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Achievements and lessons learned in restocking giant clams in the Philippines

Edgardo D. Gomez*, S. Suzanne Mingoa-Licuanan

The Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, Philippines

Abstract

For almost 20 years, the Marine Science Institute (MSI), University of the Philippines, has been culturing giant clams to restore depleted populations of these large bivalves in the Philippines, and to promote giant clam farming as a sustainable livelihood. Restocking activities were done in collaboration with local groups by providing training in the culture and ocean rearing of giant clams, and by implementing a "users pay" approach. Initially, a variety of giant clam species was used but once F1 broodstock of *Tridacna gigas* were reared, restocking focused on this species due to its scarcity and fast rate of growth. About 20 000 *T. gigas* were placed on coral reefs. In addition, >50 000 clams (*T. gigas*, *T. squamosa*, *T. derasa*, *T. crocea*, *T. maxima* and *Hippopus hippopus*) were distributed through other means. Altogether, >40 sites throughout the Philippines received cultured giant clams. Grow-out trials to test the viability of supplying giant clams for the aquarium trade to create new sources of income were conducted successfully with a group of fishers in Bolinao, Pangasinan. However, this initiative encountered legal obstacles when the government regulatory agency prohibited the export of cultured clams, regarding this as a threat to the conservation of wild individuals. The long experience in culturing and restocking giant clams in the Philippines provides many lessons for other countries wishing to restore stocks of these large bivalves. Particular care needs to be given to selection of release sites, negotiations with participating groups to safeguard the released clams, adequate transfer of technology to collaborators, and transport of large clams from nursery areas to release sites.

Keywords: Restocking; Giant clam; *Tridacna*; Culture; Conservation; Ocean rearing

1. Introduction

The efforts leading to the restocking of giant clams (Subfamily Tridacninae) in the Philippines date back almost 20 years, when the WorldFish Center (then ICLARM, the International Center for Living Aquatic Resources Management) and the Australian Centre for International Agricultural Research (ACIAR), organised a regional collaborative research programme on the culture of these bivalves. The ensuing 6-year programme involved Australia, several Pacific island nations, and the Philippines. The Marine Science Institute (MSI) of the University of the Philippines-Diliman was one of two participating academic institutions in the Philippines.

Key objectives of the initial giant clam restocking programme were to establish broodstock, as described by Newkirk (1993), and develop culture techniques. Acquiring broodstock proved to be difficult because field surveys around the Philippines revealed that the three largest species, *Tridacna gigas*, *T. derasa* and *Hippopus porcellanus*, were rare. Indeed, only two wild sub-adult *T. gigas*, and no *H. porcellanus*, were found. Other species, such as *T. squamosa* and *H. hippopus*, could be found in good numbers only in certain localities, while the two small burrowing species, *T. maxima* and *T. crocea*, were still abundant (Juinio et al., 1989).

The culture methods used at the MSI giant clam hatchery at the Bolinao Marine Laboratory in the Province of Pangasinan, northern Philippines, were based on the protocols developed by Braley (1992a). We initiated giant clam spawning trials with *T. derasa*, *T. squamosa*, *T. maxima*, and *H. hippopus* in 1985. During the field surveys, between 1989 and 1994, we were able to collect adequate numbers of *H. hippopus* and *T. crocea* for spawning trials. However, to increase the number of broodstock for the two largest species, three cohorts of *T. derasa* 'seed' (small juvenile clams) were imported from

* Corresponding author. Tel.: +63 2 981 8500x2908; fax: +63 2 924 7678.
E-mail address: edgomez@upmsi.ph (E.D. Gomez).

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Palau between 1984 and 1985; and seven cohorts of cultured *T. gigas* were imported from Australia (as seed) and from the Solomon Islands (as pediveligers) between 1987 and 1995. When funding from ACIAR expired in 1992, MSI continued work on culture of giant clams with support from the International Development Research Centre (IDRC), Canada. The aim was mass-production for restocking, and to create livelihoods based on giant clam farming. The imported cohorts were reared in the MSI hatchery at Bolinao, and then transferred to nearby ocean nurseries for rearing to broodstock. Depending on the species and age at shipment, broodstock from the first shipments were reproductively mature after 4–9 years. [*T. gigas* is reproductively mature as a female at an age of 8–9 years (unpublished data), and *T. derasa* at 5 years old (Heslinga et al., 1984)].

