AQUASEARCH

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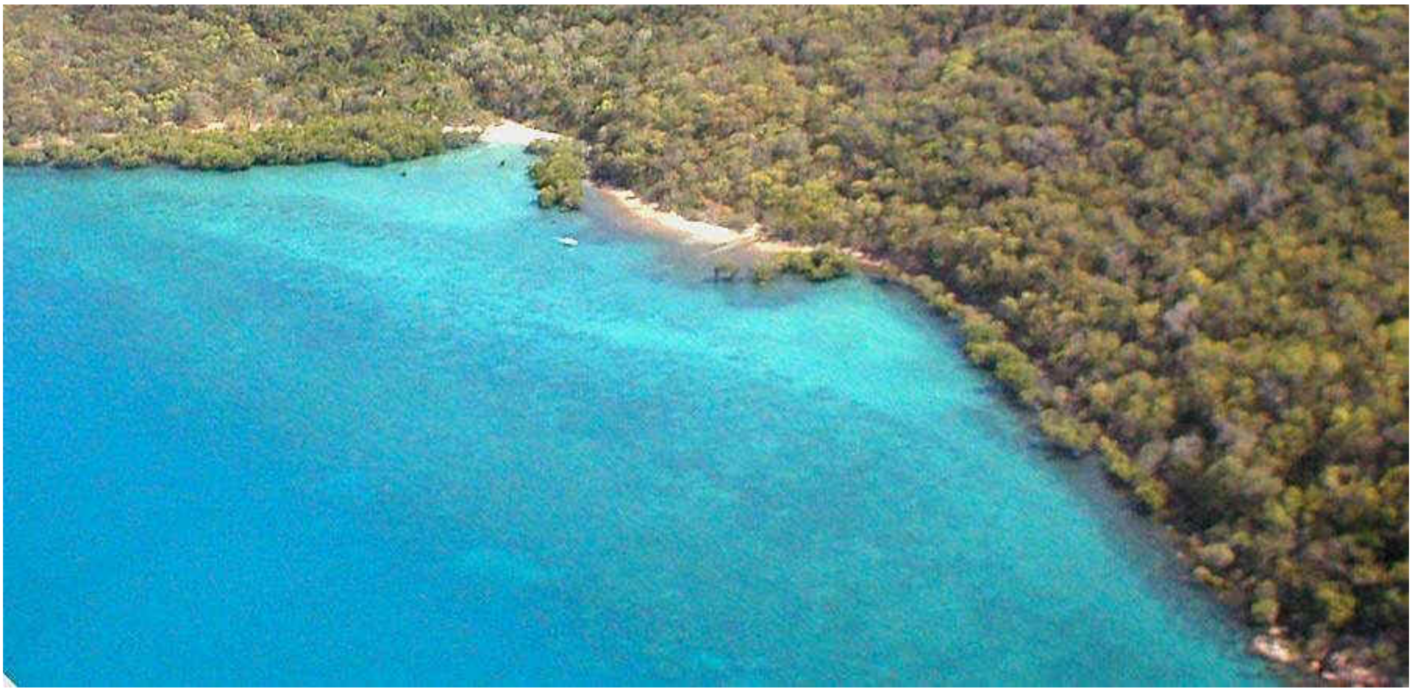
Long-Term Research on Giant Clams

The following report on Aquasearch's long-term research on giant clams was presented to the Great Barrier Reef Marine Park Authority in 1998. It details some of the research and results from 1993, and indeed, from the relocation of the clams in 1991-1992. Basically, the research sites were set up as mimics of natural high-density populations of Tridacna gigas and I have been monitoring the changes in the population over the long-term. In relation to genetics, it is my hypothesis that natural-high density populations are comprised of individuals which are somewhat closely related. Early observations on natural gamete release (see Coral Reefs paper in Dr. Rick Braley's CV, Consultancy section) indicate that 70% of gamete-releasing clams are within 9 meters of one another. When eggs are released and fertilised by other clams nearby, the developing embryos float together.

