AQUACULTURE AND STOCK ENHANCEMENT OF REEF MOLLUSCS

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ABSTRACT

Molluscan resources contribute significantly to the local dietary and monetary needs in the coral reef areas. In recent years, interests in aquaculture and stock enhancement of some reef molluscs, such as giant clams, *Trochus* and green snail have developed in many nations in the Pacific and Southeast Asia, reflecting severe and widespread decline in stocks of those molluscs by over-exploitation. There are many locally consumed edible molluscs that require basic biological and ecological studies before developing their aquaculture and stock enhancement in the coral reef habitats.

INTRODUCTION

Coral reefs harbor diverse and numerous species of molluscs. Many of them are utilized for ornamental, commercial, and industrial purposes as well as for food. They are particularly beneficial to the people in the tropics because the shells of certain species provide non-perishable commodities for export and also for the local tourist trade.

Despite the fact that there are vast numbers of shell collectors worldwide, only very few actually collect scientific data on the animals in the tropics. Thus, there is a lack of information on the great majority of species with regard to their life histories and ecology. However, pearl oysters, giant clams and some economically important gastropods have been studied intensively during the past few decades.

In this account, I exclude discussions on oysters and mussels because there is extensive literature elsewhere on these molluscs and because they are not normally important targets on coral reefs.

1. Molluscan resources from coral reefs

1-1. Cephalopods

The systematics of tropical cephalopods is not well established, except for *Nautilus* which is represented by six species (Saunders 1987). This group of so-called "living fossil" animals are not truly associated with coral reefs. but their geographical distribution is within the Indo-West Pacific (House 1987) and in certain areas people fish the animals by baited traps submerged in deep waters just beyond coral reefs. People of the Solomon Islands utilize the beach-washed shells of *Nautilus* as the material for their beautiful shell-inlayed wood carvings. There are many attractive shellcrafts of *Nautilus* shells at many souvenir shops in the Pacific and elsewhere. There is no study on the cultivation of this genus but certain public aquariums in New Caledonia and Japan have kept live animals for display and biological study.

Squid, cuttlefish and octopus are all extensively used as food in the tropics. Potential of cultivating the broadclub cuttlefish (*Sepia latimanus*) was investigated by fishery biologists in Okinawa (Inoha 1991). Females of this species lay eggs among branches of certain reef corals (such as branching *Millepora* spp.) at specific sites, called "nests" by fishermen. Therefore, it is rather simple to collect eggs from the field for tank rearing. Because this animal is a carnivore and takes live animals, such as shrimps and small fish, it is difficult to provide it with dependable food at low cost. However, the stock of this cuttlefish has been depleted by overfishing. Therefore, methods in its stock enhancement are being investigated by the Yaeyama Hatchery of Japan Sea-Farming Association.

1-2. Gastropods

The cultivation of money cowries (*Cypraea moneta*), that was practiced in the Maldives, was perhaps the oldest in the history of tropical mariculture. According to some historical accounts, cowries that had settled and grew on submerged fronds of coconut palms were harvested since ancient times, *i.e.*, the 10th century or earlier, in the atolls of the Indian Ocean. However, technical details of this culture operation were not described (Yamaguchi 1991). It is likely that the fronds worked as collectors for the pelagic larvae of cowries which settled from plankton.

Shell collecting for ornamental and commercial species is a wide-spread activity in many tropical nations but it is often overlooked as a part of the fishery. It is frequently pointed out that reef gleaning for ornamental shells, mostly gastropods of attractive colourations and shapes, would constitute a conservation issue (Wood & Wells 1988; Newton *et al.* 1992). Wells (1989) suggested a series of management options for rational and sustainable use of these resources and discussed the role of mariculture in mitigating some of the problems of overexploitation. However, there is little information about basic biology in the majority of ornamental species, so that it is difficult to consider whether or not their mariculture is practical.

From the view point of mariculture, the queen conch *Strombus gigas* is by far the most extensively studied gastropod in the tropical Atlantic (Berg & Olsen 1989). Mariculture and stock enhancement have been the topic of a series of regional symposia and workshops starting in 1981 (Berg 1981; Siddal 1983, 1984). Mass seed-production of the queen conch has been established and some field-release experiments using the hatchery-grown juveniles were conducted. Nevertheless, the outlook of successful stock enhancement is still obscure because of high initial mortality and other problems (Davis *et al.* 1987; Stoner & Waite 1991).

