3.5 The French Polynesian experience

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ABSTRACT

French Polynesia is currently the world's largest producer of cultured black pearls with exports worth US$150 millions annually. The activity has become of prime socio-economic importance the archipelagos with strong support and control of the government. In the mid-1980s, mass mortality of the black-lipped pearl oyster, *Pinctada margaritifera*, has occurred in several atolls and challenged the development of pearl farming activity. Consequent studies and surveys have described several pathological conditions. None of those is considered to pose significant threat to the industry. However, they are monitored by a surveillance program in order to prevent and control emerging diseases. The government of French Polynesia has developed efforts to maintain high quality of the pearls and sustain demand of the markets. This paper reviews a successful model of development based on proactive policy and cooperation among stakeholders.

INTRODUCTION

The pearl industry in French Polynesia is based on the culture of the black-lip pearl oyster, *Pinctada margaritifera cumingii*. Annual exports of pearls have increased over the past two decades. They reached more than 8 000 kg/year in 2005 after a peak over 11 000 in 2002. Although annual turnovers have significantly decreased since 2000 (from a record value of US$252 millions to a rather stable US$150 million figure since 2005), French Polynesia is the world's largest producer of cultured black pearls (Anon., 2007). The socio-economic importance of this activity could hardly be overemphasized as it has become a major source of livelihoods. It also contributes to maintain island communities in remote and isolated locations of the archipelagos. Approximately 1 000 farms are currently under operation in 34 islands and atolls located from Gambier Islands to northern Tuamotu. The activity generates direct and indirect employment

for about 7 000 people. While pearl farming in French Polynesia meets an undeniable success, the industry has not evenly grown. In the mid-1980s, mass mortality of oysters has occurred in several atolls and challenged the development of pearl farming activity. The government of French Polynesia has introduced stringent quality control system in order to maintain high quality of the pearls and sustain market demand. Here we review this experience and lessons learnt from the past.

OUTBREAKS OF MASS MORTALITY

In 1985, the pearl oyster industry has faced series of mass mortality outbreaks in several islands of the Tuamotu Archipelago. During these outbreaks, recorded mortality rates were over 60 percent in some locations based on enumeration of tagged individuals in wild populations (Cabral, 1990). The mortality persisted up to 1986 and also affected cultivated stocks (Intés, 1994). Mortality of pearl oysters was accompanied by shell disorders, mantle lesions and necrosis of the adductor muscle (Grizel *et al.*, 1986). These signs led to the description of complex syndrome currently known as "syndrome 85" (Comps, Herbaut and Fougerouse, 2000). While no abnormal mortality was reported, these signs have been recurrently observed although at low prevalence in some islands until 1996-1997.

Despite many investigations and attempts to give the 1985 outbreaks a cause, no infectious aetiology was demonstrated. The presence of a gregarine in affected pearl oysters was reported (Chagot *et al.*, 1993). Gregarines, when present in low numbers, are usually regarded harmless to pearl oysters and the role of this parasite was not clearly assessed later (Fougerouse *et al.*, 1994; Comps *et al.*, 2001). It is accepted that a deleterious combination of biotic and a-biotic environmental factors, along with stress caused by culture handling, crowding and grafting, contributed to cause mass mortality of pearl oysters (Grizel, 1986; Cabral, 1990; Dauphin and Cuif, 1990; Cuif and Dauphin, 1996; Dauphin and Denis, 1987).

Between 1982 and 1983, six hurricanes wiped out shallow bottom beds in certain lagoons. Takapoto lagoon revealed oligotrophic conditions characterized by nitrogen and phosphorus deficits and low concentrations in bacteria and phytoplankton. Although the pearl oysters contributed to the suspended particulate matter used by micro-organisms, this appeared to have a negative balance against the rate of oyster grazing and indicated a limited carrying capacity for the lagoon (Vacelet, Arnoux and Thomassin, 1996). Such conditions may have also exacerbated recovery of the pearl oyster lagoons which were restocked, post-typhoon.

It is likely that such poor conditions associated with local high densities of oysters on culture rafts also may have exacerbated detrimental effect of pathogens. This paper reviews the pathogens reported from *P. margaritifera* in French Polynesia.

