Coral Culture and Transplantation and Restocking of Giant Clams in the Philippines

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Introduction

Philippine reefs are among the richest and most diverse in the world with more than 400 species of scleractinian corals identified (Veron 1995). In the 1970s, Philippine reefs started to be degraded and continued to decline mostly as a result of increasing demands placed on them by humans, and their misuse. Only about 5% of Philippine reefs have excellent cover (Gomez et al 1994, Wilkinson 2004).

The alarming degradation of coral reefs in many parts of the world has resulted in growing attention to coral reef rehabilitation using transplanted corals and other invertebrates (Edwards and Clark 1998, Rinkevich 2005). The idea of planting corals and restoring reefs goes back at least 30 years. Initial activities in the Philippines were accomplished through the collaborative efforts between the then UP Marine Sciences Center and Silliman University (Alcala et al 1982). It was also around this time that other countries, like the United States of America in Hawaii (Maragos 1974) and Australia in the Great Barrier Reef (Harriot and Fisk 1988) started their rehabilitation efforts. So the Philippines is among the countries that pioneered in reef rehabilitation work.

Another local coral transplantation effort was the Coral Farm Project (CFP) in Caw-oy, Cebu (1997 to 2000). It was initiated and supervised by the Marine Biology Section of the University of San Carlos in Cebu City and funded by the Commission on Higher Education – Center of Development Fund and the German Ministry of Environment facilitated by the Tropical Ecology Program of the German Technical Cooperation (Heeger and Sotto 2000). The objectives of the coral farm were to serve as a nursery for coral fragments, maintain biodiversity, and generate income for fisherfolk by marketing the farm-grown coral fragments for rehabilitation and ecotourism. The Caw-oy coral farm was two hectares in size with about 275 coral nursery units built by members of the Caw-oy Fisherfolk's Organization, containing about 22,000 coral fragments. Unfortunately, legal and sociological constraints put an end to this effort.

Recently, the Pew Project (2001 to 2005) of the senior author entitled "Coral reef habitat and productivity enhancement through coral transplantation and giant clam restocking" was implemented with the aim to improve the biodiversity and productivity of stressed coral reef habitats in 10 selected demonstration sites in the Philippines. These were meant to serve as models for other communities. Transplantation of corals and reseeding of giant clams were the approaches. Nubbins or small fragments from nearby large coral colonies and abundant solitary forms were transplanted to the target sites. Care was exercised to avoid or reduce any negative impacts on the natural source communities. Only cultured giant clams were used, specifically the threatened *Tridacna gigas* at sizes that would ensure their chances of survival in the wild (approximately 20-30 cm shell length). Following deployment, monitoring activities were undertaken, focusing on macro-invertebrates and fish, as well as the assessment of the survival and growth of experimental animals. Liaison work was

