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I N F O R M A T I O N B U L L E T I N



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## Editorial

It is with pleasure to present Bulletin No. 7 my first issue as the editor of the *SPC Trochus Information Bulletin*.

I would like to take the opportunity to thank Kevin Passfield for so ably producing the past bulletins and to Aymeric Desurmont, Fisheries Information Specialist, SPC who helped and supported me when I first took over the position in January 2000.

It had been my original intention to produce two Trochus bulletins yearly, but alas this was not to be. Like Kevin, I find that it's harder getting contributions from our trochus bulletin readers than extracting teeth! Instead of waiting for more contributions and delaying the publication of the bulletin any further, I decided to produce Bulletin No. 7 quickly and to use the opportunity to canvass for contributions in the next bulletin. Consequently, many articles and issues in this bulletin are slanted towards ACIAR-funded reseeding projects and on items from Australia. I hope that trochus readers find them interesting and informative.

Dear readers, I stress that the *SPC Trochus Information Bulletin* is your magazine. Without your contributions, it cannot survive and without your inputs and news, it won't be of much interest to its readers. Therefore, please send me research articles, notes or even local gossips on trochus fishery events or happenings in your country and region. They will always be of interest to some people. I believe, for example, many readers would be keen to know the latest information on trochus button production in Vanuatu; the ICLARM research work on trochus enhancement in Solomon Islands; or the latest Cook Islands work on trochus or greensnail hatchery and stock enhancement work. Fiji has previously expressed inter-

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and more . . .



est in trochus hatchery and stock enhancement and Papua New Guinea, Solomon Islands and many South Pacific nations are similarly interested in hatchery production and stock enhancement work involving traditional customary management practices.

I have also received enquiries from Thailand and India on my current trochus research work. Interests on trochus are therefore out there.

Write and tell me what is happening in your country or in your region, what you would like to do in the future, and I will make sure news from your region is quickly disseminated through this bulletin.

I hope to have Bulletin No. 8 ready for printing in late 2001. Looking forward to hearing and receiving some interesting contributions from you in the next six months.

Over to you readers.

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The graphic is a tilted rectangular box with a background image of a trochus shell. It contains the title 'SPC Trochus Information Bulletin on-line' in a large, bold font. Below the title, it states that the first six issues and other publications are available online. Two URLs are provided: 'http://www.spc.int/coastfish/' and 'http://www.sidsnet.org/pacific/spc/coastfish/'. At the bottom, it instructs readers to go to Newsletters for Trochus and other information bulletins, or to Reports for other recent SPC Marine Resources Division publications.



## Testing the efficacy of restocking trochus using broodstock transplantation and juvenile seeding – an ACIAR-funded project

Steven W. Purcell<sup>1</sup> and Chan L. Lee

### Background

Programs to restock or establish populations of trochus (*Trochus niloticus*) have been undertaken in the South Pacific region with variable success since the 1920s (Gillett 1993; Crowe et al. 1997). However, most activities were unreplicated and have not been designed experimentally with control sites. This 'try-it-and-see' approach can give equivocal results, especially where there is an existing population and some natural recruitment. Additionally, while different methods are available for restocking trochus, their outcomes can be site- or region-specific (Crowe unpubl. data). Such shortcomings leave uncertainty about which method will be most appropriate for a given situation.

Trochus on the nearshore reefs off the northern coast of Western Australia (WA) are fished solely by Aboriginal peoples who have a long history in the trochus fishery and rely financially on trochus collection. In recent years, annual harvests within the fishery have declined to <20 tonnes of raw shell (Fisheries WA unpubl. data), from a peak of 135 tonnes in 1980 (Magro 1997a). The declining yields have prompted action for better management and research into stock enhancement.

A recent research project in WA (1995–1998), collaborating with researchers from Vanuatu and Indonesia, involved a set of studies on stock enhancement (funded by the Australian Centre of Agricultural Research; project PN9410). Among these were trials of grow-out of trochus in sea cages and direct seeding of 16–25 mm juveniles onto reefs with depleted (i.e. reduced) trochus stocks. Although these methods achieved some success in Vanuatu and Indonesia, they appeared ineffective on reefs in Western Australia. Therefore, the researchers concluded that alternative methods such as broodstock transplantation

or mass-release of small (1–4 mm) juveniles should be examined for WA reefs.

