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Inside this issue

Editorial

It was wonderful to visit Noumea, New Caledonia again. I wish to express my sincere thanks to Barney Smith, ACIAR, and Dr Tim Adams, SPC, for inviting me to the SPC-ACIAR Aquaculture Workshop (Friday 20–Saturday 21 July 2001) followed by the 2nd SPC Heads of Fisheries meeting (23–27 July 2001).

The visit to Noumea was a wonderful opportunity to establish contact and meet many people from the Pacific nations and elsewhere that I had heard of, interacted with by mail or email, and finally putting a face to many of the names. To all my new 'mates' may I say, 'keep in touch' with news and articles on trochus and related molluscs aquaculture / fisheries activities from your countries.

While in Noumea, Aymeric Desurmont and Jean-Paul Gaudechoux (SPC Fisheries Information Specialist and Adviser) and myself took the opportunity to hold an *ad hoc* meeting to discuss the future of the *SPC Trochus Bulletin* and determine methods of improving the services of the bulletin to our readers. We shared the view that a single species bulletin has limited potential. In addition, the current level of research and news on trochus in the Indo-Pacific region is making it difficult to have regular issues. Some readers may have noticed that the time taken to produce *Trochus Bulletins* 5 and 6 was over two years and the latest bulletin, No 7, was printed some 12 months after No 6. Similarly this issue of the bulletin, No 8, has taken about 10 months although I hope to be able to get the next one out as early as July 2002.

To keep readers interested, I believe it would be good to have at least 2–3 issues published every year. For this to happen, I

MARINE RESOURCES DIVISION – INFORMATION SECTION

am of the view that the *SPC Trochus Bulletin* should be broadened and changed into a multi-species bulletin with the proposed name changed to *SPC Molluscs (non-pearl) Bulletin,* keeping trochus as the 'anchoring' species. I believe the new title for the bulletin is the way for the future and the SPC Fisheries Information Section is in agreement.

Dear readers, it is your bulletin. I would like to hear your views on the proposed change to widen the scope and relevance of the *Trochus Bulletin* to the Indo-Pacific communities. All readers who are not keen on this change kindly send me their comments and views by the end of March 2002. If there is no opposition to the proposal, I will seek approval from Dr Tim Adams, SPC Marine Resources Director to change the title of the bulletin.

I look forward to hearing and receiving some interesting contributions to the *SPC Mollusc (non-pearl) Bulletin No. 9* from all of you.

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PS: This bulletin, as well as several other SPC Marine Resources Division publications, is available on SPC Website at: www.spc.int/coastfish

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The Torres Strait trochus fishery

Dallas D'Silva[1]

Brief history

The Torres Strait trochus (*Trochus niloticus*) fishery is a small, single-species commercial and subsistence fishery, which is an important source of income for some islanders, especially women and children.

Although trochus has been fished for subsistence purposes for centuries, it is only since the early 1900s that this tropical marine snail was commercially harvested. The commercial harvest of trochus shell began in to 1912 when trial shipments were sent from Torres Strait reefs to Japan, the United Kingdom and Europe. Within three years the annual catch was nearly 970 tonnes and by the 1920s the trochus fishery had spread south to new grounds along the east coast of Queensland, as far south as Mackay (Nash 1985).

Exported shell was used primarily in the manufacture of buttons and jewellery. The fishery continued until the mid-1950s but collapsed when plastics superseded natural shell products in the manufacture of buttons. The fishery experienced a boom in the late 1970s and early 1980s when renewed market demands from the fashion houses of Europe once again adopted the use of natural buttons on their shirts (Nash 1986).

Current fishery trends

Trochus is usually taken by free diving, although SCUBA and hookah may also be used. Fishers typically operate from dories/dinghies crewed by two to three Islanders. Reef top collection of trochus is possible at low tide.

Fishery participants comprise Australian traditional inhabitants only and there are approximately 47 Torres Strait Islander dinghies licensed to commercially fish for trochus in Torres Strait.

Participation in the fishery is relatively low at present, due largely to a recent decline in overseas market demand. Effort in the fishery, as with the adjacent fishery on the east coast of Queensland, is strongly influenced by market forces. Additionally, other fisheries, such as tropical rock lobster and sea cucumber, remain relatively more profitable for Torres Strait Islanders at this time.

While present activity in the fishery is relatively low compared with historic levels, small catches continue to be taken from the central and eastern islands. An unknown but relatively small quantity may also be taken by islanders for subsistence purposes.

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Records held by the prime mother-ship transporting trochus shell out of Torres Strait indicate approximate catches in 1999 of about 24 tonnes. Log returns from individual islands indicate that the commercial catch of trochus during 1998 was also relatively small at 1.8 tonnes. The 1997 catch was 17 tonnes, with a value of approximately AUD 0.1 million. The total catch for 1996 was 9.35 tonnes.

Management arrangements

Commercial and traditional fishing within the Australian section of the Torres Strait Protected Zone (TSPZ) is managed by the Protected Zone Joint Authority (PZJA) under the Commonwealth Torres Strait Fisheries Act 1984 (Fig. 1). The PZJA comprises the Commonwealth and Queensland Ministers responsible for fisheries. Fisheries resources of the TSPZ are managed in accordance with the provisions of the Torres Strait Treaty, ratified in 1985. The Treaty requires Australia and Papua New Guinea to cooperate in the conservation, management and optimum utilisation of resources of the region primarily for the benefit of traditional inhabitants of the two countries.

Management and licensing tasks are administered by the Australian Fisheries Management Authority and the Queensland Fisheries Service based out of Thursday Island and Brisbane. The Queensland Boating and Fisheries Patrol perform surveillance and enforcement duties on Thursday Island.

Participation in the Torres Strait trochus fishery is limited to traditional inhabitants. This fishery, as all other Torres Strait fisheries, has a policy that scopes for an increase in fishing effort — where there is latitude for such an increase — and is reserved exclusively for Torres Strait Islanders.

Management objectives

The objectives adopted for the Torres Strait Trochus Fishery are to:

- manage the resource so as to achieve optimum utilisation;
- maximise opportunities for traditional inhabitants of Australia; and
- encourage traditional inhabitants of the Torres Strait to participate in the trochus fishery.

Management regulations

A minimum and maximum size limit (8–12.5 cm) applies to trochus (except traditional fishing) and this is the most widely used management tool used throughout trochus fisheries. The minimum size limit is considered effective in protecting small trochus and allows individual trochus to spawn once before capture. Size at first maturity for trochus in the Great Barrier Reef Region has been found to be 5.5–6.5 cm. Therefore this limit is considered effective in preventing overfishing.

A maximum size limit also applies in recognition that larger trochus make a major contribution to egg production. However, the effectiveness of the upper size limit in protecting the breeding stock has been questioned, primarily because trochus larger than the upper size limit will sooner or later die of old age, disease or predation (King 1995). Additionally, once these individuals have died, the upper limit will continue to protect large, reproductive animals only if fishing pressure on the fraction of the population in the legal size range (8–12.5 cm) is light enough to allow an adequate proportion of the population to grow beyond the upper size limit. Nonetheless, from an economic perspective, the maximum size limit is useful in maintaining a high quality of marketed shell.

Trochus harvesting is restricted to hand collection or by hand-held, non-mechanical implements; the use of underwater breathing apparatus is permitted. An annual total allowable catch (TAC) of 150 tonnes also applies in the fishery.

Condition of the fishery

No specific stock assessment work has been carried out in Torres Strait to determine the size of the standing stock and rates of recruitment into the stock. The status of trochus stocks in Torres Strait is uncertain. There is also little, if any, reliable catch per unit effort information for the fishery in Torres Strait and sustainable yield estimates for the fishery must therefore incorporate a high level of uncertainty in their assessment.

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Successful cage design for intermediate culture of trochus for restocking

Steven W. Purcell[1]

Abstract

A new design for reef-based cages for the intermediate monoculture of juvenile trochus, using an aluminium frame and plastic mesh, was tested at two locations in Western Australia. The design proved to be much improved from previous cage types, providing high survivorship and no escape of juveniles. The robust cages are inexpensive, easy to construct and allow hatchery-produced juveniles as small as 12 mm to be advanced to sub-adult size for restocking.

Introduction

Trochus restocking projects in the past decade have used different approaches for advancing hatchery-produced juveniles to adulthood on reefs for replenishing stocks. The simplest of these, seeding of small juveniles from the hatchery, has had varied success. A recent ACIAR project (see Purcell and Lee 2001) has shown that releasing small (1-4 mm) juveniles can enhance stocks, but modifications are needed to improve survivorship. Intermediate culture in sea cages is a further approach, aiming to grow trochus to a larger size before seeding.

Survival of trochus released onto reefs is higher for large juveniles than for small ones (Castell 1996; T. Crowe, unpubl. data). Predation experiments conducted by Vermeij (1976) and Dobson (2000) show that reef crabs cannot kill trochus juveniles larger than 25-40 mm. Trochus also appear to gain a size refuge from gape-limited predators, like wrasses (e.g. *Choerodon* sp.), triggerfishes and pufferfishes (Order: Tetraodontiformes).

Intermediate culture of trochus in sea cages has proven to be a viable way to advance small, hatchery-produced animals to a 'sub-adult' size of 40 mm for restocking. In Solomon Islands, Clarke et al. (in review) successfully grew juvenile trochus to >40 mm in sea cages with giant clams, achieving high growth and survival. Amos and Purcell (in review) showed that juvenile trochus could also be mono-cultured in high numbers to 40 mm in reef-based cages in Vanuatu. However, for this latter work, deficiencies in cage materials allowed entry of predators and escapement of juveniles.

In the present study, a new, robust cage design was developed to minimise mortality and escape of trochus, while allowing high numbers of juveniles to reach sub-adult size. Repeated monitoring of caged juveniles in trials, conducted at two sites for up to 10 months, suggests that this design is optimal for monoculture of trochus for restocking.

Materials and methods

Two sites were selected for the caging trials: Bowlan reef, near the One Arm Point community, King Sound, and Middle Lagoon on the west coast of Dampier Peninsula in northern Western Australia (see map in Purcell and Lee 2001). The sites were selected on the basis of their habitat suitability and proximity to Aboriginal communities that expressed interest in cage culture.

Bowlan reef is a large, biogenic coral reef, probably with a significant contribution of the reef matrix built by coralline algae. It has an intertidal zone covered mainly by short macro-algae and experiences strong currents (5 to 10 knots) during every spring tidal cycle. The reef at Middle Lagoon is a sandstone, platform reef with an intertidal zone covered in short algae and experiences high wave energy on its reef crest.

The new cages designed for the trials were 0.93 m x 0.93 m x 0.15 m in size and made with a frame of angle aluminium, fastened by rivets. The

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walls, floor and roof were made of pieces of 8 mm x 8 mm plastic mesh (oystermesh) that were fastened to the frame using plastic cable ties. A separate, hinged lid was made for each cage to cover one quarter of the roof and allow access of workers to trochus and substrates (Fig. 1). Each cage costs about AUD 40.00 in materials and takes about three hours to construct, using simple tools.

Cages (*n* = 3) were placed on the intertidal zone on Bowlan reef, approximately 30 m behind the sub-tidal coral zone (Fig. 2), and on the intertidal reef flat at Middle Lagoon reef, approximately 30 m behind the reef crest. The cages were secured to the reef with roofing spikes and galvanised wire, fastened to each corner and centre-bar. Approximately 15 litres of coral rubble was placed into each cage; enough to cover the cage floor. Epilithic algae covering the coral rubble provide a productive food source for the juvenile trochus. Larger pieces of coral rock, covered in algae, were also put into cages at Middle Lagoon after one month.