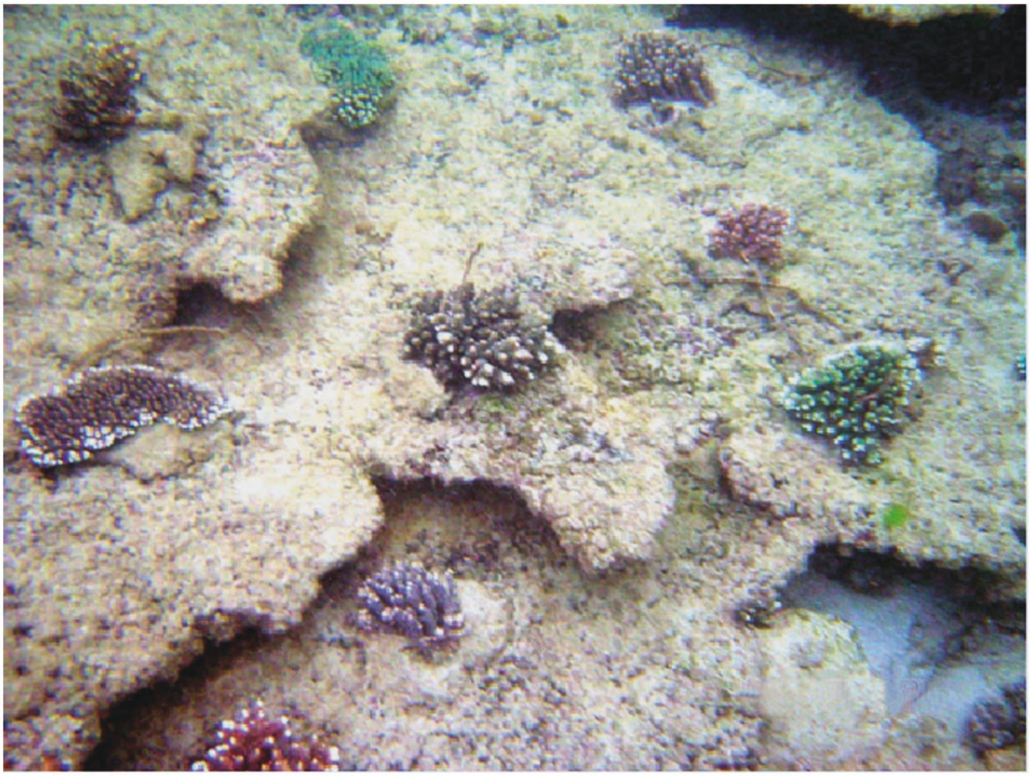

Fig. 1. *Acropora* spp. transplants cemented on dead table *Acropora* at Masinloc, Zambales (Dec. 2002 transplants).

done with local communities to raise their environmental awareness and to ensure their cooperation. This manuscript draws principally from results of the Pew Project.

At present, two other restoration projects supported by the European Union and the Global Environment Facility Coral Reef Targeted Research Project are being implemented at the Bolinao Marine Laboratory of the University of the Philippines–Marine Science Institute (UP-MSI) in Pangasinan. These projects are testing the efficiency of floating and standing coral nurseries in growing coral nubbins in addition to transplanting fragments or branches of corals to restore degraded coral reefs.

Approaches to Transplanting Corals

Direct transplantation on natural substrates

Cementing on dead reefal substrate

Cementing was the major method used in the Pew Project. This technique allows immediate firm attachment of corals on the natural substrate (Fig. 1). In collecting corals, natural broken fragments were picked up first before nubbins or small fragments were taken from locally occurring abundant, large coral colonies. Care was exercised to avoid or reduce any negative impacts on the natural communities by limiting harvest to only about 10% of the donor colony.

Months after the fragmentation, the source colonies were showing signs of recovery with new polyps forming and broken parts growing back (Fig. 2). To further check for collateral damage, the reproductive status of source colonies should also be monitored (Epstein et al 2001).

For cement preparation, a 1:3 ratio of cement to sand is usually mixed on shore. Then the final mixing with fresh water is conveniently done on the boat while on site. After adding enough fresh water to make a thick cement paste, the mixture is then placed inside plastic bags. Each plastic bag should be tightly tied, leaving no air inside and minimizing the entrance of seawater that may alter the semisolid property of the mixed cement during the actual transplantation underwater. Prior to application to the substrate, a small hole is torn off one corner of the bag just large enough to squeeze out the cement (like toothpaste). Depressions on bare, hard substrates with no living organisms is selected.

When a mound of cement is in place, the coral branch or fragment can then be embedded in the cement mound, and the cement molded gently around the coral base to form a good bond. The actual size of the cement mound depends on the size of the coral fragment with larger fragments requiring bigger mounds for firmer attachment, especially when using branching fragments.

In transplanting corals, fragments should be positioned upright towards the sunlight, so

