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# RECENT INNOVATIONS IN CULTIVATION OF MOLLUSCS IN FRENCH POLYNESIA

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## A B S T R A C T

Until recently, mollusc production in French Polynesia was only based upon fishing, for local consumption of edible bivalves mainly the oyster Saccostrea cucullata and for the exportation of pearl-oyster shells. As a consequence of parasitism problems on local oysters, a mollusc program was initiated by developping hatchery technics on introduced species of edible bivalves, Saccostrea echinata and Perna viridis, and cultivation methods in specialyy fitted up areas. Concerning pearl oyster Pinctada margaritifera the traditionnal shell production activity was recently reorganized to produce black culture pearls, inducing an increased demand of young implantable pearl-oysters. Hatchery spat production proved to be unsuccessful, and technics of collection and cultivation in lagoons were set up to supply the pearl oyster farming industry, and face the depletion of natural stock.

## I. INTRODUCTION

Till the years sixty, production of edible Bivalve molluscs in French Polynesia only consisted of the fishing of some species, mainly Saccostrea cucculata for local consumption. The development of S. cuccullata culture was initiated in the seventies by the Office de Recherche et d'Exploitation des Ressources Océaniques (O.R.E.R.O) which set up a collection and culture program (MILLAUD, 1971). After promising beginnings (22 tons marketed in 1975), this culture was progressively abandoned as a consequence of the parasitism of the culture sites by Polydora, whose pullulation followed the important increase of oysters biomass. To carry on this Mollusc program, it was necessary to find out oyster species resisting Polydora or other species unaffected by this parisite. Crassostrea gigas was first experimented, but proved to be extremely sensible to Polydora attack and was consequently abandoned in 1978. Saccostrea echinata was then introduced, and in the same time, Perna veridis and Venerupis semidecus-sata. Up to now, good results have been obtained with Perna viridis, and to a smaller extent with S. echinata.

Running this experimental program implied to dispose of spat in sufficient quantities to support growing tests. A hatchery-nursery program was initiated at the Centre Océanologique du Pacifique (C.O.P), dealing at first with Crassostrea gigas. The technic set up by AQUACOP (1977) was adapted from classical methods described by LOOSANOFF and DAVIS (1963), WALNE (1966) and DUPUY et al (1977). This technic was modified for Perna veridis (AQUACOP, 1979, 1980a) and for S. echinata as described in chapter 2. About 8.5 million P. viridis spat have been produced by the C.O.P allowing the O.R.E.R.O to develop a specific growing technic in specially fitted up sites (see chapter 3).

On the basis of the same hatchery procedure, the larval rearing of the pearl-oyster Pinctada margaritifera was investigated by the C.O.P. This work aimed at producing the quantity of pearl-oyster spat necessary to fulfil the increasing requirements of pearl-oyster farming industry in young implantable pearl-oysters, which can no longer rely on fishing of depleted wild stock. Hatchery trials gave poor results, and the problem was taken up by the O.R.E.R.O by developing spat collection in the wild as related in chapter 4.

## II. SACCOSTREA ECHINATA : HATCHERY AND NURSERY TECHNICS

### MATERIAL AND METHODS

1. The species *Saccostrea echinata* (QUOY and GAIMARD, 1835): *S. echinata* was reported by THOMSON (1954) to live on Queensland coasts, Australia. It is also found in surrounding islands, New-Caledonia, Vanuatu and Papua-New Guinea. The broodstock used at the C.O.P, Tahiti originates from New-Caledonia where the animals were detached from the intertidal zone bedrock in St-Vincent Bay. This species was choosen for its resistance to high variations of temperature and salinity and its thick shell hardly attackable by *Polydora*.

2. Conditioning and spawning : breeders are fed on *Chaetoceros gracilis* cultured in outdoor tanks. Maturation of gonads between two spawnings takes about four weeks. Spawning stimulation consists in freshening seawater from 35 ppt to 25 ppt during one hour. Spawning may happen during the salinity drop, or more often 1 or 2 hours after salinity has been brought back to 35 ppt. Males and females are isolated in separate vessels filled with 0.5 $\mu$ m filtered seawater. At the end of spawning, sperm and ovules are recovered separately and filtered on 25 $\mu$ m and 65 $\mu$ m sieves to eliminate dirts, mucus and interstitial gonadic tissue.

3. Fertilization : spermatozoids and ovules are mixed togather in the ratio 10 to 1 in a 50 liter bucket provided with a gentle aeration. The development of fertilization is controlled under microscope by the appearance of polar bodies. When more than 95 % of ovules are fertilized, the eggs are distributed in 800 liter tanks at a density not exceeding 20 million per tank, as stated by DUPUY *et al* (1977). Fertilized eggs measure about 51 $\mu$ m in diameter.

4. Hatchery technic

*S. echinata* hatchery technic is derived from the technics set up for *Crassostrea gigas* (AQUACOP, 1977) and for *Perna viridis* (AQUACOP, 1979, 1980 a).

Hatchery facilities consist of eight 800 liter cylindroconical tanks and one 10 ton U-section fiberglass tank. Temperature is regulated by circulating warmed seawater inside the double wall of 800 liter tanks and directly by heaters in the 10 ton tank. Seawater is filtered through a 0,5 $\mu$ m filter, protected by a 5 $\mu$ m filter.

Straight-hinge stage is completed one day after fertilization. Larvae are then recovered on a 48 $\mu$ m sieve (mesh side) and shared out among rearing tanks at the initial density of 3 000 larvae per liter.

Rearing tanks are completely drained every two days and larvae are recovered on sieves whose mesh is adjusted to the larvae size. 48, 65, 85, 100, 160 and 207 $\mu$ m screens are routinely used over a larval rearing. At each screening, the smallest larvae are discarded. After draining tanks are washed with soap and chlorine water, then rinsed and refilled with 0.5 $\mu$ m filtered seawater.

Algae are distributed after the water change. *Pavlova lutheri*, *Chaetoceros gracilis* and the locally isolated flagellate *Isochrysis aff. galbana* or T-ISO (EWART and EPIFANIO, 1981) are utilized in combined diets at a total density of 50 000 cells per milliliter. Algae are cultured at 25 °C in 300 liter fiberglass tubes (AQUACOP, 1982) and used as larval food when they reach the stationnary phase. Every day after changing water, algal density is controlled in larval tanks and if necessary adjusted to the required density.

All the tanks are treated with 14 mg per liter of sulfadimerazin every two days.

5. Settlement

Except peculiar trials using polyethylen or polyester sheets as collectors, most settlements were performed in 0.15 sq meter fixation boxes equipped with a 160 $\mu$ m sieve bottom, each containing about 50 g of pulverized oyster shell powder screened between 300 and 400 $\mu$ m. Fixation boxes are grouped by eight in trays. Seawater containing algae is air-lifted from a 300 liter tank placed under each tray and distributed in fixation boxes through a drop by drop system. The trays and reservoir tanks are drained everyday and rinsed with filtered seawater. Pediveligers retained on a 207 $\mu$ m sieve are disposed into the boxes at a maximum density of 120 000 per box, e.g 800 000 per sq. meter. Temperature is regulated at 29 °C and settlement duration varies from 4 to 5 days. Young spat are recovered on the fourth or fifth day on a 500 $\mu$ m sieve and transferred into the nursery facilities.

