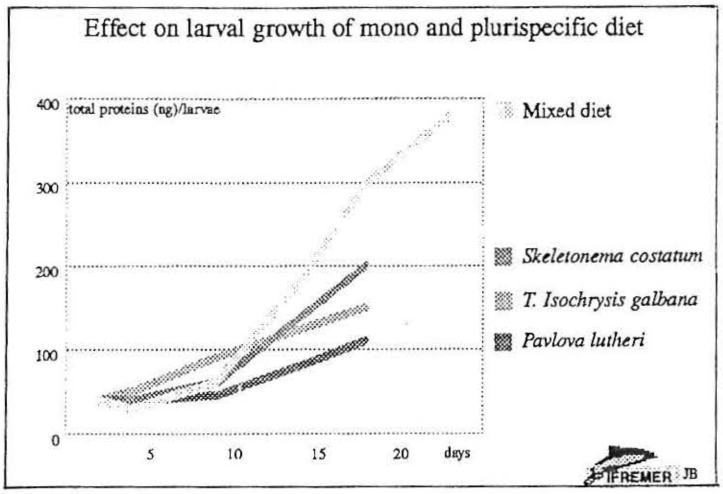
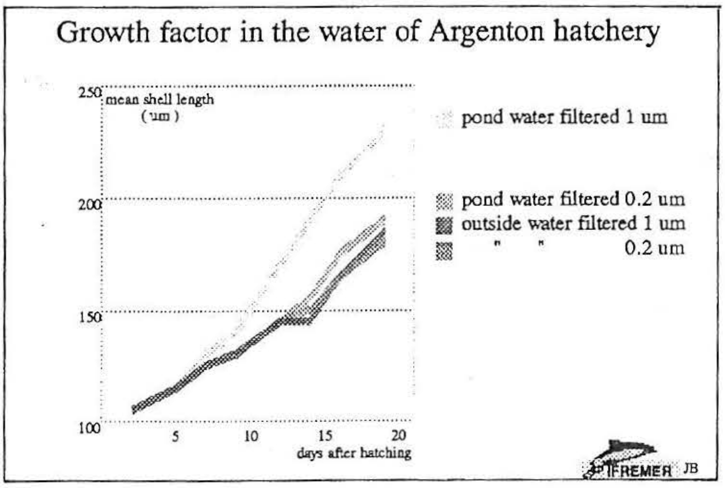


Fig. 14: Effect on larval growth of mono and pluri-specific macroalgae as diet of scallop (*Pecten maximus*)

Fig. 15: Effect of different filtered waters on larval growth showing a selected «growth factor» of particles of size between 0.2 and 1 µm in the pond water in Argenton of scallop (*Pecten maximus*)



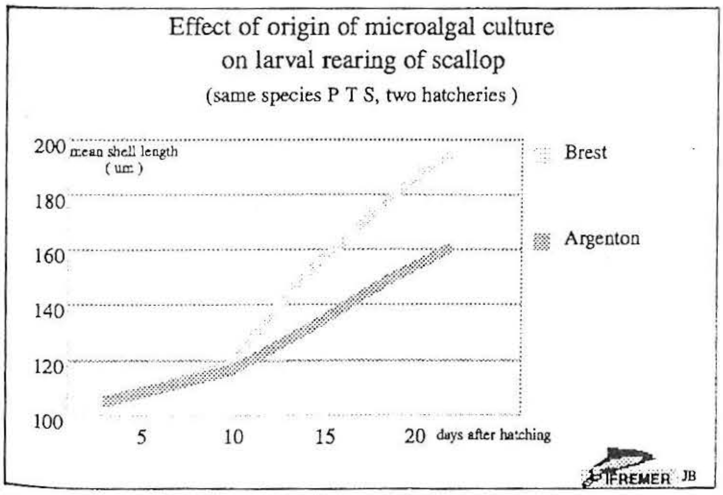


Fig. 16: Effect of origin of macroalgal culture on larval rearing of scallop (*Pecten maximus*)

difference between a mono and a pluri-specific diet (Fig. 14). Uncontrolled factors including the water quality and the occurence of a «growth factor» (Fig. 15), minor changes in microalgae culture techniques (Fig. 16), and control of the bacteriologicial environment (Fig. 17) can affect the rearing. Furthermore the results also depends on the pectinid species (Fig. 18).