On those hot, calm summer days when there are 4-7 days similar in a row it is possible for the embryos to remain together and settle together. It is a well-known fact that bivalve mollusc larvae raft in the water of large larval culture tanks. The energy created by the circular swimming behaviour actually creates a whirlpool effect which retains the larvae as they float to their settlement destination. Given the larvae are competent to settle and there is a suitable settlement substrate, the successful settlement and subsequent metamorphosis may be high. After the clams grow to Escape size (size the predators do not easily kill them), which takes 3-4 years for T. gigas, they have a higher chance at surviving for many years.

The evidence of adult clams virtually touching one another in small groups of 2-10+ is the result of such successful settlements and the chance is good that the individuals in the cohort are more closely related to each other than the wider population on the GBR. Therefore, the mimics of natural high-density populations set up at Hazard Bay, Orpheus Island, and at White Lady Bay, Magnetic Island are a valuable tool for researching what happens within a giant clam population over time, being a known cohort derived from a small number of parents.



Giant clam research site, Palm Island Group, North Queensland, Australia

REPORT TO G.B.R.M.P.A. ON RESULTS OF RESEARCH DONE UNDER MARINE PARKS PERMIT NO. G92/137.

By Dr. Richard D. Braley, 7 September 1998

Summary of Field Work:

The sites where work has been done include:
General Use 'A' Zone - White Lady Bay, Oyster Bank No. 1503, Magnetic Island; a letter of agreement to hold these clams at the oyster bank was made between myself and the oyster farmer, Mr. R. Keith Bryson prior to obtaining this permit.

A general map of the bay is shown in Figure 1 (no figure for internet yet). Site A, Site B, and Site C are noted on this map. Site A includes all of the clams (Seafarm-reared cohort) shown in a detailed map which have been closely followed (Figure 2, no figure for internet yet). The tide flat area where these clams are located is exposed at a 0.5-0.6 m tide and although both live and dead coral are present, the growth of Sargassum macroalgae is not overwhelming. Site B includes about 60 clams in groups of 8-10 along 50 m of the reef flat and crest, and 21 clams currently held in the Aquasearch Laboratory recirculation system (all Seafarm-reared cohort).

This area is only exposed on a tide less than 0.4 m and in the summer season the growth of Sargassum macroalgae is very dense, reducing the light level reaching the clams. The highly turbid water made it difficult to give an exact count of live clams which have survived deeper on the reef front slope (completely subtidal) in front of the beach at White Lady Bay (Site C). The estimate is about 35 clams (Seafarm-reared cohort) still surviving at Site C. The numbers originally placed there had the poorest survival of clams translocated to Magnetic Island from Orpheus Island, because they were placed at depths of 4+ m. The light levels were reduced at this depth on turbid days and fine silty-mud bottoms were not ideal conditions. Likewise, at Site B the dense Sargassum would have contributed to mortalities of clams as light levels were greatly reduced. Also, the third trip made from Orpheus Island took longer than the first two translocations and this contributed to mortalities from the translocation process alone. The following translocation trips and numbers of clams were made from Orpheus Island (Pioneer Bay) to White Lady Bay under Marine Parks Permits G90 / 498 and G92 / 137:

Date of translocation	No. of clams	Vessel used	Mortality	Survival to Site of placement	Species	Trip time
December 1990	144 /	Challenger III	1	134 (93%) Site A	T. gigas	3 hr
30 March 1991	240 /	Coral Supplies	8	81 (33.7%) Site B & few Site A	T. gigas	
	12 / 0	N.Q. Boat	4	(33.3%)	H.hippopus	
16 April 1992	176 /	Warripa - Warrum Katamaran	4	35 (20%) Site C	T. gigas	
				Total 250 (44.6%)		

The clams which were monitored continuously over the period of this permit are those at Site A. Tagged individuals had shell lengths, wet weights, mantle colouration patterns, mantle bleaching and other details recorded over a number of measurement periods. The tide flat area where these clams are located is exposed at a 0.5-0.6 m tide and behind a rock wall built many years ago by Mr. R. Keith Bryson, long-time oyster farmer at White Lady Bay. The rock wall faces the northerly direction and helps to reduce the effect of ground swells coming in toward the White Lady Bay beach. This is the most suitable depth for these phototrophic clams at White Lady Bay.