Broodstock translocation and mass-seeding of small, hatchery-produced juveniles are two contrasting methods for stock enhancement of trochus. The latter avoids the costs of culturing animals to a large size in the hatchery and has a potential to yield high returns for an initial, minimal effort. For example, Heslinga et al. (1983) reported enhanced numbers of juveniles at a site in Palau where 2–6 mm juveniles had been released in mass numbers. However, the success of either method may differ from one region to another depending on physical conditions and the reef environment. It is therefore important to conduct trials of these methods in proposed regions and monitor their effects prior to full-scale activities.

A current project (extension to ACIAR project - PN9410) is testing broodstock transplantation and mass-release of 1–4 mm juveniles in separate field experiments in the Buccaneer Archipelago, WA. In this paper, we present an overview of the experiments and highlight the challenges of testing their efficacy. The utility of the two methods is also compared using preliminary findings from these experiments and published reports.

### Stock enhancement studies in Western Australia

#### *Broodstock transplantation*

Transplantation of trochus broodstock has been used extensively throughout the Pacific as a method for establishing breeding populations on reefs. Introductions of broodstock to Aitutaki Atoll, Cook Islands in 1957 started a breeding population that provided for a first harvest in 1981 of almost 200 tonnes of shell (Sims 1985).

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Similarly, broodstock introduced to Tahiti, French Polynesia in 1957 started a fishery that yielded more than 350 tonnes of shell between 1971 and 1973 (Doumenge 1973). However, varying success of this method among sites and regions (Gillett 1993) shows that experimental trials are needed to establish its efficacy for other areas.

Two separate experiments are being conducted in Western Australia: one on fringing rocky reefs along Dampier Peninsula, and another on coral reefs within discrete bays surrounding Sunday Island (Fig. 1). For both experiments, broodstock trochus (>75 mm maximum basal diameter) were collected from a large offshore population at Brue Reef (15°56'S, 123°03'E) and placed within 50 m<sup>2</sup>, 30 cm high, fenced enclosures ('corrals') on the intertidal sections of the reefs. The broodstock were corralled for three months at the end of 1999 then allowed to disperse on the reef. Gimin and Lee (1997) showed that this period is likely to be the peak of the spawning season for trochus in WA.

The reefs along Dampier Peninsula are comprised mainly of sandstone and contain populations of several topshell species (e.g. *Trochus hanleyanus*,

*Tectus pyramis*, *T. fenestratus*), but not *Trochus niloticus* (trochus). Trochus shells have been found in aboriginal middens (discarded shell deposits) along this coast (C. Ostle, pers. comm.), suggesting that this species occurred previously on these reefs. In 1994, some juvenile trochus (20–30 mm) released on two reefs survived to later attain >100 mm in size, but numbers established may have been insufficient for successful breeding, as no new juveniles have been found. In the present experiment, 500 trochus broodstock were transplanted onto each of three large reefs. Broodstock sites (broodstock added) and control sites (no broodstock) were established randomly, 600–1400 m apart, on opposite ends of each reef. The sites (50 m x 50 m) were surveyed for trochus at the commencement of the experiment and thereafter at three-monthly intervals using replicate (2 m x 50 m) belt transects. This orthogonal ('crossed') experimental design, having a broodstock and control site on each reef, is not optimal as planktonic larvae from broodstock may disperse easily to control sites.

The reefs surrounding Sunday Island are comprised of biogenic limestone and contain populations of the topshells listed above. *T. niloticus* also

occurs on the reefs but most populations are depleted from overfishing. In this experiment, eight discrete reefs were randomly assigned as broodstock or control reefs, i.e. four replicate reefs for both treatments (Fig. 1).

For each broodstock reef, 275 broodstock were transplanted into enclosures at the centre of the study sites (50 m x 50 m) and released after three months. For both broodstock and control reefs, total number and sizes of trochus within the study sites were surveyed as in the Dampier Peninsula experiment. This is a nested ('hierarchical') experimental design, as there are different sets of replicate reefs for the two treatments.