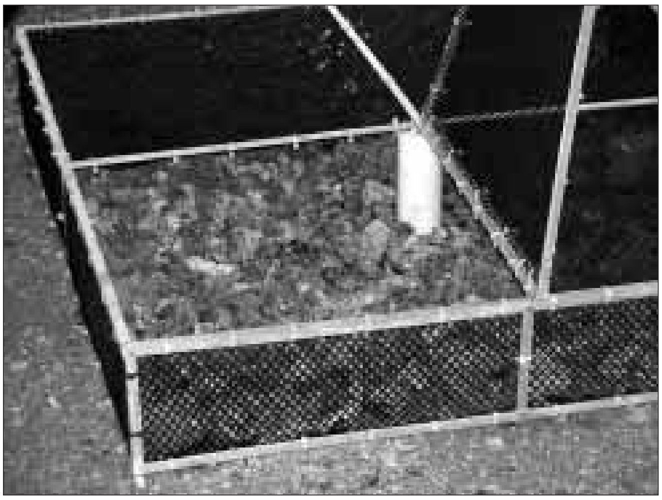

Figure 1. Cage with lid up and bottom covered with a layer of coral rubble with algae.

Juvenile trochus were produced at a pilot hatchery at One Arm Point, north of Broome, Western Australia. The initial size of the hatchery-cultured juveniles ranged from 12 to 20 mm, which is smaller than juveniles caged in Vanuatu (Amos and Purcell, in review) or Solomon Islands (Clarke et al., in review).

Figure 2. The three cages at Bowlan reef, near the sub-tidal zone at incoming tide.

The cage grow-out trial was initiated on Bowlan reef on 3 July 2000 and at Middle Lagoon Reef on 1 August 2000. Juveniles were individually tagged with plastic tags (Hallprint, FPN shellfish tags, 8 mm x 4 mm) attached to the outer whorl with cyanoacrylate glue (Loctite #454) (Fig. 3). Juveniles were measured to the nearest mm with vernier callipers and averaged 15.12 mm (± 0.12 SE; *n* = 75). They were transported to cages on the reef in small containers lined with damp paper towel. A total of 25 juveniles were placed into each cage, equating to a density of 30 juveniles m^{-2}, as suggested by Amos and Purcell (in review). After one month, additional tagged and measured juveniles were placed into cages to replace dead animals, but this was not done on subsequent occasions.

Figure 3. Tagged juvenile trochus next to callipers, prior to placing into cages.

Monitoring occurred after approximately 1, 3, 6 and 9 months from commencement of the trials. Each time, the cages were opened, the basal shell width of live trochus in cages was re-measured, and any dead or escaped trochus recorded. Coral rubble and rock accumulated around the walls outside the cages were removed to mitigate decreased water movement and sediment build-up inside cages.

Results

For both sites, growth rates for juveniles over the initial two time periods averaged about 2 mm month-1 (Table 1). At Middle Lagoon, one cage was accidentally pulled off the reef at high tide by a tourist's anchor during the first month and the remaining two cages were swept off the reef by a passing cyclone after five months.

Growth of juvenile trochus during the first month at Middle Lagoon Reef was markedly lower than at Bowlan Reef (Fig. 4), but subsequently was comparable over the following time period. The low initial growth at Middle Lagoon Reef was thought to be due to piling of rubble in the cages and low algal biomass on the rubble. The addition of larger pieces of coral rock in the cages appeared to rectify the problem and brought average growth rates to comparable levels (Table 1). On Bowlan reef where cages were not damaged, juvenile shell growth slowed through time and was low in the final period of intermediate culture (Fig. 4; Table 1). Two important findings were the low rates of mortality and escape (Table 1).

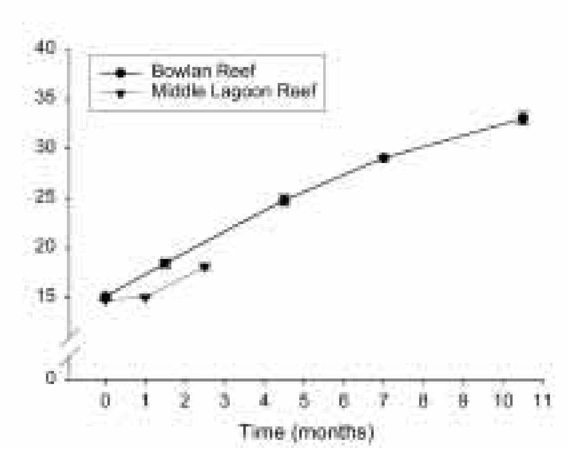

Figure 4. **Line plot of mean growth of juvenile trochus in cages at Bowlan Reef and Middle Lagoon Reef. Points are mean shell diameter of trochus from mean sizes in the replicate cages ± SE.**

At the end of the 10.5-month culture period, the cages on Bowlan reef were in very good condition and could have been used immediately for a repeat culture cycle of trochus. After the culture period of 10.5 months, the trochus (*n* = 80) were released at two sites on nearby reefs with depleted trochus stocks. The animals ranged in size from 29 to 39 mm, with an average of 33 mm.

Conclusions

The trials showed that the design of the new cages solved the problems of escape of juvenile trochus and entry of predators, encountered with the two cage types used in Vanuatu (Amos and Purcell, in review), and allowed juveniles to reach a sub-adult size for restocking. The cages proved to be highly durable and reusable, with an expected life span of at least three years, allowing repeated culture cycles of trochus. However, it is difficult to make cages that are anchor- and cyclone-proof. The damage to cages at Middle Lagoon indicates that future cage culture in cyclone-affected regions should be conducted on semi-sheltered reefs. Further, on reefs frequented by tourists, the sites should be marked and tourists informed of the location of cages.

The growth rates shown for both sites were lower than growth rates for juveniles at similar stocking densities in reef-based cages in Vanuatu (2.6 mm month-1; Amos and Purcell, in review) or Solomon Islands (3.3 mm month-1; Clarke et al., in review). I attribute this result to poor food supply

Table 1. **Summary statistics for rates of mortality, escape and shell growth of juvenile trochus in cages at the two sites. Means and standard errors (SE) are calculated from cage means.**

Site	Time (months)	Mortality rate[1]	Escape rate[2]	Growth rate[3]	*n*
Bowlan Reef	1.5	13.1 (± 4.6)	0	2.3 (± 0.5)	3
	4.5	1.9 (± 1.9)	0	2.1 (± 0.2)	3
	7.0	0	0	1.8 (± 0.3)	3
	10.5	0.7 (± 0.4)	0	1.3 (± 0.2)	3
Middle Lagoon Reef	1.0	3.6 (± 3.6)	0	0.2 (± 0.1)	3
	2.5	2.9 (± 0.1)	0	2.0 (± 0.1)	2

1. Mortality rate: % deaths • month^{-1} ± SE
2. Escape rate: % escaped • month^{-1} ± SE
3. Growth rate: mm • month^{-1} ± SE

because algae on the rubble substrates appeared to be kept at a very low biomass. Future trials should use pieces of coral rock, with established algae, that are large enough to avoid being piled up on one side of the cage and won't be easily covered by sand. Pieces of coral rock with high surface area and minimum weight should be chosen.

In the 10.5-month trial of cage culture on Bowlan reef, the cages were checked and cleaned once by members of the One Arm Point aboriginal community. Conditions on the reef, such as strong tidal currents or intense grazing by herbivores, prevented the cage mesh from becoming fouled by algae. In other regions, this may not be the case and reef-based cages are likely to require cleaning every two weeks. Provided that indigenous communities are committed to husbandry practices, intermediate culture in sea cages of the type presented here can be an effective approach for progressing juvenile trochus from the hatchery to the reef for stock replenishment. This approach is particularly suited for situations where stocks on neighbouring reefs are too low to justify collecting and translocating broodstock to depleted reefs.

Acknowledgements

I wish to thank J. Colquhoun for helping to construct cages and collect data. Field assistance was also given by D. Ah-Choo, M. Baer, J. Fong, P. Moore, K. Mortimer, and B. Sharpe. This project was supported by funding from ACIAR to the Department of Fisheries, Western Australia with Dr Chan L. Lee as the project coordinator.

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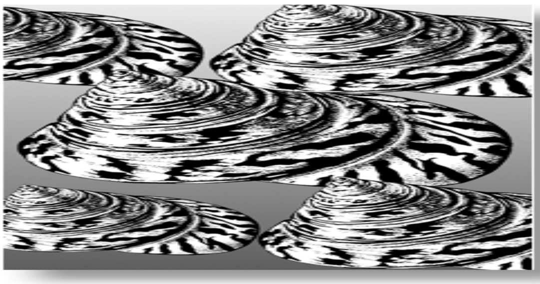

Notes on trochus in Pohnpei

R.D. Gillett[1] and J.P. Gaudechoux[2]

Trochus does not occur naturally in Pohnpei. As in many other parts of Micronesia, trochus was transplanted by the Japanese to these areas between the two World Wars. Table 1 shows the transplants to Pohnpei as recorded from available documentation. Table 2 shows that Pohnpei Island has also been the source of trochus for transplants to other islands in Pohnpei State.

The management regime for trochus in Pohnpei has usually consisted of closed seasons and minimum size restrictions. Historically, the trochus harvesting season has been during the month of August. This is for two reasons: this is a period of calm seas and the money earned from the August harvest is convenient for use during Liberation Day festivities in September.

According to the Chief of Marine Resources Development, the peak period of trochus harvesting was in the mid-1960s, with more than 300 tonnes harvested in a single year.

In 2001, the only trochus harvested was at the small Sapwvatik (Ngatik) Island, 100 miles south of Pohnpei. It was planned to harvest 20 tonnes, but only 6 tonnes were collected in the six-hour open season. Trochus were sold unprocessed

Table 1. **Trochus introductions to Pohnpei**

Year of translocation	Origin	Details	Source
Before 1927	Palau	Unsuccessful attempt	McGowan 1957
1930	Palau and Yap	Japanese Govt. and private companies transferred shells to many islands including Sapwafik, Kapingamarangi and Nukuoro	McGowan 1957
1939	Truk	Skipjack vessel transported shells	Asano & Inenami 1939
1939	Palau	6745 shells transferred	McGowan 1957

Table 2. **Trochus transplants from Pohnpei to other islands in the Federated States of Micronesia**

Year of translocation	Destination	Details	Source
1959	Kosrae	500 live trochus released at 13 locations	Gawel 1982
1989	Nukuoro and Kapingamarangi	500 shells transferred to each island	Gawel pers comm Curren pers comm
1990 (?)	Pingalap	125 one-inch trochus transplanted	Gawel pers comm

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(USD 1.05/pound) to one Japanese exporter (Mr Nakata, NOMAD Corp.). The meat was extracted and both shells and meat were sent to Okinawa for further processing. The Japanese exporter indicated a desire to harvest the remaining 14 tonnes of the quota.

No harvest took place in 2000. In 1999, 121 tonnes were harvested in Pohnpei Island in eight hours. There was reportedly only one buyer. In 1994 and 1992, 129 tonnes (in 9 hours) and 40 tonnes (in 6 hours) were harvested respectively. All of these harvests took place on Pohnpei Island.

As in many Pacific Islands countries, there have been attempts to process trochus into button blanks. Discussions with Pohnpei government officials and a former processor indicate there have been three operations in Pohnpei as shown in Table 3.

Discussions with knowledgeable individuals indicate that they feel that the non-feasibility of the trochus factories in Pohnpei were due to two factors: 1) the high cost of trochus, and 2) long periods without trochus supplies

Trochus prices during the period of operations of the factories are shown in Figure 1. When these prices are compared with that of other Pacific Island locations, it becomes apparent (contrary to the expressed opinions of Pohnpei trochus processors) that Pohnpei had one of the lowest buying prices in the region (World Bank 1997). It is interesting to note that the price in Pohnpei was highest at a period when the price in the other countries was low. The presence of several off-island buyers that year (R. Croft pers comm) is the most probable reason and highlights the importance of domestic buying competition.