General Use 'B' Zone - Casement Bay, Oyster Bank No. 1525, Great Palm Island; a letter of agreement to hold these clams at the oyster bank was made between the oyster farmer and I, Mr. Tyronne Yasserie prior to obtaining this permit.

A general map of the area on Great Palm Island and the general location within Casement Bay is shown in Figure 3 (no figure on internet yet). Four hundred of my original Seafarm-reared clams were translocated to a low tidal area in the approximate centre of Casement Bay, Palm Island from Pioneer Bay, Orpheus Island under Marine Parks Permits G90 / 498 and G92 / 137. The details are as follows:

Date of translocation Site of placement	No. of clams/ Species	Vessel used; Trip time	Mortality from trip	Survival to date of group
December 1990	144 /	Challenger III	1	134 (93%)
Site A	T. gigas	3 hr		
30 March 1991	240 /	Coral Supplies	8	81 (33.7%)
Site B & few Site A	T. gigas	N.Q. boat		
	12 /		0	4 (33.3%)
	H. hippopus			
16 April 1992	176 /	Warripa – Warrum	4	35 (20%)
Site C	T. gigas	Katamaran		

Total: 250 (44.6%)

I visited the site with Mr. Yasserie twice in 1991 and the clams were found to be growing well. I was gone in 1992 and most of 1993 on consultancy contracts in Indonesia. In latter 1993 I attempted to contact Mr. Yasserie regarding the clams, but had not reply, and, in fact, had the phone cut off when I identified myself. Through the grapevine I heard that the clams had been stolen by islanders. This is a most unfortunate situation as the potential of the site was high. I invested a large proportion of the Seafarm-reared cohort of T. gigas that had been allotted to myself at the end of the JCU-ACIAR Giant Clam Project at this site with the hope of assisting and collaborating with the residents of Palm Island. This has ended in failure with the loss of these clams which are valuable to me.

3. Marine National Park 'A' Zone - Hazard Bay (Orpheus Island)

Six hundred of my original Seafarm-reared clams were translocated from Pioneer Bay, Orpheus Island to a sub-tidal area at the northern side of Hazard Bay, Orpheus Island under Marine Parks Permits G90 / 498 and G92 / 137. The location of the site is shown in Figure 4 (no figure on internet). It is a 1 ha site near the edge of the reef front which has numerous massive coral bommies rising up around a sand bottom. The clams were placed on the sand bottom between bommies where they would cause no problem to existing corals and where they have the greatest protection in seas coming from the south or southeast. Figure 5 (no figure on internet) shows more detail on the distribution of the clams in the permitted area. The translocation details from Pioneer Bay to Hazard Bay are as follows:

Date of translocation Site of placement	No. of clams/ Species	Vessel used; Trip time	Mortality from trip	Survival to date of group
December '90 - March '91	480	JCU Barge	0	See below
June 1991	100	JCU Dingy	0	See below
April 1992	20	JCU Dingy	0	See below

Total clams: 568 (94.6%)

It should be noted that the Orpheus Island Resort in Hazard Bay has been using the site for a glass-bottom boat tour and for snorkelling to view the clams since the early 1990s. I discussed the value of these visits to the site with the former manager, Mr. Tony Spilsbry, and with the new manager (as of early 1998) Mr. Rod Black. Regular visits by the beach boy staff accompanying guests helps to check on condition of the clams. Likewise, the visitors can see a high density of giant clams living under near optimum conditions, and in summer months release of gametes may be observed.