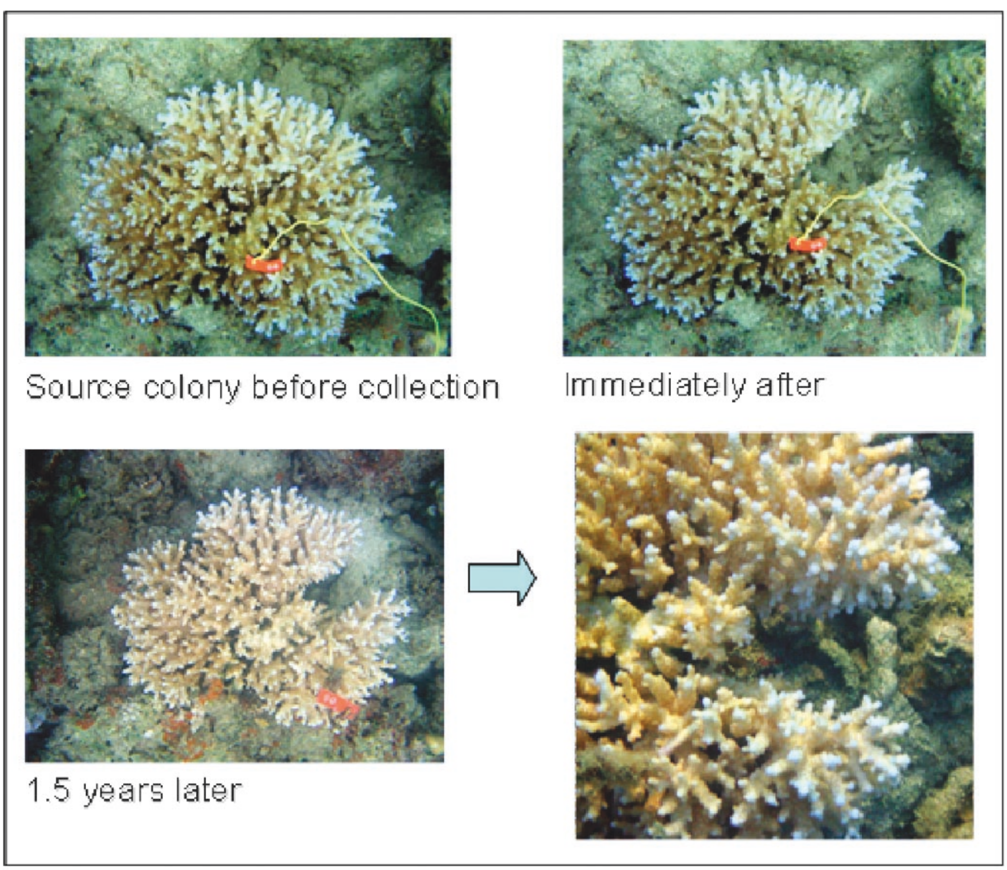

Fig. 2. Source coral colony at Alabat, Quezon showing recovery after fragmentation.

that they will grow naturally. It may be useful to brace the coral base by embedding some rocks or small pieces of rubble around the base. The cement base of the planted coral will become stable in about one hour after being placed underwater and will fully harden within 1-2 days.

The highest survival of coral transplants of about 84% was achieved in the site of Alcoy, Cebu, while the Camotes Is., Cebu site 1 obtained the lowest survival of 8% (Fig. 3). Mortality of coral fragments could be attributed to various causes such as predation by the crown-of-thorns starfish *Acanthaster planci*, burying of corals by sand, and dislodgment of transplants after a typhoon.

Tying to dead standing corals

Coral transplants may be tied directly to dead standing corals with the use of insulated copper wire (solid, #22). Dead corals should be large enough to support the coral fragment. This method reduces the disturbance brought about by sedimentation.

Relocation of solitary corals and of sub-colonies of staghorn thickets

Some reefs have areas where large monospecific thickets of corals are growing and clusters of solitary corals (fungiids) are found. Relocation of some of these corals on degraded reefs will minimize the spatial competition in the source areas. Thick branches of staghorn corals may be transplanted on sand where they are sometimes found naturally. On the other hand, the mushroom corals should preferably be relocated on hard substrates.

Use of giant clams

Using large tridacnid clams in the reef rehabilitation activities is a novel approach. This idea was derived from the observation that some of the giant clams restocked in the Hundred Islands National Park in Pangasinan province had been colonized by corals. The clams also offer a natural substrate for other invertebrates, in addition to corals and marine plants which subsequently attract grazers. Clams provide relief and structure, where fish and other invertebrates can take refuge and plants can grow. The most important reason for the use of clams in reef rehabilitation is to reestablish their breeding populations in strategic sites and eventually allow natural recruitment of juveniles to the reefs.

