On a more measured note, we are pleased to be able to publish some scholarly debate as well. This issue contains some original research from Rick Braley and Dorothy Munro, based on their recent trials at the Tongareva Marine Research Station in the Cooks. Mario Monteforte provides a review of the research and development programme at CIBNOR, La Paz, and outlines their path towards commercial farm development. Kelvin Passfield also provides an interesting assessment of the Penrhyn 'pipi' pearl fishery and market.

And we are also happy to report—albeit second-hand—on the research programmes under way on Rangiroa, in French Polynesia, and at Orpheus Island, in North Queensland. We have also excerpted an excellent article on the commercial *P. maxima* hatchery run by Pearl Oyster Propagators, Pty Ltd. in Darwin Harbour. Good reading, good pearling!

Neil Antony Sims, Editor

RESEARCH NOTES AND REPORTS

The French Polynesian Multidisciplinary Pearl Oyster Research Programme (PGRN) publishes Phase 1 results

Source: *Te Reko Parau*, no. 5, October 1996, published by EVAAM (Institute for the Development of Aquaculture and Maritime Activities), French Polynesia

Phase 1

Although the 'Plan Contract' was signed in January 1990, the first PGRN research work only officially began at the end of 1992. The first phase ended with a workshop attended in February 1995 by scientists and representatives of pearl farmers' organisations, at which the results obtained were tabled for the industry. One of the specific comments made by industry representatives was that the research carried out in Phase Two should yield more practical results.

What is the PGRN?

After the large scale-mortality which decimated pearl-oyster farms on some atolls in 1985, French Polynesia decided to set up the general Research Programme on the Pearl Oyster (PGRN), a multi-disciplinary programme involving both the various scientific organisations present in the Territory and laboratories in 'metropolitan' France. The administrative, logistical, technical and financial coordination of this research programme is the responsibility of EVAAM.

The cost of these research activities, which are included in the State–Territory 1989–1993 'Plan Contract' (10th Plan), is 210 million CFP francs (CFP francs 100.00 ≈ US$ 1.00). The PGRN is funded as follows: French Polynesia: 80 million CFP francs, the French Government: 80 million CFP francs and the European Community: 50 million CFP francs (6th FED).

The objectives of the two-phase research programme are :

- To identify causes of mortality in oyster farms;
- To improve understanding of the biology of pearl oysters;
- To establish reliable data for the management of lagoons and pearl farms.

Research topics

1. Discovery of an infectious disease. Systematic screening for pathogens
   - *What can cause disease in pearl oysters?*
   - *What parasites can be found in pearl oysters?*
2. Contribution to the knowledge of a protozoan gregarine which is a parasite of the pearl oyster (project not carried out)
   - *More detailed study of a parasite observed in the pearl oyster's intestine*
3. Study of biological deterioration of pearl oyster shells (thesis completed on 10/05/96)
   - *What plants and animals live in the thickness of the shell?*
   - *How is the pearl oyster's shell formed?*
4. Identification of molecular markers in the pearl oyster *Pinctada margaritifera*
   - *Are all the pearl oysters of French Polynesia genetically similar?*
5. Anatomy of the pearl oyster *Pinctada margaritifera*
   - *How is the mother-of-pearl formed?*
   - *What organs are observed in the pearl oyster?*
6. Cytological study of gametogenesis, sex ratio and the reproductive cycle in the pearl oyster *Pinctada margaritifera* (L) var. *cumingii* (Jameson), (Molluscs, Bivalves). Comparison with the cycle of *Pinctada maculata* (Gould) (thesis completed on 22/04/93)
   - *Microscopic study and description of the sexual cells of the pearl oyster*
   - *When and how many times does a pearl oyster spawn during the year?*
   - *Do the pearl oyster and the 'pipi' (*Pinctada maculata*) spawn at the same time?*
7. Environmental physiology of the pearl oyster; a study of the relation between the growth of the oyster *Pinctada margaritifera* and the environment in Takapoto Lagoon.
   - *How and in what conditions does the pearl oyster grow?*
8. Study of the respiration and filtration processes of the pearl oyster *Pinctada margaritifera*
   - *How does the oyster breathe?*
   - *How does the oyster eat?*
9. Contribution to the understanding of population dynamics in pearl oysters and in natural stocks in various lagoon (Thesis not completed)
   - *How many oysters are there in the natural stocks in four pearl-farming lagoons?*
10. Stock of organic particulate matter (OPM): elementary and taxonomic composition
    - *What are the very small organisms which float in the water and on which the oysters feed?*
    - *What quantity of food is available?*
11. Geochemical composition of organic particulate matter in Takapoto Lagoon
    - *What is the chemical composition of particles floating in the water?*
12. Primary productions
    - *Lagoon content in terms of very small algae*
    - *Replenishment of food that shellfish, including oysters, eat*
13. Study of the production and conversion of organic particulate matter (OPM): bacteria in the pearl oyster's environment
    - *Do pearl oysters eat anything other than small algae?*
    - *What is the role played by bacteria in the renewal of the food and the waste from pearl oysters?*
14. Study of the loss of organic particulate matter to the oyster due to planktonic competitors
    - *What small animals eat the same food as the oyster?*