Farming trials using cultured giant clams were also initiated in Dewey, Bolinao in Pangasinan to encourage municipal fishers to grow-out clams for their use, and for restocking, in a scheme similar to the trials in Solomon Islands by Bell et al. (1997). Giant clam farmers have two potential markets: the marine aquarium trade and the live seafood trade. Labour and duration of the rearing cycle are considered critical factors in determining the viability of supplying cultured clams to these markets (Hean and Cacho, 2002). For the Bolinao farming trials, the option offered by the aquarium trade was more acceptable to the fishers, since the clams can be sold sooner and are taken per piece rather than by volume. The benefits to farmers greatly outweighed the costs of culturing the clams, and the growers agreed to allocate a small percentage of the clams for restocking reefs, in a similar way to the model proposed by Bell (1999). The 6-month trial, based on a buyback or contract-growing scheme, was acceptable to the collaborating fishers, as they needed to allot just 30 min per day for husbandry of the clams in the ocean nursery. Regrettably, this initiative ran into legal obstacles when the government regulatory agency prohibited the export of cultured clams. Exports were regarded as a threat to the conservation of wild individuals.

Restocking of giant clams in the Philippines started slowly because only a limited number of the imported clams was available to place in the wild. After the imported *T. gigas* broodstock matured and spawned, many more clams were available to distribute. However, due to the high costs of dispersing the cultured clams, and monitoring their survival in an archipelagic country such as the Philippines (Fig. 1), collaborators and financial support were required. Initially, there was widespread mortality of released clams, largely due to poaching and illegal fishing. This problem was eventually overcome by teaming up with individuals and groups who protected giant clams transplanted into areas under their control. Marine protected areas were also identified as suitable sites for restocking giant clams.

Overall, the giant clam restocking programme in the Philippines has focused on *T. gigas* for three main reasons: (1) the species was virtually extinct in the Philippines due to over-fishing, (2) it has a fast growth rate (9.1 cm per year)

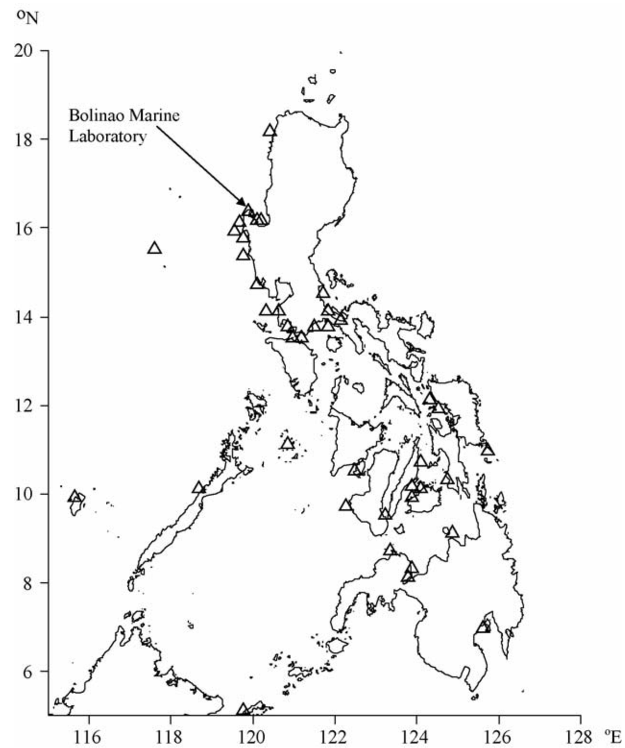

Fig. 1. Map of the Philippines showing all restocking sites with the source site, Bolinao Marine Laboratory, labeled.

(Lucas, 1994), and (3) MSI was eventually able to accumulate adequate broodstock for regular spawning.

This paper highlights the achievements of the giant clam restocking programme in the Philippines, and the lessons learned. The work presented here is the longest-running of the various giant clam restocking initiatives in Asia-Pacific described earlier by Bell (1999).