#### Mass-seeding of 1–4 mm juveniles

The recruitment-limitation paradigm of marine ecology argues that increasing the number of juveniles in a popu-

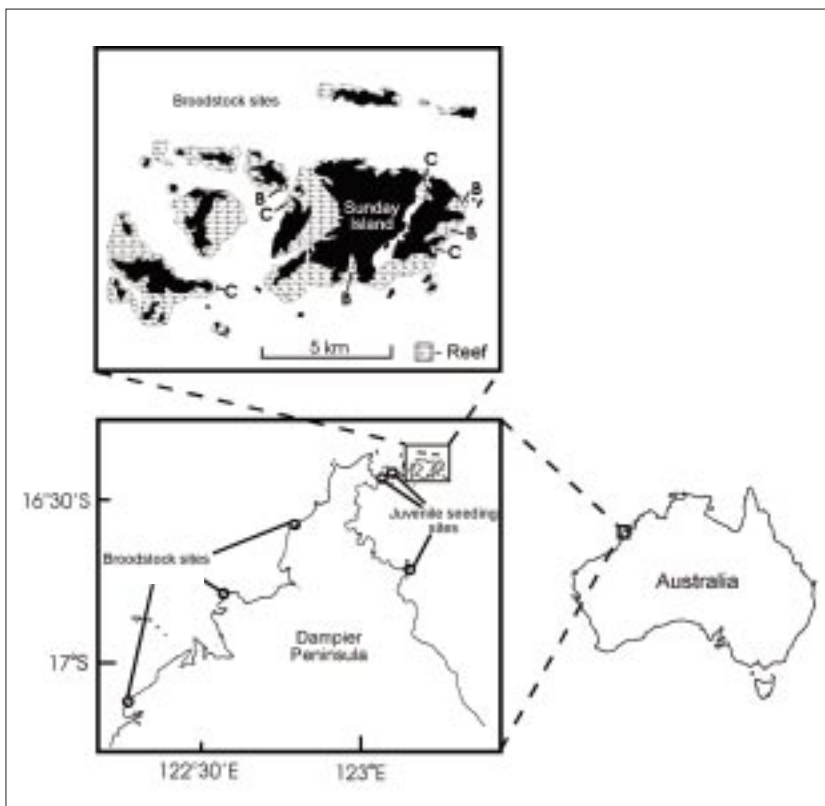


Figure 1. Study sites for broodstock translocation and juvenile seeding experiments in WA. Reef sites in upper inset denoted as: C - control; and B - broodstock transplanted.

lation will translate into future increases to adult numbers (Doherty 1999). If trochus populations on a reef are limited by recruitment, then mass-release of hatchery-produced juveniles should enhance stocks.

With increasing shell size, juvenile trochus become less prone to predation after seeding (Castell 1995; Crowe unpubl. data), but are increasingly costly to culture (Lee 1997). Newly settled juveniles can be produced in mass quantities for minimal cost and their use may avoid the risk of inferior behaviour and morphology from long periods of captivity (cf. Stoner and Davis 1994; Shepherd et al. in press; Purcell in review). Survival rates of released small juveniles are likely to be low, but seeding at this size may prove to be more cost-effective due to the scale of release.

The present experiment aims to test the enhancement of trochus populations through mass-release (seeding) of 1–4 mm juveniles onto sites on three intertidal reefs (reef names in Fig. 2) of Buccaneer Archipelago (Fig. 1). The experiment uses a blocked experimental design in which each reef was divided in half and three sites, 100–200 m apart, marked within each half.

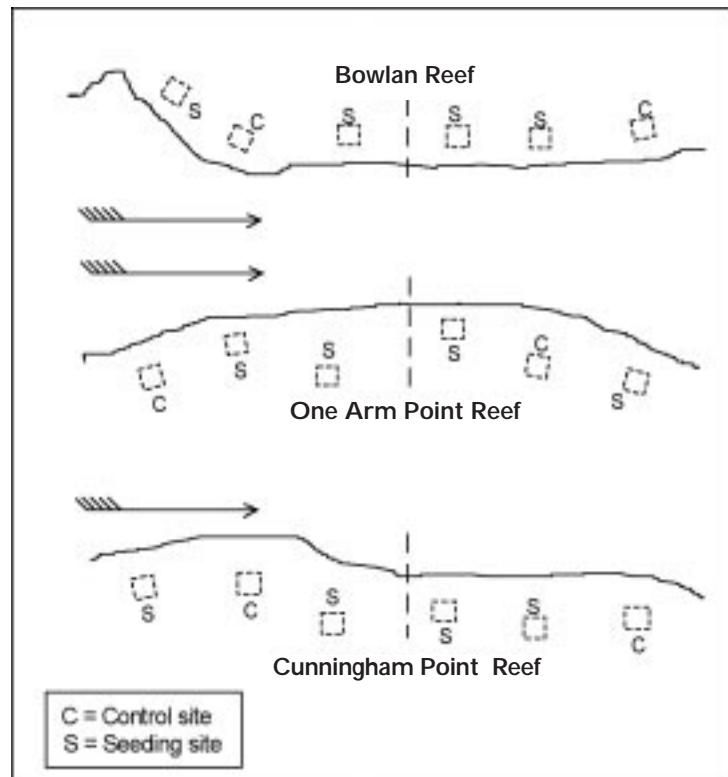
Originally, the three sites within each reef half were assigned one of the following three treatments: control, seeding, and seeding + traps (small traps to remove benthic predators experimentally). There were difficulties implementing the third treatment, so the traps were removed, leaving one control site and, effectively, two seeding sites per reef half (Fig. 2).