The situation is essentially the same for the tropical Indo-Pacific gastropods such as trochus *Trochus niloticus* and green snail *Turbo marmoratus*. Although hatchery production of juveniles is more simple for these archaeogastropods that produce lecithotrophic (non-feeding) larvae (Murakoshi *et al.* 1993), high mortality rates of field-released juveniles and other problems require more study and careful appraisal for their stock enhancement (Kubo 1991; Yamaguchi 1993).

In recent years, the muricid gastropod *Chicoreus ramosus* became a target species for aquaculture research in India and Thailand (Tropical Marine Mollusc Programme, a DANIDA sponsored programme). Larval cultivation of this species to juveniles was successful at a laboratory scale (Nugranad 1992).

1-3. Bivalves

Large scale spat production of giant clams have been established at several hatcheries in the western Pacific. In Palau, the Micronesian Mariculture Demonstration Center developed a "low-tech" production system for *Tridacna derasa* in the early 1980's (Heslinga *et al.* 1984). The largest species of the giant clams, *T. gigas*, was subjected to a more "high-tech" approach by the ACIAR (Australian Centre for International Agricultural Research) project initiated in 1984 (Copland and Lucas 1988). ICLARM (International Center for Living Aquatic Resources Management) also launched a giant clam farming project in the Solomon Islands in 1987 (Munro 1989). These projects have emphasized regional and international cooperation involving many nations in Southeast Asia and the Pacific.

The smallest giant clam *Tridacna crocea* is important in Okinawa because its flesh is considered a delicacy for "sushi" in the local cuisine. After a serious wide-spread decline of this clam by overharvesting, the government hatchery began to develop aquaculture technology for this species in the early 1980's (Murakoshi 1991). In the late 1980's, mass seed production of *T. crocea* was established and field planting of the hatchery-grown juveniles were undertaken by many fisheries cooperatives in Okinawa.

Pearl oysters *Pinctada* spp. and *Pteria penguin* are cultivated for pearl production in many tropical areas. Mass spat production of these oysters and their culture systems are developed commercially by private firms, so that most details in their technologies are not disclosed.

In French Polynesia and Cook Islands, there are atolls where natural spat of the black-lip pearl oyster *Pinctada margaritifera* are obtained by collectors submerged in their lagoons. In the Ryukyu Islands, where natural populations had been decimated, large numbers of shells had to be secured each year, by artificial cultivation, for production of black pearls at a commercial scale (Kakazu 1991).

There are many species of bivalves that may be considered as potential targets for aquaculture or stock enhancement in the coral reefs. However, very little is known about the biology of the majority of such species and we need basic study first. Recently, species of *Anadara* have become subject of intensive study in New Caledonia (Baron 1992) and at Tarawa in Kiribati (Tebano 1990). A smaller species of the same genus, *Anadara granosa*, that is found on mud-flats around the mangroves, has received a good deal of study in Malaysia and Thailand (Broom 1985).

2. Stock enhancement

2-1. Seed production

It is evident that fully ripe and healthy broodstocks are essential for successful seed production of any species. In the advanced cases, broodstocks are maintained in artificially controlled environments so that they can be induced to spawn according to work schedules. In the majority of cases, however, we need information about breeding cycles of the species in question in order to obtain ripe gametes. Wild broodstocks are often unreliable because of variable individual gonad conditions in tropical species.

Methods of spawning induction vary among mollusc species. There are several reliable methods applicable to specific groups of species. For the larger archaeogastropods, which spawn and release gametes freely in the water column, the methods developed for abalones in the temperate waters can be applied without significant modifications (*e.g.*, Uki & Kikuchi 1984). There, the broodstocks are exposed to ultraviolet-treated sea water after a brief aerial exposure.

Ripe trochus and green snail will spawn readily in clean, running sea water after being kept in still sea water under very crowded conditions with vigorous aeration for a day or so, until the sea water is fouled with excretions and mucus of the animals (Yamaguchi 1993).

Trochus in captivity tend to spawn spontaneously at monthly cycles (Heslinga & Hillmann 1981). If such cycles represent innate cyclic activities, the timing of artificial spawning may be planned to coincide with the peak of the cycle. This point should be verified by further research for not only trochus but also other species suspected to have lunar spawning cycles.