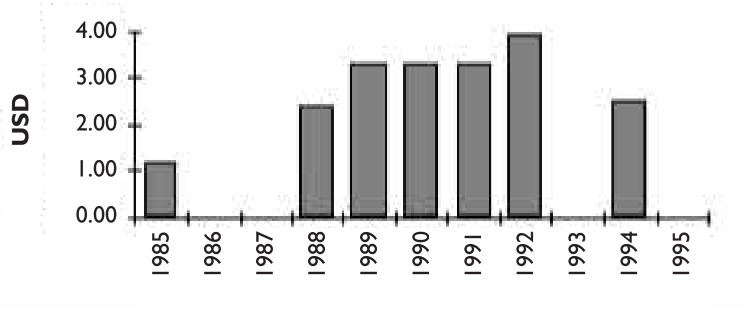

Figure 1. Average Pohnpei trochus prices

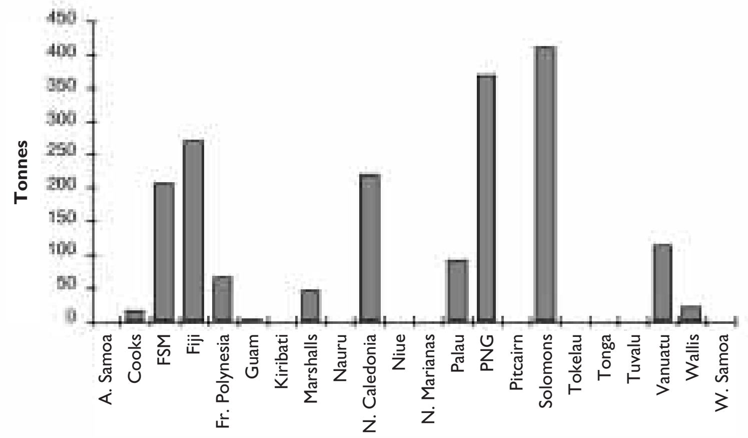

Figure 2. Average annual trochus harvest in the Pacific Island region
[extracted from: World Bank (1997) Aspects of the industry, trade and marketing of Pacific Island trochus. Discussion Paper Series No. 2. The World Bank, Washington, D.C.]

Table 3. Trochus factories in Pohnpei

Company name	Started	Closed	Comment
AHPW Inc.	1985	1995	Based in Pohnpei, 6 blanking machines; recently 13 to 14 workers; produced finished buttons except during 1995; last processed in April 1995; some years did not operate
M.L. Cho Co.	1989	1990	Based in Pohnpei; 10 blanking machines
unknown			Based in Pohnpei; Korean ownership; purchased 12 blanking machines in early 1990s; machines never used

The other cited reason for the demise of the trochus processing operations is long periods without trochus supplies. Factory records (B. Arthur pers comm) show a local processor, AHPW Inc., was completely without trochus for 80 months during its 10-year life, despite the fact that the average harvest from the island was 73 tonnes annually.

In Pohnpei there has been a long tradition of attempts at increasing trochus abundance by reseeding reefs. Because of the substantial amounts of public funds involved, it may be useful to point out the results of two studies on the subject of trochus enhancement:

Ianelli and Clarke (1995) state:

> In Micronesia, the stock replenishment through the release of hatchery reared juvenile trochus has been of questionable effectiveness. Hatcheries in general are mitigation measures for poor management practices or habitat degradation. In many cases the number of juveniles released has had an indeterminate or unrelated effect on subsequent fishable stock levels. Thus with the technical effectiveness still unproven, the economic effectiveness cannot be addressed. Experience especially in Palau and to a lesser extent in Pohnpei and Kosrae, suggests that the overtaxed capital and human management resources of typically small marine resource divisions are best allocated to alternative methods of trochus management, as opposed to being spent on a trochus hatchery for re-seeding purposes. There is an intrinsic appeal in artificial rearing, in that it is demonstrative proof that "something is being done".

World Bank (1997) states:

> Re-seeding should be considered experimental at this time and not a proven method for increasing trochus abundance. Although the on-going testing in this area should be encouraged, it is important to note that there has yet to be documented evidence that re-seeding increases fishery production. It is therefore premature to suggest that re-seeding is effective. Nevertheless, there are numerous examples in the Pacific Islands where this technique is being implemented as though it is a proven management tool.[1]

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[1] **Editor's note:**
Readers should be mindful of the following issues:

- reseeding efforts with trochus juveniles in countries involved with such research are based on very small-scale trials using hundreds and, at most, a few thousand animals at any one trial. Only Australia has carried out larger-scale release of hatchery produced juveniles e.g. between 12,000 to 20,000 juveniles per site and the latest study in Australia using 12,000/site has indicated significant percentage enhancement although the overall numbers are still low (a summary of some of the results will be published in the next *Trochus Information Bulletin*);
- no commercial-scale release of juvenile trochus has been attempted by any countries. I am therefore of the view that the enhancement of the trochus fishery through very large-scale release of hatchery juveniles (on the order of 100,000 or multiples of 1000,000) is still untested and its effectiveness is still under investigation;
- stock enhancement is not limited to the use of hatchery-produced juveniles only. Broodstock reseeding through translocation has been spectacularly successful in some Pacific countries, and results indicate that reseeding, where successful, takes time for the process to take effect. It is a long-term process that cannot be achieved within a couple of years. Fisheries staff involved in stock enhancement work need to ensure that this message is given to the communities involved to avoid unrealistic and short-term expectations.

Successful culture and release of trochus in Solomon Islands

Phillip J. Clarke[1] *and Toru Komatsu*[2]

Introduction

Between 1997 and 2000 the Japanese Overseas Fishery Cooperation Foundation (OFCF) and ICLARM - The World Fish Centre worked together in Solomon Islands on a joint program to develop methods for restocking trochus. Restocking with cultured individuals is often seen as an impractical fishery management tool for trochus due to the expense of the hatchery and rearing systems needed to raise juveniles to a size where they survive in acceptable numbers when released on reefs (Heslinga 1981; Nash 1988; Amos 1991, 1997; Crowe et al. 1997; Lee et al. 1998). The option of reducing costs by releasing trochus at a smaller size has also been problematic due to high rates of predation on juveniles.

It is now widely accepted that the larger the juvenile trochus are when released, the higher the rate of survival (Nash 1987; Castell 1995; Isa et al. 1997; Lee et al. 1998). Consequently, a priority for research is to develop methods for producing trochus of at least 40 mm at low cost. The research by OFCF and ICLARM tested whether trochus could be reared effectively to a size > 40 mm in land-based tanks previously used to rear giant clam seed, and whether trochus could then be transferred to the sea cages used to farm giant clams. An experiment was also designed to test the hypothesis that hatchery-reared trochus > 40 mm have acceptable rates of survival when released in the wild. The results presented here summarise the full report of the study by Clarke et al. (2001) and present further details of the movement of trochus after release.

Combined culture of trochus and giant clams

The trochus used for this study were derived from wild broodstock spawned at the joint ICLARM-OFCF facilities in Solomon Islands in September 1998. The larvae were settled in outdoor one-tonne fibreglass nursery tanks, where they fed on the tank walls and on introduced flat polycarbonate plates covered with sessile diatoms and bacterial film. After five months, the trochus were transferred to concrete tanks for polyculture with giant clams under various treatments.

After 22 weeks in the concrete tanks, a subset of trochus of about 30 mm were placed in sea cages (0.6 m^2 with 18 mm mesh) with and without juvenile giant clams, *Tridacna derasa*, under various treatments. After 18 weeks in the sea cages, the trochus were a mean size of 46 mm. They were then transferred to ICLARM's field station at Nusa Tupe in Western Province, Solomon Islands for release into coral reef habitats.

Release method

On 31 January, 20 trochus were released at each of seven sites on Nusa Nane reef (8°8'S, 156°54'E). This location was chosen because a preliminary survey showed that juvenile wild trochus of 40–50 mm occurred on the reef flat, and it is locally respected as a research area. The seven sites were 20 m apart, 200 m leeward of the reef crest, and had substrata ranging from coral bench to mixed rubble/rocks with varying coverage of coralline and filamentous algae.

All trochus were measured and tagged prior to release and placed within a 1-m radius of a central release point (marked by a rod) near rocks that provided protection from predators. Every second day after the release for four weeks, the surviving trochus at each site were located and their distance and bearing from the release marker was noted. This required systematic searching of a site for up to 45 minutes by a team of four to six people using snorkels and masks. When all trochus were located at a site, or the time limit expired, the next site was searched. When dead trochus were located, entire or broken shells were collected and the nature of the predation was recorded.

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If the trochus moved more than 8 m from the release point they were moved back to the marker (re-zeroed). This facilitated the location of the trochus and reduced the risk of attributing unlocated living trochus as mortalities. We tested the effects of relocation and found that it did not cause greater susceptibility to predation for relocated animals. Crowe et al. (1997) also suggested that readjustment and trauma associated with relocation of trochus following initial placement on the reef are not as significant for individuals > 40 mm.

Survival

Four weeks after release 107 (76%) trochus were retrieved alive, 21 (15%) were found dead, and 12 (8.6%) were missing. Eleven (52%) of the dead trochus were killed by crushing, i.e. only shell fragments were found. For the remaining dead individuals, the shells were intact but five were occupied by the hermit crab *Dardanus lagopodes*, three were being eaten by whelks, and two were dead and partially eaten. If the tagged individuals that were missing were actually alive but could not be located due to crypsis, then survival was as high as 85%.

The survival of trochus released into coral reef flat habitats was far greater than recorded by Castell (1995), or Castell and Sweatman (1997) for trochus < 40 mm, and for estimates of survival in several restocking experiments (Hoffschir 1990; Amos 1991; Kubo 1991; Isa et al. 1997). This finding supports the supposition that a size of > 40 mm may represent the practical threshold size for release of trochus in the wild. Previously, 30 mm was regarded as the most effective size for releasing trochus to enhance stocks (Nash 1993). Although the rates of survival we recorded are most encouraging, the merit of releasing trochus > 40 mm needs to be measured against the results of releasing larger numbers of smaller trochus. Economic modelling, taking into account the advantages of combined culture with giant clams and similar initiatives in rearing trochus, is also needed to demonstrate whether restocking with hatchery-reared juveniles is a viable management option.

Contemporary restocking theory suggests that the first few days after release are when the animals are the most vulnerable; however, the rate of mortality in the first two weeks after release was slightly less than for the second two weeks, suggesting an almost linear rate of mortality (Fig. 1). This might suggest that the method of release was successful in protecting the trochus when they were most vulnerable, or that they were subject to a continuing level of vulnerability, potentially perpetuated by the practice of returning trochus outside the 8 m mark back to the release point. The comparatively good rates of survival would suggest the former.

Movement of released trochus

On the great majority of occasions, released trochus dispersed immediately towards the reef crest. This uniform behaviour indicates that the rearing process did not cause variation in the initial locomotory response of trochus placed in the wild, which otherwise might be expected to lead to increased vulnerability of released animals. Daily movements ranged from 0 to 24 m per individual, however, some trochus often remained near a rock or patch of rubble for several days. The mean vector daily movement for 2193 individual observations (including relocated trochus) was 0.64 m in a south to south-south-westerly direction. The mean net daily movement per individual was 1.77 m . day^{-1}.

Movement towards the reef crest appears to be an inherent behaviour and has also been observed in release studies in Vanuatu (Amos 1991) and Japan, although dispersion may become almost random after a longer period after release (Isa et al. 1997). However**,** in one study, migration of wild trochus from the reef flat to the windward side of the reef crest occurred at a threshold size of about 65 mm (Castell 1997). Movement of released trochus towards the reef crest at smaller sizes may therefore be premature and due to influences other than the size of the trochus.

The effect suggested by these movements is that hatchery-reared trochus are over-sensitised to water currents when released, which causes them to over-compensate for the effect of the wave and current action and steadily move against the prevailing current, i.e. towards the reef crest. The more uniform dispersion of trochus after 74 days (Isa et al. 1997) suggests that, over time, hatchery trochus become normally sensitised to the directional influences of current and compensate accordingly. Presumably this normalisation happens gradually and could be observed as a reduction in directional preference in movement by released individuals. Trochus released in our study showed a strong pattern of movement south over all observations throughout the term of the study (Fig. 2). The highest recorded mean daily movement south was after the trochus were not surveyed for three days, suggesting that rates of dispersion would increase if the trochus were not surveyed, and that movements may have been affected by the disturbances associated with locating trochus and moving those outside the 8 m mark back to the release point. A continuous southerly preference that settles down around 0.9 m . day^{-1} (Fig. 2) suggests that there has been some level of acclimatisation to the prevailing currents, but still a strong pattern of movement towards the reef-crest. Wave action and the predominant direction of the current might necessitate a level of movement compensation that in a short-term study like this may continue to appear as an over-compensation, but is in fact necessary for the animals under normal circumstances to maintain some kind of geographical stasis.