In total, approximately 146,000 juveniles were seeded; approximately 12,000 onto each of the twelve seeding sites. At three-monthly intervals, replicate belt transects are surveyed at each site and the numbers of trochus within 10 mm size classes recorded. Repeated measures ANOVA statistics will be used to test for enhancement of trochus populations through time.

## Testing the success of stock enhancement

### Juvenile life history

One of the dilemmas with trochus research in Western Australia is that juveniles with a basal



**Figure 2.** Schematic diagram of layout of sites (dashed boxes) for control and juvenile seeding treatments in the mass-seeding experiment. Arrows denote direction of flooding tidal currents. Dashed lines represent the reef split for the design.

diameter of <25 mm can rarely be found. Cryptic behaviour of juveniles is a trait common to other stock enhancement candidates such as sea cucumbers (Battaglene and Bell 1999), green snail *Turbo marmoratus* (Yamaguchi 1993), and temperate abalone (McShane 1992). We have surveyed 600 quadrats (0.5 m<sup>2</sup>) and 1584 belt transects (2 x 50 m) on reef flat habitats and have recorded hundreds of juveniles 25–50 mm but only three individuals <25 mm. Magro (1997b) and Crowe (unpubl. data) had similar findings after extensive surveys in WA. Juveniles <25 mm are too vulnerable to predators and probably live in holes and spaces within the three-dimensional reef matrix or packed rubble, i.e. under the reef surface. Only after they reach about 25–30 mm (about one year old) will they venture onto the upper surface of these reefs where they can be sighted in surveys.

The life history of trochus therefore presents a problem: the success of the restocking method(s) will be evident only after the animals have reached 30 mm in size. Monitoring before this time is still useful because it provides 'before' data of the temporal and spatial variations in abundances of larger juveniles within and among sites, giving a more rigorous final test. Ideally, monitoring of

restocking trials should occur on a regular basis (e.g. every two to three months) for a period of about three years to allow time for restocked trochus to attain harvest size.

### Protocols for design of restocking experiments

In cases with depleted trochus populations, experiments on restocking need to show that subsequent increases are due to enhancement activities rather than natural recruitment; this requires replication of enhancement sites and comparison to the past natural recruitment at control sites. Trochus abundance (per unit area) at sites should be estimated, usually by surveys using timed searches, transects or quadrats. Most of the published experiments on trochus seeding have been limited by poor site replication and frequency of monitoring.

Presented here are data from two reefs (Bowlan Reef and One Arm Point Reef; see Figs. 1 and 2) 500 m apart, which have existing juvenile and adult stocks. On four occasions over a six-month period, trochus were counted and measured within 12 random replicate strip transects (2 m x 50 m) at each of six sites within the reef platform habitat on both reefs. Data were examined for 20–50 mm trochus, i.e. juveniles that can be found in visual surveys. The juveniles released at these sites would not have yet grown to 25 mm basal diameter (the smallest size found) during the time periods presented, so abundance estimates are of wild stock, and illustrate natural variability in time and space. Figure 3 shows that the number of 20–50 mm juveniles varied markedly between the two reefs, among sites within a reef and among survey occasions. High variability in juvenile abundance within sites highlights the need for adequate within-site replication of surveys.

