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Some aspects of the abnormal mortalities of the pearl oysters, *Pinctada margaritifera* L. in the Tuamotu Archipelago, (French Polynesia)

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Abstract — *The black-lip pearl oyster* ***Pinctada margaritifera*** *L. lives and reproduces with high performance in most of Tuamotu Lagoons. Technics to collect spats, to culture juveniles and to operate oysters were quickly found and applicated.*

Nevertheless, the sudden rise of this activity has been correlated with an anarchic development. For instance, large occupation of areas in the lagoons, cultivation of numerous oysters in confined areas, lack of knowledge on the basic culture technics in many farms.

In 1985, mass mortalities have appeared in some lagoons and 50 to 80 % of cultured stock died. Some investigations have been done but no explanation was found.

In 1988, the mortalities are still very high. An analysis of cooperative production results from 1979 to 1988 shows that many factors might explain in part these mortalities, like the graft operation and the environmental conditions.

INTRODUCTION

In 1985, mass mortalities have affected pearl oyster culture farms in the Tuamotu islands. Despite various studies on the etiology of the disease (Grizel, 1985) and on environmental disturbances (Chung Sao, 1986) during the high mortality period, no satisfactory explanation has been found. Rapidly, some measures to protect healthy lagoons were adopted like transfers prohibition, whatever the age and the origins of the pearl oysters.

Other researches done in Takapoto atoll, which was one of the most attacked islands, showed that the mortality was also high on the natural stocks of pearl oysters as well as different species of molluscs during the same period (Richard, 1987; Cheffort, 1988).

The biotic capacity of the lagoon of Takapoto has been consequently suspected to be responsible for high mortalities according to the rise of cultured pearl oyster biomass in some areas of the lagoons these last years (Intes, 1988).

Nevertheless, some indications have shown a spreading of the disease to other atolls with an epidemic pattern, independent of the cultured level in these lagoons. Also, since the first apparition of the disease, there are always high mortalities, but spaced in time and mainly on grafted oysters.

Zootechnical aspects have rarely been taken into account in the former studies. The following review is a preliminary study on the results of numerous farms with a comparison of different aspects on the mortalities of grafted oysters as the importance of graft technicians, of cultivation techniques and cultured areas (islands) also.

METHODS AND MATERIAL

Data from pearl oysters cooperatives have been analyzed from 1979 to 1988. These cooperatives are dispersed in all the Tuamotu islands. They are managed by the GIE Poe Rava Nui which organizes the harvest of pearls each year and computes all the data concerning the cooperatives.

The farms plotted in this study are not the same each year as well as their number.

Only data on grafted oysters have been analyzed. The mortality of the spats or the juveniles have not been checked because of insufficient data.

The cultivation time of grafted oysters is approximately two years after the operation. For each farm, the number of oysters varies from 200 to 3000 with a mean of 1000 oysters. The grafting seasons are generally similar every year, between May and August. However, over the past three years, due to the high number of shells to be operated on, the graft period takes place in the first half-year.

At the harvest, the number of live shells is counted but no data is available during the cultivation period. To distinguish between dead oysters and missing ones was not possible; however, each time the disappearance of oysters was explained (hurricane, stealing...), it was taken into account for the analysis.

Because graft technicians sometimes operate all together in the same islands or farms, comparisons between them are only on the 1986/1988 cycle for which we have separated data.

X2 test have been done on the percentages for the different analyses to test the homogeneity of the samples.

RESULTS

General survival rates

With the increase in cooperatives, the number of grafted oysters has been multiplied by 5 in 8 years (Fig. 1). So, the graft technician team has

been reinforced and the operation season extended. Until 1985, the mean survival rate was between 60 % and 70 % but in 1986, it dropped to only 35 %. As the pearl rates (the number of pearls over the number of live shells) are rarely more than 40 % with approximately 15 % of really marketable pearls, these low survival rates of grafted oysters represent a major problem for the future of this aquaculture industry.