2. Hatchery production of giant clams

MSI began experimenting with various methods to spawn giant clams ex situ (in land-based tanks) at the Bolinao Marine Laboratory, with initial but inconsistent success using the gonad slurry injection method (Gwyther and Munro, 1981; Trinidad-Roa, 1988). The first cohorts produced were of *T. derasa*, *T. maxima*, and *H. hippopus* (Trinidad-Roa, 1988). Later, to conserve broodstock (which needed to be sacrificed in order to obtain gonad slurry), the serotonin injection method was used (Braley, 1985). The protocol developed by Braley (1992a) based on the lunar and diel spawning patterns of giant clams produced the best results. It combined several spawning induction methods, such as temperature shock treatment (using heated water or half-hour exposure to the sun), and intra-gonadal injection of serotonin (see Braley, 1992a).

Although most cohorts of giant clams for restocking were produced entirely in the hatchery, induced in situ

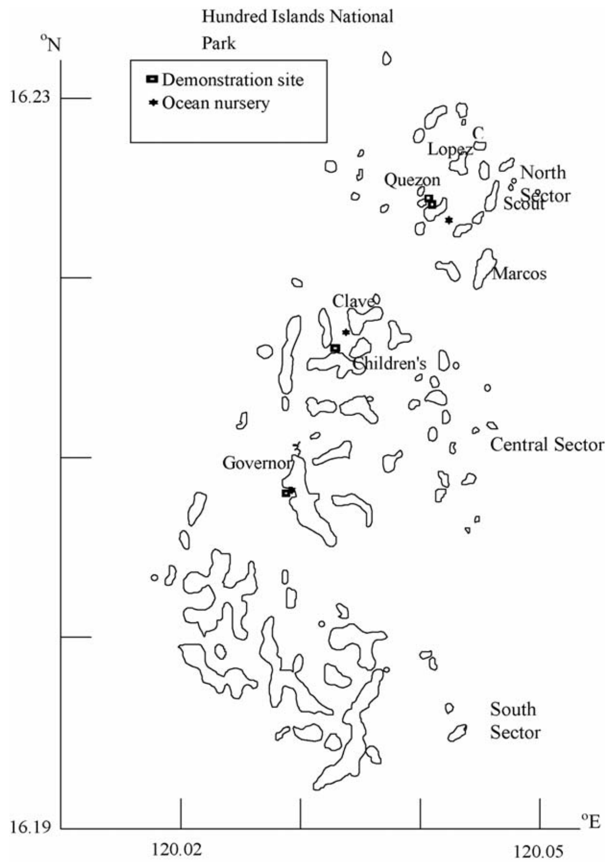

Fig. 2. Map of the Hundred Islands National Park showing the clam demonstration sites and ocean nurseries.

spawning (=artificial induction of broodstock in the sea to release gametes) was used on occasions to bypass the effort needed to transport large clams to the hatchery. We based this method on the earlier work of R. D. Braley (personal communication), who induced the release of eggs and sperm from wild *T. gigas* and *T. derasa* underwater, but did not rear the larvae. In 1992, we attempted to take the induced in situ spawning technique a step further by retrieving the spawned gametes for fertilisation and hatchery rearing of larvae. However, difficulties were encountered in retrieving sufficient gametes underwater during the 1992 trials. The attempts at in situ spawning of a greater number of *T. gigas* F1 broodstock in an ocean nursery within the Hundred Islands National Park (Fig. 2) in 2002 were successful. Scuba divers collected gametes from different parents in plastic bags and took them to a boat, where the eggs were fertilized immediately. Oxygenated bags containing the fertilized eggs were then sealed and insulated to maintain ambient temperature during the 2-h transport to the hatchery. Induced in situ spawning was also successful for *T. squamosa* (Mingoa-Licuanan, unpublished data).

Juvenile giant clams resulting from locally produced and imported broodstock were used for restocking throughout the Philippines. The protocols that we used for quarantine and packing of juvenile clams are described by Braley (1992b), Lopez and Heslinga (1985), Solis and Heslinga (1989), and Mingoa-Licuanan et al. (2000).