The data demonstrate not only that (juvenile) trochus abundance varies considerably over short time scales, but the patterns of change can be quite different among neighbouring sites within a reef. This temporal variability could be due to local movements of trochus, spatial patchiness in predation and to cryptic behaviour of juvenile trochus being expressed at particular times. Experiments and monitoring of restocking meth-

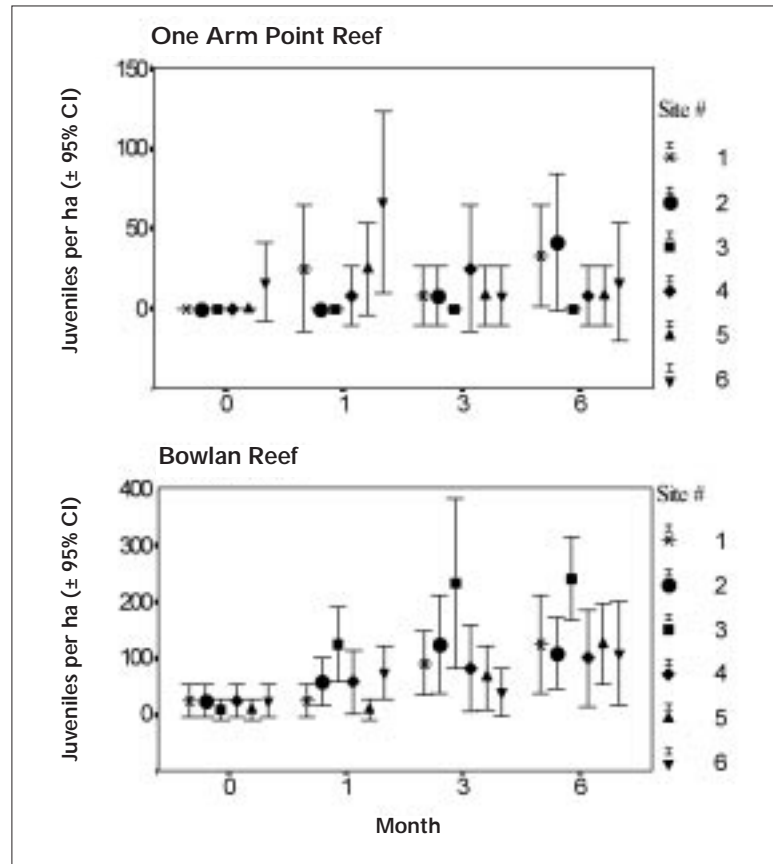


Figure 3. Error-bar plots for mean abundance of 20–50 mm juveniles at each of six sites on two study reefs over a six-month period. Note change in scale between graphs.

ods need to be designed to account for the natural temporal and spatial variability of stocks. The data presented suggest that restocking experiments need to be tested using multiple reefs, replication of treatments within reefs and monitoring at frequent intervals.

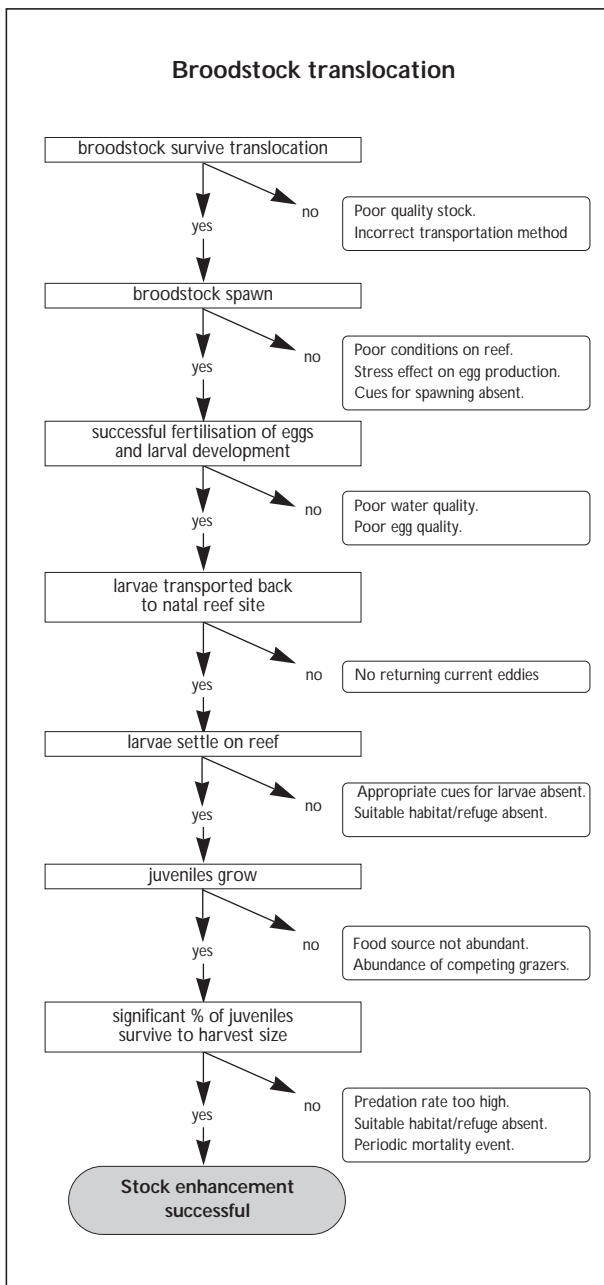
### Broodstock translocation vs. juvenile seeding

