GLOBAL RE-INTRODUCTION PERSPECTIVES

Re-introduction case-studies from around the globe

Edited by

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Cover photo: Clockwise starting from top-left:
- Formosan salmon stream, Taiwan
- Students in Madagascar with tree seedlings
- Virgin Islands boa

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Re-introduction of giant clams in the Indo-Pacific

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Introduction

Giant clams (Tridacnidae) are the largest marine bivalves found in coastal areas of the Indo-Pacific region. Eight species of giant clam of varying size and habitat preference have been described (***Tridacna gigas, T. derasa, T. squamosa, T. maxima, T. crocea, T. tevora, Hippopus hippopus*** and ***H. porcellanus***). In addition to the colourful smaller boring clams such as ***T. maxima*** and ***T. crocea*** which are found within limestone substrates, larger free living species such as ***T. squamosa, T. derasa*** and ***T. gigas*** are usually recorded near reef or over sand. Similarly, ***Hippopus*** spp. are often found on soft substrata, e.g. within seagrass beds. These bivalves are unusual in that they host symbiotic zooxanthellae within their mantle tissue, and benefit from the products of photosynthesis which provides part of their nutrition. Giant clams are a highly prized food source, and both exports of clam meat and harvesting by subsistence fishers has been responsible for stock depletion across their range. Giant clams are also harvested for their shells and for live export to the marine aquarium trade. Although fishing by foreign vessels (for adductor muscle) caused much of the depletion of the largest species, today giant clams are mostly under pressure from subsistence and semi-commercial (artisanal) fishers.

Giant clams have been depleted from coral reefs because they are slow growing, non cryptic and generally easily accessible to fishers. Habitat degradation is also responsible for declines in abundance, especially close to larger urban centres. Due to these pressures, their depletion and slow recovery from overfishing, giant clams are listed under Annex II of CITES, and are considered vulnerable under IUCN Red List of threatened species. Although there are examples of local extinctions (***T. gigas*** at Guam and the Mariana Islands, the Federated States of Micronesia, New Caledonia, Taiwan, the Ryukyu Islands and Vanuatu; ***T. derasa***, at Vanuatu; and ***H. hippopus***, at Fiji, Tonga, Western and American Samoa, Guam, Mariana Islands and Taiwan) in most cases giant clams are not eradicated through fishing and habitat change. In

WorldFish Broodstock at Nusatupe Island, Solomon Islands

general, declines in the abundance result in a pronounced constriction in range, and reduced spawning success as giant clams are sessile and cannot actively aggregate for sexual reproduction.

Efforts to re-establish or supplement depleted populations of giant clams have centred around two main activities. The first is to protect and aggregate remaining wild adults, in order to facilitate spawning and fertilisation success and subsequent 'downstream' recruitment. The second group of programs concentrated on breeding and releasing hatchery reared clams. In the early 1980's, several governmental and private institutions throughout the Indo-Pacific region agreed to a joint effort to propagate giant clams and restock the reefs of Pacific Island Nations (Bell ***et al.***, 2005). Initially, the organizations involved in hatchery and early culture research were the Okinawa Prefectural Fisheries Experimental Station, The University of Papua New Guinea, the Micronesian Mariculture Demonstration Center, the Australian Center for International Agricultural Research, the Marine Science Institute at the University of Philippines and the WorldFish Center (formerly known as ICLARM). Re-establishment, re-enforcement and increased awareness of the plight of giant clams stemmed from these initiatives.

Goals

- Goal 1: Preserve through re-enforcement (restocking) giant clams at overfished sites in the Indo-Pacific region. This goal cannot succeed in isolation of general management of remaining stocks which is not covered in this submission.
- Goal 2: Re-introduce giant clam species where they have become extinct.
- Goal 3: Improve aquaculture technology and early grow-out systems to assist restocking stocks.

Success Indicators

- Indicator 1: Supplementation (and related protection) of larger, more viable giant clam populations in the Indo-Pacific region.
- Indicator 2: Re-establishment of giant clam populations, capable of effective self-replenishment.
- Indicator 3: Successful long-term breeding and early grow-out program developed.