Transplantation on artificial substrates

Tying to terracotta tiles and marble chips

If suitable natural surfaces are limited, coral transplantation may be done on artificial substrates. One approach used in the project “Rehabilitation of the Hundred Islands National Park” was tying of coral fragments to marble chip rejects with the use of insulated copper wire. The marble chips were then fastened onto the natural substrate with concrete nails for permanent attachment. In the Coral Farm Project, corals were tied to terracotta tiles for restocking purposes (Heeger and Sotto 2000). Mortality among corals fastened to tiles often resulted from detachment or overturning.

Attachment to introduced boulders

Coral fragments may be transplanted to introduced boulders in areas such as extensive sand patches where hard substrate is limited. This approach was employed in Infanta, Quezon where some patch reefs are buried by sand from river run-off. Deployed boulders can stabilize the substrate and can also provide substrate for other fauna (Fox et al 2005). In Infanta, coral transplants were arranged around each boulder using nylon nets to hold them in

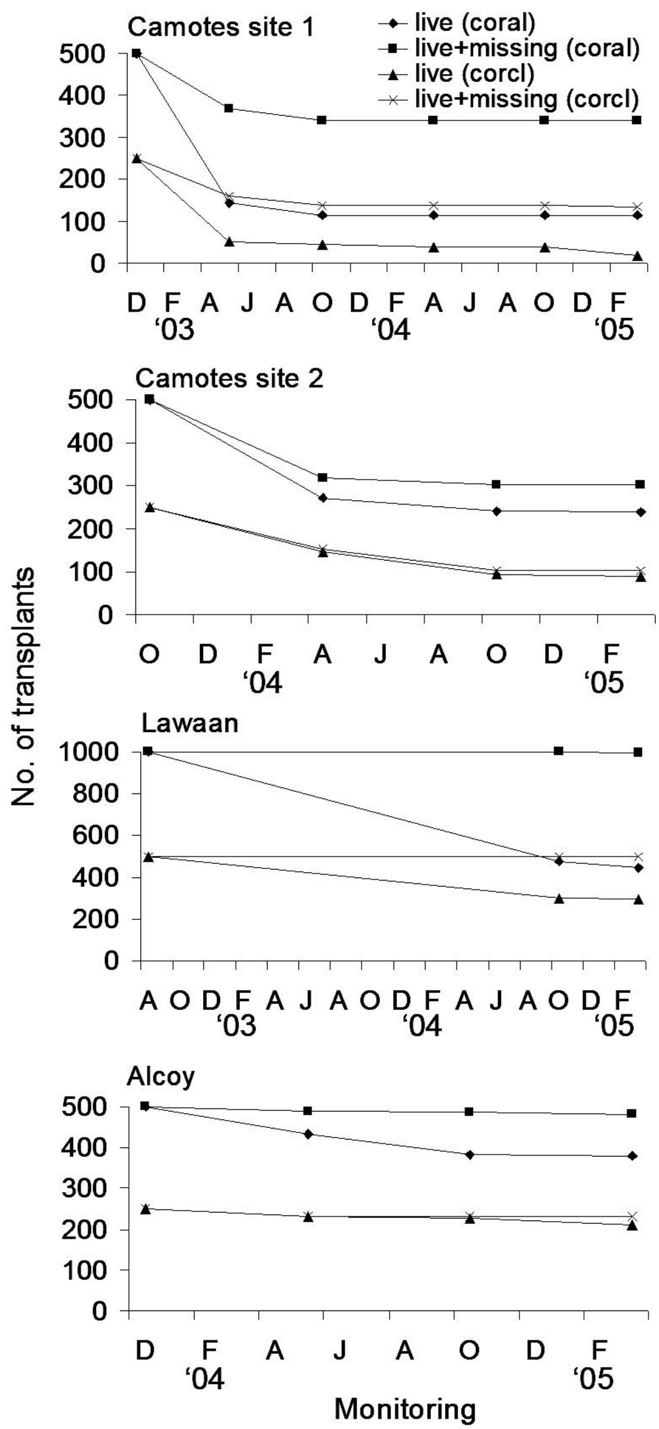

Fig. 3. Representative sites of the Pew Project showing highest (Alcoy: 84%) and lowest (Camotes 1: 8%) survival of coral transplants obtained. (Legend: coral = plots with coral transplants only; corcl = plots with corals and clams).

place until they could attach to the boulders. Alternate means of attachment such as underwater epoxy might also be tried. The use of boulders can add relief and structure to the reef where marine organisms can attach or take shelter.

