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6-10 Elena St., Nelly Bay, Magnetic Island, Queensland 4819 AUSTRALIA

# A follow-up on the translocations of cultured giant clams (Fam Tridacindae) from Australia to the Philippines and Pacific Islands – Growth and survival.

Dr. Richard D. Braley

ABSTRACT

Giant clams reared under a quarantine system in tropical Australia and translocated to the Philippines and the Pacific Islands between 1987-1991, have resulted in acceptable growth but relatively low survival by mid-1997.

Of the 3 cohorts of Tridacna gigas sent from OIRS (Orpheus Island Research Station, James Cook University) the October '85 cohort showed the highest survival, averaging 17.2 % between the Philippines and Fiji, but with a higher growth rate in Fiji probably due to site conditions. The improved survival over other cohorts was due to the age of the clams sent, these being over 16 mo. of age and lower initial numbers. The December '90 cohort (sent at 2, 3, & 6 mo. of age) averaged 3.6 % survival between the Philippines, Tonga, and Cook Islands and growth rate was similar for all, averaging 6.4 cm / yr. The single cohort of Hippopus hippopus (sent at 3, 3, & 5 mo. of age) averaged 1.79 % survival for Fiji, Tonga, and Philippines. However, in Tonga the survival (5.2%) and growth was higher than at other countries, possibly a result of placing the clams in the most suitable habitat. Cyclones were one cause of mass mortalities of translocated giant clam juveniles in Pacific Island countries. In the Philippines, the October '85 cohort of T. gigas had reached male/female-phase sexual maturity with several f2 offspring produced thus far. In the Cook Islands the January '91 cohort of H. hippopus had reached male/female-phase sexual maturity by July '97 and new f2 offspring produced.

## INTRODUCTION

In the mid-1980s to early 1990s there was a surge of interest and funding to bring the culture of giant clams from the initial small-scale culture (LaBarbera, 1975; Jameson, 1976; Gwyther and Munro, 1981; Beckvar, 1981) to mass culture (Heslinga et al., 1984; Crawford et al., 1986; Heslinga et al., 1990; Braley, 1992a). A number of hatcheries and culture operations were started during this period of high interest, including those at Aitutaki (Cook Islands), Makogai (Fiji), Sopu (Tonga), Bolinao and Dumaguete (Philippines), all of which were collaborators with the former ACIAR-JCU (Australian Centre for International Agricultural Research - James Cook University) giant clam project. During that project, there was a considerable effort put into developing a quarantine hatchery and land-nursery system at the JCU Orpheus Island Research Station (OIRS). Out of this quarantine system, 'seed' clams were tested by a pathologist and then translocated to various collaborating countries in the project. The details of the quarantine protocol for the export and the import of giant clams are shown in Chapters 12 and 13, respectively, of Braley (1992a).

The purpose of this paper is to follow-up on the results of these translocations by comparing the growth and survival: 1) of cohorts sent to various countries, and 2) between different cohorts.

## MATERIALS AND METHODS

In the late 1980s and early 1990s the OIRS quarantine hatchery facility was fully operable. Some of the quarantine system requirements were that each cohort of clams held in a tank(s) in the system:

- be separated from other tanks by plastic or shadecloth walls 2 m high to stop aerosol drift contamination,
- be identified as a restricted area and only allow access by authorised staff,
- have cartridge filtration with 3 online filters being 10, 1, and 1 microns (duplicated 1 micron filters)
- have a different set of equipment from other tanks,
- have a daily log kept of cleaning, nutrient applications, water quality, mortalities, water exchange, abnormalities,
- have samples taken at week 0, week 3, and every 8 weeks thereafter up to 6 months for testing of pathogens [virus, protozoan, fungus or parasite].