MAIN PATHOGENS RECORDED IN FRENCH POLYNESIA

There is very little known about diseases of pearl oysters in French Polynesia before any development of the industry. Initial studies focused on parasites having potential to induce pearl formation (Seurat, 1906; Dubois, 1907) and it was only during the 1985 mass mortality that light has been shed on pathogens of pearl oysters in French Polynesia.

Shell disorder, or disease, is part of the "syndrome 85" (Grizel *et al.,* 1986; Comps *et al.*, 2001). This disorder is characterised by brown organic matter deposits on the inner shell associated with inflammation in the mantle displaying yellowish coloration and swelling. Bio-mineralization disorders had previously been interpreted as consequences of mechanical trauma or chemical stress (Grizel, 1986; Dauphin and Cuif, 1990; Fougerouse *et al.*, 1994). Although the disorder has persistently been recorded by farmers in numerous areas from 1996 to 1997, the prevalence was low in comparison with the prevalence observed in 1985 (Comps *et al.*, 2001).

Microstructure and composition of the affected shells have shown malformations in the nacreous layer associated with biochemical abnormalities occurring during the biomineralisation process (Marin and Dauphin, 1991, 1992; Cuif and Dauphin, 1996). Electron-dense particles were observed in the granulomatous tissue contiguous to similar organic deposits and interpreted as possible virus-like particles (Combs *et al.*, 2001). This condition has also been compared with brown ring disease of clams, *Tapes philippinarum* and *T. decussatus*, caused by *Vibrio tapetis* (Paillard, Maes and Oubella, 1994; Borrego *et al.*, 1996) and a contagious aetiology was suggested (Cabral, 1994 cited in Cuif and Dauphin, 1996), although evidence of a pathogen has yet to be found (Cuif and Dauphin, 1996). In the course of brown ring disease of clam, infection with *V. tapetis* provokes disorganization of the periostracal lamina and a brown periostracum deposit in the inner surface of the shell (Paillard and Maes, 1990, 1995) very similar to those reported in *P. margaritifera* (Comps *et al.*, 2001). According to the authors, this might also result from physiological changes caused by the environmental, culture handling and grafting conditions considering that such organic deposits in the shell of marine bivalves are a frequent sign of reaction stimulated by wounds, parasites or debris (Aldermann and Gareth-Jones, 1971; Perkins, 1996).

Abscess-like lesions were reported in the adductor muscle of weak oysters displaying also abnormal mucus secretion. These lesions are characterised in histology by focal necrosis of the muscular tissue and haemocytic infiltration (Comps *et al.*, 2001). The study shows that prevalence of these symptoms vary; with highest prevalence being observed in Raiatea, Manihi and Takapoto lagoons. Virus-like particles – the very nature and role of which is still unknown – were reported from similar granulomatous tissues (Comps, Herbaut and Fougerouse, 1999). Similar lesions of necrosis, atrophy, swelling and vacuolization of muscle fibres were associated with virus particles in *P. fucata martensii* during a mass mortality which occurred in western regions of Japan in 1996 and 1997 (Miyazaki *et al.*, 1999). The size of the particles is apparently slightly different with virus-like particles in *P. margaritifera* of 40 nm while akoya-virus particles measure 33 nm (Comps *et al.*, 2001). A papova-type viral infection is also reported from the gold-lip pearl oyster *P. maxima* associated with nucleus hypertrophy of the epithelial cells of the labial palps (Norton, Shepherd and Prior, 1993).

Abscesses in the pearl bag are reported in the course of grafting and certain cases were possibly associated with the presence of intracellular procaryotes (Comps *et al.*, 2001). The secretory epithelium of the pearl sac may be highly damaged with accumulation of haemocytes and cellular debris surrounded by strong inflammatory reaction. Micro-organisms may be introduced in the pearl bag with mantle tissue introduction during the course of grafting and become a cause of abscess formation. In response to mechanical wound or to the accidental introduction of a foreign body during grafting, local abnormal secretion of periostracum by the epithelium of the pearl sac sometimes induces formation of whitish paraspherical bodies (Comps, Herbaut and Fougerouse, 2000).

Micro-colonies of bacteria were found in the epithelial cells of the digestive tubules (Comps, Fougerouse and Buestel, 1998; Comps *et al.*, 2001). The bacteria exhibit characteristics of members of Rickettsiales. All of these were reported during routine examinations and were not associated with significant disorder of pearl oysters, except in certain instances where fibrous layer surrounds some of these micro-colonies of bacteria.