Permit No. 92 / 137 included the relocation of 200 clams of the species T. gigas from Hazard Bay, Orpheus Island, to Oyster Bank 1503, White Lady Bay, Magnetic Island. This was never carried out, because Aquasearch has been attempting to find an alternative site on Magnetic Island where these clams and specimens of cohorts from the publicly-funded JCU-ACIAR giant clam project (at Pioneer Bay) could be moved to so that in the event of a destructive cyclone all the clams would not be lost by being at the same site, facing the same direction to sea. Initially, a research site was applied for behind the minor breakwater wall, Magnetic Quays project (Nelly Bay Harbour project), but this became enmeshed in red tape. In May of 1996 Aquasearch applied for a 1 ha. research site at Picnic Bay, Magnetic Island (Gen. Use A), alongside Hawkings Point. Public advertising was carried out in July and August 1997 without comment. Again, red tape dominated. Finally, in mid-June 1998 the Great Barrier Reef Aquarium together with Aquasearch applied for commercial use of the same site in Picnic Bay for giant clam culture and coral culture. The site at Picnic Bay would include depths similar to White Lady Bay sites A and B, but shallower than C. There is protection from southeasterly winds just behind Hawkings Point and as the area where the clams would be placed is mostly sand and silt there is no Sargassum to cover the clams and reduce the light level as is common at White Lady Bay (especially sites B and C).

4. Marine National Park 'B' Zone - Pioneer Bay (Orpheus Island)

Figure 6 (no figure on internet) shows an updated map of the giant clam growout area in the northern end of Pioneer Bay, Orpheus Island, near to James Cook University's (JCU) Orpheus Island Research Station. This map was drawn by myself on 26 July 1998 following a 1-week consultancy I carried out for JCU to select and tag samples of known spawning cohorts. Counts were made of known spawning cohorts remaining within pens and one of the old exclosures. Mixed cohorts from other exclosures and culture areas were not counted. Permit No. 92 / 137 included the relocation of 300 clams of the species T. gigas and H. hippopus from Pioneer Bay, Orpheus Island. These were to be samples taken from various known spawning cohorts for use in a proper animal husbandry breeding program.

Prior to the short consultancy with JCU, I had a discussion with Professor John S. Lucas (Zoology Dept., JCU), former leader of the JCU-ACIAR Giant Clam Project. Prof. Lucas offered for me to tag five (5) clam specimens from each of the known spawning cohorts for translocation to Magnetic Island and for potential use by Aquasearch as f1 breeding stock (see letter in Appendix 1; no letter on internet). Thirty (30) clam specimens from each of the known spawning cohorts were also tagged for potential use by JCU as f1 breeding stock and to be left at Orpheus Island. The selection and tagging program was accomplished during the low tides in July prior to the proposed sale of the remainder of the clams at Orpheus Island. Therefore, the 300 clams indicated for translocation to Magnetic Island from Pioneer Bay under the current permit have been reduced by agreement with Prof. Lucas to 5 x 6 cohorts T. gigas = 30 T. gigas and 5 x 2 cohorts H. hippopus = 10 H. hippopus. This modification will be requested in the new permit application being submitted along with this report. It is hoped that these clams will be able to be moved to either Picnic Bay (if this site is granted approval), White Lady Bay, or direct to the Aquasearch seawater recirculation laboratory.

Some results of the on-going research

It is important to state the long-term nature of this work. Giant clams are long-lived invertebrates. During my PhD research in the early - mid-1980s I found that in high-density natural populations of T. gigas where I took monthly gonad biopsies on the same individuals, release of eggs did not occur every austral summer spawning season though release of sperm was more common. Regression and resorption of gametes occurred when spawning did not take place. The clam can ‘wait’ until the right conditions (or triggers) develop for release of eggs because they live for many many seasons. Another example during my years of research on giant clams was the major mortality that affected 50% of the standing stock population in and around Lizard Island lagoon in the winter of 1985. Normal mortality levels are about 1-2% of the standing stock per year, while recruitment is also about 1-2% of the standing stock per year. In the case at Lizard Island a major recruitment (about 50% of the former standing stock prior to the mortality) was found to have occurred in the summer breeding season following that major mortality of winter 1985. If a population were not followed over a long period, it would not be possible to understand the population dynamics and reproductive strategy of this endangered species.