There was also a mean west-east movement over all observations of 0.08 m . day^{-1}, indicating a marginal preference for movement to the west (Fig. 2). This was potentially due to site-specific substratum influences, but not nearly as strong as the movement against the prevailing current.

The average distance of the trochus from the release point can be estimated in meters as ((Release Radius + (Average Daily Movement away from Release Point x Days Between Surveys)) / 2), in this case, ((8+(0.64x2)) / 2) = 4.64 m. The average recorded distance from the marker approaches this value (Fig. 3), suggesting that the level of dispersion in the demarcation zone had not yet stabilised.

Assuming the tendency with time towards random directional movement of the trochus around the release point (Isa et al. 1997), half the trochus in a release should be able to be located on each survey within the average estimated radius. Surveying resource requirements for locating the majority of trochus can thus be estimated based on the constraints of the number of surveyors, their rate of searching (m^2 . minute^{-1}), the release radius (8 m in this experiment) and days between surveys. Unfortunately, a minority of trochus individuals require the larger investment in search

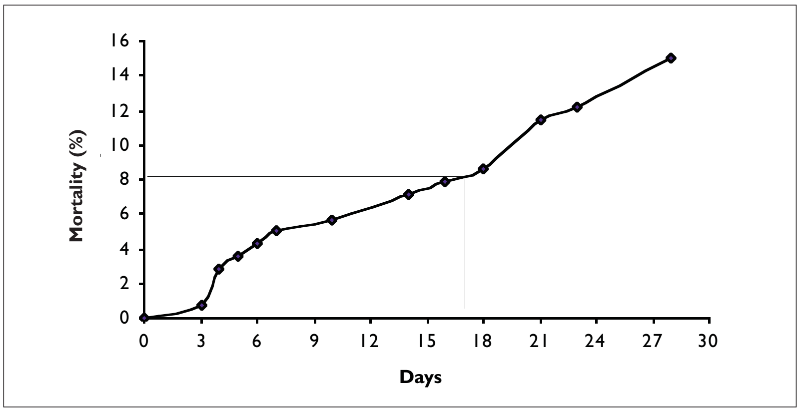
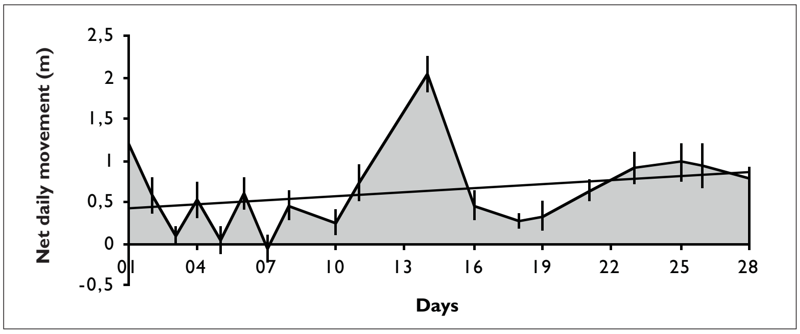


Figure 1. Cumulative mortality of trochus >40 mm after release on reefs in Western Province, Solomon Islands

(a) South–north movements (south as positive Y axis)



(b) West-east movements (west as positive Y axis)

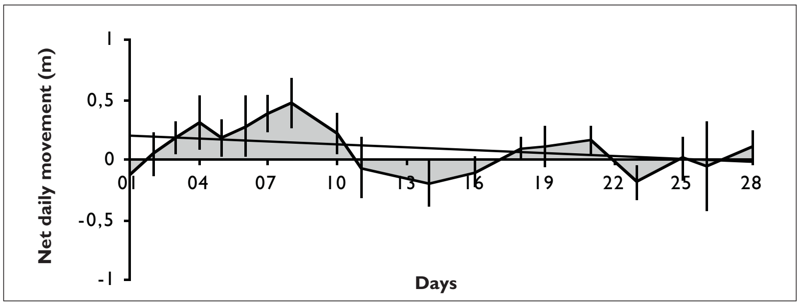


Figure 2. Net daily average direction of movements to the south and west by trochus released in Solomon Islands

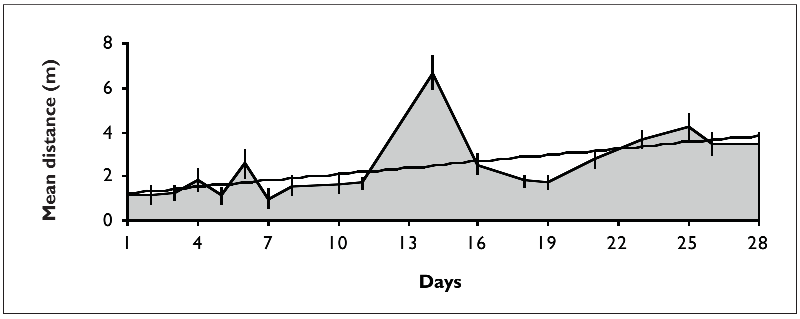


Figure 3. Mean distance of trochus from the release markers (logarithmic trend-line) during a one-month release experiment in Solomon Islands

resources. The high-observed variance in the daily movement of the trochus, and the data we collected, suggest a Poisson distribution of the rates of dispersion, with a minority dispersing at a far greater rate. For a full recovery of all trochus in a release, the necessary search area increases proportionally by the square of the maximum distance an animal travels between surveys. For practical purposes, search areas could be based around the assumed recapture of a majority of animals in a defined area, writing off an expected proportion of more mobile trochus that would escape the defined area per survey. Such a method would need to assume the stabilised movements of the released trochus, and results could be influenced by factors such as subtratum, crypsis, food availability and currents.

Although our survey results suggest that there will be no shortcuts in limiting the area that needs to be searched for a full account of released trochus, they help to identify the likely direction and rates of dispersion of trochus in a defined environment.

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Dietary effects on shell microstructures of cultured, maculate top shell (Trochidae: *Trochus maculatus*, Linnaeus, 1758)

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Abstract

Maculated top shells grew rapidly when co-cultured in tanks with fish and fed on leftover fish feed and fish wastes. During rapid growth on this high protein diet, top shells deposited a red band on their outer shell surface. Top shells reared in tanks without fish and fed only algal diets decreased in size. With the nutritionally deficient diet, top shells deposited a purple band on their outer shell surface. Shell microstructures were observed and described for these two conditions using a scanning electron microscope, which revealed substantial differences between shell structures under well-fed and nutritionally deficient conditions.

Introduction

An individual's life history, or ontogenetic growth is often preserved in its mineralised or otherwise refractory structures. With shell-forming molluscs, changes in the animal's environment are reflected in shell structures. These preserved shell records include growth increments and discontinuities; or changes in shell allometry structure, mineralogy, and/or chemistry. These features are observed on whole shell surfaces, or using special shell preparations. Environmental factors known to effect shell structures include: temperature (Phillips et al. 1973), salinity, dissolved oxygen, substratum conditions, water turbidity (Rhoads and Lutz 1980), and food concentrations (Ino 1949, 1953).

There are about 40,000 described species of living gastropods (Brusca and Brusca 1990), or about three-quarters of the phylum Mollusca. Molluscs have a mantle, which is a fold of the dorsal body wall that creates a mantle cavity. The mantle cavity usually houses the ctenidia, anus and pores of the nephridial and reproductive systems. Just under the mantle epithelium are shell glands responsible for biomineralisation and shell formation.

Maculated top shell (*Trochus maculatus*) is one of three top shell species found in Thailand. Before it became depleted due to overfishing and perhaps pollution, this species was economically important for island residents in the upper Gulf of Thailand (Chunhabundit and Thapanand 1994). The outer shell is covered with light green, radiating lines that create a maculated surface (Thapanand and Chunhabundit 1993).

The aim of this study was to document changes in shell microstructures associated with dietary changes and food availability in top shells. This study was part of a larger programme to develop appropriate propagation methods for top shell stock enhancement.

Materials and methods

Food types

Top shells of 14.5–45.0 mm shell base diameter were collected from the ocean in their natural habitat and held in an acclimation tank for one week at Sichang Marine Science Research and Training Station (SMaRT), Sichang Island. After acclimation, 35 and 36 top shells were transferred to two red snapper (*Lutjanus argenticulatus*) fish-rearing tanks (designated as Tanks 2 and 3, respectively). Stocking densities were 35 top shells/m^2. Top shells in both tanks were fed organic fish wastes (mostly faeces) and on uneaten fish pellets that remained on the tank bottom. Another 80 top shells were reared in a separate high-density tank (designated as Tank 1), and fed only algae (*Enteromorpha* sp. and diatoms). Seawater at 32 ppt salinity and 29° C was flow-through in all rearing tanks. After one week, shell diameters and heights were measured, and whole body weights calcu-

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lated using the equation (Thapanand and Chunhabundit 1993): $W = 9.5 \times 10^{-5} L^3$; where W = whole body weight (g), and L = shell diameter (mm). At that time, colour bands that appeared on the shell surfaces were also measured.

Scanning electron microscopic analyses

Five top shells were collected from the high density rearing tank (Tank 1) and from the two red snapper rearing tanks (Tanks 2 and 3) at SMaRT. The living animals were removed, and the shells thoroughly rinsed with distilled water three times. Each shell was cut cross-sectionally through its midline with a cutting disc. All samples were washed again with distilled water and air-dried overnight in a dust free cabinet. They were then mounted on metal stubs and gold coated, before being examined using a scanning electron microscope (JEOL JSM-5410LV) with 20 kV acceleration voltage.

Results

Feeding trials

After one-week of culture, top shell size increased substantially in the fish-rearing tanks. Average shell lengths increased from 28.4 to 29.2 mm in Tank 2, and from 26.8 to 28.4 mm in Tank 3 (Table 1). At the same time, average whole body weights increased from 2.32 to 2.55 g in Tank 2, and from 2.14 to 2.45 g in Tank 3. The “red band” phenomenon appeared on top shell surfaces in the fish tanks, starting from the outer lip of the shell aperture. Average red band area in Tank 2 was 18.8 mm^2, which on average covered 5.4% of the shell’s outer surface. In Tank 3, the red band area averaged 19.0 mm^2 and 8.5%, respectively. At the same time, top shell size in the algal fed tank (Tank 1) increased (Table 1) while the whole body weight decreased. Whole body weight decreased from 3.5 to 2.7 g during the 17 days. The “purple band” phenomenon appeared on shell surfaces of these top shells starting from the shell apexes, extending to the middle of the shell. Average purple band area was 477 mm^2, which covered 56% of the outer shell surface.

Microstructures of a normal shell

Normal *T. maculatus* shells consisted of layers of crystalline calcium carbonate separated by thin sheets of protein (Fig. 1). The outer surface was mostly covered by periostracum, which is a thin organic layer composed mainly of sclerotized protein. Periostracum protects shells from corrosion and erosion, provides an initial substratum for mineral deposition at shell’s edge, seals the extrapallial space, protects shells from infestation by organisms, and possibly helps camouflage top shells (Fig. 2). There are four microstructures in a normal *T. maculatus* shell composition (Table 2). The first microstructure consists of spherulitic, prismatic structures (Fig. 3 and Fig. 4). These include sub-units radiating in three dimensions from a single nucleation site, or spherulite, towards the depositional surface. This first microstructure consists of aragonite and calcite. The second microstructure group consists of laminar, columnar nacreous structures (Fig. 5). These structures are deposited near the shell margin.