Project Summary

Feasibility: In some areas of the Indo-Pacific, natural recruitment was thought to have been almost extinguished (other than self-fertilisation events), as large mature clams were so scattered that they were thought to be beyond the threshold density required for natural cross-fertilisation (e.g. Tonga, see Chesher, 1995). Augmentation of stocks through the aggregation of adult clams was trialled, to increase the chance of successful external fertilisation, and subsequently increase downstream recruitment. In theory, aggregation of adults in 'clam circles' (Chesher, 1995) overcomes 'Allee' or 'depensatory' effects, although there are few quantitative studies that empirically show the success of

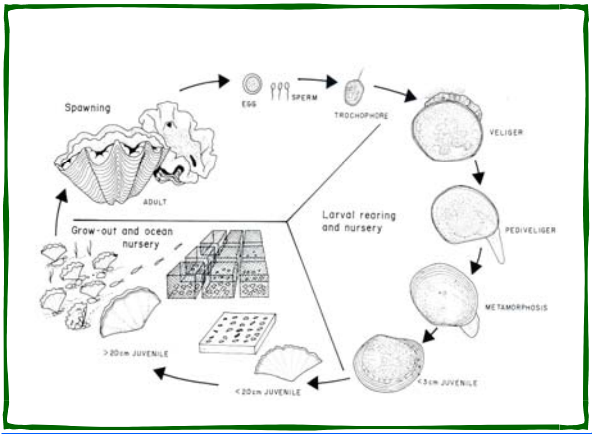

Fig. 1. Basic stages in clam Culture
Source: Adapted from Braley (1992)

this initiative. However, the simplicity of this low cost and eminently workable system encouraged the establishment of clam 'circles' in many countries (Tonga, Fiji, Vanuatu and Solomon Islands), and the practise of concentrating clams in "clam gardens" has been long documented in northern Papua New Guinea.

The availability of spat to be used for re-introduction projects generally relies on hatchery production and early grow-out technology, as most Indo-Pacific countries do not have access to sufficient juveniles from the wild (French Polynesia is an exception, using 'collectors' to settle spat of ***T. maxima*** in atolls with exceptionally large clam populations). Manuals have been produced that document hatchery and culture methods for giant clams (see Fig. 1, Braley, 1992).

According to the species and the location, it takes between eight and 14 days after fertilisation for giant clam larvae to settle on the bottom of tanks. They are then held in nursery grow-out (generally land based raceways) for around three to six months before first handling, and up to 12 months before clams are transferred to ocean nurseries. Usually, simple mesh cages, kept off the bottom, are used to protect the giant clams against most large predators, and growth varies greatly amongst species (Munro, 1993). Even in this protected environment, predatory gastropods such as ***Cymatium*** spp. and pyramidellid snails can settle into cages as larvae, making predation unpredictable until giant clams reach a larger 'escape' size where they are less susceptible. Site selection and juvenile management practices have proved to be critical factors in improving survival of cultured clams (Hart ***et al.***, 1999). A range of hatchery and nursery production systems are currently employed in over 21 Indo-Pacific countries, but even low-tech operations still require trained personnel and specialized equipment. Indirectly, the process of maintaining large numbers of broodstock for hatchery production also necessitates the holding of adults near hatchery sites. These aggregations of broodstock, in more than 11 countries in the Pacific, also have the ability to contribute to egg production and downstream settlement of clams.

Implementation: Clam re-introduction and re-enforcement projects have been carried out at various locations in the Indo-Pacific (see Table 1, pg. 16). These IUCN terms define what is termed restocking and stock enhancement in other literature. Although programs to aggregate adults have generally operated independently of commercial ventures, projects reliant on hatchery production have generally coupled re-establishment and re-enforcement programs to commercial clam farming activities.

Post-release monitoring: After the establishment of adult clams 'circles', there has been little definitive proof of enhanced recruitment, although quantitative studies have detected increased settlement of ***T. derasa*** and ***T. squamosa*** on nearby reefs (Chesher, 1995). For example, monitoring around the clam 'circle' site of Falevai, in the Vavau Group of Tonga, showed that the number of juvenile ***T. derasa*** (individuals per hour of searching) increased following establishment of the 'circles' from 0 in 1987 to 1.48 in 1990. The increase was consistent over yearly assessments, and was even greater for the medium-sized clam, ***T. squamosa*** (there was no change in the average number of ***T. maxima*** which were not aggregated). The real number of new recruits detected after the establishment of clam 'circles' is low, but detection rates for juvenile clams is normally low, and this rate is higher than reported by some other surveys of clam recruitment elsewhere in the Pacific.