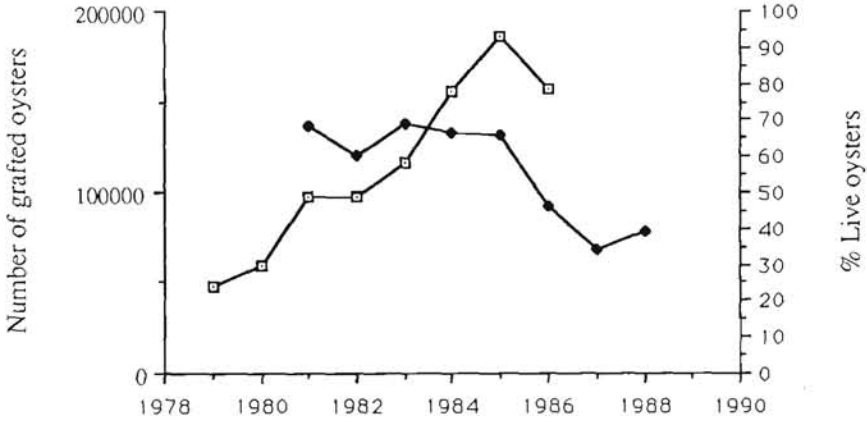

Figure 1. — Evolution of the survival rates in the cooperatives since 1981.

Variations between islands

A few islands which have had pearl oyster activities since 1979 are plotted.

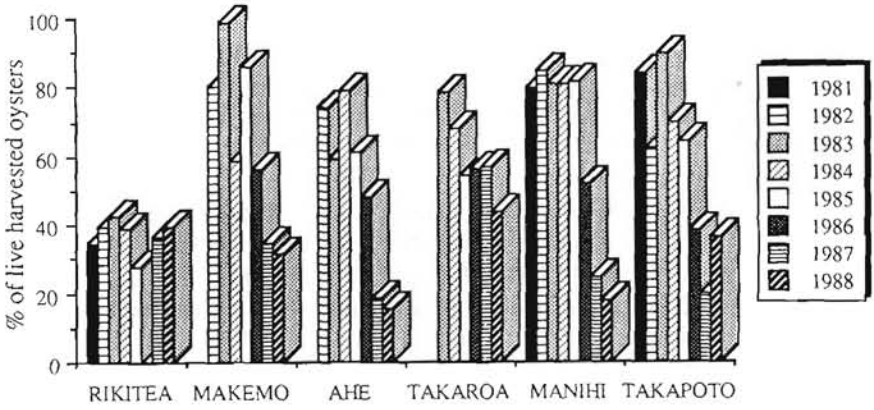

Figure 2. — Survival rates in different islands (1981/1988).

Except for Rikitea island, the other atolls show the same evolution (Fig. 2). The survival rates vary from 50 % to 90 % between 1981 and 1985. Since 1986 and mainly in 1987, in the atolls of Makemo, Ahe, Manihi and Takapoto, the survival rates became very low, often less than 40 %. Despite a similar general tendency, Takaroa seemed to suffer less mortality.

Concerning Rikitea island, the survival rates are a particular problem for this island since the beginning of the cultivation as they have never reached 45 %.

For 1988, the mortalities have greatly varied between exploited lagoons. However, except for Raraka and Katiu islands where the results were quite satisfying, all the other atolls had low survival rates, between 53.2 % in Hao to only 18 % in Manihi. (Fig. 3).

It is noted that the survival rates seem independent of the number of oysters grafted in each island.

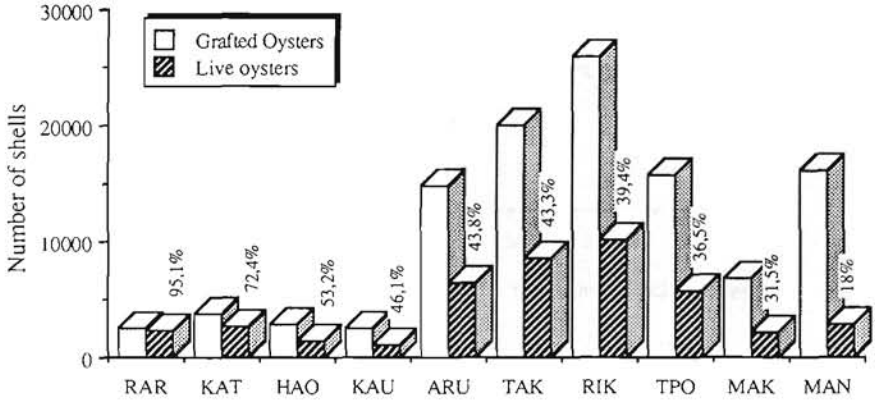

Figure 3. — Survival rates in the cooperatives from different islands in 1988.

Variations between graft technicians

Zootechnical stress during the five year culture period are numerous but among them, the graft operation seems preponderant. The harvest results of the 1986/1988 culture cycle have been plotted according to the graft technicians. (Fig. 4).