- *What quantity of food do they consume?*

15. Loss of organic particulate matter (OPM) to the pearl oyster and organic sedimentation. Production and consumption of ammonium in pearl oyster farms

    - *What happens to the food not consumed by the oyster: is it lost?*

16. Takapoto Atoll molluscs: quantitative evaluation of the lagoon population. Malacological survey of the reef flat. 1993 study and interpretations

    - *How many shellfish are there on Takapoto Atoll?*

    - *What are the different species of shellfish present in the Takapoto Lagoon?*

17. Study of the metabolism of the pearl oyster's main competitors.

    - *What other shellfish have the same diet as the oyster?*

    - *How do other shellfish which eat the same things as the oyster feed and breathe?*

18. Studies designed to evaluate the impact of pearl farming and produce a development strategy (quality; production; new markets) (study not carried out, postponed to Phase 2)

    - *What is the effect of pearl farming on French Polynesia as a whole?*

    - *What tactics should be used to develop this activity successfully?*

19. Study of the nutrition of the pearl oyster *Pinctada margaritifera*

    - *What exactly does this oyster eat?*

Results

The many topics addressed now make it possible:

- To more fully understand the way the pearl oyster functions in terms of reproduction, growth and general biology;

- To appraise the nutritional potential of Takapoto Lagoon and obtain information on the way the lagoon functions.

Most of this research work was carried out on Takapoto.

The new knowledge acquired may be summarised as follows:

Activity 1

Systematic screening for organisms causing diseases in farm pearl oysters and the natural stock was carried out. Only one type of parasite of the digestive tract was discovered. This was a gregarine. But this parasite is present in all the animals studied, whether healthy or diseased. This gregarine cannot therefore be considered, according to current understanding, as being responsible for the mortality observed.

At the same time, and in connection with the disease and mortality problems, research on the graft, the nucleus, the formation of the pearl sac and the nacreous layer secretion process was carried out. Healing after grafting is very quick and does not usually lead to any infection. After five weeks, the pearl sac has completely enveloped the nucleus; the pearl then begins to form.

The causes of mortality after grafting are not yet understood, but it should be borne in mind that the graft is nothing less than a surgical operation, with all the risks that this may involve.

Activity 2

More specific research on the gregarine could not be carried out, because the scientists concerned were not available.

Activity 3

This activity concerned oyster shell damage problems caused by various drilling organisms, and also the shell formation process. These boring organisms make the shells fragile by boring tunnels and cavities, which means that they often break when being opened. The mother-of-pearl is lost when this happens. Also, they may cause growth problems.