The gregarine described by Chagot *et al.* (1993) is commonly reported from several lagoons (Gambier, Raiatea and Manihi) in the digestive tract of *P. margaritifera* with no particular impact on the host (Fougerouse *et al.*, 1994; Comps *et al.*, 2001).

Although scarcely observed, stages of a cestode, possibly related to the genus *Tylocephalum*, were recently reported from Raiatea and Gambier islands (Combs *et al.*,

2001). Such observations confirm previously reported occurrence of helminths from the same islands (Seurat, 1906).

Shell damages in the black-lip pearl of French Polynesia may be caused by various boring organisms (Mao Che *et al.,* 1996). These include cyanobacteria, green algae, the marine phycomycete fungus *Ostracoblabe implexa* and clionid sponges, *Cliona margaritifera* and *C. vastifica*. Apparently, *Ostracoblabe implexa* would be more damaging to the nacreous layers of the shell compared to clionid sponges limited to outer prismatic region of the shell (Cuif and Dauphin, 1996, Comps, Herbaut and Fougerouse, 2000). However, clionid sponges have been shown to produce perforation throughout the shell three layers and even induce haemocytic response in adjacent muscular tissue of edible oysters (Groman and Berthe, unpublished data).

HEALTH MANAGEMENT

These different studies have shown a reasonably good health condition of *P. margaritifera* in French Polynesia despite persistent manifestation of the syndrome 85. The most serious concern probably comes from described virus-like particles and intracellular prokaryotes. The mass mortality outbreaks encountered by the pearl industry in Japan strongly contributed to reinforce this concern (Miyazaki *et al.*, 1999).

Transfers of pathogens via movements of live molluscs are generally recognized as a major cause of disease outbreaks and epizootics. In French Polynesia, hatchery production is still in development and despite the economic importance of this industry, the pearl oyster culture is strongly dependent on natural spat collection. This collection occurs in atolls where natural stocks are abundant and where spat production is significant. Closed lagoons, such as Takapoto or Hikueru, were traditionally exploited for this specific purpose. Collected spat are then spread to non-collecting atolls where there is usually limited or no natural stock. The spatio-temporal variability in production of wild spat as well as lack of regulation regarding transfers of spat from collection to farming areas are underlying causes of numerous transfers between islands (Cabral, Mizuno and Tauru, 1985; Prou, Benett and Tiapari, 1999).

The exponential development of the pearl oyster industry has been accompanied by an increasing number of farms and farmed atolls. A direct consequence of this has been a rise in the frequency and volume of oyster transfers from collecting to non-collecting atolls. Animal exchanges increase mixing of oysters populations from the different atolls among Polynesian archipelagos (Society Islands, Marquesas Islands and Tuamotu–Gambier) as underlined by the significant genetic homogenization trend between populations previously distinct (Arnaud-Haond, 2003). The oyster transfers also generate anemone dissemination and this is becoming an important ecological problem in some islands with economic consequences as a result of the increased frequency needed for cleaning livestock and rearing structures (LeMoullac *et al.*, 2003). The great demand for spat also had, as a consequence, high densities of reared pearl oysters in the collecting atolls, such as, for example, Takaroa.

In order to prevent and control spreading of any emerging disease in the French Polynesian pearl farming sector, surveys were undertaken and a basic surveillance programme was proposed for implementation (Combs *et al.*, 2001; Thébault, 1999). This program was initiated in 2003 as a network based on five islands of the French Polynesian archipelagos. The programme is based on monitoring of pearl oyster farms and producing areas by routine collection of samples and investigation of abnormal mortality outbreaks. The strong collaboration between actors of the scientific community and delegates of pearl oyster administration in atolls (through meetings, coordination, training courses) enabled increased awareness of farmers for the benefit of the industry.

CONCLUSION

The pearl farming in French Polynesia has been extremely successful. Involvement of the government and cooperation of research and private sectors are two key components of this model. French Polynesia has developed a strong proactive policy in support of the pearl industry with efforts to develop and implement a national strategy for pearl oyster health management. This policy is still under review with new management measures being considered. Among those, quotas of pearl farms are discussed to reduce the risk of diseases of pearl oysters and avoid problems of poor quality of the pearls.

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