For 6 technicians, the survival rates greatly differ from 3 % to 48 %. However, 4 technicians have similar rates in a fork of about 10 %. This rate seems independent of the number of oysters operated.

As technicians often operate in a defined region, these results might represent the environmental variation as seen before, more than the influence of the graft technician.

The results of graft technicians in same islands at approximately the same period were compared. In this case also, the differences are often significant, particularly at Takapoto and Manihi where the mortalities were important (Table. 1).

The difference is still high with the comparison of technicians in the same farm. In one case, it was possible to plot the survival rates of 3 technicians. The results of the survival rates are statistically different ($P < \mathbf{0.001}$).

For one technician, it was possible to compare the survival rates in various islands, (Fig. 5). Even in that case, the variations are very important between islands and confirm that for a same technique and independently of the biomass of oysters, the mortalities may greatly differ.

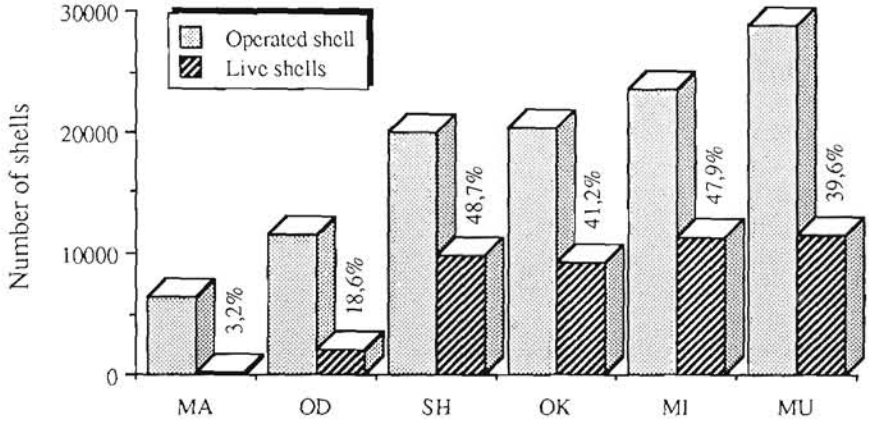

Figure 4. — Survival rates for different graft tecnicians.

Tab. 1. — Oyster survival rate results (%) for different technicians in various islands

	OD	MA	MI	SH	OK
TAKAPOTO	23,39	4,86	28,19	59,99	—
MANIHI	17,74	1,63	45,90	—	—
ARUTUA	—	—	—	43,69	44,27
TAKAROA	—	—	—	39,00	41,00

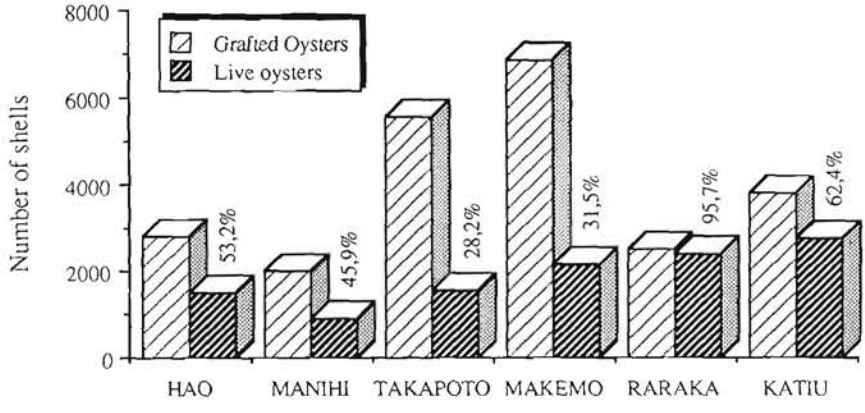

Figure 5. — Survival rates in different islands for the same technician.

The last factor used to appreciate the impact of the graft technicians and their techniques on the mortalities is the relationship between the pearl rate and the survival rate (Fig. 6). The coefficient of correlation obtained

by the Spearman nonparametric test for 6 technicians ($r = \mathbf{0.886}$; $P < \mathbf{0.02}$) shows a good correlation between these two rates, and lets us suppose that generally, the graft technique might affect the mortalities.