The tablets are stacked in columns with coinciding centers, an arrangement only found in some gastropods and cephalopods. The mineralogy of this group is aragonite. The third microstructure group is a fibrous, prismatic structure (Fig. 5). The prisms are simple, but have large length / width ratios. The mineralogy of this group is aragonite with fibrous calcite prisms. Prism boundaries are well defined and generally non-interdigitating. The fourth microstructure group is an irregular complex, cross-foliated. This group commonly appeared in the inner shell layer, and was a distinct type of shell structure at the point of pallial muscle attachment (Fig. 5). This group was adjacent to aggregations of numerous parallel, elongate sub-units that showed three or more predominant dip directions. The sub-units were calcite blades or laths.

Microstructure of defective shells

Defective shell conditions occurred in top shells when they were reared under high density with nutritional deficiencies. Shell deformities included purple bands on the outer shell surface, shell dissolution (Fig. 6), and variation in periostracum thickness (Fig. 7). In addition, a thick spherulitic structure was deposited with an organic matrix, and the thickness of the columnar nacreous structure increased. At the same time, the thickness of the fibrous, prismatic structure and the irregular, complex cross-lamella structures were reduced (Fig. 8 and Fig. 9).

The prism boundaries of the spherulitic, prismatic structures were poorly defined and non-interdigitating. Prism length and height ratios were more complicated. The columnar, nacre structure interdigitated and increased in thickness. The irregular complex, cross-foliated structure also interdigitated, but the layer thickness decreased (Fig. 9). The interface zones between normal and defective areas (the purple bands) of defective shells (Fig. 10 and Fig. 11) were clearly different compared with normal shells (Fig. 2). Figure 12 shows the nature of this transition zone, with an exposed cut through the purple band.

Table 1. **Average shell dimensions and whole body weights of maculated top shells (*Trochus maculatus*) reared in an algal tank (Tank 1), and in two fish culture tanks (Tanks 2 and 3). Shell "red bands" and "purple bands" were measured and respective areas calculated for each shell, where: PL = length of purple band, PW = width of purple band, RL = length of red band, and RW = width of red band. Numbers in parentheses are standard deviations.**

Tanks	Shell diam. (mm)	Shell height (mm)	Whole weight (g)	Shell area (mm^2)	PL (mm)	PW (mm)	RL (mm)	RW (mm)	Shell area (mm^2)	Band area (%)	N
Tank 1	29.5	26.2	3.48	875	-	-	-	-	-	-	79
Day 0	(5.5)	(6.1)	(1.69)	(332)							
Tank 1	32.2	27.5	2.68	836	20.9	18.5	-	-	477	56.1	80
Day 17	(5.7)	(5.1)	(1.39)	(290)	(10.2)	(9.2)			(326)	(27.5)	
Tank 2	28.4	20.1	2.32	595	-	-	-	-	-	-	35
Day 0	(5.5)	(4.3)	(1.11)	(211)							
Tank 2	29.2	22.4	2.55	664	-	-	18.8	1.9	40	5.4	31
Day 7	(5.0)	(4.3)	(1.21)	(230)			(3.6)	(2.2)	(54)	(5.2)	
Tank 3	26.8	19.2	2.14	546	-	-	-	-	-	-	36
Day 0	(6.4)	(5.4)	(1.42)	(274)							
Tank 3	28.4	21.8	2.45	648	-	-	19.0	2.4	49	8.5	36
Day 7	(5.9)	(5.4)	(1.43)	(287)			(4.7)	(2.1)	(53)	(9.7)	

Table 2. **Shell microstructure guide for maculated top shell *Trochus maculatus* Linnaeus, 1758.**

Microstructure group and Figures	Microstructure varieties	Mineralogy
1. Prismatic		
Figures 3 and 4	**Sp** - Spherulitic prismatic structure. Prisms show a substructure of elongate subunits radiating in three dimensions from a single nucleation site of spherulite toward the depositional surface.	Aragonite+Calcite
Figure 5	**Lc** - Fibrous prismatic structure. Prisms lack a substructure of elongate subunits diverging toward the depositional surface. Prismatic boundaries are well defined and generally noninterdigitating. Prisms show a large length / width ratio.	Aragonite+Calcite
2. Laminar		
Figure 5	**Lr** - Nacreous structure. Laminae consist of polygonal to rounded tablets lying essentially parallel to the general depositional surface. Spiral growth of the tablets may locally disrupt the laminar arrangement. Columnar nacreous structure. Deposited near the margin of the shell, and the tablets show vertical stacking in all vertical sections.	Aragonite
3. Crossed		
Figure 5	**Ic** Irregular complex cross-foliated structure. This structure is a particular variety of crossed lamellar structure (adjacent aggregations of elongate subunits show three or more predominant, or they are arranged on the surfaced cones) in which the elongate subunits are calcitic blades or laths.	Calcite

Discussion

In our trials, top shells readily fed and grew well on fish wastes and uneaten, prepared red snapper feed. This protein and nutrient-rich diet resulted in the formation of a red band starting from the outer lip of the shell aperture and extending to the outer shell surface. A purple band formed on top shells that were fed an inadequate algal diet. This band started at the shell's apex and continued to the middle zone of the shell. These red and purple bands contrasted with the natural maculated green coloration of wild top shells. In their natural habitat, top shells forage on a mixture of plants, animals, and detritus.

Most gastropod growth studies measure shell size and shape. Thapanand and Chunhabundit (1993) found that *Trochus maculatus* growth was isometric, keeping the same proportions throughout life. Body weight was directly proportional to internal shell volume. Shell growth can occur even during starvation (Rhoads and Lutz 1980). Since a more or less complete record of post-larval ontogeny is preserved in gastropod shells, and since their shells reflect environmental conditions, gastropod shells are valuable indicators of environmental changes. Environmental conditions such as temperature and food have profound effects on gastropod shell form, growth rate and sculpture (Phillips et al. 1973).

Figure 1.
SEM microphotograph of normal maculated top shell (*Trochus maculatus*) rearing under low density condition, shell length was 35 mm. Photography shows the apex area of the shell, the outer most surface is protected by a periostracum layer. Bar = 0.5 mm.

Figure 2.
SEM microphotograph of the mid-shell area of normal maculated top shell. The outer layer of organic periostracum protects the shell from corrosions and provides an initial substratum for mineral decomposition at the shell's edge. Bar = 20 µm

Figure 3.
SEM microphotograph of cross-section of normal maculated top shell showing shell layers: Sp = Simple prismatic layer; Lc = Laminar columnar, nacreous layer; Lr = Laminar, regularly foliated layer; and Ic = Irregular complex, cross-lamellar layer. The outermost layer is the periostracum (not labeled). Bar = 20 µm

Figure 4.
High magnification view of Figure 3 showing: simple prismatic layer (Sp) and laminae columnar, nacreous layer (Lc). Bar = 10 µm

Figure 5.
High magnification view of Figure 3 showing: the middle layer; laminae columnar nacreous layer (Lc); laminae regularly foliated layer (Lr); and the inner layer of irregular complex, cross-lamellar layer (Ic). Bar = 10 µm

Figure 6.
Microphotograph of defective shell (the apex area) of maculated top shell caused by rearing under high density with inadequate nutrition. The periostracum was reduced and shell structure was dissolved and replaced by fouling organisms.

Figure 7.
Enlargement of a "purple band" on the defective shell of maculated top shell. The shell surface was particle dissolved.

Figure 8.
Microphotograph cross-section of defective maculated top shell, shell showing all shell layers. The outermost layer has fouling deposits, and the inner most layer was reduced in thickness.

Figure 9.
Enlargement of defective shell layers of maculated top shell.

Figure 10.
Microphotograph of maculated top shell showing the interface zone between normal shell area (N), and the "purple band" area (P) of a detective shell.

Figure 11.
Enlarged section of Figure 10. Benthic diatoms (*Cocconeis* sp.) were attached to the shell's surface.

Figure 12.
High magnification of a cross-sectional area of the simple prismatic layer of defective maculated top shell in the "purple band" area. The simple prismatic layer of the defective shell changed form. Boundaries were not well defined, and generally interdigitating.

Figure 1

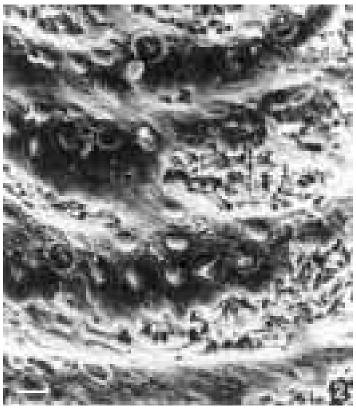
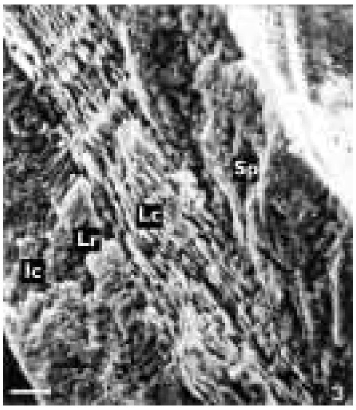


Figure 2



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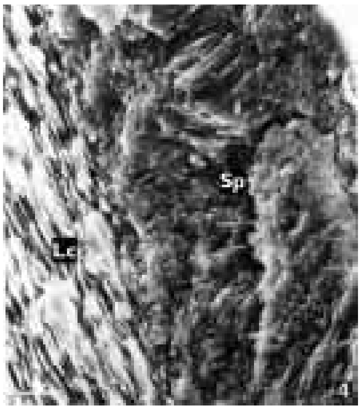