More recently IFREMER started to investigate the physiology of the animal and the microalgae. The quality of the diet and particularly the poly-unsaturated fatty acid content seem to have a determinant effect interfering with the structure of the cell membranes. DHA (22:6 n-3) and EPA (20:5 n-3) appear to be required components and their production depends on the algal species present (Fig. 19) and the cultivation conditions employed (Fig. 20).

c) **metamorphosis** and **postlarval rearing** have yet not been given detailed physiological research. Very rapidly the animals are transferred from filtered water containing a known diet, to natural sea water both with and without supplementary microalgae which involve uncontrolled factors. These techniques correspond to a selection of management practices of which the first is the induction of metamorphosis with the use of chemical inducers (Fig. 21).

Rearing techniques

The rearing techniques used in the hatchery/nursery are described by Cochard and Gérard (1987), Devauchelle and Mingant (1993), and Robert *et al.* (1994), from progressive selection of the most effective procedures during the research/development programme.

The broodstock conditioning is conducted in 500 liter tanks with a double bottom containing sand: spawners can lay on the sand and the water is recirculated by an air-lift. The animal density is between 5 and 10 m-2 and fed 10 to 15 billions microalgae/animal/day.

Wild animals are spawned on arrival at the hatchery in order to empty the gonad. Then they are conditioned for 2 months at 15°C, with an increasing photoperiod. Spawning is induced by thermal shock, 40 animals are necessary for spawning, and several individuals are used to collect ovocytes and sperm. Selection is conducted after 48 hours when the «D» larvae appear. Empirical criteria are used: form and size of eggs, eclosion rate, trochophores mor-

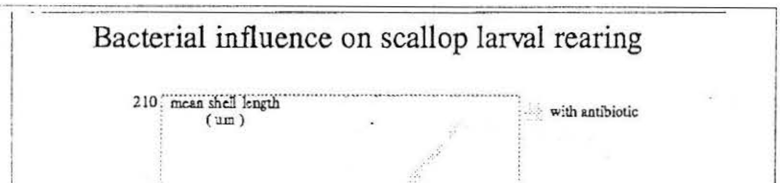


Fig. 17: Effect of bacteria on scallop larval rearing (*Pecten maximus*)

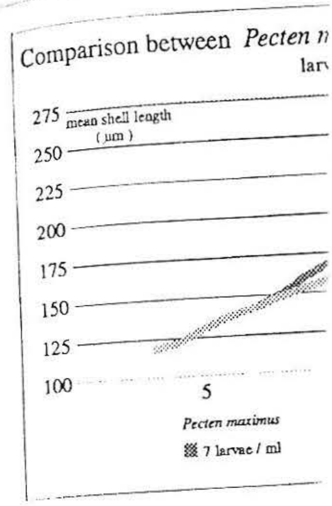
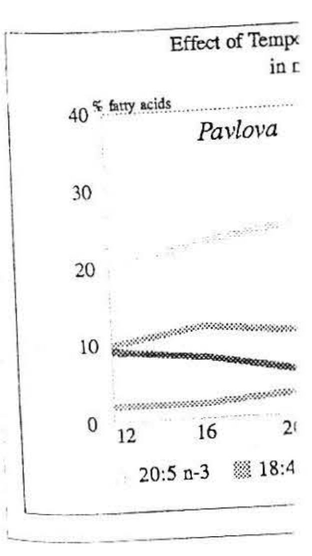