6. Nursery

Nursery facilities are derived from the system set up at the SATMAR hatchery-nursery, BARFLEUR, France (LEBORGNE, 1977, 1981). A concrete tank contains two rows of fifteen 50 cm in diameter and 50 cm high fiberglass tubes equipped with a nylon screen bottom. 500, 750, 1 000 and 2 000 $\mu$ m sieves are used in accordance with spat size. The nursery tank is supplied with a mixture of unfiltered seawater and *Chaetoceros gracilis* cultured in four 8 ton and four 35 ton outdoor fiberglass tanks (AQUACOP, 1982). The total flow-rate of the mixture algae-seawater arriving in the tank is about 20 cubic meters per hour. Everyday about 30 cubic meters of cultured C. gracilis at a mean density of one million cells per milliter are used as nursery food. In tubes containing spat, water is circulating upwards through the bottom sieve and spat, and overflows into a central exhaust gutter. The whole tank is drained daily and tubes are rinsed with fresh water.

## RESULTS

### 1. Hatchery

Fertilization: 95 % to 100 % fertilization rates were commonly obtained, provided that the time between the beginning of spawning and the fertilization operation did not exceed one hour.

Algal diet influence : A first experiment was conducted in 800 liter tanks at a mean temperature of 29 °C and a 35 ppt salinity. Two diets consisting of three species of algae were used, T-Iso and *Pavlova lutheri* versus T-Iso and *Chaetoceros gracilis*. The evolution of the survival rate and the size of larvae is given in Table 1. Data mentioned are the average from three replicate tanks for each diet. Larval rearings fed on T-Iso. *Pavlova lutheri* were all stopped at day 13 after a complete mortality. Rearings fed on T-Iso and *Chaetoceros gracilis* were transferred at day 19 in settlement trays containing a thin layer of pulverized pearl-oyster shell powder.

Temperature influence : Three larval rearings were carried out in 10 ton tank at the temperatures of 25 °C, 27 °C, 29 °C and a 35 ppt salinity. As shown in Table 2, the larval rearing duration is inversely proportional to temperature. Transferring of pediveligers for settlement took place on day 18 at 29 °C and on day 22 at 27 °C. Best results of growth and survival were obtained at 29 °C. At 25 °C, the end of the rearing was characterized by a high mortality and a poor growth, leading to no settlement.

Salinity influence : Several experiments were conducted in 800 liter tank at salinities ranging from 15 ppt to 35 ppt. At 15 ppt, a slow growth and a high mortality were recorded, whereas best results were generally obtained within the range 20-30 ppt. Consistency of these results will be discussed later on.

Settlement : All settlements were realized at a 35 ppt salinity and fed on T-Iso and *Chaetoceros gracilis*. Parameters having a effect upon the settlement rate were tested such as temperature, size and density of pediveligers, nature of substratum used as collector. Temperature is conditioning the duration and the success of the settlement : 4 days at 29 °C with 50 % to 75 % settlement rates ; up to 10 days at 24 °C with high mortality of the pediveligers.

Densities of 400 000 to 800 000 pediveligers per sq meter gave optimum settlement rates. As shown in table 3, better results were obtained with larvae larger than 260 $\mu$ m, e.g retained on a 207 $\mu$ m sieve. Polyester sheets and screened coral sand gave poor settlement rates, compared with those obtained on polyethylen sheets and pulverized shells of S. echinata and pearl-oyster Pinctada margaritifera. S. echinata powder composed of flat particles induced a significantly higher settlement rate than pearl-oyster powder made of rounded globulous grains.

2. Nursery

Young spat are placed into nursery tubes at a density of 50 000 per tube, which will be reduced at 20 000 per tube when spat reach a 6 mm size. At the nursery tank entrance the algal density varies between 60 000 and 100 000 cells per milliliter, in relation with the density of outdoor Chaetoceros gracilis tanks. When all the tubes contain spat, more than 90 % of algae are consumed. Algal consumption establishes around 600. $10^6$ C. gracilis cells per day per gram of spat (wet weight). Spat are grown until they reach a 4 to 6 mm size. Weekly screenings allow to separate the size classes, biggest spat being shipped towards growing facilities. At day 90 after spawning, an average of 80 % of spat reach the marketable size of 4 to 6 mm (40 to 50 mg mean weight).

## DISCUSSION

Since 1978, year of introduction of S. echinata at Tahiti, 32 larval rearings have been performed. No peculiar problems have been encountered in conditioning animals on Chaetoceros gracilis and in spawning obtention.

Best larval growth were obtained with the combination T-Iso - Chaetoceros gracilis, two tropical species adapted to rearing temperature and keeping on dividing in rearing tanks. These results confirm the good value of T-Iso as larval food, as it was shown by EWART and EPIFANIO (1981). The combination T-Iso -Chaetoceros gracilis seems to be a suitable food, and this is to be compared to the results obtained by EPIFANIO (1979) when combining T-Iso with an other diatom, Thalassiosira. Contrary to some authors' technics (DUPUY et al, 1977), algal density in rearing tanks does not vary over the rearing period. But when assuming a 20 % final survival rate due to the regular mortality during the larval rearing, the actual number of algal cells available per larva increases from 16 000 at day 1 to more than 80 000 at day 18.

The optimum temperature and salinity, respectively 29 °C and 20 to 30 ppt, correspond to the natural conditions prevailing in New - Caledonia in summertime when maximum spawning activity occurs. However, results concerning salinity obtained in 800 liter hatchery tanks are still to be confirmed, as they are not wholly consistent with those obtained in the 10 ton tank.

Survival rates are generally low. Only 5 to 20 % of larvae reach settlement stage, whereas these rates are about 50 % for C. gigas (AQUACOP, 1977) or P. viridis (AQUACOP, 1980 a).Even in rearings unaffected by diseases, many larvae grow slowly, and are discarded at the moment of screenings, which explains the low final survival rates. Such larvae if maintained in rearing do not recover a normal growth and become a risk for the rest of animals as they finally die after being contaminated by bacteria. More generally, S. echinata show a reduced larval activity when compared with C. gigas or P. viridis : swimming is less active, and if no aeration is provided, most larvae rapidly deposit on the bottom of the tank. Mortalities from bacterial origin were recorded in about one third of rearings. Larvae showed a slackened feeding activity, a pale and empty digestive gland and necrosis of velum. Bacterial analysis revealed the presence of Vibrio sp . Identical symptoms were described on C. virginica by ELSTON et al (1981) and were attributed to a vibriosis. Such contaminated tanks must be discarded, as sulfadimerazin treatment routinely used as bacteriostatic cannot stop this vibriosis.

Settlement technic on pulverized oyster shell powder is commonly used in several hatcheries and gives fairly good results which are still improvable by increasing the pediveliger density in settlement trays.

The nursery of young spat remains the main constraint to increase the hatchery productivity. Phytoplanktonic content of lagoon waters at Tahiti is too low to support any growth of spat to a marketable size. Thus the whole nursery culture must rely on mass cultivation of algae. T-Iso, as indicated by EWART and PRUDER (1981), could be a valuable source of food. Chaetoceros gracilis was preferred as it proved to be easier to cultivate in large outdoor tanks, either in batch cultures (AQUACOP,1982) or in continuous cultures at 1/3 to 1/2 daily renewal rates during two to five weeks periods. The present Chaetoceros gracilis culture capacity set limits to the nursery productivity at 1 to 1.5 million spat per two month periods.