A form of declaration that the export protocol had been adhered to (including a veterinary examinaton certificate) and the Australian National Parks and Wildlife Permit to Export an organism listed under CITES (Convention on International Trrade in Endangered Species of Wild Fauna and Flora) had to be obtained for each of the cohorts which were to be translocated. In the country of import, the relevant authorities were contacted by the organisation within the country which was collaborating with the ACIAR-JCU giant clam project. Shipments were sent as airfreight and efforts were made to assure that rapid transfers at transit airports were made. Some shipments were made at the same time as a visit by the author to the importing countries, so as to assist with the task of reducing stress on the clam seed after it arrived and was unpacked and stocked into a quarantine tank. The method of packing for shipment varied from the first two cohorts of clam seed being shipped in esky-bins and packed with seawater dampened towels, to the largest cohorts of Tridacna gigas and Hippopus hippopus being shipped by an improved method utilising plastic bags inside of polystyrene fish boxes with a small amount of seawater plus antibiotic in the bag along with the clam seed. Industrial oxygen was placed in the plastic bag and then tied off (see Braley, 1982b).

Generally, quarantine tanks in the country of import were set up so that they received at least 25-micron bag filtered seawater, were off-limits to unauthorised staff, and effluent seawater would run into a pit which drained into the ground rather than allowing this water to drain directly to sea. Again, samples of clam seed for pathogen testing were required to be sent to Australia from the cohort batch that was imported. There was an example of a rickettsia-like organism appearing in the tissues of the cohort of Hippopus hippopus that remained at OIRS after batches were sent to the Cook Islands, Tonga, and Fiji. Samples of preserved clam seed were sent to Australia for analyses by Cook Islands and Tonga.

Records were kept of the early mortalities following the shipment at most of the importing countries, but sketchy information was available on their progressive growth and survival. The author requested the various former collaborators of the ACIAR-JCU giant clam project to assist with forwarding information on the mean size (cm shell length), wet weight (kg), and number of survivors from each imported cohort of giant clams as of early to mid-1997. Sufficient information was obtained from the University of the Philippines, Cook Islands Ministry of Marine Resources (the author was able to personally participate in measurements as he was consulting on an Asian Development Bank pearl oyster project in the Cook Islands during 1997), the Fiji Fisheries Division - Ministry of Agriculture, Fisheries & Forestry, and the Tonga Ministry of Fisheries (Aquaculture Research and Development Follow-Up Project - JICA).

Data obtained was analysed by a two-sample t-test where appropriate, or by simple comparison of means by percentage differences.

## RESULTS

### Survival

The smallest (~1,000 clams) cohort of T. gigas [Tg85] was sent to Fiji and the Philippines in the first quarter of 1987. The juvenile clams were over 16 mo. of age when sent and the resulting survival to mid-1997 was much higher (average of 17.2% between the 2 countries), with Fiji having the highest survival rate (Table 1). ippHippH. The second cohort (~7,000 clams) of T. gigas [Tg89] was sent to the Philippines at 4 mo. of age and the final survival to mid-1997 was the lowest for all the shipments of this species (0.51%). The third cohort (~33,000 clams) of T. gigas [Tg90] was sent to the Cook Islands, Philippines, and Tonga resulting in an average survival of 3.6%. The age of the clams when shipped was 2 mo. (Philippines), 4 mo. (Tonga), and 6 mo. (Cook Islands). Here, Tonga showed the highest survival and Philippines the lowest (Table 1). Table 2 shows some information on survival of the clams from the Cook Islands and Tonga after the translocations of the Tg90 cohort. Many of the clams died during the winter months in the Cook Islands, resulting in 42.7% survival just 3.5 mo. after the translocation took place. In Tonga, translocated clams were held under a greenhouse system with recirculating seawater which maintained higher water temperatures than ambient over that first winter. Without having the data, the author recalls that this system worked well with mortalities which were considerably lower than those experienced in the Cook Islands where clams were at an ambient temperature. In December ’91 there were 1500 clams remaining in Tonga (13.4% survival) 8 mo. after the translocation (Table 2). Some clams were moved to patch reefs and sand flats with varying survival. It was estimated that 13.3% mortality of the 1500 clams was a result of stealing, an 6.7% mortality was due to a marketting study. Cyclone Kina (1993) was noted as a cause of major losses.