3. Monitoring growth and survival

The restocking of giant clams commenced in 1987 and, as links were established with local collaborators, interest in setting up giant clam ocean nurseries increased among the private and public sectors. This enabled us to adopt a "users pay" approach to restocking. With the exception of two recent major initiatives, described later, this approach resulted in the expenses for restocking being shouldered by the recipients (individual or group coordinating the reseeding activity with MSI). Recipients or stewards (a person designated to monitor the giant clam ocean nursery) were advised and/or trained to monitor survival and growth of the restocked clams. For short-term effects of transport on survival, there was immediate feedback. Mortality rates of 15% occurred within 24 h of re-immersion due to transport stress but were considered acceptable. Beyond 24 h, higher rates of mortality were due to presence of large predators, delays in re-immersion and over-exposure to air. Long-term monitoring of clam survival depended largely on the site visits by the steward, and varied among sites. Monitoring growth rates was less of a concern to stewards than monitoring clam survival. A semestral schedule of measuring clam shell length was recommended, but depended on the commitment of the stewards, as well as availability of funds and materials.

4. Number of cohorts produced

Overall, 46 cohorts of giant clams have been cultured by MSI, resulting in 'seed' large enough to place in the ocean nursery (Table 1). Most (98%) of the spawnings were induced; 2% were spontaneous. Since 1987, >397 000 seed were produced, ∼89% of these were 2 to <4 cm shell length (SL), and ∼11% were 4 to <9 cm SL (Table 1). The most cohorts were produced in 1998, but the greatest annual production of seed occurred in 2002 when a particularly strong cohort of 100 000 *T. squamosa* was reared. This cohort was derived from an induced in situ spawning in the province of Davao del Norte, about 1100 km from the hatchery at Bolinao.

Over a 15-year period, ∼50% of all seed produced (∼199 000 clams) were *T. gigas* (Table 1). The oldest cohort of *T. gigas* broodstock (imported from Australia) first spawned successfully in 1994 at age 9 years. However, this cohort was excluded from the production total for *T. gigas* seed because there was 100% mortality before reaching 2 cm SL. The second largest production of seed (∼25%) was for *T. squamosa* (derived from four cohorts between 1993 and 2002), followed by *H. hippopus*, which contributed ∼19% of seed from 8 cohorts between 1987 and 2000.

Table 1
Number of seed clams produced for five species of giant clams at the Marine Science Institute, University of the Philippines, from 1987 to 2002

Year	Species	Number of clams produced	
		Shell length, 2 to <4 cm	Shell length, 4 to <9 cm
1987	Tm [2]		59
	Hh		234
1989	Td		134
1992	Tc		188
	Td		16
	Tm		128
1993	Td [2]		1155
	Ts		15
	Hh		519
	Tc	125	
1994	Tc	554	
1995	Tg		30000
	Ts		247
	Hh		211
1996	Tg		37
	Tm		30
	Tc [2]	47	
	Hh		2253
1997	Td	393	
	Ts	53	
	Tc [2]	213	
	Hh		5080
1998	Tg [4]	47861	
	Tc [2]	15102	
1999	Hh [2]	64684	
2000	Tg	22500	
	Hh	4375	
2001	Tg [2]	74221	
	Td [2]		2111
2002	Tg [3]	24077	
	Td		1152
	Ts	100000	
Total for all species			397774

Tm: *T. maxima*; Hh: *H. hippopus*; Td: *T. derasa*; Tc: *T. crocea*; Ts: *T. squamosa*; Tg: *T. gigas*; []: no. cohorts.

5. Distribution of released juveniles, sub-adults, and adults

To date, >45 000 *T. gigas* have been restocked in the Philippines (Table 2), together with >30 000 juvenile giant clams from other species (Table 3). The largest number of *T. gigas* were placed in the northern (Luzon) and central (Visayas) regions, whereas *T. squamosa* dominated releases in the south (Mindanao) (Table 4). *T. gigas* comprised ∼35% of all clams restocked. From incidental reports on survival of restocked *T. gigas*, ∼25% of individuals released as juveniles were lost, whereas animals restocked as sub-adults and adults suffered only ∼1% mortality.