Growth and survival of clams at several sites

The several sites where the clams are located show differing conditions of water turbidity, shading from macroalgae (Sargassum), crowding, and protection from direct wave action. That the clams continue to grow under all these conditions attests to the hardiness of this species, but variations in the growth and survival indicate the most suitable conditions. The average size of T. gigas (Seafarm-reared cohort spawned January 1986) at the several sites at the time translocation of clams began (late September 1990) was 26.5 cm shell length. The Seafarm-reared cohort at Pioneer Bay averaged 30 cm shell length by mid-March 1991. Table 1 compares growth and survival of this cohort at Pioneer Bay, Hazard Bay and White Lady Bay.

TABLE 1:
Mean size in shell length (SL in cm) and survival of the Seafarm-reared cohort of Tridacna gigas (January 1986) at 3 sites: Pioneer Bay (Orpheus Island), Hazard Bay (Orpheus Island); White Lady Bay-Site A (Magnetic Island). Wet weight (kg) shown for White Lady Bay clams

Date	**Pioneer Bay** SL-cm / % Survival	**Hazard Bay** SL-cm / % Survival	**White Lady Bay** SL-cm / % Survival
		[wet wt. in kg]	
24.7.94			42.4±1.7 / 97.9
13.12.94	38.9±3.5 /?	45.1±4.1 / 98.8	
14.3.96		49.6±3.3 / 96.6	
26.3.96	43.4±3.3 /?		
14.10.97			51.0±5.1 / 97.2
			[38.6±5.9]
29.4.98			54.4±3.6 / 92.4
			[40.6±5.9]
21.7.98	51.1±3.7 /?	58.0±3.8 / 94.6	
Overall growth in cm / yr. from 9.90			
	3.3	3.9	3.5

The T. gigas from this Seafarm-reared cohort had the highest growth rates and survival at Hazard Bay, Orpheus Island at a subtidal site on sand surrounded by massive coral bommies. They were 13.5% larger in SL than the Pioneer Bay group of the cohort. The White Lady Bay clams had already been measured 3 months prior to this final measurement so would have increased in SL during this time but using the data the White Lady Bay group of the cohort was 6.4% larger in SL than the Pioneer Bay group of the cohort. Survival was not recorded at the Pioneer Bay site because a large number of clams was crowded into a penned area perhaps 15m x 15m. In 1996 a count estimate of 596 was made for the Seafarm-reared cohort pen and in the current map (Figure 6; no figure on internet) an estimate of 450 clams were counted. This indicates a 24.5% mortality. It is not known if some clam specimens were taken for research purposes by JCU students between the two count estimates. The first count estimate may have been high and the recent estimate low, but clearly there has been a significant reduction in numbers of clams from this pen. The survival would be considerably lower than the very high survival seen at both Hazard Bay, Orpheus Island and White Lady Bay - Site A, Magnetic Island. The hardiness of this animal is shown by the overall growth rate annually from the start of the translocations. Even the poorest growth (Pioneer Bay) is over 3.0 cm / yr shell length increase.

Colouration Pattern of the Mantle

The four colour patterns recognised were:

Colour 1: Light to medium brown mantle.

Colour 2: Dark brown mantle.

Colour 3: Colour 1 background mantle with smaller patches or edges in colour 2.

Colour 4: Colour 2 background mantle with smaller patches or edges in colour 1.

Table 2 presents the percentage of the 4 colour patterns in the groups of cohorts at Pioneer Bay, Hazard Bay and White Lady Bay.

TABLE 2:
Percent colouration patterns recorded from the mantles of T. gigas at three locations: Pioneer Bay, Orpheus Island; Hazard Bay, Orpheus Island; White Lady Bay - Site A, Magnetic Island.

Location/Date	Pattern 1	Pattern 2	Pattern 3	Pattern 4
Pioneer Bay				
21.7.98	60%	20%	20%	0%
Hazard Bay				
13.12.94	45.1%	6.2%	31.5%	17.1%
14.3.96	28.6%	18.1%	40.0%	13.3%
21.7.98	53.6%	11.0%	28.2%	7.2%
White Lady Bay				
--.11.95	50.0%	5.8%	51.0%	7.2%
14.10.97	56.6%	7.5%	30.2%	5.7%
15.4-7.5.98	46.2%	17.6%	24.2%	12.1%

At the White Lady Bay site, the changes in colouration pattern was observed in the tagged clams from the initial count. At the 14.10.97 count 19.8% of the clams had changed colouration patterns and at the last count (15.4-7.5.98) there had been a 37.4% change in colouration patterns. The bleaching event (discussed below) may have been one of the factors causing a higher percentage change in colouration patterns during this period. Further work is being done on details of the mantle colouration changes and this could be followed for some years yet before publishing.