Figure 4

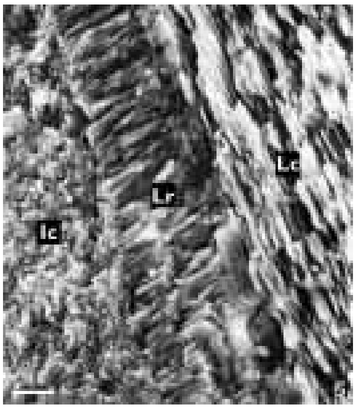

Figure 5

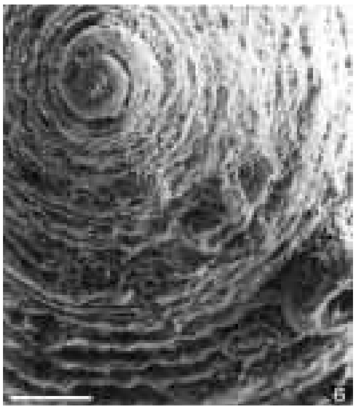

Figure 6

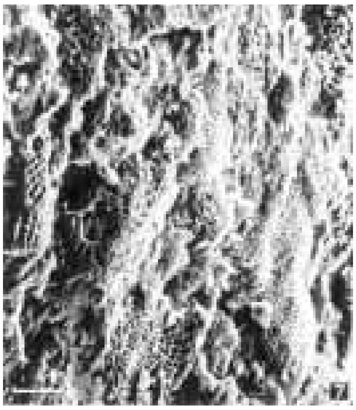

Figure 7

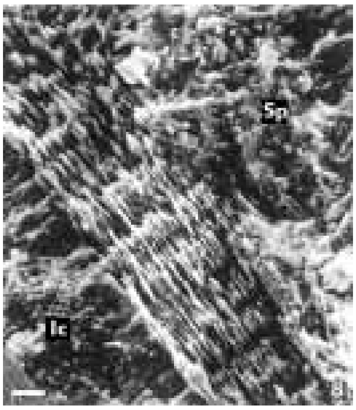

Figure 8

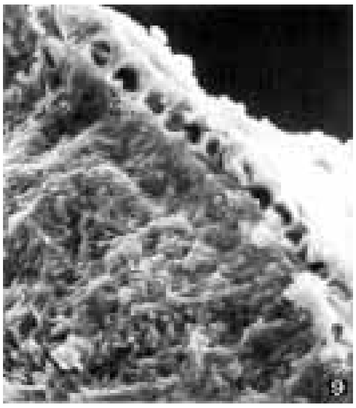

Figure 9

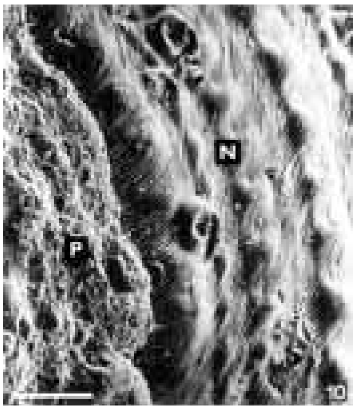

Figure 10

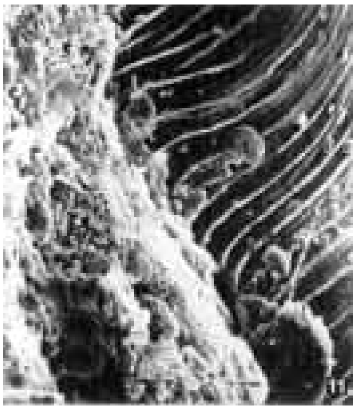

Figure 11

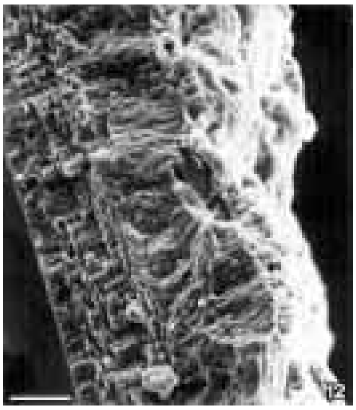

Figure 12

With archaeogastropods, and perhaps other snails, shell pigmentation is affected by diet. When Japanese turban snails (*Turbo cornatus*) were fed with brown algae (*Eisenia bicyclis*), the shell became white, whereas those fed red algae (*Cheilosporum maximum* and *Corallina pilulifera*) retained the greenish-brown colour typical of specimens collected in the field (Ino 1949, 1953). Red abalone (*Haliotis rufescens*) shells in California were white when fed the holdfasts of brown kelp (*Macrocystis pyrifera*), whereas their shells were dark, brick-red when fed red algae (Leighton 1961). With maculated top shell (*Trochus maculatus*) reared using commercial abalone diet, we found in our earlier studies that shell colour became red starting on the outer lip, whereas shell colour was greenish when the snail fed green algae (*Enteromorpha* sp.) (Chunhabundit and Thapanand 1995). In our present study with maculated top shells, the red band appeared on the outermost portion of the shell when reared with red snapper and fed fish wastes and excess fish feed.

The innermost layer of top shell contains the nacreous, or mother-of-pearl (MOP) layer. After grinding or otherwise removing the prismatic layers of red band shell, the nacreous layer remains. Potential exists for enhancing the lustre or orientation of the aragonite, columnar nacreous structure by feeding appropriate diets. This enhancement can greatly increase the retail value of shell products, and correspondingly also greatly increase the value of raw, unprocessed shells. Trochus shells are used to produce high quality pearl buttons, while shell wastes after button production are used to produce MOP chips, or crushed into powder for use in making paint and nail polish (Hahn 1989).

There are four categories of microstructure in the shell layers of *Trochus maculatus*. The first category is an aragonite and spherulitic, prismatic structure, which probably occurs in all bivalves (Taylor et al. 1973). The second category is a columnar, nacreous layer. This category is found in some gastropods and cephalopods, such as *Haliotis cracherodi, Tectus pyramis* and *Perotrochus quoyanus* (Hedegaard and Wenk 1998). This microstructure category consists of flattened aragonite blades or laths, common to Bivalvia, including Pterioda, Pectinacea, Anomiacea and Ostreacea (Waller 1972, 1978). With gastropods, Hedgaard and Wenk (1998) reported that the nacreous structures are "argonitic laminar" consisting of polygonal to rounded tablets, broadly arranged. The third category of top shell microstructure is an aragonitic, fibrous and prismatic structure. The structure's prisms lack a substructure of elongate sub-units diverging toward the depositional surface. The prisms have a large length / width ratio. The fourth category is an irregular complex, cross-foliated. This complex, cross-lamellar structure consists of elongate sub-units of calcite blades or laths. A summary of maculated top shell, shell microstructure is shown in Table 2. There are two nacreous layers with top shells; one which is a columnar, nacreous layer, while the other layer is a fibrous, prismatic structure. This top shell feature differentiates it from other mollusc shells.

Top shells are herbivores and detritivores (Hahn 1989), and non-selective grazers (Thapanand and Chunhabundit 1993). They can readily adapt to seasonally changing food availability when their preferred food items are not available. During adverse food or other environmental conditions, shell growth is represented by a purple band of many closely packed rings, as shown in Figures 9 and 12. The outer shell is dissolved, while the nacreous, inner layer increases in thickness. The inner aragonite, fibrous prismatic structure becomes thinner. The prismatic layer dissolves and is replaced by an organic matrix. The columnar, nacreous layer increases in thickness and becomes more interdigitating. In this condition, the columnar, nacre layer accretes faster than the sheet nacre layers, such as those found in shell microstructures of the Bivalvia. Vertically stacked, columnar nacre exposes greater numbers of growing tablet edges per unit area of depositional surface, thus allowing more rapid shell deposition. This agrees with the hypothesis concerning correlations between columnar nacre and low aperture expansion rates in the gastropod and cephalopod, and between sheet nacre and high aperture expansion rates in the Bivalvia. Wise (1970) stated that columnar nacre can accrete faster than sheet nacre because its vertical stacking exposes more growing tablet edges per unit area of depositional surface. Nacre is particularly strong, but because it is so often absent from the nacreous layer, it appears that its energetic expense sometimes outweighs its structural advantages.

Hedegaard and Wenk (1998) stated that shell textures may correlate with microstructures (as with cross-foliated structures), or similar microstructure may have very different textures (such as with nacre). The strength and thickness of the nacreous layer in top shells can be enhanced through diet, thus providing higher quality MOP. From our present work, it appears that it may be feasible to rear top shells with the carnivorous animals in pond rearing systems (polyculture systems) and thereby increase top shell quality and value.

Three species of *Trochus* top shells are fished in Thai waters. Local fishermen readily consumed meats of *T. maculatus, T. niloticus* and *T. pyramis* until natural stock were depleted (Thapanand and Chaunhabundit 1993; Chunhabundit and

Thapanand 1994). Propagation of juvenile top shell for reseeding depleted natural stocks offers an opportunity to re-establish the *Trochus* fishery at a higher level in Thailand (Chunhabundit and Thapanand 1993a, b).

While *Trochus* top shells are used to make jewellery, inlays in carvings, and paint additives, their greatest economic value is for production of MOP, for making buttons. Such buttons are still in high demand in the fashion industry. The potential exists for re-establishing wild populations of top shells using mariculture and ocean ranching. This would provide both a supplemental food resource for local fishermen, and an added source of cash income from sale of shells for commercial uses.

Acknowledgements

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An improved method of packing to minimise mortality in juvenile trochus during transport

Graeme Dobson[1]

Summary

The improved method described for transporting juvenile trochus gave a mortality rate of <10% after being packed 24 hours, and <20% after being packed for up to 36 hours for large juveniles 15–30 mm in diameter. Smaller juveniles between 5 and 12 mm showed slightly higher mortality.

Introduction

Sites designated for trochus reseeding are often remote, and in some cases thousands of kilometres from the hatchery. To get stock from the hatchery to the field may involve complex travel arrangements, with stock being transferred from one form of transport to another a number of times before finally being released.

The ACIAR / NTU Trochus Reseeding Project conducted extensive trochus reseeding trials in two locations in the Kimberley, West Australia, using juveniles produced in the pilot hatchery managed by the Northern Territory University, Darwin. These trials called for the air transport of juvenile trochus from Darwin to Broome, a distance of more than 1000 km, followed by a journey of more than 200 km on dirt track to One Arm Point before reseeding them on selected sites at Dampier Peninsula. For reseeding on Sunday Island, sea travel is also involved. Total travel time often exceeds 24 hours and is extremely stressful for the juveniles involved.

Initially the trochus were packed for transport in plastic bags with pieces of damp paper or cloth to maintain humidity. The bags were inflated with industrial oxygen, sealed with rubber bands and packed into polystyrene boxes for transportation. This oxygen-charged plastic (OCP) method proved unsatisfactory even over comparatively short periods (12 hours), as mortality was unacceptably high. If the trochus were alive, they were often lethargic and slow to recover. There was a clear need to develop a specific method of packing juvenile trochus that would ensure survival over periods of at least 24 hours.

Methods

Observations of juvenile trochus in the hatchery and mature trochus in their natural environment showed they commonly remained out of the water for long periods. This suggested that, if near natural conditions could be recreated in a packaging system, survival during transit could be enhanced.

There were two major factors that appeared to contribute to the survival of the trochus: high humidity and a solid substrate. Packing in oxy-

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gen inflated bags provided high humidity but did not provide a solid substrate for the trochus to grip onto.

Table 1. **Survival of juvenile trochus 24 hours after release from packing.**

Time packed	Fibre cement sheet		Newspaper	
	15–30 mm trochus	5–12 mm trochus	15–30 mm trochus	5–12 mm trochus
24 hours	95%	75%	90%	65%
36 hours	95%	55%	85%	25%
42 hours	70%	50%	65%	50%
48 hours	65%	—	65%	—

After a series of trials, wet fibre-cement sheeting (fibro) or damp newspaper were found to be suitable substrate materials. Prior to packing, the newspaper was soaked in seawater for approximately one minute and then squeezed by hand to eliminate free water, and the fibro was soaked in seawater for 24 hours.

The fibro or newspaper were then placed in the bottom of re-sealable, rigid plastic containers each measuring 150 x 100 x 50 mm deep (the type used for take away food). Trochus were packed upright directly onto the substrates in single layers of 10–50 per layer and covered with a layer of damp foam plastic. A single box could normally take up to four layers of juveniles.

The containers were filled with foam plastic and sealed (Fig. 1 on next page). The foam plastic, which had been soaked in seawater and wrung out by hand immediately prior to packing, was used to hold the trochus in place and provide a moist environment during the transport duration.

This packing method resulted in good survival rates for juveniles in the 15–30 mm size class (Table 1), despite the unexplained anomaly for the small trochus after 36 hours. Fibro is a better material, but newspaper is adequate. However, trochus were more lethargic and slower to recover when being packed on newspaper.

A likely explanation for the improved survival over the OCP method may lie in reduced levels of stress.

When the trochus are packed in plastic bags using the OCP method and transported they are continuously disturbed; even under the best conditions, the process of transportation involves a certain amount of jarring. When the trochus were packed in bags they gripped onto whatever is available e.g. over each other, the damp clothing or paper, or the plastic bag itself.

Observations showed that jarring often caused the trochus to release their grip and retreat into their shells. As trochus withdraw into their shells in response to threat, withdrawal is probably a stressful situation. When a stressful situation is repeated or sustained over a period of time, the animal will inevitably suffer and may eventually die.

The advantage gained from packing on a solid substrate in a rigid container is probably derived from using foam plastic to hold the trochus onto the substrate, preventing the trochus from being jarred loose, thus reducing stress.