Two types of boring organisms may be distinguished: micro- boring organisms invisible to the naked eye and micro- boring organisms visible to the naked eye. These organisms are algae and fungi which attack the shells first. These then open the way for macro- boring organisms such as orange sponges, worms and a type of shellfish. Orange sponges are sometimes visible inside the shells under several layers of mother-of-pearl. Such shells are very badly damaged and cannot be polished or fashioned.

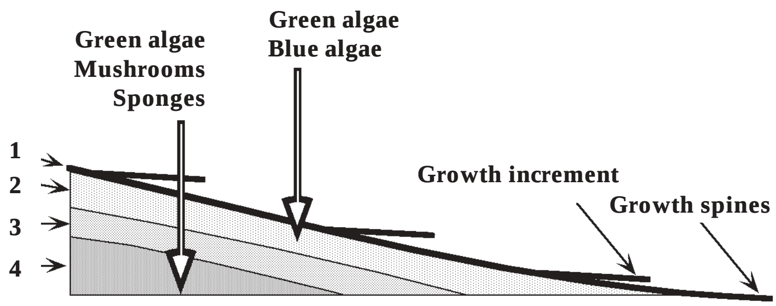
The shell is secreted by the outer surface of the mantle (facing the shell). From the outside to the inside, four layers may be observed (see figure):

1. The periostracum, which is a thin (black) organic layer, covering the mineral part, which is white;

2. A non-nacreous white calcitic layer;

3. A transition layer formed of fibrous aragonite;

4. The layer of mother-of-pearl, pigmented and non-pigmented, formed of aragonite. This layer is the nearest to the inside of the shell and also the thickest.



Electron microscope examination of the general form of the aragonite crystals (the mother-of-pearl) is thought to be an indicator of the growth status and good health of the oysters.

This study also revealed that frequently-brushed shells suffer more damage than unbrushed shells and that the boring orange sponges are more likely to appear on brushed shells. But not cleaning the oysters is also conducive to fouling, which may hinder the oysters' growth.

Brushing must not be carried out too frequently, because it favours shell perforation. Neither is it necessary to completely remove the 'kapi-kapi' during cleaning, because they protect the mother-of-pearl from being invaded by drilling sponges.

This is particularly important for re-grafts or re-re-grafts, because they represent a significant source of added value to the pearl farmer: repeated use of the oysters requires a shell-cleaning frequency to be determined that will enable the oysters to grow properly with minimum shell damage . This system of cleaning depends on the lagoon environment, in other words, the amount and speed of fouling of the oysters' shells.

Activity 4

This task involved checking whether all the pearl oysters in French Polynesia were genetically similar. This activity is unfortunately only in its preliminary stages for the moment and should be pursued in order, for example, to provide important answers to the many questions concerning oyster transfers and the dangers thereof.

The initial results, carried out on proteins from the adductor, revealed that the Takapoto and Marquesas oysters are different from those of Manihi, Takaroa and Arutua. These differences particularly concern the pigment in the mother-of-pearl and the pearl, which may be characteristic in some atolls.

Activity 5

The production of a complete anatomical diagram was essential for the animal to be fully understood. It presents all the organs of the oyster with many photographs. Thus, everyone can now give the same name to all the parts of the oyster and there will be no mis-understandings. This activity made it possible to better comprehend how the oyster functions.