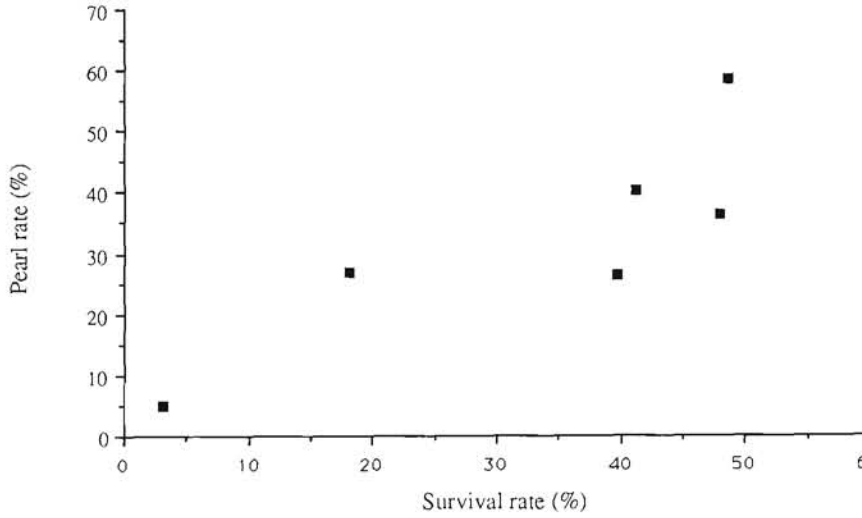

Figure 6. — Relationship between the survival rate and the pearl rate.

Variations between the farms

Although results of private farms are not well known, it is a real fact that their results (survival rates and pearl rates) are better than the cooperatives ones. The reasons which lead to this situation are numerous and will not be discussed here. Nevertheless, among the cooperatives, the results are often very variable, even with the same technician or in the same island.

Tab. 2. — Survival rates (%) in different farms

HAO	RIKITEA	TAKAROA	MAKEMO
51,00	45,2	45,1	27,25
51,00	58,3	47,25	57,55
48,45	45,7	47,45	38,2
59,00	15,4	48,25	27,9
47,9	35,45	34,4	33,65
73,00	51,9	24,85	17,5
42,6	13,9	45,00	—
61,3	—	46,9	—

Table 2 shows the comparison of survival rates in 4 islands with at least **6** farms and where the graft technicians have had average results. The farms have significant different results according to the X2 test for all the islands plotted except Takaroa. On this island with 9 farms, 7 have approximately the same average results, but with the low rates of the other

two, the test also confirms the heterogeneity of the samples. This might be the consequence of inadequate choice in the culture grounds (poor renewal of water or extra pollution). It might also be the consequence of bad cultivation techniques as some lagoons like Takaroa seem to have good hydrological conditions and a large pass. Here again, the results do not refer to the number of grafted oysters for each farm.

DISCUSSION

Concerning the pearl oysters culture, various types of diseases have been noted : (1) in Japan, Kotake et *al.* (1954) have suspected bacteria to be responsible for high mortalities in the rearing ground *of Pinctada fucata martensii* (Dunker); (2) in Australia, Dix (1972) has described tumors in *Pinctada margaritifera.* Wolf and Sprague (1977) have found an unidentified protist on the digestive gland of *Pinctada maxima* (Jameson) and Pass et *al.* (1988) have described virus-like particles in the same organ. Dybdahl and Pass (1985) and Pass et *al.* (1987) have also shown the importance of bacterial breakdown during transfers of oysters and the high mortalities which followed this stress in *Pinctada maxima*; (3) in the red sea, high mortalities have been observed on the rearing of *Pinctada margaritifera* in 1969 and 1973. Causes are still unknown but an unidentified protozoan parasite has been isolated, (Nasr,1982); (4) in India, mortalities were noted on *Pinctada fucata* after a long exposure to biofouling (Alagarswami and Chellam, 1976); (5) in French Polynesia, Grizel (1986) has shown the physiological disturbance of cultured *Pinctada margaritifera* and its relation with an abnormal lysosomal activity. He observed also mantle lesions in some samples. However, no direct relation with the mortalities has been clearly established.

There are numerous examples of failure in the culture of bivalve molluscs because of mass or long-lasting mortalities without any control or explanation (Van Banning, 1985; Sindermann, 1986).

Generally, epizootics, change in the environmental conditions, infectious pathogens or undetermined tumors and lesions are the causes of the diseases in the mollusc cultures (Balouet and Poder, 1985).

Many of the actual works on reared molluscan diseases highlight the importance of the environmental condition and the necessity to improve our knowledge about it. (Grizel, 1986; Maurer and Comps, 1986; Mori, 1986; Sindermann, 1986).