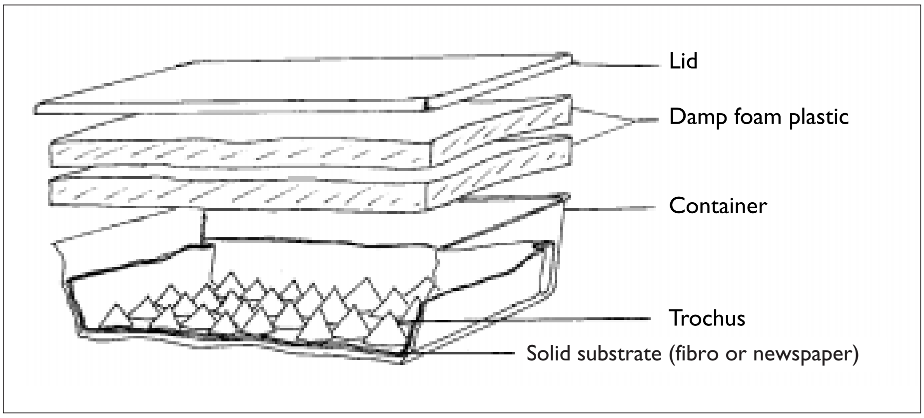

Figure 1: **Packing in rigid plastic containers**

Aquacultured giant clams, *Tridacna gigas* and *Hippopus hippopus*, used as the main biofilter in a saltwater aquarium recirculation system

Dr Richard D. Braley

Abstract

Two 1000 L fibreglass and glass aquaria, each with their own simple filter and reservoir tanks, held three specimens of the giant clam *Tridacna gigas* and two specimens of the giant clam *Hippopus hippopus* as well as an assortment of damselfish. The *T. gigas* weighed up to 40 kg and all the clams were given no nutrients to support their zooxanthellae symbionts other than organic products produced by the fish, invertebrates, and excess fish food. These aquaria operated for over seven months without any problems. Some fish increased to breeding size over this period. The *T. gigas* increased in shell length and total wet weight by 5.5% and 13.4%, respectively, while the *H. hippopus* increased in shell length and total wet weight by 4.3% and 20.4%, respectively. A larger system holding a total volume of 20,000 litres with 16 *T. gigas*, 3 *H. hippopus*, 35 *T. crocea*, corals, and a large assortment of damselfish and anemones has opened as a small public viewing aquarium and operated for two months trouble-free. The giant clam, particularly the large species *T. gigas* acts as an excellent natural bio-filter for large aquariums.

Introduction

Improved technology for the maintenance of saltwater aquaria has facilitated the holding of many new marine species. Much of the improved technology involves the use of filtration and bio-filtration in recirculating aquarium systems.

Cultured giant clams have been shown to take up inorganic nitrogen and phosphate and to speed up their growth rates compared to controls with these nutrient additions (Braley et al. 1992; Fitt et al. 1993). A 75% increase in growth was shown in small *Tridacna derasa* when given 50 *uM* NH3 or NO3 compared to controls (Fitt et al. 1993) and an 88% increase in growth was shown in small *Tridacna gigas* when given 40 *uM* NH3 compared to controls in a recirculation seawater system (Braley et al. 1992).

Although the smaller giant clam species, *Tridacna maxima* and *Tridacna crocea* have been popular aquarium specimens for some time, the large *T. gigas* has never been purposefully used in an aquarium system as the main bio-filtration system. The purpose of this paper is to show the effectiveness of *T. gigas* and other giant clams in this role.

Methods

Two 1000 L tanks each with a 250 L circular plastic tank acting as a combined bio-filter and reservoir tank were placed on the pergola of the Aquasearch Pty Ltd office. The tanks had 1.8-cm long glass windows on the straight front, while the back and sides of the tanks were semi-circular fibreglass. Sunlight transmission was reduced to about 41% under a high-set (50% light transmission) shade-cloth and highly translucent (82% light transmission) plastic material (Solargro). During mid-day in the tropics this equates with about 820 μ-ensteins . m^{-2} . s^{-1}. The position of the tanks allowed for morning sunlight through about 1400 hrs before the building cut out the direct sunlight. An Eheim model 1060 centrifugal pump (240 v) was placed in each of the reservoir tanks. The flow rate was about 25 L per minute so over a 24-hour period there were 36 water changes to the main 1000 L tanks. Water overflowed from one side of the 1000 L tanks by gravity into a plastic milk carton box full of black plastic bio-filter medium (about 48-litre volume; filter media about 150 m^2 . m^{-3}, thus about 7.2 m^2 of bio-filter medium per tank). The remainder of the 250 L circular plastic tank served as the reservoir from which the

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water was pumped back up to the 1000 L tank. Aeration was provided inside the 1000 L tank. Seawater was changed only once over the 7.5 month study when a storm caused partial collapse of the solargro canopy and freshwater inundated one tank lowering the salinity. New seawater was immediately changed in both tanks.

The biomass of giant clams, fish, anemones and corals in each tank would have been close to 30 kg of soft tissue (excluding shell). Initial wet weights and shell lengths (cm) of clams were recorded, then recorded again at three month and 7.5 month. Fish size increases were approximated from initial introduction at two month into the study and again at 7.5 month.

Filamentous algae were regularly cleaned from the aquarium window and irregularly from the fibreglass sides of the tanks.

Records of temperature and salinity were kept during the period of the study. As salinity increased up to 37 ppt, freshwater was added to the reservoir tank to lower the salinity back down to 34-35 ppt. During the austral winter months (May–September) a complete greenhouse was constructed around the tanks by joining Solargro sides and a zip-door to the existing Solargro ceiling. This helped to maintain temperatures in the range of 20° C – 25° C through the winter months, despite ambient air temperatures on the coldest nights reaching as low as 7° C.

Records of nutrient levels in the aquaria were kept. The nutrients tested were ammonia, nitrite, and nitrate. Simple aquarium test kits (Aquasonic) were used. Although these colour-comparison tests are not accurate for fine detail they gave acceptable results for the purpose of this study.

Fish species and numbers, and other organisms kept in the aquaria were as follows:

Tank 1:

> 10 *Dascyllus trimaculatus* (three-spot damselfish); 2 *Chrysiptera cyanea* (blue devil); 6 *Acanthochromis polyacanthus* (spiny chromis); 2 *Pomacentrus amboinensis* (ambon damsel). The coral *Goniastrea* sp.; the coral *Turbinaria* sp.; the green macroalgae *Caulerpa sertularioides*; the brown macroalgae *Padina* sp.; filamentous brown algae; filamentous green algae.
> Note: all fish were 2.5–3.5 cm length at the start.

Tank 2:

> 10 *Dascyllus aruanus* (humbug damsel); 6 *Acanthochromis polyacanthus* (spiny chromis); 2 *Pomacentrus ambionensis* (ambon damsel); 2 *Amphiprion melanopus* (red and black anemonefish). The coral *Turbinaria* sp.; the coral *Catalaphyllia jardinei*; the soft coral *Sarcophyton* sp.; the bulb-tentacle sea anemone, *Entacmaea quadricolor;* the green macroalgae *Caulerpa sertularioides;* the brown macroalgae *Padina* sp.; filamentous brown algae; filamentous green algae.
> Note: all fish were 2.5–3.5 cm length at the start except for the pair of red and black anemone fish which were 5 cm and 8 cm in total length.

The fish were fed twice daily at about 0800 and 1700 hrs. Food consisted mainly of commercial flakes (Wardley's Total Marine Flakes), but every three days a special feeding of pilchard baitfish and small bait-shrimp was given to the fish, the anemone and fleshy tentacled corals.

Results

Clam growth rates are shown in Table 1. The overall mean increase (for clams in both tanks) in shell length and wet weight for *T. gigas* was 5.5% and 13.4%, respectively. For *H. hippopus*, the overall mean increase (for clams in both tanks) in shell length and wet weight was 4.3% and 20.4%, respectively. When comparing the growth of clams between the two tanks the results were:

Tridacna gigas:

> Tank 2 resulted in 68% higher cumulative % increase in shell length and 111.6% higher cumulative % increase in wet weight compared with Tank 1. Testing growth increment resulted in only wet weight being significantly higher ($p=0.028$) in Tank 2 compared with Tank 1 (1-way ANOVA). Shell length was not significant ($p>0.05$).

Hippopus hippopus:

> Tank 2 resulted in 110.9% higher cumulative % increase in shell length and 97.8% higher cumulative % increase in wet weigh compared with Tank 1. Growth increments tested by 1-way ANOVA resulted in no significant differences between Tank 1 and Tank 2 for either parameter.

Table 2 shows the temperature in the tanks over the period of the study in weekly intervals. Mean weekly temperatures ranged from 21.1–30.3° C. The coldest period was in late July.

Table 3 shows the levels of the nutrients ammonia, nitrite and nitrate over time in the tanks. Ammonia was found to be 0.1 ppm only about 2.5 weeks after the study began. From the second month onwards the level of ammonia was always less than 0.1 ppm. The level of nitrite in the tanks was 1 ppm for the first two months and thereafter the levels were nil. The level of nitrate was 5 ppm

Table 1. **Giant Clam (*Tridacna gigas* (Tg) and *Hippopus hippopus* (Hh)) growth rates in two recirculating aquaria over 7.5 months.**

Species/Tank/ Tag No.	Date	Shell Length (cm)/ Cumulative % incr.	Wet Weight (kg)/ Cumulative % incr.
Tg / 1 / 1	27.12.97	50.3	30.1
	04.04.98	51.0 / 1.4	32.3 / 7.3
	15.08.98	51.5 / 2.4	33.0 / 9.6
Tg / 1 / 2	27.12.98	47.9	31.2
	04.04.98	49.6 / 3.5	33.0 / 5.8
	15.08.98	50.6 / 5.6	33.5 / 7.4
Tg / 1 / 3	27.12.98	50.4	35.8
	04.04.98	51.7 / 2.6	37.5 / 4.7
	15.8.98	52.5 / 4.2	39.0 / 8.9
Hh / 1 / 1	27.12.98	26.5	6
	04.04.98	27.0 / 1.9	6.8 / 13.3
	15.08.98	27.3 / 3.0	7.0 / 16.6
Hh / 1 / 2	27.12.98	28.1	7.4
	04.04.98	28.9 / 2.8	8.0 / 8.1
	15.08.98	29.3 / 4.3	8.2 / 10.8
Tg / 2 / Liz	27.12.98	54.2	38.2
	04.04.98	55.7 / 2.7	40.0 / 2.1
	15.08.98	56.0 / 3.3	43.0 / 12.6
Tg / 2 / 4	27.12.98	45.9	27.6
	04.04.98	47.5 / 3.5	29.7 / 7.6
	15.08.98	51.8 / 12.8	35.0 / 26.8
Tg / 2 / 5	27.12.98	50.6	33
	04.04.98	51.0 / 0.8	33.8 / 2.4
	15.08.98	53.0 / 4.7	38.0 / 15.1
Hh / 2 / 3	27.12.98	28.1	7.1
	04.04.98	28.7 / 2.1	7.8 / 9.8
	15.08.98	31.0 / 10.3	9.8 / 38.0
Hh / 2 / 4	27.12.98	28.9	9.2
	04.04.98	29.8 / 3.1	9.9 / 7.6
	15.08.98	30.4 / 5.2	10.7 / 16.3

Table 2. **Weekly average water temperatures (°C) in the tanks over the period of the study. Note that temperatures begin in February 1998, not late December 1997.**

Dates	Tank 1	Tank 2
1–7.2.98	29.9±0.1	30.0±0.2
8–14.2.98	30.2±0.4	30.3±0.4
15–21.2.98	30.0±0.8	30.2±0.7
22–28.2.98	30.1±1.1	30.3±1.0
1–7.3.98	27.4±1.0	27.8±0.9
8–14.3.98	29.7±0.4	29.9±0.6
15–21.3.98	29.8±0.2	30.1±0.4
22–28.3.98	29.5±0.2	29.8±0.3
29.3–4.4.98	29.3±0.8	29.7±0.9
5–11.4.98	27.5±1.3	26.9±1.5
12–18.4.98	28.4±0.6	28.5±0.4
19–25.4.98	27.2±0.5	27.3±0.5
26.4–2.5.98	28.8±2.5	29.2±3.0
3–9.5.98	25.7±1.4	25.7±1.2
10–16.5.98	25.4±0.9	25.3±0.9
17–23.5.98	23.4±1.7	23.0±1.6
24–30.5.98	24.2±0.9	24.7±1.0
31.5–6.6.98	26.7±0.7	26.0±0.8
7–13.6.98	25.3±1.3	24.6±1.2
14–20.6.98	25.0±1.2	24.6±0.4
21–27.6.98	24.0±1.3	23.2±1.3
28.6–4.7.98	25.4±0.9	25.1±0.2
5–11.7.98	25.2±1.8	24.4±1.3
12–18.7.98	25.0±0.0	24.0±0.0
19–25.7.98	25.8±0.6	25.2±0.9
26.7–1.8.98	21.6±1.3	21.1±1.5
2–8.8.98	22.3±0.7	22.1±0.7
9–15.8.98	23.6±0.8	23.8±1.4

in the first two months of testing, and on the third month less than 5 ppm. From the fourth month of testing onwards the level of nitrate was either almost nil or nil. The larger 20,000 L volume recirculation system with seven large aquaria/tanks has been operating for 1.5 months and appears to be following the pattern of nutrient levels seen in the two tanks described above.