These are extensive (broodstock translocation) and semi-extensive (juvenile seeding) methods, requiring minimal costs and initial effort. This contrasts with costly, long-term culturing or grow-out of trochus to a large size for release (Lee 1997). However, the cost-efficiency of broodstock translocation and juvenile seeding may be compromised by intrinsic features of the reef environment. For both methods, many steps need to be achieved and should be assessed when evaluating sites for restocking.

For most cases, broodstock translocation is a cheaper and simpler method. In WA, enclosures were constructed easily on the reef and keep the broodstock together for spawning. We believe that

this method would increase synchronous spawning and fertilisation of eggs compared to freely released broodstock, although this idea has not been proven. Successful stock enhancement of trochus through broodstock translocation relies on suitable environmental conditions for spawning, larval development, larval settlement, growth and survival of juveniles to adulthood (Fig. 4).

In comparison, releasing cultured juveniles onto reef sites relies on fewer steps to be achieved on the reef than broodstock translocation (Fig. 5).



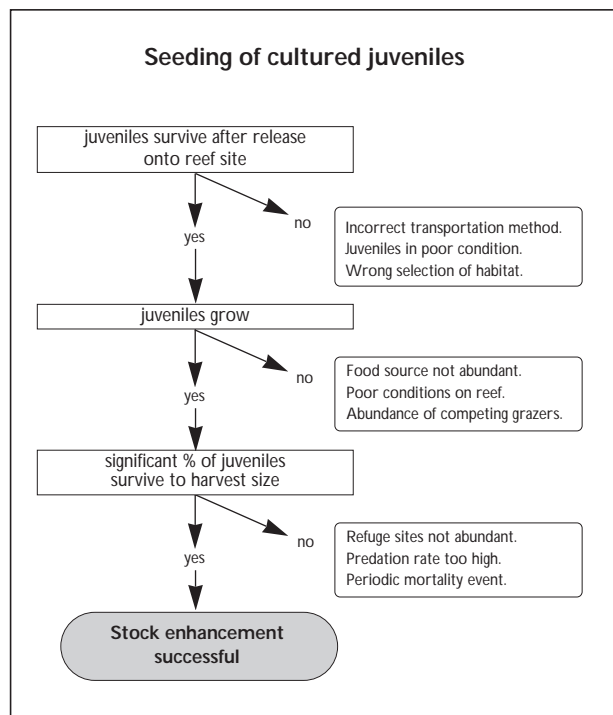
**Figure 4. Broodstock translocation:** flow-chart of critical steps during the process of stock enhancement. Likely causes for failure during successive steps are provided in boxes on right.

Much of the uncertainty is removed because development and settlement steps are assured in the hatchery. Juvenile seeding is the preferred method where reef sites are unsuitable for larval settlement and/or self-recruitment but are good for juvenile growth and survival.

The costs and time required for culturing juveniles are obvious disadvantages. In addition, greater care is needed in site selection because juveniles are less mobile than planktonic larvae and must be seeded near refuge in a suitable habitat.

Appropriate site selection when seeding juveniles has been shown to be a critical factor for the subsequent survival of trochus (T. Crowe unpubl. data) and queen conch (Stoner 1994). Unfortunately, there is still little information available on the specific habitat characteristics preferred by trochus, although this has been studied recently (Colquhoun pers. comm.).

The broodstock and juvenile seeding experiments in WA will reveal which method is most cost-effective for aboriginal communities to implement on these reefs. Together with appropriate management, the restocking methods are expected to be used for broad-scale activities to provide lasting benefits to this trochus fishery.



**Figure 5. Juvenile seeding:** flow-chart of critical steps during the process of stock enhancement using hatchery produced juveniles. Likely causes for failure during successive steps are provided in boxes on right.