Also, prophylactic techniques or treatments are often difficult to find and employ and mean serious epidemiological studies (Grizel, 1986) or complex researches on the poorly known immune defenses of the molluscs. The most useful techniques are actually the management of cultured areas and the improvement of cultivation techniques in relation with the environment to avoid problems like overcrowding, limited biotic capacity, etc...(Heral et *al.*, 1983; Deslous-Paoli et *al.*, 1981 and 1982).

Evolution of the mortalities between 1981 and 1988

The rapid adjusting, in a few years, of simple techniques to cultivate the black lip pearl oysters in French Polynesia (see Coeroli et *al.*, 1983;

Coeroli and Mizuno, 1985; Cabral et *al.* 1985) has allowed the sudden rise of this aquaculture activity and particularly of small farms. However, it has been correlated with the growing of the oyster biomass, often in the same areas, and with a lack of knowledge on the basic techniques for the new farmers as the technical fishery service was too busy to control and advise all these new farms in this vast multiple island territory.

The high mortalities analyzed in this paper are obviously the result of a complex situation, where human factors cannot be neglected. However, the difference between the survival rates until 1984 and after is without any doubt the consequence of the growth on the cultivation of this species. Moreover, mainly because of the environmental features of its lagoons, the pearl oyster culture in the Tuamotu islands is typical and any extrapolation with diseases problems on pearl oysters in other countries, (as far as they are recognized), might be analyzed with great expectation. As we have had the opportunity to examine some data of the cooperatives, we have tried to understand the director indirect influences of various factors on the high mortalities of grafted oysters.

Distribution of the mortalities

The mortalities occur in many lagoons and cannot be correlated with disturbance of the environmental conditions, as this fact will mean synergical problems in more than ten lagoons with different hydrological and biological conditions, which is unrealistic. Nevertheless, in some overcrowding lagoons like Takapoto and Manihi, the deterioration of the environmental conditions were observed during the outbreak of the disease. Except Rikitea Island, where the mortalities were observed several years ago, there is however a similar temporal and symptomatic evolution of the disease in numerous islands which suppose a common problem for all of them.

As no infectious disease has been isolated despite sampling during the high mortality outbreaks, it seems unlikely that such a pathogen, if it really exists, was missed. If the hypothesis of an infectious disease cannot be completely excluded, particulary during the high mortality period, (1985/86), mainly because of the appearance of the mortalities in some lagoons after the transfers of oysters from attained lagoons (observations of the farmers), other causes can be advanced particularly concerning the grafted oysters.

However, as the differences on the survival rates are also important in various conditions for the same technician, the operation does not seem sufficient to explain the high mortalities in grafted oysters.

The influences of the cultivation techniques

Some of the mortalities are due to inadequate culture techniques. Numerous stressing factors, as regular washing, drilling of the shells, the graft operation and the cultivation duration (about 5 years), are important contributors to the mortalities. Moreover, overcrowding and irregular controls of shells, sometimes observed in cooperatives farms might induce unfavorable conditions and the weakness of the oysters, more susceptible to the culture stresses.

The importance of the pearl oysters origin

Since several years, most of the shells used for the operation came from the spat collection and are reared 2 to 3 years before the operation. In the lagoons where the survival rates were satisfying in 1988, the grafted oysters were issued from the natural stock (graft technician com.). It seems possible that selective pressures were less important on the collected oysters, leading to less resistant oysters during the various culture stresses. This fact will be in accordance with the regular bad results of all the graft technicians these last years, as they cannot obtain similar results as during the first year of the pearl oyster culture, when all the shells were issued from the natural stocks.

These results highlight the extreme complexity of the mortalities outbreaks over four years in the pearl farms of French Polynesia. The area diversity, the numerous biologic and hydrological characteristics, the particularity of the cultivation techniques all along the rearing time, the heavy stress of the grafting operation, the rise of the cultured biomass these last years and the overcrowding of some cultured areas are many factors that might have a great importance in the recent mortalities of grafted shells. The next step will focus on the observation of a few farms, with a particular attention on the zootechnical problems, the origin of the oysters and the chronology of these mortalities. These studies will be simultaneously done with researches on the biology of *Pinctada margaritifera* (reproduction, nutrition, genetics), the lagoon environment and particularly the change under the cultured ground and a new approach of the pathological and parasitic problems in cultured shells.

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