The giant clam restocking programme has now placed clams at >40 sites (Figs. 1–3) spread over >20 of the 62 coastal provinces of the Philippines. The northern region (Luzon) has received the greatest number of large clams because it is closer to MSIs hatchery (Table 4). The Hundred Islands National Park in the northern region has been the focus of a special project funded by the Philippine Tourism Authority (PTA). The main objectives of this project, which began in 2002, included establishment of giant clam ocean nurseries as demonstration sites for clam conservation, and restocking of clams in several places (Fig. 2). In 2002, ∼10 000 clams were placed at seven sites (Table 5). About 40% of these clams were large (21–66 cm SL); the remainder (10–19 cm SL) were put in cages to be grown-out to an ‘escape’ size of >20 cm SL, at

Table 2
The number of *T. gigas* restocked in the Philippines derived from imported reared cohorts and from cohorts produced locally

Origin	Cohort	No. restocked
Imported	October 1985	104
	March 1990	432
	December 1990	239
	February 1991	1488
	April 1994	2232
	August 1995	14293
Total		18788
Marine Science Institute	April 1995	10
	May 1997	360
	February 1998	50
	April 1998	93
	May 1998	8500
	June 1998	70
	January 2000	62
	May 2000	9063
	May 2001	4837
	December 2001	200
	Mixed[a]	3753
Total		26998

[a] Cohorts 1990–1998, May 2000, May 2001, December 2001, April 2002.

Table 3
Numbers of giant clams produced and restocked by the Marine Science Institute, University of the Philippines (excluding *T. gigas*)

Species	Cohort	No. clams restocked	Subtotal per species
T. squamosa	December 1995	20	
	October 2002	23600	23620
H. hippopus	August 1985	25	
	February 1987	622	
	May 1993	480	
	January 1997	208	
	October 1999	1529	2864
T. derasa	February 1989	25	
	February 1992	30	
	February 1993	1544	
	April 1994	146	
	April 1989	9	
	February 2001	200	1954
T. crocea	February 1993	1800	1800
T. maxima	February 1987	12	
	February 1992	100	
	August 1993	8	120
Total			30358

Table 4
Numbers of juvenile (=small), sub-adult and adult (=large) clams restocked in the three major regions of the Philippines

Species	Luzon (north)			Visayas (central)			Mindanao (south)		
	Small	Large	Total	Small	Large	Total	Small	Large	Total
Tg	12720	9281	22001	17783	599	18382	2098	572	2670
Td	130	454	584	900	9	909	520	0	520
Ts	0	0	0	20	0	20	21600	0	21600
Tm	112	0	112	0	8	8	0	0	0
Tc	0	0	0	1800	0	1800	0	0	0
Hh	1402	817	2219	90	0	90	530	0	530

Tg: *T. gigas*; Td: *T. derasa*; Ts: *T. squamosa*; Tm: *T. maxima*; Tc: *T. crocea*; Hh: *H. hippopus*.

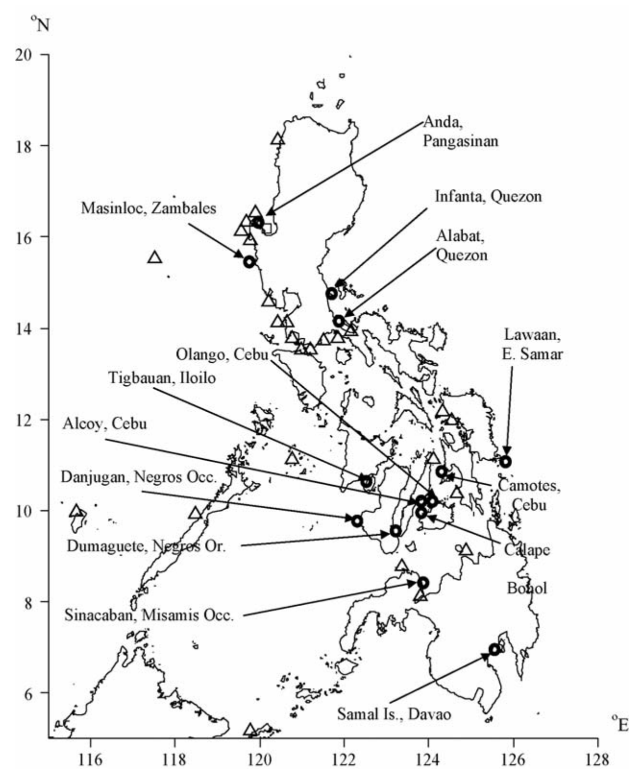

Fig. 3. Location of the demonstration sites and other sites (◯) used to prepare juvenile giant clams for release during the Pew Foundation project. Hundred Islands National Park (□); other restocking sites (△).