Fish species held in the two recirculation systems survived well and grew. Most of the damselfish reached lengths of 4.5–5.5 cm, while the red and black anemone fish reached 6 cm and 9.5 cm length respectively. Several humbug damselfish, *Dascyllus aruanus*, and spiny chromis, *Acanthochromis polyacanthus*, began to reside in terra-cotta flower pots and to clear patches of filamentous algae on clam shells. This was an indication of sexual maturity and preparedness for spawning and egg-laying.

Discussion and conclusions

The positive growth seen in the giant clams held in replicate recirculating seawater systems gives an indication regarding the capacity of this animal for use as a bio-filter. The small surface area of plastic bio-filter material used in the replicate systems was far below the recommended base figure of 0.6 m^2 . 1 kg^{-1} biomass (3 ft^2 . 1 lb.$^{-1}$ biomass). The founder and general manager of the successful Instant Ocean Hatcheries - Aquarium Systems recommended that in a closed system growing tropical reef fish, the base figure is minimal and should be doubled to 1.2 $m^2 . 1\ kg^{-1}$ biomass (Hoff 1996). In comparison, the ratio of filter material per kg of biomass in this study was about 0.24 $m^2 . 1\ kg^{-1}$ biomass. Nutrient levels never reached dangerous levels in the tanks, despite the low ratio of traditional bio-filter material, because of the presence of the giant clams.

Giant clams have been shown to uptake ammonia more rapidly than nitrate, but the uptake of nitrate was repressed in the presence of ammonia (Fitt et al. 1993). In that study ammonium nitrate was used and it was found that nitrate became depleted from the tank only after the ammonia concentration dropped below 2.5 *uM*. In addition, about half the ammonia was taken up by the clams and the other half presumably taken up by the algae and other organisms in the tank (Fitt et al. 1993). In the present study this may explain the consistently low ammonia levels while nitrate took longer to drop to almost nil or zero reading.

Table 3. **Nutrient levels in tanks over the study period. Tests were made with Aquasonic Aquarium Test Kits for ammonia, nitrite, and nitrate.**

Date	Tank	Ammonia	Nitrite	Nitrate
15.1.98	1	0.1ppm	1ppm	5ppm
	2	0.1ppm	1ppm	5ppm
15.2.98	1	<0.1ppm	1ppm	5ppm
	2	<0.1ppm	1ppm	5ppm
16.3.98	1	<0.1ppm	nil	<5ppm
	2	<0.1ppm	nil	<5ppm
14.4.98	1	<0.1ppm	nil	almost nil
	2	<0.1ppm	nil	nil
15.5.98	1	<0.1ppm	nil	almost nil
	2	<0.1ppm	nil	almost nil
14.6.98	1	<0.1ppm	nil	almost nil
	2	<0.1ppm	nil	nil
14.7.98	1	<0.1ppm	nil	nil
	2	<0.1ppm	nil	nil
13.8.98	1	<0.1ppm	nil	almost nil
	2	<0.1ppm	nil	nil

Fish all grew in size and remained healthy throughout the study. Some fish attained sexual maturity and appeared close to spawning and egg-laying.

A larger recirculation seawater system has been operating for about two months at the time of this writing. This system includes 7 x 1000 L aquaria of the same type as those used in the present study. There is a 1300 L sedimentation tank, a 1200 L pit, and a 10,500 L reservoir tank. In the aquaria there are 16 *T. gigas*, 3 *H. hippopus*, 35 *T. crocea*, corals, and a large assortment of damselfish and anemones. This system is doubling as a small public viewing aquarium and broodstock holding tanks for the clams and fish. There have been no problems to this stage.

Giant clams, particularly the largest species *T. gigas* have proven to be excellent natural bio-filters and well suited to living in large aquaria with natural sunlight. *T. gigas* may be known in future to the marine aquarists as a natural bio-filter which is guaranteed to increase in size and filtering capacity over time, a unique case.

Acknowledgements

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The SPC-ACIAR Aquaculture Workshop, 20–21 July 2001 Noumea, New Caledonia, a brief summary

Chan L. Lee[1]

I was most fortunate to be invited by Barney Smith and Dr Tim Adams to attend the special SPC-ACIAR Aquaculture Workshop held in Noumea on the 20 and 21 July 2001. The meeting was held immediately before the second SPC Heads of Fisheries meeting in Noumea.

The two-day Aquaculture Workshop was a relatively informal affair officially opened by Tim Adams, Director of Marine Resources Division, SPC. Following his welcome address, Barney Smith, ACIAR Fisheries Program Manager gave an outline of ACIAR aquaculture initiatives in the Pacific. ACIAR is very supportive of aquaculture development in the Pacific and currently has bilateral and multilateral projects in nine SPC countries. Barney strongly believes that aquaculture could play a major role on poverty alleviation, particularly at the community level. He sees his organisation supplementing and enhancing the regional programme to be funded by AusAID.

During the two-day meeting, three topics of great interest to SPC member countries were discussed during three different sessions.

Session 1: Trochus stock enhancement

The major outcomes and recommendations arising from the ACIAR trochus project are:

Outcomes

- The ACIAR funded trochus project 'Reef reseeding research of the topshell *Trochus niloticus* in northern Australia, eastern Indonesia and Pacific – FIS/94/10' was successfully completed in July 2001 and the results reported to the meeting
- The meeting supported the results and outcomes arising from the ACIAR Trochus reseeding research project
- A one-day trochus workshop in Vanuatu recommended a trochus broodstock enhancement project incorporating community-based management to restore trochus fisheries

Recommendations

- The workshop endorsed the development of a trochus stock enhancement project integrating

Figure 1. Gathering of 'Trochus believers' during the SPC-ACIAR Aquaculture Workshop, 20-21 July 2001, Noumea, New Caledonia (Right to left around the table: Gideon Tiroba, Malaki Tihala, Alofa Tuaumu, Chan Lee, Danny Jack, Maruia Kamatie, Moses Amos, Ueta Fa'asili, Fatima Sauafea and Antonio Mulipola)

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broodstock replenishment with community-based management
- The proposed project to be submitted to ACIAR for funding

Session 2: ACIAR black pearl project

The ACIAR-funded black pearl project 'Pearl oyster resource development in the Pacific islands – FIS/97/31' was successfully completed and reported to the meeting. The next phase of the black pearl project was presented

Session 3: Regional aquaculture initiative

A summary on the origin and current status of the Regional Aquaculture Initiative was provided by Ben Ponia, SPC Aquaculture Adviser. AusAID was approached in 1999 to take the project concept further resulting in the concept proposal for a SPC-AusAID Aquaculture Project. A presentation of the SPC-AusAID Aquaculture Project was presented for discussion and supported by all member countries present in the meeting.

During the meeting, I was extremely happy to be able to catch up with many delegates from the SPC member countries. I took the opportunity to talk informally to many members on their interests on the trochus broodstock enhancement project and on other aquaculture projects that may be of interest to the region. Figure 1 shows a group of 'trochus believers' gathered for a picture. I believe that I have got all the names correct. If anyone can point out to me that I have spelt any name incorrectly or provided a wrong name in Figure 1, please let me know and I will buy you a beer or kava when we next meet!!. 'Tank Yu Tumas' to all the delegates.

Translocation of trochus to Tapana Island, Tonga. A success story?

Bob Gillett[1]

In August 1992 we collected 545 shells in Lakeba Island, Lau, Fiji and flew them by commercial aircraft to Tongatapu, Tonga. Of these shells, more than 250 were flown to Vava'u and placed on a reef east of Tapana Island. In early 1998 there were reports that some juvenile trochus were seen near the Pangaimotu causeway. In April 2001, while doing a 34 km swim to a dozen islands in Vava'u (that's a different story), I crossed a reef near the eastern tip of Kapa Island and spotted a 10 cm trochus shown in the picture.

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[1] PO Box 3344 , Lami, Fiji

[2] Editor's note: Is this one of the survivors from the 1992 stocking or is it an F1 or F2 from the 1992 stocking? Comments from readers would be most welcome.

Snapshots of the trochus button factory in Port Vila, Vanuatu

Chan L. Lee[1] and Moses Amos[2]

During a visit to Port Vila from 23 to 25 May 2001 to attend the ACIAR trochus end of project meeting, Moses Amos was kind enough to organise a visit to the largest trochus button factory on the island of Efate.

We hope the snapshots provided in this brief article will give a good insight on the trochus fishery in Vanuatu and the operations of its largest button factory in Port Vila.

Trochus fishery in Vanautu

Trochus shell is a valuable commodity to the artisanal fishermen in Vanuatu. Data provided by the Department of Fisheries (Fisheries Division Annual Report 1998 and 1999) indicated that export of raw and processed shells fluctuated between about 28 t and 84 t in the last decade (Table 1).

Table 1. **Trochus shell export (raw and processed) from Vanuatu, 1990–1999.**

Year	Quantity (kg)
1990	51,000
1991	67,009
1992	19,539
1993	61,296
1994	25,400
1995	56,091
1996	84,317
1997	78,229
1998	57,049
1999	27,900

Source: Fisheries Division Annual Report, Port Vila, Vanuatu.

The export value of the trochus shells was about USD 482,000 (VUV 77.1 million using a conversion of USD 1.00 = VUV 160) and USD 697,000 in 1998 and 1999, respectively. Since the export value for 1999 is about 45% higher than 1998 and yet the harvest is about half that of 1998, it could be assumed that most of the 1999 shells were sold as higher priced processed button blanks to overseas countries. This move to export semi-processed shells is highly desirable and is a good outcome for Vanautu. By adding value to the raw shells, it creates additional employment and stimulates other economic activities in Port Vila.

Snapshots of the button factory in Port Vila

Port Vila has two factories producing button blanks. The larger factory produced >22 t of raw button blanks in 1999 with an export value of >USD 500,000. The processes involved in many button blanks are relatively simple and fairly labour intensive, and involves the following steps:

- grading the raw shells,
- producing blanks from the shells,
- automatic grading of blanks,
- semi-polishing of blanks,
- sizing of semi-polished blanks, and
- exporting.

The shell wastes resulting from the blanking operation also has a market value and are normally collected and packed in bags and exported. Figures 1 to 9 provide a snapshot of the production process of making raw button blanks for export.

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Figure 1. Raw shells delivered to the button factory for sorting

Figure 2. A row of 'button blanking' machines

Figure 3. Workers 'punching' button blanks

Figure 4. Close-up of blanking

Figure 5. 'Waste' shell after blanking

Figure 6.
Automatic grading of button blanks

Figure 7.
Rough polishing of button blanks

Figure 8.
Sorting of blanks into different size groups for export

Figure 9.
Packing waste shells for export

PIMRIS is a joint project of 5 international organisations concerned with fisheries and marine resource development in the Pacific Islands region. The project is executed by the Secretariat of the Pacific Community (SPC), the South Pacific Forum Fisheries Agency (FFA), the University of the South Pacific (USP), the South Pacific Applied Geoscience Commission (SOPAC), and the South Pacific Regional Environment Programme (SPREP). This bulletin is produced by SPC as part of its commitment to PIMRIS. The aim of PIMRIS is to improve the availability of information on marine resources to users in the region, so as to support their rational development and management. PIMRIS activities include: the active collection, cataloguing and archiving of technical documents, especially ephemera ('grey literature'); evaluation, repackaging and dissemination of information; provision of literature searches, question-and-answer services and bibliographic support; and assistance with the development of in-country reference collections and databases on marine resources.

PIMRIS

Pacific Islands Marine Resources
Information System