A single cohort (~70,000 clams) of Hippopus hippopus was sent to Fiji and Tonga at 3 mo. of age, and to the Cook Islands at 5 mo. of age (Table 1). Survival to mid-1997 averaged 1.79% between all countries but was much higher in

Tonga (5.2%) compared with Fiji (0.04%) and the Cook Islands (0.13%). High mortalities in Fiji were attributed to Cyclone Kina [2-3 January 1993] in which cages were overturned and buried in sand. Table 2 shows survival data of this cohort in the Cook Islands and Tonga. The survival was 91.8% in the Cook Islands 3.5 mo. after the translocation. This was notably better than the survival of T. gigas over that first winter period. The frequency and cause of mortalities after this time was not recorded for the Cook Islands. In Tonga, 4,100 clams remained 9 mo. after the translocation (16.4%). By May '93 some clams were moved direct onto a seagrass bed in a 10 m x 10 m area. By June '97 the survival was 72.0% whilst those left in the protective cages in the sand flats had 23.5% survival (Table 2). As for Fiji, Cylcone Kina was noted as a cause of major losses.

The Queensland DPI veterinary laboratory which found evidence of rickettsia-like organisms in some of the tissue samples of H. hippopus seed from OIRS in August or September of 1991 notified the project leaders of the Cook Islands, Fiji and Tonga that samples should be taken of their shipments (about 125-150 animals) to also look for the rickettsia-ike organisms. Samples were sent from Tonga and the Cook Islands. Tonga Fisheries also sent samples of local Tridacna derasa juveniles which were cultured at the hatchery. The results from Tonga indicated that both the H. hippopus and the local T. derasa did have some incidence of a rickettsia-like organism, but that it was not possible to tell if the organisms were different varieties or originated from Tongan waters. The Cook Islands samples also showed an incidence of the organism. The projects in the three countries weighed the pros and cons of destroying the cohort, and all decided to keep the cohort. It should be noted that samples of the Tg90 cohort were also tested and found to be free of any rickettsia-like organisms.

### Growth

The average shell length (cm) and wet weight (kg) are shown for each of the cohort batches sent to the importing countries (Table 1). Wet weights were collected from only 3 countries, and not for all cohorts. Table 3 shows the growth in cm / yr and in kg / yr for the cohorts at each country. A two-sample t-test was done to compare growth rates between the Tg85 batch and the Tg90 batch, each of which were replicated by sending to more than one country. There was no significant difference between growth rates of the cohorts ($p>0.05$). Within the Tg85 cohort there was a large difference in growth rates between Fiji and the Philippines, with the growth rate being 52% higher in Fiji than the Philippines. Within the Tg90 cohort the growth rates were similar between the Cook Islands, Philippines and Tonga, averaging 6.31 cm / yr (Table 3). Here, Tonga showed the best growth rate, but it was only 13% higher than the lowest growth rate in the Cook Islands. Within the Philippines, the Tg85 cohort showed the lowest growth rate followed by the Tg89 cohort and the best growth rate from the Tg90 cohort (45% higher than the Tg85 cohort). The wet weights were only taken for Fiji's Tg85 cohort (3.85 kg / yr) and for the Cook Islands Tg90 cohort (2.06 kg / yr).

The average SL and WW of the single Hippopus hippopus cohort are shown for each country in Table 1. Table 3 shows the growth rates in cm / yr and in kg / yr for the 3 countries which imported this cohort (Hh91). The average growth rate between the 3 countries was 3.01 cm / yr, with the highest growth rate (Tonga) being 35.7% higher than the lowest growth rate (Fiji). The average wet weight growth rate which was taken from the Cook Islands and Tonga was 0.35 kg / yr. Here, the Tonga clams weighed 74% more than the Cook Island clams.