Bleaching event

The record rainfall in January followed by the warm water mass that entered the Great Barrier Reef lagoon in February appeared to be the major factors which caused widespread coral bleaching. Likewise, bleaching in giant clams (particularly, T. gigas) was observed in all of the beds of f1 cultured clams both at Orpheus Island and Magnetic Island. James Cook University researchers suggested that bleaching affected over 50% of the clams on the Pioneer Bay reef flat growout area. Aquasearch clams held at White Lady Bay, Magnetic Island, were also observed to have bleached. An American student with the SIT (School for International Training), Mr. Paul Seilo, carried out a project under my supervision which help to collect baseline data on this unique bleaching event amongst the clams at White Lady Bay. In his report to SIT he found 29.3% of the T. gigas at the White Lady Bay - Site A had bleached to various degrees. Of the individuals affected 16 had bleaching covering 50% + on the mantle and over the period of this short study seven individuals of this group died.

At Site B and C 25% of the clams had bleached. About 34% of the clams were bleached in the 10.85 cohort of T. gigas belonging to James Cook University at White Lady Bay. These have been held in boxes near the base of the beach. The bleached clams at Site A it was found to recover from the bleaching differently. During the same time period, some clams slowly recovered, others completely recovered, some began to recover and then regressed again, and a few clams remained with highly bleached mantles prior to dying. No significant difference was found (1-way ANOVA) in average amount of mantle bleached between shell length classes. Varying levels of wet weight did affect the average amount of mantle bleached ($p = 0.0062$; 1-way ANOVA). Looking at patterns of zooxanthellae return, there was no pattern found. Rather, random blotches on both mantle edge and centre of mantle was the result observed. There did not appear to be a significant difference in bleaching between mantle colouration patterns. Samples of mantle from colouration patterns 1 and 2 were taken for laboratory analysis of numbers of zooxanthellae. There was no apparent difference between zooxanthellae densities and these colouration patterns. Final recovery of all the bleached clams needs to be documented as well as future documentation of whether these bleached clams are more likely to bleach in future compared to those that did not bleach this time. This will take years of observation to better understand.

Reproductive maturity

Tridacna gigas, a hermaphroditic bivalve, reaches male-phase maturity at about 4-5 years of age, but the female-phase is not reached until about 9-10 years old. Clams were checked by using the hypodermic extraction method into the gonadal area, a method developed by myself during my PhD study in the early to mid-1980s. Samples were taken from Seafarm-reared clams (spawning date January 1986) at Pioneer Bay and Hazard Bay, Orpheus Island in December 1994 and in March 1996. Table 3 below shows the results of microscopic analysis of the collected gonad biopsy samples.

TABLE 3:
Results of microscopic analysis of gonad biopsy samples taken from f1 Tridacna gigas, Seafarm-reared cohort from January 1986.

Date / Site	% with Sperm	% with Eggs	% non-descript
15.12.94 / Hazard Bay	50%	0%	50%
15.12.94 / Pioneer Bay	70%	0%	30%
14.3.96 / Hazard Bay	85%	30%	15%
14.3.96 / Pioneer Bay	80%	27%	20%

Thus, at almost 9 years of age, this cohort of T. gigas had not yet developed the female-phase of reproductive maturity. In the Philippines, a February 1985 cohort of T. gigas translocated from the Orpheus Island hatchery reached female-phase reproductive maturity in 9 years. By March 1996 (10 yr. 2 mo. of age) the clams of this January 1986 cohort had reached female-phase reproductive maturity with about 30% of the clams showing eggs in the biopsy samples.