Meshed grids for substrate stabilization

Another technique in substrate stabilization is the use of meshed grids. Stabilizing the substrate is a prerequisite to actual coral recruitment because unstable substrates can decrease the survival of both transplants and natural recruits. One collaborator in the Pew Project (L. Raymundo) used meshed plastic grids with cemented rock piles to stabilize rubble substrates. Preliminary results showed that the mesh remained fixed during stormy weather, though rock piles required additional cementing. Coral transplants showed 91% survival after one month. After 3 mo, obvious growth, natural attachment to the base and fusion between adjacent corals were observed. Coral recruits (1-2 cm diameter) also appeared on rock piles 4 mo after placement.

Coral farming

The inherent pressure on the source colonies during collection and the need for mass production of coral fragments for restoration create a need for coral farming. The first significant coral farming effort in the Philippines was the Coral Farm Project in Caw-oy, Cebu as earlier mentioned. Fragments were carefully chosen and cut from the donor colonies using pliers (for branching types) or hammer and chisel (for encrusting and massive types). The donor site was near the farm allowing the close monitoring of the health and impact on donor colonies after fragment collection and minimizing stress on the coral fragments caused by long transport. The collected fragments were tied firmly to terracotta tiles with galvanized iron wire, then transported to coral nursery units where they were left to regenerate and attach to the substrate. After three to four weeks, fragments were observed to have securely attached to the substrate. Monitoring and cleaning of sediment and algae from the coral nursery units were done regularly to obtain a higher survival rate of the transplants.

Another coral faming initiative at present is in Silaki Island, Bolinao, Pangasinan. Coral nubbins with a maximum size of 2 cm diameter or height were used. Nubbins were attached onto plastic meshed nets or plastic tubing, depending on the lifeforms, using cyanoacrylate adhesive. The method employed is similar to that described by Shafir et al (2006). The plastic meshed nets and plastic tubing with corals are then secured to the floating or standing coral nursery platforms. These field-reared coral nubbins will be used to rehabilitate damaged reefs in the future. The nursery method also has great potential for the culture of corals for the aquarium trade. In addition to the use of nubbins, future nurseries may also use coral planulae produced by spawning induction or collected from the wild (Heyward et al 2002).

Restocking of Giant Clams

Giant clams (Family Tridacnidae) are essential components of the coral reef ecosystem and contribute to reef production. They are primary producers because of the presence of their algal symbionts, supporting various marine organisms by serving as nursery grounds of numerous invertebrates and fishes when present in large numbers. Their calcified shells are good substrata for sedentary organisms thus contributing to reef diversity. Tridacnids are exploited for their meat and shells to various degrees in the Indo-Pacific region, their distribution range. In the Philippines, giant clam meat is utilized as food and is