## References

- Battaglione, S.C. and J. Bell. 1999. Potential of the tropical Indo-Pacific sea cucumber, *Holothuria scabra*, for stock enhancement. In: B.R. Howell, E. Moksness & T. Svåsand (eds). Stock enhancement and sea ranching. Oxford: Fishing News Books. 479–490.
- Castell, L.L. 1995. Relevant findings from research into seeding with *Trochus niloticus* in Australia and Vanuatu. Report submitted to James Cook University, Townsville, Queensland, 17 p.
- Crowe, T.P., M.J. Amos and C.L. Lee. 1997. The potential of reseeding with juveniles as a tool for the management of trochus fisheries. In: C.L. Lee and P.W. Lynch (eds), Trochus: status, hatchery practice and nutrition. ACIAR Proceedings No. 79. 170–177.
- Doherty, P.J. 1999. Recruitment limitation is the theoretical basis for stock enhancement in marine populations. In: B.R. Howell, E. Moksness & T. Svåsand (eds), Stock enhancement and sea ranching. Oxford: Fishing News Books. 9–21.
- Doumenge, F. 1973. Developing the exploitation of *Trochus niloticus* stock on the Tahiti reefs. South Pacific Commission Fisheries Newsletter 10:35–36.
- Gillett, R. 1993. Pacific Islands trochus introductions. South Pacific Commission Trochus Information Bulletin 2:13–16.
- Gimin, R. and C.L. Lee. 1997. The reproductive cycle of *Trochus niloticus* in King Sound, Western Australia. In: C.L. Lee and P.W. Lynch (eds), Trochus: status, hatchery practice and nutrition. ACIAR Proceedings No. 79. 52–59.
- Heslinga, G.A., O. Orak and M. Ngramengior. 1983. Trochus reseeding for commercial exploitation - Republic of Palau. Pacific Tuna Development Foundation report. p. 38.
- Lee, C.L. 1997. Design and operation of a land-based closed recirculating hatchery system for the topshell, *Trochus niloticus*, using treated bore water. In: C.L. Lee and P.W. Lynch (eds), Trochus: status, hatchery practice and nutrition. ACIAR Proceedings No. 79. 27–32.
- Magro, K.L. 1997a. Catch history of trochus in King Sound, Northwestern Australia between 1980 and 1995. In: C.L. Lee and P.W. Lynch (eds), Trochus: status, hatchery practice and nutrition. ACIAR Proceedings No. 79. 131–142.
- Magro, K.L. 1997b. Establishing a relationship between habitat and abundance of trochus in King Sound, Northwestern Australia. In: C.L. Lee and P.W. Lynch (eds), Trochus: status, hatchery practice and nutrition. ACIAR Proceedings No. 79. 150–163.
- McShane, P.E. 1992. Early life history of abalone: a review. In: S.A. Shepherd, M.J. Tegner and S.A. Guzmán del Prío (eds) Abalone of the world: biology, fisheries and culture. Oxford: Blackwell Science Ltd. 120–138.
- Purcell, S.W. In review. Cultured vs. wild juvenile trochus: disparate shell morphologies sends caution for seeding.
- Shepherd, S.A., P.A. Preece and R.W.G. White. In press. Tired nature's sweet restorer? Ecology of abalone stock enhancement in Australia. Canadian Journal of Fisheries and Aquatic Sciences.
- Sims, N. 1985. The abundance, distribution and exploitation of *Trochus niloticus* in the Cook Islands. Proceedings of the 5th International Coral Reef Symposium. 5:539–544.
- Stoner, A.W. 1994. Significance of habitat and stock pre-testing for enhancement of natural fisheries: experimental analyses with queen conch *Strombus gigas*. Journal of the World Aquaculture Society 25:155–165.
- Stoner, A.W. and M. Davis. 1994. Experimental outplanting of juvenile queen conch, *Strombus gigas*: comparison of wild and hatchery-reared stocks. Fishery Bulletin 92:390–411.
- Yamaguchi, M. 1993. Green snail. In: A. Wright and L. Hill (eds), Nearshore marine resources of the South Pacific. Institute for Pacific Studies, Suva. 710 p.







## Spawning and seed production of the green snail (*Turbo marmoratus* L.) in Indonesia

Sigit A.P. Dwiono<sup>1</sup>, Pradina<sup>1</sup> and P.C. Makatipu<sup>1</sup>

### Abstract

Of five adult green snails, *Turbo marmoratus* used for spawning (shell opening diameters between 10.25 to 14.35 cm), two males and 1 female successfully spawned. The female produced 1,825,750 eggs, each measuring  $0.24 \pm 0.02$  mm in diameter. Hatching rate was estimated to be 66.7%.

Eggs hatched into planktonic trochophore 14 hours after fertilisation. They metamorphosed into benthic juveniles 60 hours later and began feeding on sessile diatoms.