## III. CULTIVATION OF GREEN MUSSEL PERNA VIRIDIS

### MATERIAL AND METHODS

#### 1. Environmental factors

*P. viridis* cultivation has been investigated in Society Islands, an area interested by superficial seawater presenting oceanic characteristics : annual temperature range 25 °C-30 °C ; annual salinity range 34 to 36 ppt ; poor nutrient content. Rainfalls are most abundant from November to April, sometimes exceeding 1 mm per minute during heavy storms. Most of these islands are high ones, of volcanic origin, and are surrounded by a barrier reef delimitating a lagoon. Lagoons are fed in oceanic water by the breaking of waves over the reef, and flow out into the ocean through passes. The resulting renewal rates are generally so important that lagoon waters present oceanic characteristics and low phytoplancton content (2 000 to 10 000 algal cells per liter). Some of these islands are cut up into sheltered deep bays which most often receive a little river at their deepest part, and present environment conditions favouring a certain phytoplankton development (up to 350 000 algal cells per liter) :

. protection against violent winds
. shallow water (0,5 to 2 meters)
. limited water movement and renewal
. high contents of organic matter and nutrient resulting from the leaching of surrounding basaltic soils (Table 4).

Some bays have been separated from the lagoon by a carriageable dyke pierced by several communicating pipes. In the so created "ponds", water exchanges are ensured by the tide (0,4 meter amplitude). Water renewal and movements are extremely reduced and phytoplankton density can reach high values. Further details on phytoplanktonic and physico-chemical conditions in lagoons and bavs are given by RICARD (1977) and ROUGERIE and RICARD (1980).

The first trials conducted in Tahiti concluded to the inadequacy of lagoon and bays for mussel culture. Better results were obtained in the ponds though they are affected during the rainy season by great variations of temperature and salinity, causing damages to cultures.

Further studies were thus carried out in these specific sites, with two purposes : understand and master the problems in connection with this kind of environment, and in the same time, set up an adapted cultivation technic of P. viridis. Two sites have been studied : TATUTU pond in Tahiti island, and UTUROTO pond in Raiatea island.

* Tatutu pond

In this representative pond, maximum depth is 0.8 meter at low tide, and total area 3.5 hectares. Great variations of physico-chemical parameters are commonly recorded, mainly in the rainy season when temperature and salinity stratification appear in the water (Table 5). The extreme values reached can be lethal for mussels. About once a year, these conditions can be emphasized by the exceptionnal combination of climatic circumstances :

. heavy rains inducing in a few hours the freshening of water (0 to 5 ppt in surface, 10 to 15 ppt on the bottom).

. immediatly followed by a bright sun warming the air temperature up to 33 °C.

. no wind and no tide (only 2 to 4 cm of amplitude).

In such a case, water temperature reaches 36 to 37 °C in surface and 40 °C on the bottom. This phenomenon lasts only 1 to 3 days, inducing the spawning and weakening of mussels sometimes followed by mortality. The phytoplanctonic population is affected by seasonal conditions and short-term hydrological variations. Average densities over the year are indicated in Table 6. Diatoms mainly Nitzschia sp represent 50 to 90 % of phytoplancton. Exceptionnal blooms of Chaetoceros sp or unidentified little square diatoms, generally occuring after rainfalls, can increase the algal density up to 60 million cells per liter. The minimum algal density so far recorded is 400 000 cells per liter in the dry season.

* Uturoto pond

In this 22 hectares pond, rece i ving a permanent little river, temperature never exceeds 36 °C and mortality problems are mainly due to prolongated freshening of water when the river is swollen with rainfalls. It was thus decided in 1981 to improve this culture facility by canalizing the freshwater flow. The pond was cut into two parts by a second dyke (Figure 1) crossed through by six communicating pipes, equipped at one end with sluice-gates.

- Part A (4.8 hectares) : it receives the fresh waters enriched in nutrients and communicates with the lagoon by a lock fitted with swing-gates leaving the lagoon water enter during the flow. Swing-gates close by themselves at the beginning of the ebb. This part A is ordinarily used as a phytoplancton reservoir, the six sluice-gates being closed during the flow. During the ebb, sluice-gates are opened and Part A waters are discharged into Part B. In case of heavy rains, swing-gates are drawn-up to allow direct draining of freshwaters into the lagoon.

- Part B (17 hectares) : it is used as culture area, mainly along the separating dyke. This part is constantly communicating with the lagoon, the tide ensuring water exchanges.

2. Rearing technic

a) Material : Spat settlement is performed in cases or in a specially designed raceway (Figures 2 and 3). Varied materials have been tested as settlement substrate (bamboo, coral, wood, ropes) but the best results were obtained with 0.85 meter long round iron bars. Rearing structures consist of 6 meter long units described in figure 4. Nylon cord is used to hang up the racks and adjust their level in water.

b) Settlement : When they leave the C.O.P nursery, spat are 7 to 11 mm long (90 to 250 mg). Two methods are utilized :

+ Cases : iron bars are disposed on the cases bottom, spaced of about 1 cm. Spat are simply sown on them, and cases, weighed down with bars, are immersed on the racks. Protection against waves and predators (crabs) is realized by fastening covers on the cases. 2 to 3 days later, bars with attached mussels can be removed from cases, and have to be thinned out manually to keep only about 150 mussels per bar. After thinning, a one week period is necessary to get a good strengthening of attachment. This is performed in strengthening cases, fitted with wood laths which support the iron bars and separate them from the case bottom. When set--tlement seems to be satifactory, bars are directly put onto the rearing racks. Spat detached from bars during strengthening are recovered and put back into settlement cases.

+ Race-way : handlings are the same that precedently, but the advantage of this device is to allow a better settlement, and to reduce the duration of the whole process and the number of cases. The race-way used in Tatutu Pond (Figure 3) can content 200 000 spat. Bars can be removed after one day and left only 2 to 3 days in strengthening cases.

c) Growing up : Bars are disposed on the racks, at a number of 20 per 6 meter unit. A particular handling of the racks had to be found to keep mussels in tolerable conditions during the rainy season. It consits, by means of the nylon cords, in moving them up or down according to the temperature and salinity of the water layers. Culture areas can be pro-tected against predators (mainly Scylla serrata) with wirenetting enclo-sures where are placed some crab-pots.

d) Harvest : Marketable mussels are easily harvested, simply by sliding them down the iron bars. In spite of a continuous immersion, fouling is reduced and mussels can be rapidly cleaned by means of a simple water--hose.

## RESULTS

Mussels have a good resistance to variations of temperature and salinity. The lethal values are respectively 37 °C and 5 ppt, during more than two days. In ponds, the best growth and fattening of mussels are obtained in the rainy season, when phytoplankton is abundant.

In Tatutu Pond, spat settlement is performed in May-June, just after the rainy season, when water has still a high phytoplanktonic content. First harvest can be effected the same year in November, and from then, till the first natural spawning occurs. The mean weight obtained varies from 17 g (about 6.5 cm) in November to 40g (about 9 cm) in March. The best survival rate so far observed is 63 % for the 1981 rearing, whose harvest prolonged up to late February 1982, main mortality occuring during the fixation time in the race-way. Natural spawning can happen in the pond at any time between December and March, and is mainly conditioned by abrupt variations of the water physico-chemical parameters, resulting from meteorological incidents. For instance, for 1978 to 1980 rearings, the first spawning took place during the last week of December, whereas for 1981 rearing, it was delayed up to early March 1982. Spawning is generally followed by a weakening of mussels. Recovery is very slow and mussels can stay unmarketable for several months. Moreover, when conditions are still worse, mortality can result, reaching a 50 to 70 % rate. The mean survival rate of rearings performed in Tatutu Pond since 1978 establishes around 40 %.

In Uturoto Pond, the first stocking after the fitting up of the pond was realized in Fébruary 1982. First results indicate a growth slightly lower than in Tatutu Pond (25 g in 9 months), but definitive results will be known early 1983.