Some information was obtained on the sexual maturity of these translocated clams (Table 4). Thus far, only cohort Tg85 has become female phase mature in the Philippines as early as April 1995. Some f2 juveniles have resulted from the spawnings of the f1 T. gigas, but survival is reported to be low. Female-phase maturity of H. hippopus in the Cook Islands has been recently reported after an induced spawning attempt in July 1997, which has resulted in some f2 offspring (Table 4). Only male-phase sexual maturity has been reported in H. hippopus elsewhere.

## DISCUSSION

### Survival

The Tg85 cohort had the highest survival rate to mid-1997 because it was sent at the age of 16 + mo. compared with other cohorts which were shipped from 2-6 mo. of age. The larger size (and stronger shell) of the 16+ mo. clams would have favoured a higher survival rate. Likewise, this cohort was the smallest one sent from the ACIAR-JCU giant clam project at OIRS. Individuals were more carefully checked before they were chosen for shipment at OIRS when compared with much smaller seed from the other cohorts. The larger cohorts were chosen for shipment in a more random fashion, as the main interest was in getting volumetric measurements to correctly estimate numbers of clams being sent. It is more likely that in the country of import there was greater individual attention also given to this first smaller cohort sent than was probable with the later, larger cohorts.

Survival of both Tg90 and Hh91 were highest in Tonga by June 1997 compared with the other countries. In the case of Tg90, the survival of small seed over the austral winter in 1991 would have been increased in Tonga with the use of a greenhouse and recirculation seawater quarantine system when compared with the Aitutaki clam hatchery (Cook Islands) which had only ambient temperatures. Winter mortality was the term given to the death of T. gigas seed in tanks at OIRS during the ACIAR-JCU giant clam project (Braley, 1992a). The combination of greenhouse heating, recirculation, and nutrient addition was shown to significantly increase survival and boost growth of the T. gigas juveniles (Braley et al., 1992). Also, the improved method to ship seed clams used with this cohort (Braley, 1992b) may have been an important factor to allow >90% to survive the shipment and get equal opportunity to grow at each locality where they were translocated. The survival of Hh91 at Aitutaki, Cook Islands was still very high 3.5 mo. after the translocation, probably higher than in Tonga as there were only 4,100 juveniles remaining in Tonga 3 mo. after this. The high mortality at Aitutaki may have been due to clams being left too long in the nursery tanks, getting a low rate of water exchange and filamentous algae growing over the shells (noted several months after the shipment). Nevertheless, it appears that H. hippopus handles ambient winter temperatures much better than T. gigas. The movement of some Hh91 to the seagrass bed site in Tonga resulted in a high survival rate of 72% over 4 years. The author would like to comment that when he lived and worked in Tonga between early 1973-late 1976 the local extinction of H. hippopus had not yet occurred, though they were rare and almost alway found in seagrass beds which were common from Sopu and toward ‘Atata. The Philippines also utilise seagrass beds for giant clam ocean nurseries (Calumpong, 1992). The very poor survival of Hh91 experienced in Fiji was mainly due to high mortality as a result of Cyclone Kina, and this was also noted for Tonga. Even in a generally protected bay where the ocean nursery is located on Makogai Island, Fiji, the wrath of a destructive cyclone shows no preference.

The presence of the rickettsia-like organism in some H. hippopus tissues was an issue to consider the destruction of the cohort batches exported from Australia. Rikettsiales-like infections appear to be widespread in marine bivalves (Elson and Peacock, 1984) and although not usually associated with host mortality there were mortalities associated with a gill infection in Placopecten magellanicus (Gulka et al., 1983). However, given that local T.derasa from Tonga were also found to have rickettsia-like organisms, it was decided that the Hh91 cohort would be kept. It should be noted that hatchery-reared juvenile T. derasa had also been translocated to the Cook Islands (and many islands in Micronesia) from the Micronesian Mariculture Demonstration Center (MMDC), Palau, in the mid-late 1980s, and there was no quarantine system in operation that was comparable to the one at OIRS. Likewise, Trochus niloticus, the commercial top shell, had been translocated numerous times around the Pacific islands without any type of quarantine system. Fortunately, no known disease outbreak has occurred as a result of these translocations. It is not wise to be complacent, because although to date there have been no virus, chlamyia, mycoplasma, fungus, or neoplasm reported in giant clams (Braley, 1992a), there have been mass mortalities of T. gigas and T. derasa on the Great Barrier Reef (Alder and Braley, 1989) without any pathogen noted in tissues. More recently mass mortalities of T. gigas and H. hippopus were also observed in the Solomon Islands (Gervis, 1992), again without tissues revealing any pathogens. Lucas (1994) suggests that pollutants, toxins and pathogens must be looked at as possible causes of such mass mortalities.