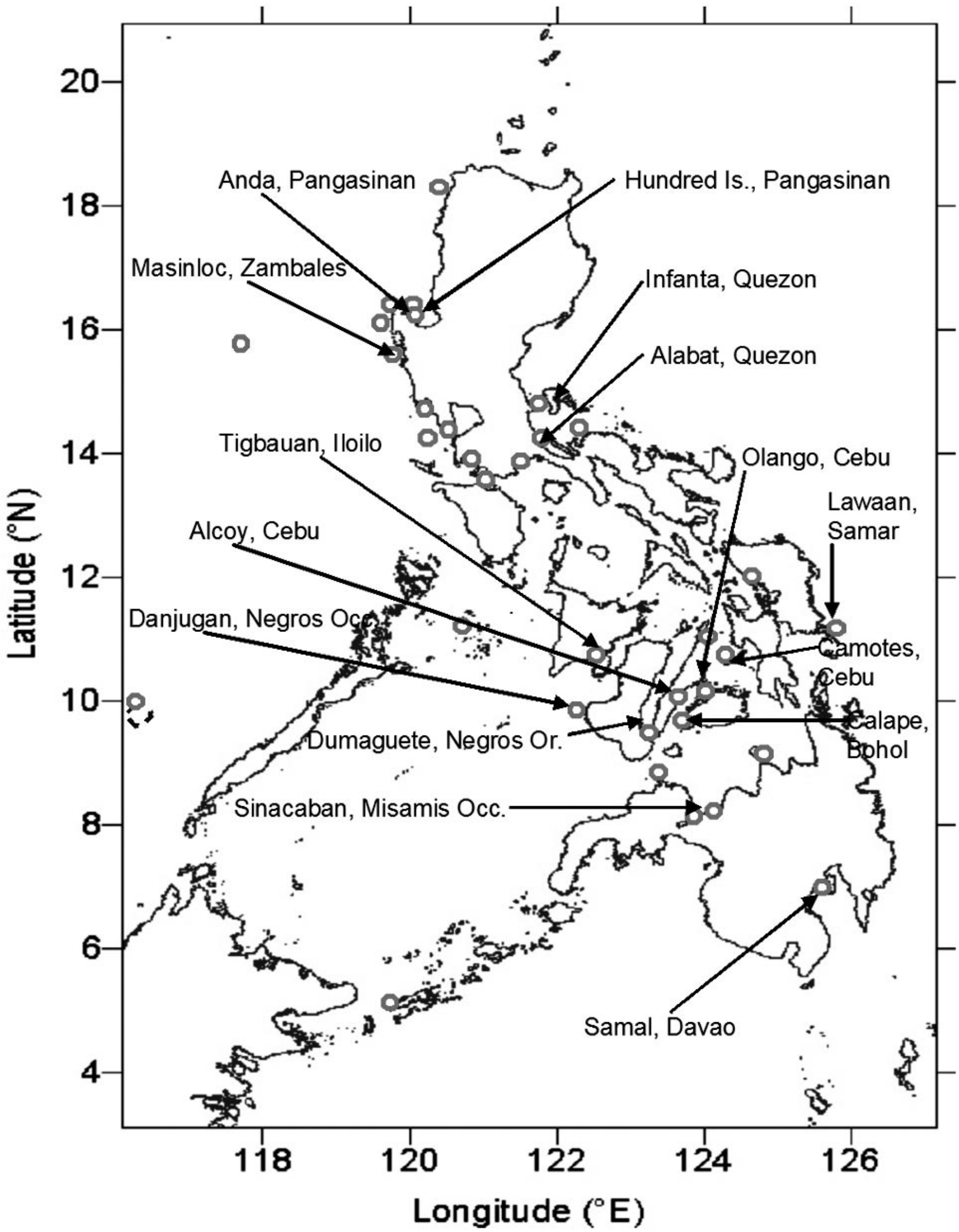

Fig. 4. Location map of the Pew Project demonstration sites for coral transplants, the Hundred Islands National Park, and sites of giant clam culture.

being sold in local markets. Overexploitation has resulted in the scarcity of most of the indigenous species.

The remaining giant clam populations are threatened by commercial exploitation, poaching, illegal fishing practices that degrade their habitats, bleaching, disease, and pollution (Mingoa-Licuanan and Gomez 2002). Due to intense use of giant clams, harvesting natural clam stocks is no longer sustainable. As a result, there is a need to culture these bivalves to supply clam seeds for restocking purposes and to provide alternative source of clams for the demands of commercial trade. It is important that the remaining wild stocks should be allowed to recover, either naturally or by restocking of cultured seed stocks.

Conservation efforts to restore giant clam populations are being practiced in the Philippines by the UP-MSI. In the 1980s, the WorldFish Center (then ICLARM, the International Center for Living Aquatic Resources Management) and the Australian Centre for International Agricultural Research (ACIAR) organized a regional collaborative research program whose key objectives were to establish tridacnid broodstocks and develop mariculture technology. The ensuing six-year program involved Australia, several South Pacific island nations, and the Philippines with the UP–MSI as one of two participating academic institutions in the country. A publication from this program (Copland and Lucas 1988) provides an overview of giant clam biology and culture.

Obtaining broodstock was not easy because the three largest species, *Tridacna gigas*, *T. derasa* and *Hippopus porcellanus*, were uncommon. The small burrowing species, *T. maxima* and *T. crocea* were still abundant while *T. squamosa* and *H. hippopus*, could be found in good numbers only in certain localities (Juinio et al 1989).