Table 7 gives the production results of the experimental rearings carried out since 1978.

## DISCUSSION

After the first trials, further extension to mussel culture was only performed in ponds. However the characteristics of these sites made it necessary to utilize a technic rather different than that ordinarily used in other countries, such as rafts or poles. The small depth available constrained to adapt a flat off-bottom culture on racks. Mussels stay immersed permanently because of little tidal amplitude and to avoid excessive heating by the sun.

The most favourable season for fishing mussels in Tatutu Pond corresponds to the rainy season, when the planktonic algal food is the most abundant. Unluckily this season is also the most hazardous one, as heavy mortalities resulting from major climatic accidents are to be feared at any time. This is why harwest is generally performed early December, before the heaviest rainfalls. Such a production cycle within one year implies that spat be available from the C.O.P hatchery as early as May. To avoid any delay in settlement, spat of good quality and sufficient size are required, and raceway rather than cases are used as settlement structure.

At Uturoto, the management of the pond have been facilitated after it was fitted-up by canalizing fresh waters by means of a dyke. Stocking and harvesting can be distributed all over the year. In this site, an annual production of 30 to 40 tons is expected for the next years which should allow to prove the economic feasibility of mussel culture.

Some other potential sites usable for mussel culture are known. Small scale experimentation will allow to point out their specific problems, to decide of their further exploitation in case of increase of the local market demand.

# IV. CULTIVATION OF THE BLACK-LIP PEARL OYSTER

## INTRODUCTION

The black-lip pearl oyster is a bivalve belonging to the family of Pteriidae. There is a number of varieties distinguished by their origin ; the French Polynesia one is the giant Pinctada margaritifera. (L) Var. Cumingi (Jameson). It usually attains 15 centimeters in diameter but can grow as big as 30 centimeters. The shell is relatively thin, the outside marked with radial black lines embossed on grey and the inner surface coated with a subtle smoky silver, pearly film.

The first exploitation of Pinctada margaritifera began in GAMBIER Islands in 1802, for its shell (used in button factory) and its natural black pearls. This industry was based on the collection of native oysters, by the local people. But it rapidly decreased since 1940, on account of "overfishing" and competition of nacre buttons by synthetic ones. Since the first experiments of pearlculture in 1963, the natural pearl oyster is now used as a source of supply for pearl culture.

Many attempts of seed production of black lip pearl oyster have been made at the COP from January 1976 to October 1977 (AQUACOP, 1980b). To explain the failure of the larval rearing of this species, which put an end to these experiments, the hypothesis of a genetic problem had been advanced. The present studies conducted by F. BLANC (personnal com munication, 1982) have concluded to genetic differences between the isolated groups of Pinctada margaritifera from different atolls of the Tuamotu archipelago, and are expected to bring more information about this presumption.

Although the native oysters are still collected, the new methods of culture by collecting the spat have assumed greater importance, in order to remedy the situation created by overfishing. The method of natural collection has been developed by MIZUNO on Takapoto Atoll, in 1976. It relies on catching spatfall in natural growing areas.

With favourable marine conditions, the male pearl oyster ejaculates a smoky screen of sperm, which stimulates the female to ovulate. Fertilization occurs in the water. Usually within 21 to 28 days, the planktonic larvae metamorphose and "set", forming shells and attaching themselves to a substrate.

## MATERIAL AND METHODS

The practice of gathering oyster spat and cultivating the young pearl-oysters is widespread now throughout the Tuamotu Islands.

### 1. Spat collection

The early experiments in spat collecting consisted simply in submerging branches of "uu" (*Phemphis acidula*), a small bush widespread on the atolls and waiting for the spat to settle. Then they were taken up and moved to sheltered areas.

At present, collectors e.g. material upon which spat will settle (Table 8), are placed suspended from a collection station at a 3 meters depth for a period of 4 to 6 months. After the spat have settled and grown to a reasonnable size, they are removed and transported to the growing area.

The collection station is made of a double line of polypropylen ropes, 30 meter long and 16 mm in diameter maintained at a 3 meters depth by floats and mooring blocks. There are 120 collectors hanging from the principal rope. The station is anchored on areas where experience has shown that the best "set" of spat can be expected (Figure 6).

### 2. Rearing

At harvest time, the young oysters are removed from the spat collecting bags, sorted out and then transferred into rearing boxes or lantern-shape baskets according to their size (Table 9).

The platform where baskets and boxes are suspended, is made of a framework of galvanized pipes from different diameters. Each platform measures about six by six meters, with the longitudinal and transverse pipes lashed together at about 60 centimeters intervals. The framework is supported by poles fixed on a sandy bottom about 6 meter deep (Figure 7).

After one month on the platform, the spat from the rearing boxes are removed, cleaned, measured, divided by size, and put in rearing baskets. Those of the rearing baskets are also removed every 3 months. When their size is over 50 mm, they can resist attacks from predators, and are put in suspended pockets (Table 9). The biggest ones, more than 100 mm, are drilled and attached on strings (10 per string).

When about three years old and nearing maximum size and vitality, the oysters are brought to the laboratory for the nucleus insertion operation. The method employed by the Japanese technicians is to implant a nucleus of a selected size and shape togather with a specially selected piece of mantle tissue into a choosen pearl oyster and place that implanted oyster in an optimum grow out location. After a brief convalescence period, during which the injured animals and those which fail to survive the operation are removed from the baskets, the oysters are returned to the sea in baskets suspended from platforms, and remain undisturbed for a two years period, after which the cultured pearl is harvested.

## RESULTS

Most of the studies on spat collection have been conducted in Takapoto, a closed atoll of the Tuamotu archipelago at 145°20 W and 14°30 S.

### 1. Physical conditions in Takapoto lagoon

The lagoon is 19 kilometer long and 7 kilometer wide. The maximum depth is 40 meters, and there are large areas of dead coral reefs 15 to 20 meter deep, which are suitable for the fixation and growth of pearl oysters. The lagoon is sheltered from very rough weather and, because of almost total absence of tides, the currents are very gentle. The sea temperature as shown by figure 8 varies from 26°C-27°C during August and September to 29°C-30°C during March and April. The salinity varies from 37 ppt in January and August to 39 ppt in November and December.

2. Spat collection

Collectors (Hyzex film) harvested from may 1979 to January 1980, after five months on the same collection station gave the results indicated in Table10. In 1981, the efficience of different types of collectors on spat collection was investigated. The collectors, immersed in April-May 1981, were harvested in October 1981 and the results are reported in Table 11.

3. Rearing

The pearl oyster is protected from its biological enemies by confining the culture stock in rearing baskets which either bar the attack of the enemy or make possible the removal, by periodic cleanings, of the attacking organisms which settle and grow on the baskets. The mortality rate recorded during the rearing period and the post larval growth performance of Pinctada margaritifera are given in tables 12 and 13. The figure 9 draws the curve of the collected spat number from 1977 to 1981, in connection with the number of collectors immersed during the same period.

4. Economical aspects

In 1982, the pearl oyster culture industry in French Polynesia interests 26 cooperative farms, operated by about 360 employees, and 13 private companies, operated by about 50 employees, the private companies ensuring nearly 90 % of the pearl production. From July 1981 to July 1982, 400 000 young oysters (12 to 15 centimeters) have been implanted, 60 % coming from direct fishing and 40 % from collected spat. About one third of these implanted oysters will produce a marketable pearl in two years.

In 1981, the pearl production reached a declared value of about 3 million US $, making of this industry the second economical activity of the French Polynesia Territory.