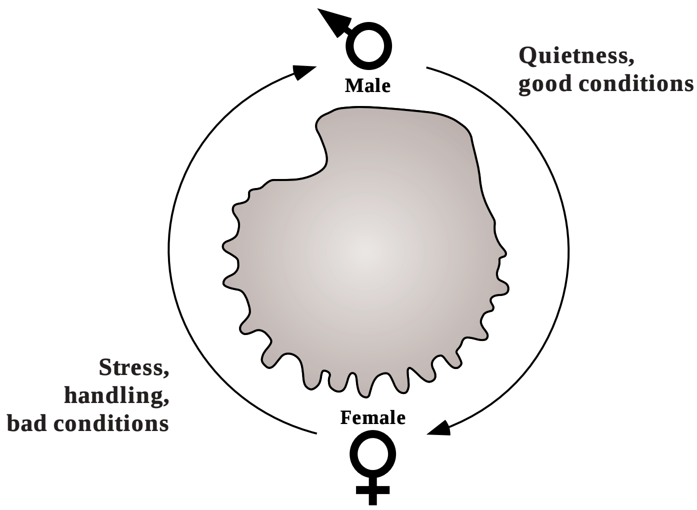
This first publication (available at EVAAM to pearl farmers for 1000 CFP) is very technical. A laminated booklet entitled 'Pearl oyster anatomy and filtration' is available free of charge, as are the previous issues of *Te Reko Parau*.

Activity 6

This project has yielded information on how and under what conditions the oyster and the 'pipi' (*Pinctada maculata*) reproduce. The oyster reproduces all year round, with peaks at the time of seasonal changes, from May to July and from September to December. In fact, it is usually abrupt temperature variations which trigger off spawning.

The oyster is first male, then experiences a hermaphrodite phase (male and female simultaneously) which is non-functional, subsequently becoming female when all the conditions are conducive to this change. This phase is reversible. Under unfavourable conditions, females may revert to a male identity and become female again later.

Most grafted pearl oysters are males, as are the majority of farmed pearl oysters. It is therefore essential to maintain a natural stock of oysters in order to be sure of collecting enough spats. The 'pipi' reproduces in the same way as the oyster and spawns abundantly in July / August (winter) and December / January / February (summer), but the 'pipi' reproduces much more rapidly than the oysters. The collecting of the 'pipi' therefore corresponds to a 'pipi' farm, where the 'pipi' spawn when conditions are unfavourable (water cleaning, declamping, submerging stations to greater depths, etc.) which makes 'pipi' collection easier.



Activity 7

A better knowledge of the growth characteristics of farmed oysters on Takapoto was gained through this study. Oysters grow regularly and do not show any marked seasonal variations. This reflects the stability of the lagoon environment. The oysters do not have any reserve organs (similar to the human liver, for example). Only the gametes (spermatozoids and eggs) contain reserves.

The gametes could be re-used by the oysters in the event of famine, an event which is known to empty the oysters, whose pearl pouch is invaded by the gonad (sexual gland).

Activity 8

This research has made it possible to understand how the oyster breathes and what it filters in order to feed. It was used as a basis for the design of a laminated leaflet called 'Anatomy and Filtration' which also appeared in the fourth issue of *Te Reko Parau*.

The size of the particles (microscopic algae) which are the oyster's preferred food varies between 5 and 60 µ, in other words 0.005 and 0.06 mm.

The oysters are more open at night than during the day; this event has not yet been explained . Perhaps they are not so frequently disturbed by fish at night and therefore open more fully.

The results concerning filtration rates suggest a very high volume, but need to be confirmed by other research work. Such data are important for gaining a better knowledge of the requirements for oyster transfer and handling.

Activity 9

This study was to yield information about the number of oysters naturally present on Takapoto (apart from those in farms and collector systems). It was unfortunately not completed.

However, more recent work, (November–December 1995), carried out by another team indicates that there are approximately 4.5 million natural oysters on the bottom of Takapoto Lagoon (51% between 30 and 40 m).

Activity 10

This project was designed to gather information about the quantity of organic particulate matter (OPM, which is in suspension in the water and makes it murky) present in the water of the lagoon and what proportion of the oysters' diet it accounts for.

The OPM of Takapoto Lagoon is very small in size. Seventy-five per cent of the particles are less than 0.003 mm in diameter, and 50 per cent are less than 0.001 mm. In other words, they are too small to be ingested by the oysters. The percentage of debris (non-living particles) is high and represents more than 70 per cent of particles smaller than 0.001 mm in size. The quantity of bacteria (smaller than 0.001 mm) is very high.