An interesting opportunity now exists for detecting increased recruitment around ***T. gigas*** release sites on Australia's Great Barrier Reef. Concentrations of hatchery reared ***T. gigas*** were relocated to reefs some distance away from the hatchery, and these clams have now had sufficient time to become egg-producing adults (giant clams mature first as males and later become functional hermaphrodites). It would be interesting to study whether additional recruitment is taking place 'downstream' of these clam concentrations. For clams restocked to the wild at the end of nursery culture, high mortality still proves to be a major problem and further husbandry, for a period of up to three years, is required to maximise survival (Bell ***et al.***, 2005). In the Philippines, where >75,000 clams have been restocked (Gomez & Mingoa-Licuanan, 2006), 10,000 were placed in the Hundred Islands National Park. From the initial 10,000 clams restocked, as many as 7,531 remained after 2.5 years, with the last inventory revealing that losses were predominantly among the juveniles size classes. Only 2% of sub-adults and 1% of broodstock were lost. Mortalities were attributed to typhoons, fouling, crowding, predation and poaching (Gomez & Mingoa-Licuanan, 2006).

T. gigas imported from Australia into the Philippines became female-phase mature as early as 1995, with second generation clams being recorded at low density (R. Braley, pers comm.). Yap is another example where re-establishment has arisen from translocated hatchery-reared clams. In the case of Yap, re-introduction of approx 25,000 ***T. derasa*** from neighbouring Palau in 1984 resulted in only ~8% survival of the introduced stock. However, these ***T. derasa*** matured, reproduced and re-established viable populations on nearby reefs. Surveys conducted by the Secretariat of the Pacific Community (PROCFish/C - COFish programs) noted the continued presence of ***T. derasa*** in low numbers in mid 2006. In the case of restocking the smaller boring species (***T. crocea***) in Japan, survival of clams ranged from 0.3% - 56% three years after release. Survival was found to be higher when individual clams were settled into pits on ***Porites*** heads or onto artificial substrates and then released ***in situ***, rather than releasing loose clams onto limestone substrates directly. In Australia, predation of ***T. gigas*** was

Table 1. Outline of Indo-Pacific[1] giant clam restocking program

Location	Organization involved	Start	Species (translocated species in brackets)
American Samoa	Office of Marine and Wildlife Resources	1986	*(T. derasa), (T. gigas)*
Australia	James Cook University, ACIAR, Private company – Aquasearch	1984	*T. gigas, T. derasa,*
Cook Islands	Ministry of Marine Resources	1986	*T. maxima, T. squamosa (T. derasa), (T. gigas) (H. hippopus)*
Fiji	Fiji Fisheries Division	1985	*T. maxima, T. derasa, T. squamosa, (T. gigas), (T. tevoroa), (H. hippopus)*
French Polynesia	Service de la Peche	2002	*T. maxima*
FSM [2]	National Aquaculture Centre, Marine and Environmental Res Institute of Phonepei	1984	*(T. derasa), (T. gigas), (H. hippopus)*
Guam	Dept of Agriculture	1982	*(T. derasa), (T. gigas), (T. squamosa)*
Japan	Okinawa Prefectural Fisheries Experimental Station, Private Company - Okinawa Kuruma-ebi Co., Ltd	1987	*T. crocea, T. squamosa, T. maxima (T. derasa)*
Kiribati	Private company – Atoll Beauties	2000	*T. maxima, T. squamosa*
Marshall Islands	Marshal Islands Marine Resource Authority Private Company x 2 – Robert Reimers Enteprises & Mili Atoll	1985	*(T. derasa), T. gigas, T. squamosa, H, hippopus*
New Caledonia	IFREMER	1993	*H. hippopus, T. derasa, T. maxima, T. crocea, T. squamosa*
Northern Mariana Islands	Dept of Lands and Natural Resources	1986	*(T. derasa) (T. gigas), (H. hippopus)*
Palau	Micronesian Mariculture Demonstration Centre	Late 1970's	*T. derasa, T. gigas, T. squamosa, T. maxima, T. crocea, H, hippopus, H, porcellanus*
Papua New Guinea	UPNG – Motupore Island Research Centre	1983	*T. gigas, T. squamosa, T. crocea, H. hippopus*
Philippines	University of the Philippines Marine Science Institute	1987	*T. maxima T. squamosa, H. hippopus, (T. derasa), (T. gigas)*
Samoa	Samoan Fisheries Dept, SPADP	1988	*T. maxima T. squamosa, (H. hippopus), (T. derasa), (T. gigas), (T. squamosa)*
Solomon Islands	WorldFish Centre	1989	*T. maxima, T. squamosa, T. derasa, H. hippopus, T. gigas*
Thailand	Department of Fisheries	1997	*T. squamosa*
Tonga	Ministry of the Lands, Survey and Natural Resources, JICA, EarthWatch	1989	*T. maxima, T. squamosa, T. derasa, T. tevoroa, (T. gigas), (H. hippopus), (T. crocea)*
Tuvalu	SPC/Tuvalu Fish	1989	*(T. derasa)*
USA (Hawaii)	Not available	1951	*(T. crocea), (T. squamosa), (T. gigas)*
Vanuatu	Vanuatu Fisheries Dept., Japanese International Cooperation Agency, Private company – Reef Life and Reef Solutions. Ringi Te Suh Marine Conservation Reserve, Maskelynes, Malekula.	1998	*T. maxima, T. squamosa, T. crocea, H. hippopus, (T. derasa), (T. gigas)*