## DISCUSSION

The most important peculiarity of Takapoto lagoon is probably the great annual variation in water temperature. It is probably the temperature, more than other factors, which influences the spawning of pearl oysters.

The spat collection seemsto occur throughout the year, but the date of setting out the collectors is important. Thus, from August to October (austral winter) collection is better than during the other months. These results seem to be in relation with changes of water temperature during this period. However, further studies are needed to find in which way the temperature has an influence on spat collection, and to know if a second spat collection peak is not occurring from February to May when water temperature is high, as it might be supposed with the results obtained in may 1979. The spat collection occurring the whole year, the harvest of collectors are planed twice a year, to get the maximum of spat. Spat seem to select collectors to set, natural collectors looking more efficient than the artificial ones.

During the nursery stage, the young oysters are very vulnerable ; their chief predators are the fishes from family Balistidae and Tetrodontidae. And during the growing stage, attacks of parasites like red boring sponges, Clione, a polychaete worm, Polydora, and date mussels, Lithophaga, can cause damages (Reed, 1966). Fouling organisms like algae can also cause mortality and stunting by clogging the rearing baskets. Periodic cleanings of the baskets by the divers, resolve this problem.

## V. GENERAL CONCLUSION

* Saccostrea echinata : the experimental larval rearings performed in the COP hatchery have produced more than 2 million spat, which have allowed the development of an experimental culture program in French Polynesia and New-Caledonia. The hatchery results show up the difficulty to perform good larval survival rates. This problem is compensated by the high resistance acquired after the settlement and during the nursery stage. A few hundreds of kilograms have been produced after a one year rearing in Tatutu pond, and have been tested on the market, receiving a rather unfriendly welcome.

* Perna viridis : technical feasibility of the Philippines green mussel cultivation has been demonstrated. According to the possibility of fitting up the culture sites, an annual harvest or a regular production all over the year can be obtained. Economical feasibility of this culture will have to be proved in the next years. The first aim of this production is to supply the local demand (about 30 tons of mussels imported in 1981). This demand will very likely increase, because of the availability of a fresh product and of the unexpected success obtained by these mussels with the local consumers.

* Pinctada margaritifera : pearl-oyster industry is, without question, the most important activity concerning Molluscs culture in French Polynesia. Pearl-oyster farming is still depending at 60 % on fishing of natural implantable oysters from an already depleted stocks, and future program will have to focus on collection problems. Prospects for 1985 are to obtain 500 000 implantable oysters, coming exclusively from collected and reared spat, which implies a one million spat harvest per year from 1983 forward. The success of such a program should allow

to stop completely the fishing of wild oysters, permitting the restoration of the natural stock. Improvements are also to be performed on the implantation technic and the rearing method of implanted oysters, in order to augment the rate of success (at present 30 %). The French Polynesia market has already reached its saturation point, and the black pearl production is mainly exported, the pearl industry becoming the second economical activity at exportation in French Polynesia, behind the copra production.

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| Algal Diet | A + B | | A + C | |
|---|---|---|---|---|
| Day | Survival (%) | Size ($\mu$ m) | Survival (%) | Size ($\mu$ m) |
| 1 | 100 | 59 | 100 | 59 |
| 3 | | | 100 | 72 |
| 4 | 93 | 70 | | |
| 5 | | | 50 | 85 (a) |
| 6 | 30 | 77 (a) | | |
| 7 | | | 39 | 95 |
| 8 | 6 | 85 | | |
| 9 | | | 39 | 113 |
| 12 | 1 | 133 | 22 | 144 (b) |
| 13 | 0 | | 18 | 172 (c) |
| 15 | | | 13 | 214 |
| 19 | | | 7 | 285 (d) |

/ TABLE 1 /

Algal diet influence on larval growth and survival of *Saccostrea echinata*. A = T-Iso ; B = *P. lutheri* ; C = *C. gracilis*. Screenings : (a) on 65 $\mu$ m ; (b) on 85 $\mu$ m ; (c) on 100 $\mu$ m ; (d) on 207 $\mu$ m sieve.

| Temperature (°C) | 25 °C | | 27 °C | | 29 °C | |
|---|---|---|---|---|---|---|
| Day | Survival (%) | Size (µ m) | Survival (%) | Size (µ m) | Survival (%) | Size (µ m) |
| 1 | 100 | 60 | 100 | 60 | 100 | 60 |
| 2 | | | 97 | 69 | 100 | 68 |
| 4 | | | | | 100 | 78 |
| 6 | 67 | 79(a) | 77 | 83(a) | 93 | 96(a) |
| 8 | 65 | 88 | 67 | 103 | | 111 |
| 9 | | | | | 72 | 124(b) |
| 10 | 61 | 100 | 43 | 125(b) | | |
| 11 | | | | | 67 | 143 |
| 13 | 48 | 111 | 43 | 154 | 50 | 171(c) |
| 15 | 45 | 126 | 40 | 185(c) | | |
| 16 | | | | | 46 | 212 |
| 17 | 32 | 136(b) | 38 | 203 | | |
| 18 | | | | | 21 | 267(d) |
| 19 | 24 | 150(c) | | | | |
| 20 | | | 38 | 215 | | |
| 22 | | | 13 | 252(d) | | |
| 25 | 4 | 185 | | | | |

/ TABLE 2 /

Influence of temperature on larval growth and survival of S. echinata. Screenings : (a) on 65 µ m ; (b) on 85 µ m ; (c) on 100 µ m ; (d) on 207 µ m sieve.

| Size of pediveligers | > 260 µm | < 260 µm |
|---|---|---|
| Collectors | | |
| S. echinata powder | 74 | 20 |
| Pearl oyster powder | 55 | 18 |
| Polyethylen sheet | 40 | |
| Polyester sheet | 3 | |
| Screened coral sand | 4 | |
| Rearing tank walls | 0 | |

/ TABLE 3 / Settlement rates (%) of *S. echinata* in relation with the size of pediveligers and the nature of collecting substrates.

| | $N-NO_3$ | $N-NO_2$ | $N-NH_4$ | $P-PO_4$ | $Si-SiO_3$ |
|---|---|---|---|---|---|
| Lagoon water in dry season | 0.3 | 0.1 | 0 | 0.4 | 4.5 |
| Lagoon water after heavy rains | 5.0 | 0.1 | 0.1 | 17.1 | 112.1 |

/ Table 4 / Nutrient contents in µatg/l of sea water in the Vairao lagoon, Tahiti island (from ORSTOM (1976) and AQUACOP (1976).

| | DRY SEASON | | RAINY SEASON | |
|---|---|---|---|---|
| | T (°C) | S (ppt) | T (°C) | S (ppt) |
| SURFACE | 27-30 | 30-35 | 30-35 | 10-20 |
| BOTTOM | | | 35-38 | 25-35 |

/ Table 5 / Mean temperature and salinity in Tatutu Pond.

| | Phytoplancton density (million cells per liter) |
|---|---|
| rainy season | 20-30 |
| transition season | 10-15 |
| dry season | 3-8 |

/ Table 6 / Average phytoplancton density in Polynesian ponds.

| YEAR | HARVEST (Kg) | |
|---|---|---|
| | TATUTU POND | UTUROTO POND |
| 1978 | 165 | |
| 1979 | 1878 | 2050 |
| 1980 | 147 | 650 |
| 1981 | 5541 | |
| TOTAL | 7731 | 2700 |

/ Table 7 / Experimental production of green mussel *Perna viridis*, in French Polynesia.