Between 1989 and 1994, the UP–MSI was able to collect adequate numbers of *H. hippopus*, *T. squamosa*, *T. maxima* and *T. crocea* for experiments on spawning. Of the rare species, three cohorts of *T. derasa* seed were imported from Palau between 1984 and 1985; and seven cohorts of cultured *T. gigas* were imported from the Solomon Islands (as pediveligers) and from Australia (as juveniles) and between 1987 and 1995.

The UP–MSI has been able to culture the six species mentioned above. Lack of *H. porcellanus* broodstock did not allow UP–MSI to culture this species successfully, though the technology is available.

When funding from ACIAR terminated in 1992, MSI continued work on the culture of giant clams with support from the International Development Research Centre (IDRC) of Canada. Its objectives were to mass produce juveniles for restocking purposes and to create livelihood programs through giant clam farming. With the success of giant clam rearing, UP-MSI started to restock in various parts of the country focusing on the largest tridacnid, *T. gigas*.

In 2001, the program received significant support through the Pew Marine Conservation Fellowship for the senior author. The project "Coral Reef Habitat and Productivity Enhancement" aimed to improve the biodiversity and productivity of degraded coral reef habitats in ten selected demonstration sites in the Philippines through coral transplantation and giant clam reseeding, particularly the threatened *T. gigas*. A total of 1,125 sub-adult clams were deployed in 11 demonstration sites (one site added to the 10 sites originally proposed) and about 10,145 juvenile clams were transported to other sites for rearing (Table 1 and Fig. 4).

An earlier clam restocking project in the Hundred Islands National Park funded and

Table 1. *Tridacna gigas* and *Hippopus hippopus* clams distributed through the Pew Project, 2002-2004.

Demonstration sites (sub-adult clams)	**Quantity**	**Other sites (juvenile clams)**	**Quantity**
Northern Philippines			
Anda, Pangasinan	225		
Masinloc, Zambales	225		
Infanta, Quezon	75		
Alabat, Quezon	75		
Central Philippines			
Alcoy, Cebu	75	Tigbauan, Iloilo	500
Camotes, Cebu	150	Danjugan, Negros Occ.	500
Calape, Bohol	75	Dumaguete, Negros Or.	5000
Lawaan, Eastern Samar	75	Olango, Cebu	1250
		Lawaan, Eastern Samar	2350
Southern Philippines		Sinacaban, Misamis Occ. (sub-adults)	25
Samal Island, Davao	150	Samal Island, Davao	520
Total (all *T. gigas*)	1125	Total (all *T. gigas* + 40 *H. hippopus*)	10145
Approx. survival of sub-adults	92%	Approx. survival of juveniles	15%

supported the Philippine Tourism Authority had for its main objective the establishment of giant clam ocean nurseries as demonstration sites for clam conservation. At the end of that project in 2002, about 10,000 giant clams of various sizes had been deployed in different sites in the park. See Gomez and Licuanan (in press) for a full account of this effort.

Constraints

In the Philippines, it is unfortunate that present government policies do not allow commercial production of corals and the export of both corals and giant clams for the aquarium trade, even if they are cultured. This results from a misunderstanding of CITES regulations. Both scleractinian corals and giant clams are listed in Appendix II of the Convention, which means that their international trade should be managed, but not prohibited.

It is noteworthy that other countries, notably Indonesia, trade both wild collected and cultured corals, while other countries such as the Solomon Islands and the Marshall Islands trade cultured clams in the international market. This simply means that the Philippines is missing an opportunity to help coastal inhabitants develop an alternative livelihood, unless the laws and regulations are modified. There is no valid reason for countries not to engage in appropriate coral and giant clam culture and trade.

There is a need to improve the techniques briefly described here. A few manuals already exist for coral restoration (e.g., Omori and Fujiwara 2004) which outline some of the culture approaches. Fortunately, there are two ongoing initiatives on coral restoration that are being funded by the Global Environment Facility and the European Union. In a few years, the state of the art in coral culture and transplantation should be significantly improved. For giant clams, the culture techniques have been in existence for the past two decades.

Acknowledgements

We wish to thank SEAFDEC/AQD for the invitation to the senior author to participate in the workshop on stock enhancement. Much of this work is derived from the project, "Coral reef habitat and productivity enhancement through coral transplantation and giant clam restocking", of the senior author, a Pew Fellow in Marine Conservation. This paper is UP–MSI Contribution No. 348.

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