Growth

Growth rates (shell length) of translocated clams were within the normal range for both T. gigas and H. hippopus. The highest growth rate for T. gigas was found in Fiji for the Tg85 cohort while the same cohort grew considerably slower in the Philippines. However, the Tg90 cohort grew at nearly the same high growth rate in the Philippines, but there was a much smaller difference in the rate of growth at the other locations than was seen with the Tg85 cohort. There may have been genetic factors within the cohort that made the variation in growth of the Tg85 batch so different at different localities. Another factor may be that the Fiji site for the ocean nursery is on sand at about 4+ m in relatively clear water (with nearby oceanic water exchanging some water in the bay), whilst the ocean nursery site in the Philippines was located in a seagrass bed (always subtidal, about 2-3 m deep) within the reef crest. The site near Sopu in Tonga may receive more exchange of oceanic water than the site in the Philippines, but the site at Aitutaki, Cook Islands is inside of a relatively shallow atoll-in-the-making lagoon where there is a poor exchange of oceanic seawater. Growth rates (both shell length and wet weight) of Hh91 were better in Tonga than either Fiji or the Cook Islands. The high survival rate noted above in seagrass beds in Tonga may indicate that this site is the most appropriate habitat for H. hippopus.

Maximum growth rates seen in the Philippines were 6.36 cm / yr for H. hippopus and 10.9 cm / yr for T. gigas (Calumpong, 1992; Gomez and Mingoa, 1993). On the Great Barrier Reef (GBR) a large natural cohort of T. gigas grew at a rate of about 6.54 cm / yr compared with cultured T. gigas which grew at a rate of about 5.54 cm / yr (Braley and Muir, 1995). Cultured T. gigas at inshore reefs in the GBR which have a higher silt loading have shown slower growth rates in terms of shell length (4.44 cm / yr) but growth in wet weight (3.35 kg / yr) that is similar to less silty sites (Aquasearch, unpublished data, 1997). The data on growth of cultured giant clams supports the use of maricultured clams for use in re-stocking (Braley and Muir, 1995; this paper).

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TABLE 1: Translocations of hatchery-reared quarantined tridacnid clams from the JCU hatchery (Orpheus Island) and results of survival and growth at different locations. C - Cook Islands; F - Fiji; P - Philippines; T - Tonga. Species are Tridacna gigas - Tg, and Hippopus hippopus - Hh.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Loca-tion | Clam species | Orig. # Clams | Spawn Date | Date Sent | # Clams 1997 | % survival | Aver.SL (cm) | Aver. WW (kg) |
| C | Tg | 11,000 | Dec-90 | Jun-91 | 400 | 3.64% | 39.7 cm | 13.6 kg |
| C | Hh | 20,000 | Jan-91 | Jun-91 | 27 | 0.13% | 18.8 cm | 1.65 kg |
| F | Tg | 500 | Oct-85 | Mar-87 | 102 | 19.90% | 80.0 cm | 45.0 kg |
| F | Hh | 25,000 | Jan-91 | Apr-91 | 9 | 0.04% | 17.0 cm | |
| P | Tg | 511 | Oct-85 | Feb-87 | 74 | 14.48% | 45-60 cm | |
| P | Tg | 7,000 | Nov-89 | Mar-90 | 36 | 0.51% | 45 cm | |
| P | Tg | 11,000 | Dec-90 | Feb-91 | 306 | 2.78% | 40 cm | |
| T | Tg | 11,000 | Dec-90 | Apr-91 | 500 | 4.54% | 44.9 cm | |
| T | Hh | 25,000 | Jan-91 | Apr-91 | 1,300 | 5.20% | 21.3 cm | 2.65 kg |