| | | |
|---|---|---|
| Artificial | - Hyzex film | Black polyethylen film, 1 meter long, 15 centimeter wide, protected by a polyethylen net bag, 2 mm mesh. |
| | - Netron tube | Blue polyethylen mesh, 1 meter long, 15 centimeter wide, 2.5 mm mesh protected by a polyethylen net bag, 2 mm mesh. |
| | - Baron screen | Polyethylen screen (50 %) for shade |
| Natural | "uu" | Branches of *Phemphis acidula* dried or green, protected by a polyethylen net bag, 2 mm mesh |

/ Table 8 / Types of collectors used

| Young oysters size (mm) | Mesh size (mm) of rearing structures | Density per rearing structure |
|---|---|---|
| 2 - 7 | 2 (boxes) | 200 |
| 7 - 10 | 4,5 (baskets) | 100 |
| 10 - 15 | 4,5 (baskets) | 50 |
| 15 - 20 | 9 " | 50 |
| 20 - 30 | 9 " | 40 |
| 30 - 40 | 9 " | 30 |
| 40 - 50 | 9 " | 20 |
| 50 - 70 | 20 (pockets) | 30 |
| 70 - 90 | 30 " | 30 |
| 100 - 120 | 40 " | 12 |

/ Table 9 / Repartition of young pearl-oysters in rearing boxes, baskets and pockets.

| 1979 | | | | | | | | 1980 | |
|---|---|---|---|---|---|---|---|---|---|
| May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. |
| 90 | 13 | 43 | 197 | 137 | 608 | 11 | 27 | 22 | 28 |

/ Table 10 / Average spat number per Hyzex film collector during the 1979-1980 collection season.

| Collector type | Average spat per collector |
|---|---|
| Baron screen | 2 |
| Hyrex film | 19 |
| Netron tube | 33 |
| " dried | 48 |
| " green | 81 |

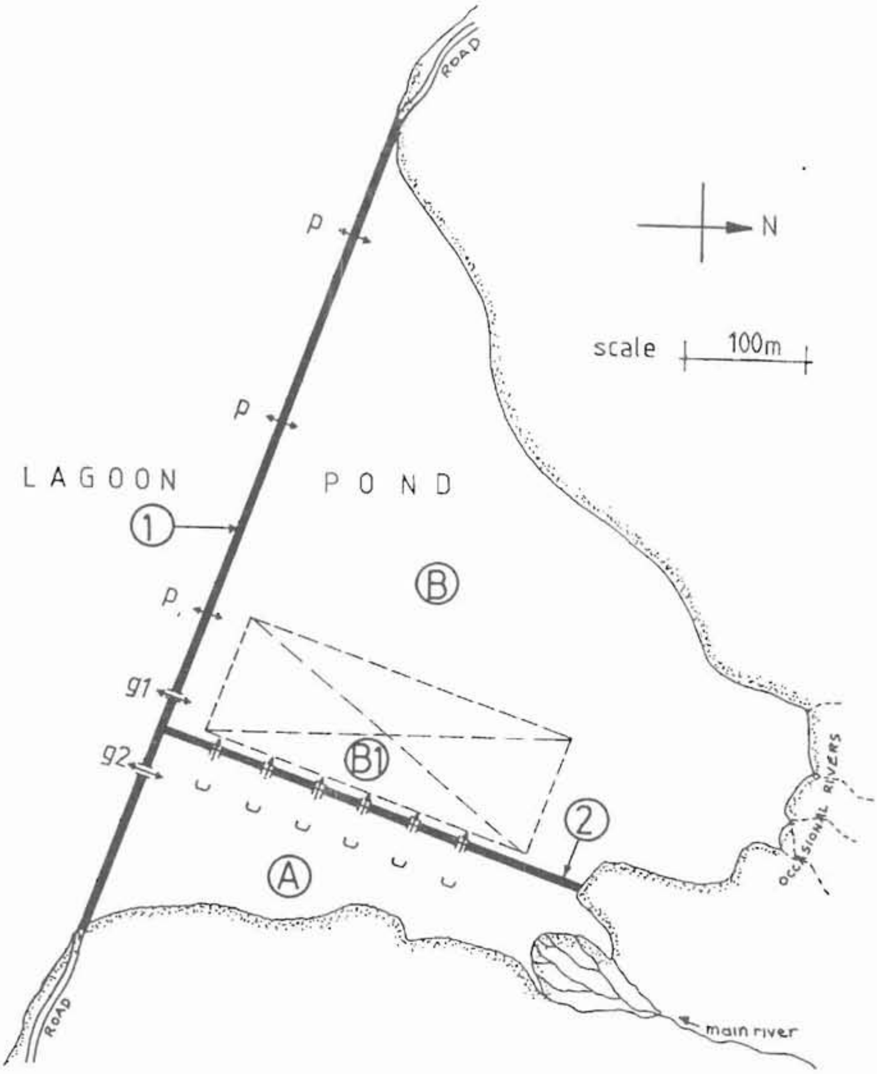
/ Table 11 / Average spat density per different type of collector in 1981.

| Age | % Mortality |
|---|---|
| 0 - 6 months | |
| 6 - 12 " | 30 % |
| 12 - 18 " | 35 % |
| 18 - 24 " | 40 % |
| 24 - 30 " | 45 % |
| 30 - 36 " | 50 % |

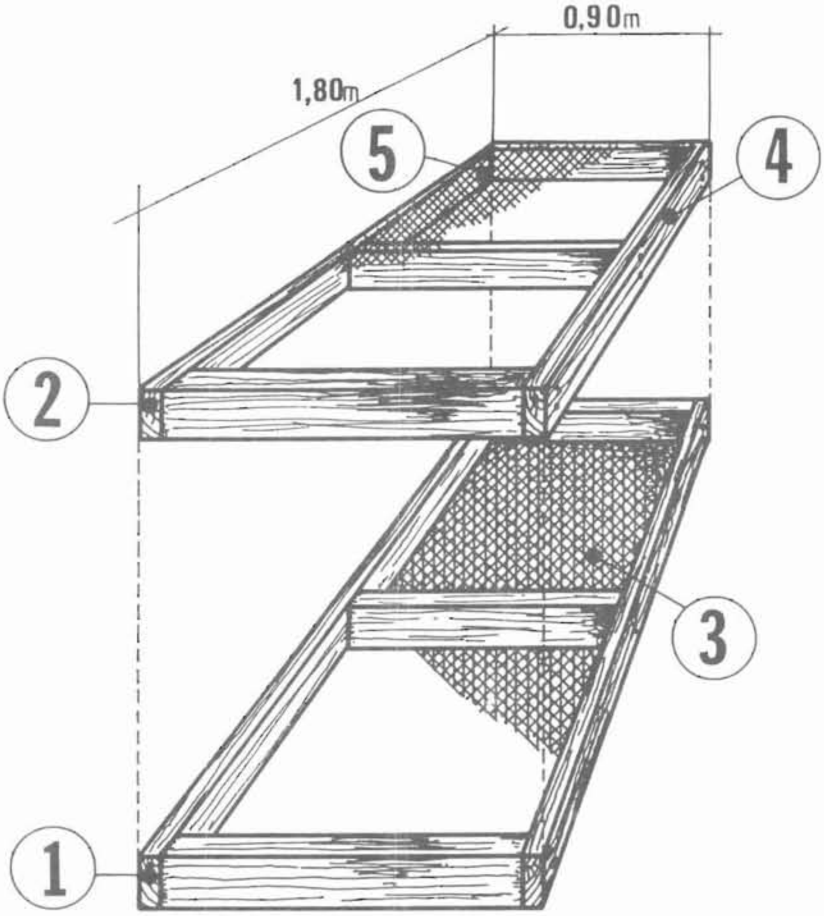
/ Table 12 / Mortality cumulative rate during the rearing period (after ORERO, 1980).

| AGE | LENGTH (mm) | AGE | LENGTH (mm) |
|---|---|---|---|
| 1 month | 0,2 - 0,3 | 2 years | 100-120 |
| 2 months | 2 - 3 | 3 " | 120-150 |
| 3 " | 8 - 10 | 4 " | 140-150 |
| 6 " | 40 - 50 | 5 " | 140-150 |
| 1 year | 70 - 80 | | |

/ Table 13 / Post-larval growth of P. margaritifera on rearing platforms in Takapoto lagoon.