Fig. 19: EPA and DHA abundance in 4 species of cultivated microalgae



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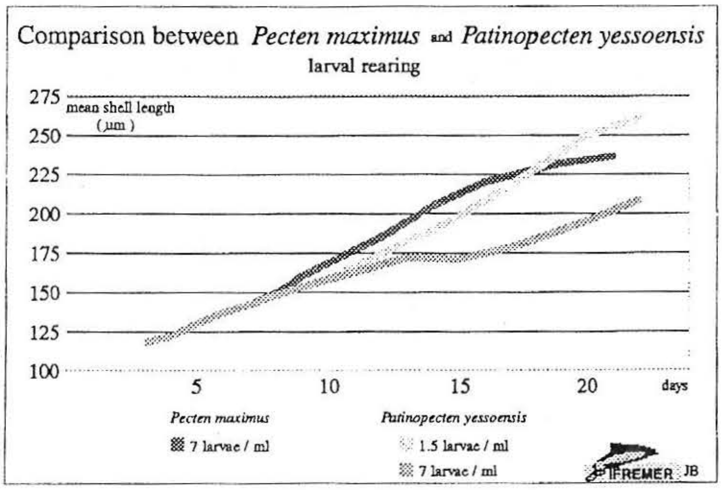
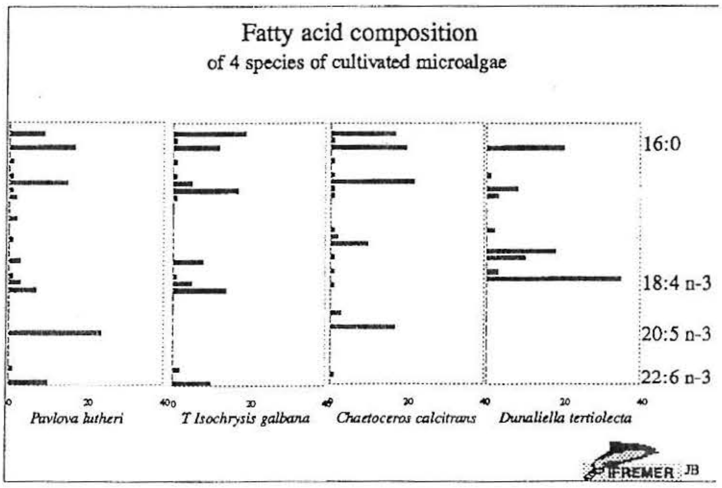


Fig. 18: Variability of scallop larval rearing depending of the species: comparison between Pecten *maximus* and *Patinopecten yessoensis*.



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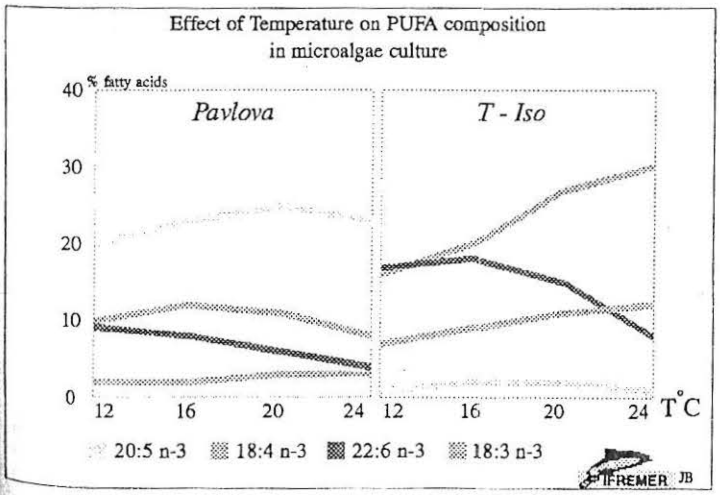

Fig. 20: Change in PUFA acid composition in 2 species of microalgae cultured at different temperatures.