Particles in suspension comprise a mixture of living organisms (algae and microscopic animals) and debris on which very large quantities of bacteria develop. There is no seasonal variation in the quantity (but possibly in the quality) of particles in suspension in the lagoon . However, the quantity of particles in suspension in the water depends on how agitated the lagoon water has been (wind and swell). It increases by 54 per cent when the lagoon waters are disturbed.

Activity 11

The purpose of this project is to determine the composition of particles in suspension in the water and their nutritional value for oysters. Their protein content is 40 per cent higher in summer than in winter (0.025 to 0.035 mg/l).

Analysis indicates that the chlorophyll content of the sea water (which is responsible for the photosynthesis process in the phytoplankton) does not vary in time or space over the eight study sites on the atoll.

The means are very low, as in other lagoons of French Polynesia, unlike those recorded in temperate zones where they may be from 4 to 100 times higher.

Activity 12

The purpose of this study is to gain a clearer understanding of the abundance of phytoplankton (microscopic algae) in suspension and their renewal rates.

If the lagoon were to be compared with a field containing grass and cows, with the cows representing the oysters and the grass the algae, what we would be trying to do is know how much grass was available for the cows and at what speed browsed grass grows again.

The question then is what quantity of algae is available for the oysters and how fast the microscopic algae reproduce.

The maximum quantity of microscopic algae for oysters on Takapoto is located at a depth of around 20 m. But the maximum production (speed of growth) of microscopic algae is observed at depths at about 5–7 m on Takapoto. The daily raw production rate was found to be 0.9 mg of carbon per m^2 per day.

Activity 13

The purpose of this project was to define the role in the oyster's diet of the many bacteria present in the lagoon water.

The role of the bacteria would appear to be important from the mineralisation point of view: the bacteria make it possible to sustain growth and renew the microscopic algae consumed by the oysters.

The bacteria therefore also play the role of fertilizer-producing factory for the lagoon. Oysters appear to consume very few (almost no) bacteria.

Activity 14

This project's aim was to show whether the animals in suspension in the water (the zooplankton) were in competition with oysters for food. The oyster is not the only animal feeding off particles and microscopic organisms in suspension in the water.

The zooplankton represent 17 per cent of the living organisms in suspension in the water. They consume 30 per cent to 80 per cent of the microscopic algae present in the water, with the percentage varying from atoll to atoll.

The consumption of microscopic algae in suspension in the water by zooplankton is quite considerable, meaning that the zooplankton is a strong competitor with the oyster for food .

However, if it were confirmed that oysters consume particles smaller than 0.035 mm (size of the small zooplankton), the zooplankton would then itself become an abundant food source for the oysters.

Activity 15

The objective of this activity was to determine what happened to particles in suspension in the water which were not consumed by the oysters.

Seventy per cent of the particles form sediment on the lagoon floor and are thus lost to all the living organisms in suspension in the water.

This organic matter is either consumed on the bottom by other organisms or re-mineralised by the bacteria living on the lagoon floor, which will produce the minerals necessary for the growth of the microscopic algae in suspension in the water.

If the lagoon waters are stirred up, this organic matter will return to a state of suspension in the water and again become available for the oysters.

Activity 16

Better knowledge of the main shellfish of Takapoto was gained through this study. The main species concerned are the 'pipi' (*Pinctada maculata*), 'pahua' (*Tridacna maxima*), 'uu' (*Arca ventricosa*) and another shellfish (*Chama iostoma*). This work was carried out only to a depth of 7 m and was just a preliminary survey.

In 1993, in the zone between 0 and 7 m alone, it was estimated that there were 500,000 oysters (*Pinctada margaritifera*), 11 million 'pahua' (*Tridacna maxima*), 6 million *Chama iostoma*, 26 million 'uu' (*Arca ventricosa*) and 125 million 'pipi' (*Pinctada maculata*).