which survival is least affected by predation. Local staff were trained to take responsibility for monitoring the three clam ocean nurseries and the four demonstration sites. Regrettably, political changes meant that PTA did not continue to support conservation of giant clams. The last inventory of clams in the park in mid-2004 revealed that 7531 remained; 19% of which were broodstock; 11% sub-adult females/mature males (20–38 cm SL); and 43% juvenile (15–26 cm SL). The 27% loss of giant clams (2798 individuals) was made up of 1% of broodstock due to poaching, and 2% and 24% of sub-adults and juveniles, respectively, due to typhoons, fouling, crowding, and poaching. The great distance between the hatchery and the central (Visayas) and southern regions (Mindanao) made it necessary to use mainly smaller clams for restocking initiatives there (Table 4).

MSI also collaborated with other organisations in attempts to restock more clams. Our partners have been Silliman University and the Guiuan Development Foundation Inc. in the Visayas, and Davao del Norte State College in Mindanao. The collaboration also involved intermittent exchanges of seed for *T. derasa*, *T. crocea* and *H. hippopus* to enhance the genetic diversity of broodstock held by different organisations. Unfortunately, grow-out of clams to larger sizes was not successful in the Visayas but did succeed in Mindanao, where larger individuals were eventually established at two demonstration sites and donated to a marine protected area in a neighboring province.

A fellowship grant for 2002–2005 to enhance coral reef habitats through giant clam restocking invigorated efforts to release cultured clams in the Philippines. The project addressed the need to remediate coral reefs that have been reduced largely to rubble by blast fishing. Giant clams were used to provide hard substrata for sessile biota, shelter for mobile reef organisms, and additional biodiversity and aesthetics. At each of the demonstration sites for the project (Fig. 3), at least 75, but up to 225, sub-adult *T. gigas* (i.e., greater than the predation 'escape' size of 20 cm SL) were

Table 5
Inventory of restocked giant clams in demonstration and ocean nursery sites at the Hundred Islands National Park in December 2002

Site	*T. gigas*	*T. derasa*	*H. hippopus*	Total
Quezon Is. (Demo Site for Wading)	48	–	–	48
Quezon Is. (Demo Site for Snorkeling)	35	–	–	35
Quezon Is. (Ocean Nursery)	4381	3	433	4817
Clave Is. (Ocean Nursery)	423	–	–	423
Children's Is. (Demo Site for Snorkeling)	35	–	–	35
Governor Is. (Demo Site/Ocean Nursery)	4317	–	334	4651
Total				10009

Table 6
Giant clams distributed in the Philippines during the Pew Foundation Project from 2002 to 2004

Demonstration sites	No. sub-adult clams	Other sites	No. juvenile clams
Anda, Pangasinan	225	Tigbauan, Iloilo	500
Masinloc, Zambales	225	Danjugan, Negros Occ.	500
Infanta, Quezon	75	Dumaguete, Negros Or.	5000[a]
Alabat, Quezon	75	Olango, Cebu	1250[b]
Alcoy, Cebu	75	Lawaan, Eastern Samar	2350[a]
Camotes, Cebu	150	Sinacaban, Misamis Occ.	25[c]
Calape, Bohol	75	Samal Island, Davao	520
Lawaan, Eastern Samar	75		
Samal Island, Davao	150		
Total (all *T. gigas*)	1125	Total (*T. gigas* + 40 *H. hippopus*)	10145
Approx. survival of sub-adults: 92%		Approx. survival of juveniles: 15%	

Note that all clams were *T. gigas* except for 40 *H. hippopus*.
[a] No survivors.
[b] Source of some sub-adults deployed.
[c] Sub-adults.

established (Table 6). In addition, many juveniles were placed in cages at other sites in preparation for release (Fig. 3, Table 6). In total, >1000 sub-adult *T. gigas* were restocked at the demonstration sites, and ∼10 000 juveniles were distributed in preparation for restocking. Unfortunately, due to the lack of sufficient on-site personnel, large numbers of juveniles perished within a year (Table 6). By contrast, ∼92% of sub-adults survived, with the relatively minor losses being due to poaching where security was inadequate. Overall, however, the project promoted a growing interest on the part of collaborators in protecting and culturing giant clams.