TABLE 2: Information on the survival of translocated clams from the ACIAR- JCU giant clam project to the Cook Islands and Tonga [Tonga information supplied by the Aquaculture Research and Development Follow-up Project - JICA). SON - Sopu Ocean Nursery; AVON - ‘Atata Village Ocean Nursery; KVON - Kolonga Village Ocean Nursery.

| Location | Tridacna gigas | Hippopus hippopus |
|---|---|---|
| Cook Islands | Oct.’91: 6,305 juveniles dead cumulative mortality; 42.7% survival 3.5 mo. after translocation.<br><br>Final overall survival of 3.6% by Jun’97 | Oct.’91: 1,625 juveniles dead cumulative mortality; 91.8% survival 3.5 mo. after translocation.<br><br>Final overall survival of 0.13% by Jun’97 |
| Tonga Islands | Dec.’91: 1,500 in protective cages (SON); 13.6% survival 8 mo. after translocation.<br><br>Mar.’93: 20 clams to patch reef AVON.<br><br>Nov.’93: 5 clams to sand flat KVON.<br><br>Apr.’97: 3 survived at AVON; 15% survival.<br><br>Jun.’97: 500 at SON; 33% survival from Dec.’91.<br><br>200 stolen; 13.3% mortality.<br><br>100 marketing study; 6.7% mortality.<br><br>Cyclone Kina ’93 caused major losses<br><br>Final overall survival 4.5% by Jun’97 | Jan.’92: 4,100 juveniles in protective cages sand flat; 16.4% survival 9 mo. after translocation.<br><br>May’93: 694 clams placed in seagrass bed (10m x 10m area).<br><br>Jun’97: 800 clams survived on sand flat; 23.5% from Jan.’92.<br><br>Jun.’97: 500 clams survived on seagrass bed; 72.0% from May’93.<br><br>Cyclone Kina ’93 caused major losses<br><br>Final overall survival 5.2% by Jun’97 |

TABLE 3:
Growth rates in cm / yr and kg / yr of translocated clams to various locations. C - Cook Islands; F - Fiji; P - Philippines; T - Tonga.

Tridacna gigas - Tg; Hippopus hippopus - Hh. Cohort date of spawning, e.g. Tg85 - T. gigas spawned 1985.

| Location | Tg85<br><br>140 mo.= 11.6 yr | Tg89<br><br>91 mo. = 7.6 yr | Tg90<br><br>79 mo. = 6.6 yr | Hh91<br><br>78 mo. = 6.5 yr |
|---|---|---|---|---|
| C | | | cm / yr<br><br>2.06 kg / yr | cm / yr<br><br>0.25 kg / yr |
| F | cm / yr<br><br>3.87 kg / yr | | | 2.62 cm / yr |
| P | 4.50 cm / yr | 5.93 cm / yr | 6.08 cm / yr | |
| T | | | 6.82 cm / yr | cm / yr<br><br>0.44 kg / yr |

TABLE 4: Notes on sexual maturity of translocated clams. For example, Tg85 = Tridacna gigas cohort from 1985 spawning.

| Location | Tridacna gigas | Hippopus hippopus |
|---|---|---|
| Cook Islands | | Jul. ’97: Spawning induction of Hh91 - sperm & eggs [male & female mature]<br><br>some f2 produced |
| Fiji | Aug.’96: Sunbaking induction of Tg85 - sperm only [male mature]<br><br>Mar.’97: Sunbaking induction of Tg85 - sperm only [male mature] | Sep.’86: Sunbaking induction of Hh91 - sperm only [male mature] |
| Philippines | Apr.’95: Sperm and eggs obtained [fully male & female mature]<br><br>some f2 produced but survival low | |
| Tonga | Jun.’97: immature | Jan.’97: sperm released<br><br>[male mature] |