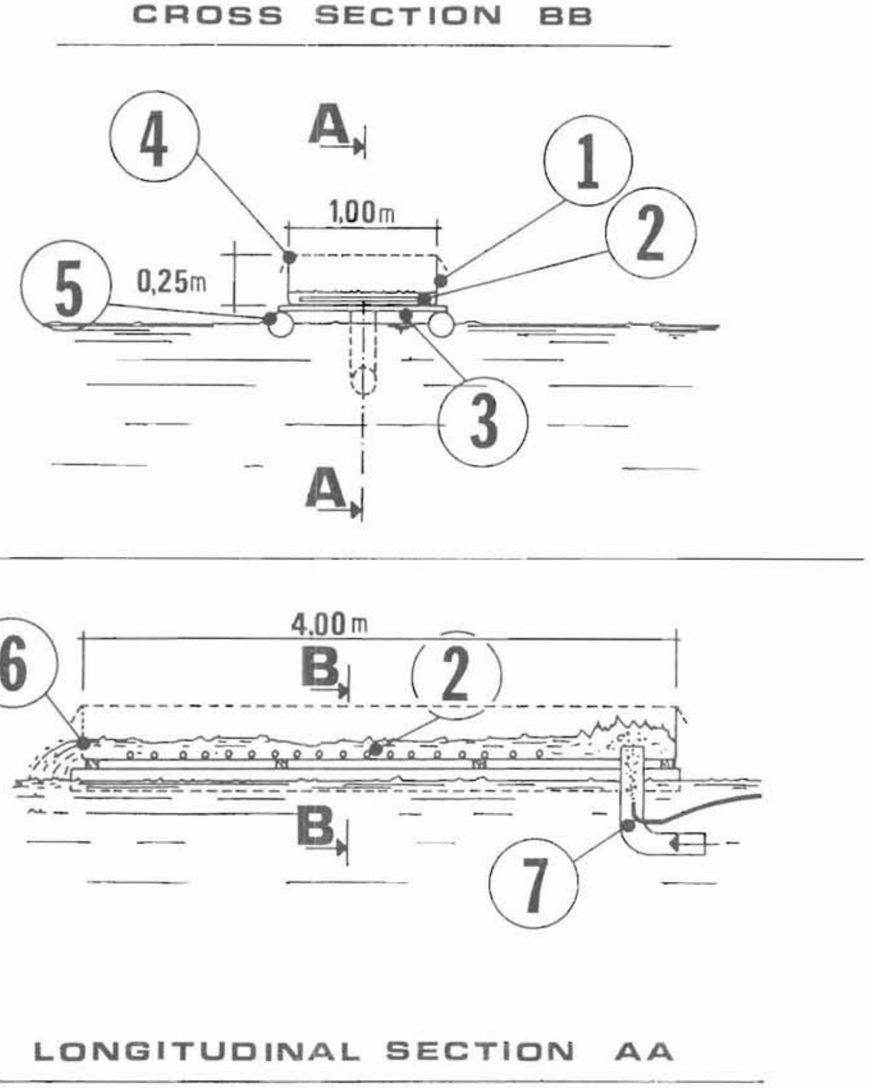



/ Figure 1 / UTUROTO Pond rearing facility, Raiatea Island
1 : carriageable dyke - 2 : dyke separating part A (4.8 ha) and part B (17 ha) - C : pipes fitted with sluice-gates
P : pipes - g1 : two-way communication - g2 : lock with swing gates - B1 : culture area



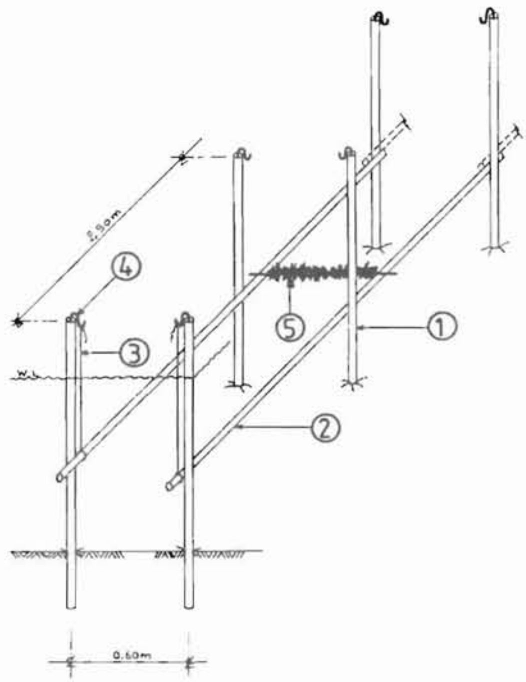

/ Figure 2 / Settlement case

1 : case - 2 : cover - 3 : moskito wire-netting protected by a 5 mm wire-netting - 4 : treated wood 1"x3" - 5 : 5 mm wire-netting



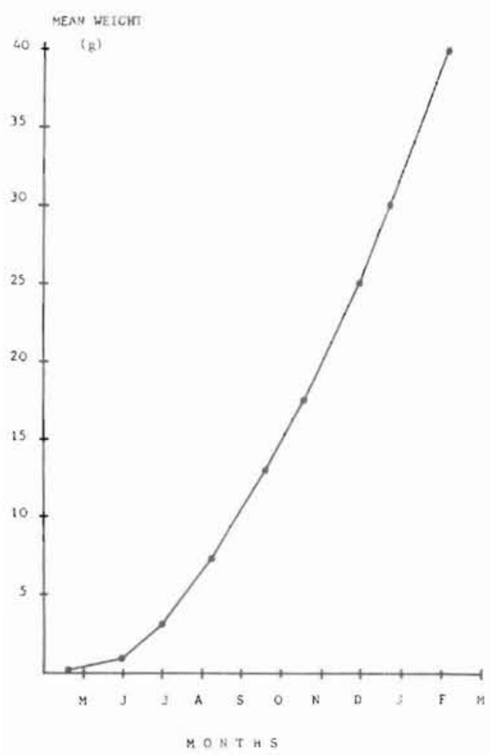

/ Figure 3 / Settlement raceway

1 : plywood covered with polyester resin - 2 : round iron bars
3 : treated wood 2"x3" - 4 : shading net - 5 : floats PVC 15 cm diameter - 6 : plastic mesh 3 mm - 7 : air-lift system