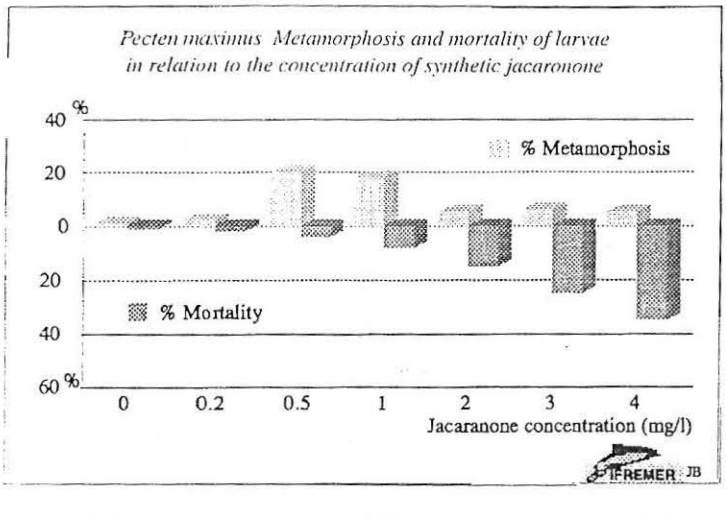

Fig. 21: First results of metamorphosis chemical inducers with optimum concentration of jacaranone on scallop (*Pecten maximus*)

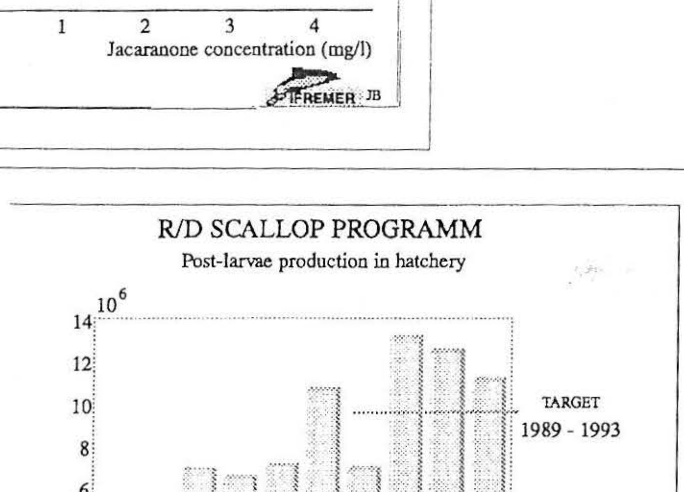

Fig. 22: Hatchery production results of scallop postlarvae (*Pecten maximus*) during the R&D programme

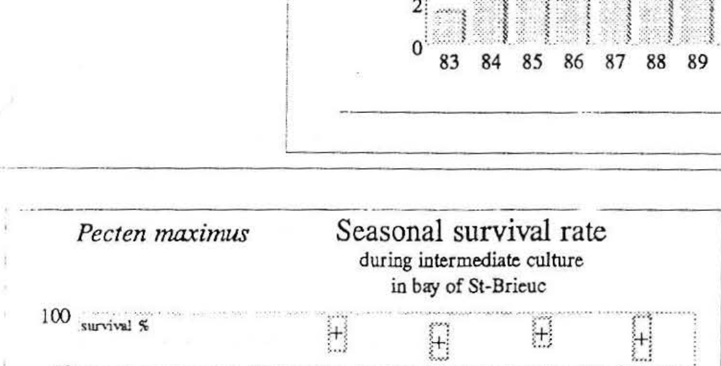

Fig. 23: Seasonal survival rate of scallop (*Pecten maximus*) during intermediate culture 1 and 2 in bay of St-Brieuc

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Only 45 to 50 millions larva

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phology, mobility and abnormal larvae rate. Only 45 to 50 millions larvae are retained.

Larval rearing is conducted in 400 liter cylindro-conical tanks, in which 4.5 millions D-larvae are placed. A light air-lift maintains the larvae in the water column. The water is changed every two days. Rearing takes 21 to 28 days at a temperature of 17 to 19°C. 60 cells of microalgae per microliter are fed daily. Selection is operated at each water change. This phase is considered satisfactorly when the survival rate pediveliger/D larvae is 30 % or more (best result 60 %).