These data only concerned the 'pipi' living in a natural environment, not those 'farmed' with the oysters. It is estimated that there are 25 times more 'pipi' than farmed oysters. These oyster-stock figures are not very highly representative of the natural lagoon stock because most of the wild oyster population lives at greater depths (see Activity 9).

Apparently, stocks of shellfish other than 'pipi' have become impoverished since the first studies were carried out in 1976. In addition, the mollusc fauna of Takapoto is twice as rich in term of species numbers as the 1976 estimate.

Activity 17

This project made it possible to verify whether certain filtering bivalve shellfish are really in competition with oysters. Research was carried out on the respiration and filtration of these shellfish (first indicators of their diet and oxygen consumption) and their stock.

The 'uu' may well be in competition with the oyster, but the 'pipi' is its primary competitor. It behaviour, reproduction, speed of growth and diet make it a real competitor for filtration and respiration and for space. There are 25 times more 'pipi' than oysters. Research still remains to be done on diet to establish whether or not these competitors consume the same foods as the oysters.

Activity 18

The purpose of this study was to evaluate the impact of pearl farming on the social and economic fabric of French Polynesia and was intended to subsequently define a pearl culture development strategy. Unfortunately, this project could not be carried out and was postponed to the second phase of the PGRN.

Activity 19

The aim of this activity was to define exactly what oysters eat so as to be aware of their food requirements. The filtration and respiration process was illustrated in diagrammatical form, and published in the fourth issue of *Te Reko Parau*.

Oysters principally retain particles of between 0.005 and 0.06 mm. Particles under 0.002 mm in size are not retained by the gills and therefore not consumed. This is the case of the free (unagglomerated) bacteria. The oysters would appear to be more active at night than in the daytime, but these results still require confirmation.

PGRN – What about Phase 2?

Now that the first series of activities has been carried out, EVAAM has coordinated meetings with scientists and pearl-culture industry representatives in order to determine the research projects to be carried out under Phase 2 of PGRN. These activities have been carefully outlined to meet pearl farmers' expectations, to form a consistent set of projects with regard to the scientific resources committed and also to remain within the limits of available funding.

The agreement between the French Government, French Polynesia and EVAAM, defining the general framework for this second phase, was signed on 18 March 1996, but the specific agreements between donors and scientists, for practical implementation of the activities selected are still under discussion. Let us hope this sorted out quickly and that the scientists can at last begin work.

Since the beginning of 1996, implementation of Phase 2 of PGRN has slowed right down or indeed come to a complete standstill in administrative difficulties and strategic choices which are important for the future of pearl farming in French Polynesia, but which appear to be difficult to effect.

In addition to EVAAM, the organisations involved in PGRN Phase 1 are: the *Centre d'Océanologie de Marseille* (COM), the *École Pratique des Hautes Études* (EPHE), the French Institute of Research for Ocean Development (IFREMER), the French Institute of Scientific Research for Cooperative Development (ORSTOM), the French University of the Pacific (UFP), the Montpellier University Genetic Animal Geography Laboratory and the Organic Geochemistry Laboratory of the University of Orleans.

Preference for spat collector materials in tanks by larvae of *Pinctada margaritifera* (Linnaeus) at Penrhyn Atoll, Cook Islands

by Richard D. Braley and Dorothy Munro

Abstract

A variety of spat collector materials were tested on two hatchery-reared batches of *Pinctada margaritifera* larvae, including some materials used commercially to collect spat of *P. margaritifera* in the Cook Islands and French Polynesia. The plastic tank bottom collected significant numbers of larvae, particularly in Trial 1 in which collectors were deployed at 23 days post-spawning compared to 19 days post-spawning in Trial 2. Of the collector materials deployed in the tank, the black polyethylene plastic boxes were the best collectors, surpassing collectors used commercially in the field. The