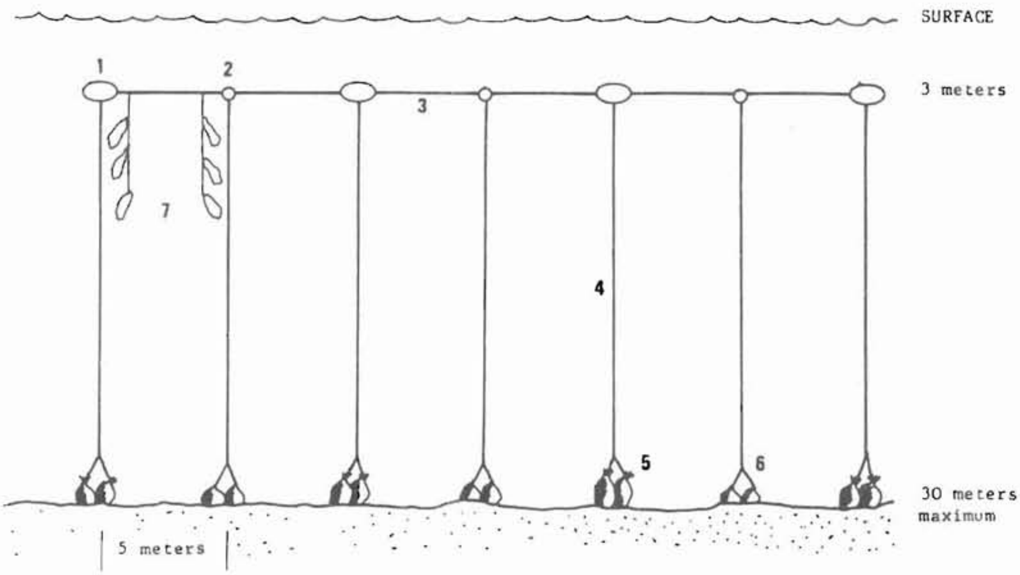



/ Figure 4 / *Perna viridis* rearing units

1 : posts (3/4" galvanized pipes) - 2 : racks (6 meter long ½" pipes) - 3 : nylon cord - 4 : hooks - 5 : mussels attached on round iron bars

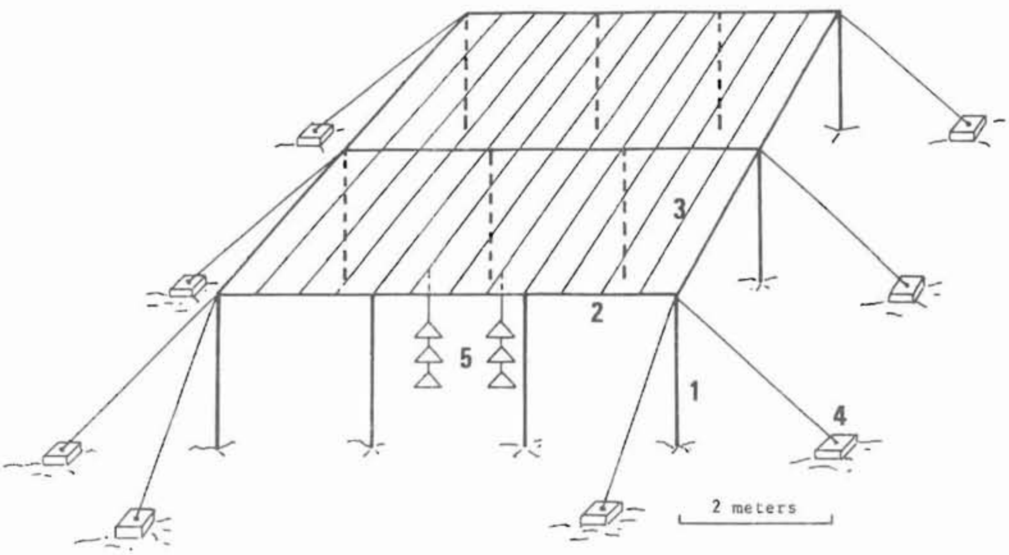



/ Figure 5 / Average growth of *Perna viridis* in Tatutu Pond during 1980-1981 rearing



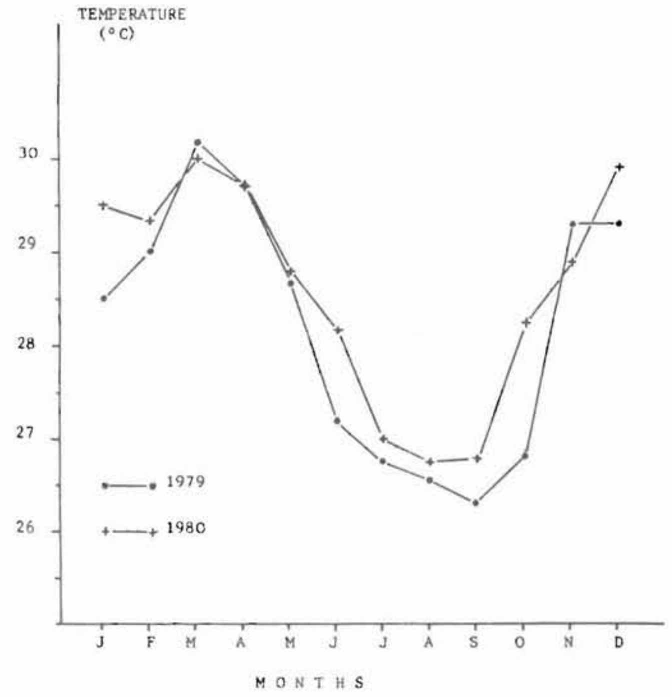

/ Figure 6 / Collection station

1 : 30 Kg buoyancy float - 2 : 13 Kg buoyancy float - 3 : 16 mm rope - 4 : 12 mm rope - 5 : 80 Kg mooring blocks - 6 : 40 kg mooring blocks - 7 : collectors

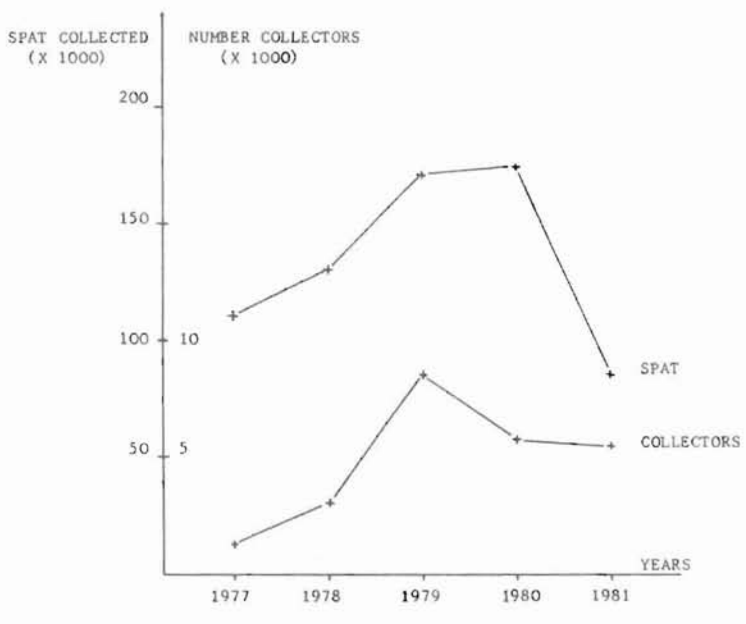



/ Figure 7 / Immersed rearing platform (6 per 6 meters)

1 : 3 meter poles (galvanized pipe 1") - 2 : framework (pipe 3/4") - 3 : suspension pipes 0,6 meter spaced (pipe ½") - 4 : mooring blocks - 5 : lantern-shape rearing baskets




/ Figure 8 / Monthly average sea water temperature in Takapoto Atoll in 1979 and 1980




/ Figure 9 / Number of spat collected and collectors immersed from 1977 to 1981 by the ORERO in Tuamotu Atolls