Nursery techniques are adapted from clam hatcheries (Gérard, 1984). Plastic cylinders are used with a bottom net of 135 or 300 micron mesh. Sea water is pumped into a re-circulation system which is air-lifted to induce a down-welling effect. The cylinder has a section of 0.2 m^2 and 0.45 m depth. Larvae are stocked in the pediveliger stage at 100,000/cylinder. Metamorphosis rate can reach up to 85 %. The un-settled animals are eliminated at each cleaning. This last operation is most important in spring during the phytoplankton bloom. Cylinders are put into 2.5 m^3 tanks which reduce the stress caused by changes in environmental factors. A «normal» cylinder produces 20,000 postlarvae of 2 mm size, but for good batches this can reach up to 70 to 80,000.

Algae cultures were initially undersized and were unable to provide food for all rearings, especially during winter when the natural sea water does not contain phytoplankton.

Status of hatchery/nursery production

Evolution of the spat production for the French programme is given in Fig. 22. From the last five years programme the yearly production can be summarized as follows:

one batch (yearly production: 3 batches): hatchery: 50 million larvae; nursery: 10 million pediveligers; production: 6.5 million postlarvae. First batch (end of winter): 6.5 million post larvae; second batch (spring): 2 to 6.5 million according to intermediate culture facilities, third batch (summer): problems for the last 3 years

INTERMEDIATE CULTURE

This stage represents the final culture activities. Postlarvae are reared in the open sea in hanging culture. In France, due to the combined effects of rough weather (winds up to 80 knots) and tide currents (change of sea level up to 14 meters), intermediate cultures were installed on the sea bottom at a depth between 10 to 20 meters to avoid wave action. Iron frames are adjusted to receive trays with meshes corresponding to the size of the animals. When the juveniles reach 30 mm in shell height, they are considered to be adequate for seeding in the wild, but preliminary experiments are still required before starting large-scale operations.

Rearing techniques for intermediate culture n°1

Intermediate culture n°1 begins after the nursery phase, when juveniles have reached a size of 2 mm and finishes when a first operation is required, i.e. to change the trays which become fouled with filtering organisms settled on the nets, and to decrease the biomass of scallops by tray. At this stage the spat reaches 10 to 15 mm shell height.

Each tray receives 10,000 postlarvae from the nursery. The spat stays 24 hours in tanks to give them the time to develop their byssus so that they can be attached when transferred to the sea. The main cause of stress is the transfer and prolonged air exposure. The yield at the end of this intermediate culture is evaluated to be 30 % and exhibits seasonal variations (Fig. 23).

Most of the mortalities occur at the beginning of the intermediate culture as a result of transfer stress.

Rearing techniques for intermediate culture n°2

Spat at this stage are much more resilient and usually 90 to 100 % survival is obtained (Fig. 23). This is achieved by stocking a limited biomass (maximum 2,000 spats/tray at seeding size), a control of the predators inside the tray, and limiting the development of the fouling on the structures. The inside net in the tray has a 5 mm mesh, giving a much better circulation of the water than during the first intermediate culture. This phase of the culture requires 3 months during the summer period, but 6 months during the winter at low temperature.

The second intermediate culture is the bottleneck for the development of scallop rearing. Investments for the frames and trays are expensive and the equipment remains the same for a long time for a single batch, with little flexibility for the management of the whole rearing process.

Status of the intermediate culture

Evolution of the spat production for the French programme is given in Fig. 24. From the last five years programme the annual production can be summarized as followed:

- intermediate culture n°1: spat size from 2 to 10/15 mm, survival rate 35 %, density at transfer 12 to 20,000 postlarvae/m^2 in small mesh tray.
- intermediate culture n°2: spat size from 10/15 mm to 30 mm, survival rate 92 %, density 2,000 spat/m^2 in 5mm mesh tray.
- average survival rate 32 %

Results show large seasonal fluctuations, with particularly low efficiency during winter. This is not considered as a major limiting factor because it requires production of postlarvae during the cold season which results in high water heating costs. The integrated production of spat is outlined as follow:

- scallop conditioning for a first spawning at the end of the winter (February), transfer to the sea in spring (May), seeding in autumn (October).
- scallop conditioning for a second spawning in the end of the spring (May/Jun e), or wild spawners from the natural reproduction cycle, transfer to the sea in summer (July) when the first batch is moved to

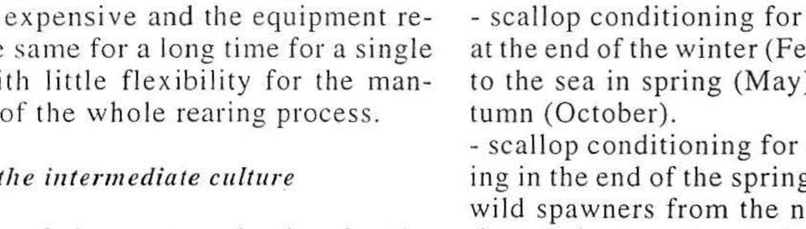

Fig. 24: Juveniles production results of scallop at seeding size (*Pecten maximus*) during the R&D programme.

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year or early spring.
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IMPROVEMENT OF THE SP

The programme aimed at
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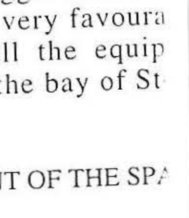

Fig. 25: Effect of toxic phy
nagasakiense) on scallop sp

5mm mesh trays, and seeding end of the year or early spring.

- scallop conditioning for a third spawning in the end of the summer (August/September), or wild spawners if possible, transfer to the sea in autumn when the frames from the first batch are again available.

These operations combine two different sites. The technique has been selected after various trials close to the hatchery/nursery site. In the bay of Brest, intermediate culture has always given poorer results on average, but it has also suffered from abnormal mortalities due to toxic phytoplankton bloom. Regularly in early summer (June/July), a bloom of the dinoflagellate *Gyrodinium aureolum*, induces mortalities up to 100 % of spat below 10 mm size, mortalities or malformation of the shell for bigger animals (Fig. 25). Since this period is very favourable for the spat production, all the equipment has been transfered to the bay of St-Brieuc.

IMPROVEMENT OF THE SPAT PRODUCTION

The programme aimed at producing a sufficient number of juveniles to investigate the entire technical pathway from hatchery to the commercial dredging fleet. Part of the efforts were devoted to bottom culture and economical analysis but not to attempt maximizing the spat production and/or minimizing the cost of the operations. From all results it can be concluded that improvements could be obtained from the topics given below:

Hatchery/nursery

Production costs are calculated on an annual yield of 10 million postlarvae, obtained on two main batches between late winter and early summer (January to July). The number of postlarvae per batch can easily be increased since only a limited number of D larvae were retained. Bigger facilities for microalgal production were completed very recently and a better coordination of the transfer to the sea will avoid overcrowding in the cylinders.

A summer spawning, with the transfer of the postlarvae to the sea, before winter represents an important advantage, because of the availability of frames and trays for the intermediate culture. It has not been considered to be a bottleneck during the