6. Lessons learned

The long experience of rearing and releasing giant clams in the Philippines builds on the knowledge about the potential and problems of restocking these species outlined by Bell (1999). In particular, the refinements to practices and methods we have made have provided lessons in the following areas:

1. *Site selection*: The importance of the approval of the local community for restocking activities cannot be overemphasised. Any security measures needed must become their responsibility. A coalition of groups, comprising, for example, a local community, non-government organisations, the local government unit and academe, can be particularly effective at safeguarding restocked giant clams. Resolute guarding by local teams has been the key to preventing poaching in the face of strong incentives to take clams to overcome poverty, lack of food, poor fish catches, and even enhancement of private tourist developments.
2. *Technology and training*: To encourage and sustain the interest of local stewards in restocking giant clams, the establishment of ocean nurseries needs to be complemented with a training programme. After preliminary discussions with most of the collaborators, they recognized both the value of the giant clams and the inadequacies in their knowledge about habitat requirements, and about rearing, transporting and monitoring methods. As a consequence, they generally agreed to bear some of the costs of training stewards. Such training should include modules for hatchery and land-based production methods (up to 2 weeks), and monitoring the ocean nursery phase (up to 2 days).
3. *Transport methods for large clams*: We found that the minimal maintenance required for large clams in the ocean nursery, and the shorter time to maturity, was a strong incentive for locals to shift from restocking small to large clams. This necessitated modifications to the transport protocol for small clams to make it suitable for larger individuals. Factors that needed particular attention were weight, size, water volume, emersion tolerance, and mantle lesions. Despite the archipelagic nature of the Philippines, transport by road was more practical and affordable than moving clams by sea or air. Large clams (30–40 cm SL) can be transported over land for distances of up 450 km, and durations of 10 h, with 99% survival. However, it is not advisable to move clams when bad weather is likely to increase transport time, e.g., during typhoons. Another consideration is road conditions. Large clams became stressed more readily when transported over rough roads. However, our recommendation is to select the shortest route to the destination.

Persistent poaching remains a problem needing multifaceted solutions. From the reports of witnesses to poaching incidents, clam poaching may be related to community fiestas, fisher's lack of daily catch, and even steward's lack of food, and tourist resort enhancement. The bottom line must be enforcement of local and national laws against poaching of endangered species.

7. Conclusions

The restocking of giant clams in the Philippines has required long-term commitment. Investing time to maintain imported lineages of broodstock of the fastest growing species, *T. gigas,* resulted in production of F2 broodstock. It is now evident that ex situ spawning of *T. gigas* and *T. squamosa* broodstock in tanks can be complemented by in situ spawning in ocean nurseries. The in situ technique promises to increase the options for producing future cohorts of giant clams for restocking.

The concerted efforts to rear more broodstock allowed enough seed clams to be produced to restock giant clams at >40 sites. The decision to culture many of the imported seed until they became broodstock proved to be important because seed clams from Australia and Solomon Islands ceased to be available when the research efforts there concluded.

It is now apparent, however, that biological 'know-how' is only part of the process of restocking giant clams. The investment in production and distribution of giant clams for restocking will be wasted unless they and their progeny are protected so that they reproduce in the wild. Community involvement is critically needed to overcome the multiple sources of mortality for giant clams, including poaching, predation, fouling of cages (in the case of small clams), typhoons and water temperature anomalies. Further expansion of giant clam restocking in the Philippines, or elsewhere, needs to be based on the strong commitment of local communities to provide the necessary protection and husbandry. In addition to the necessary training, this will often require creating appropriate incentives.

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