Notes: [1] Also see Eldredge, 1994.
[2] There are separate facilities in Yap, Chuuk, Kosrae and Phonpei States.

lower when clams were held in the intertidal zone (Lucas, 1994), and in Solomon Islands, ***H. hippopus*** was held on the bottom but behind suspended cargo netting, to protect medium sized hatchery reared clams from predation by large rays.

Major difficulties faced

- When placed at sea, survival of juvenile giant clams (<25 mm shell length) is generally low even with protection and husbandry, and therefore clams require ~9 months in land based nurseries. Clams only reach a general escape size at approx 150 mm shell length, and then are still vulnerable to rays, trigger fish and turtles (Heslinga ***et al.***, 1990).
- Producing giant clam spat in hatcheries, and holding them in early juvenile culture is relatively expensive. Estimates for each juvenile ready for transfer to the sea, range from US$ 0.27 - US$ 0.36 (Tidsdell ***et al.***, 1993). These estimates do not fully reflect the full capital cost of hatchery developments.
- Skills needed for spawning giant clams and rearing spat until escape size are varied and not always available or funded for long periods, making operations unsustainable in some cases.
- Poaching of broodstock, from 'clam circles' and hatchery programs, was high in some cases.
- Biological issues: Genetic diversity (gene frequency) of hatchery-reared stock is likely to be lower, or in some cases different to that found in wild populations. Hatcheries also increase the potential for introduction of pathogens (Eldredge, 1994). Although to date there have been no virus, chlamydia, mycoplasma, fungus, or neoplasm mortality events reported, rickettsia-like organisms have been noted in local and translocated giant clams, and mass mortalities of ***T. gigas*** and ***T. derasa*** has been recorded on the Great Barrier Reef without any responsible pathogen recorded in testing.

Major lessons learned

- Managing wild stocks can be more cost efficient than investing in hatcheries to re-stock overfished giant clam populations.
- Site selection and early stock husbandry are critical to survival of giant clams, especially hatchery reared juveniles. Selection of a site with suitable environmental conditions, and where there is social cohesion, assists the growth and general condition of stocks, while minimising losses to predation and/or poachers.
- Restocking of giant clams requires greater effort to be put into stakeholder consultation. Attaining an intellectual concord between researchers, government workers and local villagers requires extended periods of awareness raising and information sharing. Special care should be taken for programs to respond appropriately to traditional reef tenure systems and encourage direct community and fisher participation in re-introduction and re-enforcement programs.
- The original premise of the ICLARM/ACIAR Giant Clam Project started in 1984, that one could spread the economic burden of producing large enough clams for re-stocking by coupling restocking programs with commercial

farming, has been supported. The technology developed for clam production has in some cases been transferred to the private sector and a number of people across the Pacific are employed to produce clams for the marine ornamental trade. A proportion of production is also available for restocking.

Success of project

Highly Successful	Successful	**Partially Successful**	Failure
		√	

Reasons for success/failure:

- Success in simple hatchery and early rearing production saw a good spread in technology and a high adoption rate.
- Small scale industry development offered incentives to support this initiative.
- High mortality of juvenile clams lowered the extent of the success.
- High cost and extended time period required limited the sustainability of many operations.
- Lack of social adhesion in communities participating in these projects caused some failures. In some cases, the projects were not well matched to the communities needs or wants.
- Lack of funding for monitoring and a lack of uniform protocols limited the reporting of results that arose from re-introduction and re-enforcement programs.

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