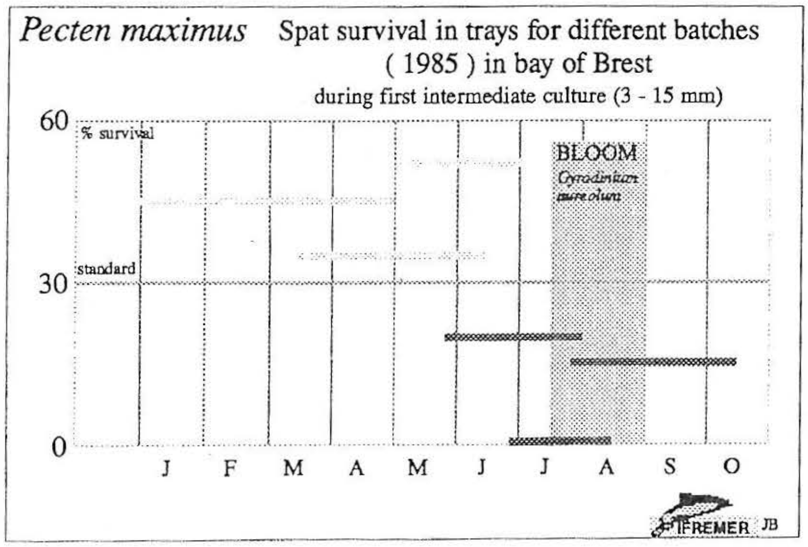

Fig. 25: Effect of toxic phytoplankton bloom (*Gyrodinium aureolum* = *Gymnodinium cf. nagasakiense*) on scallop spat (*Pecten maximus*) during intermediate culture.

past, but the trials of the last 3 years were completely negative, i.e. maturation state and larvae quality are insufficient to reach metamorphosis successfully. The last experiment on maturation showed more optimistic results for conditioning during early summer.

Zootechnical improvement during intermediate culture

From experience, mortality during intermediate culture occurs at each handling. Animals are sensitive to various forms of str[illegible] as sorting from the water, over-stocking in trays, or in the nursery. Part of the results can be attributed to the quality of he site for the intermediate culture which s in a very exposed part of the bay of St-3rieuc, at 2 to 3 hours from the hatchery. In iumber of cases operations must be deayed because of bad weather. It seems mpossible to avoid all the main stress but second site for intermediate culture in the ay with different conditions of exposure s presently being researched, in connection vith an increase in hatchery production.

asic biological knowledge on the scallop odel

he level of knowledge on the scallop model nd[illegible] re generally bivalves and marine ivertebrates is poor compared to verte-ates and specially domestic animals. Also itural spat collection was largely suffient to provide spats for the industry and i-growing was obtained from the natural imary productivity. Moreover, the exact od consumption of the bivalves in the ild is still not well understood.

Physiological research programmes must conducted in order to have a better unrstanding of the animal's food requirent in quantity as well as quality, the gulations occurring between gonadic and matic tissues, the effects of the environntal conditions on growth, mortality or istance to pathogens, the relation been maturation and egg quality. There is l no factor which could provide an index of desirable or undesirable physiological condition for the metabolism of the animal.

In this field, advanced hatchery technologies appear to belong to the near future. Genetic studies are being conducted on bivalves species for several purposes such as the use of polyploïds, selection of strain resistant to pathogens, and improving the quality of animals. Other components are also being developed including mass production of microalgae adapted to food requirements, control of broodstock for continuous production of larvae,etc. The list of factors improving the hatchery results in terms of cost and management is not limited.

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GROWTH AND
purpurатus (La

URI

Laboratorio Biológico Pesquer

Growth studies of the Chilean scallop
(IFOP) in Chiloé island, X región. C
from nursery cages to pearl nets sus
periodically on the experimental ro
variability of growth rate. By Octob
height of 65.7 mm. During the 19 m
a minimum of 0.11 %.day⁻¹. Growth
Individual growth in marked animal
rate of between 3.0 and 3.5 mm.mo
between 4.5 and 5.5 mm.month-1. In
of the adductor muscle (r=-0.63) an
in September 1994, the scallops had
g and a total meat weight of 13.1 g. T
in comparison with the northern regi
in the South of Chile are discussed.

INTRODUCTIC

The culture for Chilean scall
purpuratus, was establish
Chile as a consequence of
and technological i
developped by many auth
and Illanes, 1983; Disalv
Illanes *et al.*,1985; Wolff,
ing increased rapidly from
first year (1984) to a maxi
in 1993 (SERNAP, 1978-1
resented the total product
Argopecten purpuratus in

Available information o
hanging culture of *Argope*
in the north of Chile indica
about 19 months for scallop
ketable size (9 cm) (Akabo
1983). The culture of the
in southern Chile, where t
not exist naturally, began
in 1989. In February 1989,
A. purpuratus were tra
Tongoy (IV Región, 30°15'
Estero de Castro (X Reg
73°45'W) to start hatchery
climatization for the cult