In order to avoid polyspermy, artificial insemination should be conducted by gametes taken from males and females that were kept in separate chambers. In the case of the green snail, live animals can be sexed by examination of external sex characteristics. However, it is hard to sex the majority of species visually. The broodstocks may be carefully isolated as soon as their spawning activities start, usually males first. Alternatively, broodstocks may be kept in running sea water with a trap which collects spawned and fertilized eggs. Collected eggs should be kept very clean by repetitive washing to exclude contaminants and debris to avoid bacterial growth and ciliate infestation in the culture chambers.

Ripe giant clams are easily induced to spawn by stimulation from excised gonads. In case of larger clam species, however, sacrifice of a part of the broodstock for this is costly. Thus, the serotonin injection to clams that are known to be ripe by biopsy, can be used (Braley 1985).

After brief aerial exposure, while being kept at elevated temperature in darkness, the noble scallop (Chlamys *nobilis*) was induced to spawn in the light (Kobayashi et al. 1991). The black-lip pearl oyster (*Pinctada margaritifera*) can be induced to spawn by repeatedly elevating sea water temperature by 5 °C for 30 min. (Kakazu 1991).

Seedstocks of the above molluscs are produced by standard hatchery procedures, with various phytoplankton as food in case of filter-feeding larvae. Coutteau and Sorgeloos (1992) discussed algal substitutes for live algae used in mollusc hatcheries. It would be beneficial for hatcheries located in the tropics to get dependable algal substitutes because the cultivation of live phytoplankton usually requires intensive care with facilities and manpower that are hard afford, or they are unavailable in most developing nations.

2-2. Field release and monitoring

Juvenile molluscs would suffer heavy mortality after being released in the field without protection. Even within protective cages which may exclude larger predators, juvenile giant clams are attacked by small gastropods that settle from the plankton onto the prey (Perron *et al.* 1984).

It is costly to rear juveniles in tanks until they can attain size-refuge. Tank-reared juveniles are often non-adaptive: they rarely develop any evasive behaviour to thwart predation. Thus, the usefulness of releasing juveniles, that are cultivated in hatcheries, is often questioned (*e.g.*, Tegner 1989).

In the tropics, stock enhancement of reef molluscs has been tried only in recent years and for only a limited number of species. For example, juveniles of *Tridacna derasa* were planted at many places under communal care by local villages in Yap (Price & Fagolimul 1988). They survived rather well and grew to an average size of up to 20 cm at 30-42 months old. Whether or not these clams grew to adult size and reproduced has not been reported.

Seed planting of *T. crocea* was conducted at many locations in Okinawa but results of these activities have not been reported.

Reef reseeding of trochus and green snail using hatchery-grown juveniles is still at the experimental stage (Kubo 1991; Nakamura 1992). Because these herbivorous gastropods require very large quantities of algae for food as they grow larger, their tank cultivation to large juvenile stage depends on abundant food supply.

2-3. Environmental manipulation

In order to improve production of target mollusc populations, predator control, nursery habitat construction and other modifications by artificial means may be employed. For example, artificial nursery reefs may be designed specifically for some species, just like they are tried for temperate species such as abalones by constructing boulder beds. This approach may be costly in initial investment for construction and would require extensive research for development in the tropics.

Pelagic larvae may be trapped to settle on artificial and natural substrata located around small-scale gyres formed by fences or any effective artificial structures.

2-4. Transplantation

Some of the commercially important molluscs are distributed only along the continental land mass or on nearby continental islands. Transplantation of such species as trochus and green snail to oceanic islands have been conducted extensively in the western Pacific (Yamaguchi 1987; Yen 1991).

It is often noted that juvenile bivalves are found in dense aggregations at nursery habitats. Harvesting and transplanting such juvenile populations may be executed to enhance yield after the grow-out period. Natural spat may also be collected on artificial collectors and transplanted likewise.

2-5. Cultivation

The main problem in cultivation of reef molluscs is predation during the field grow-out phase in the sea. Hanging culture techniques, with protection by cages, provide high survival rates in cultured filter-feeding molluscs such as pearl oysters, although these procedures require man-power for maintenance and cost for supplies and equipment.

Parasites and disease may also contribute to high mortalities in cultured animals (Elston 1990) but there is very little information about those affecting molluscs, particularly in the tropics. Alder and Braley (1988) reported a mass mortality of *Tridacna gigas* in the Great Barrier Reef in the 1980's, and associated pathogens were suspected as the cause of death.

The cultivation for edible oysters did not succeed in French Polynesia as they became heavily infested with parasitic polychaete worms (Grand 1988).

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