In the laboratory, the juveniles were fed with cultured sessile diatoms of the genus *Navicula* in 2.25-tonne rectangular fibreglass tanks. Juveniles measuring  $0.49 \pm 0.05$  mm in shell diameter grew into young juveniles of  $7.07 \pm 2.03$  mm within a 28-week period.

### Introduction

Green snail (*Turbo marmoratus* L.), locally known as Batulaga, Matabulan or Burgos is the biggest marine gastropod species of the genus *Turbo*, family Turbinidae (Gastropoda: Archaeogastropoda: Trochidea) (Eisenberg 1981; Abbott and Dance 1986; Wilson 1993). The maximum shell diameter encountered is 25 cm, weighing more than 2 kg (Kubo 1991; Yamaguchi 1993).

*T. marmoratus* inhabits similar habitats as other marine snail species such as topshell (*Trochus niloticus*), *Tectus pyramis* and turbinid snails (*Turbo argyrostomus* and *Turbo chrysostomus*): reef flats with constant clear flowing water, down to depths of 20 m. The animal is active at night (nocturnal) and prefers dead coral beds where micro- and macroalgae grow abundantly. Natural distribution of the green snail includes the Indo-Pacific region from the western Indian Ocean (Kenya, Seychelles, Chagos, Andaman and Nicobar Islands); Southeast Asian waters (Malaysia, Indonesia, Thailand and the Philippines) to Fiji in the South Pacific. In the western Pacific, its distribution extends to 29° north latitude in the Ryukyu Islands. As a result of its introduction in 1960, the green snail is currently found in French Polynesia (Yamaguchi 1993).

Like the topshell (*T. niloticus*), the green snail is harvested for its valuable shell, which has a very high mother of pearl content; its meat is a protein source and is eaten by the fishers. The pearly shell of green snail is used in the ornamental, handicraft, paint and cosmetic industries. According to the Food and Agriculture Organization (FAO) of the United Nations, world production of green snail shell was estimated at 800 tonnes and 1000 tonnes for 1986 and 1987, respectively (Yamaguchi 1993). It is believed that green snail harvesting in Indonesia started early this century. Indonesian Central Bureau of Statistic stated that green snail exports from Indonesia between 1970 and 1981 ranged from 44.25 tonnes to 144.60 tonnes with two main export harbours: Ujung Pandang (now Makassar) and Ambon (Usher 1984). In the Moluccas Province of Indonesia, green snail production between 1985 and 1989 ranged from 1.6 tonnes to 16.6 tonnes (Arifin and Setyono 1992). In the Ambon market, green snail shells sold for IDR 60,000 (about USD 7.5) per kilogram.

As a commercial commodity, the shell does not require special handling at the post-harvest stage and can be readily stock-piled without deterioration to its quality. This advantage leads to intensive harvesting, which in turn endangers the natural population. In order to preserve endangered

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marine resources, the government of Indonesia prohibited the harvesting of several animal species, including green snail, through a ministerial decree (No. 12/Kpts-II/1987). However, in anticipation of its potential for aquaculture, the Indonesian government issued another decree (No. 07/Kpts/DJ-VI/1988) allowing utilisation of protected animals if they are obtained through culture activity. Unfortunately, this decree does not attain its objective since the aquaculture technique for green snail in Indonesia is not available.

In order to fill this gap, research on green snail aquaculture was conducted at the Division of Marine Resources, R&D Center for Oceanology, Indonesian Institute of Sciences (LIPI) in Ambon. This paper describes the results of the first attempt at induced spawning and larval rearing of green snail in the LIPI laboratory in Ambon, Indonesia.

## Materials and methods

Broodstocks were collected by SCUBA diving at coastal reefs off the Lontor village, Banda Island, Central Moluccas in October 1996. The broodstocks were brought to Ambon by ship in a tank containing seawater with moderate aeration.

Induced spawning was initiated during the new moon (27 and 28 October 1996). Prior to induction, the selected spawners were cleaned free of epiflora, epifauna and dirt on the morning of spawning induction. They were then rinsed and placed in a 40-litre plastic bin filled with sufficient filtered seawater to immerse all animals. Strong aeration was then supplied to the water in the bin for approximately eight hours. At 6.00 pm, the broodstocks were transferred into a 2.25-tonne rectangular fibreglass tank filled with UV-treated and filtered (2  $\mu$ m) seawater. Spawning usually occurred during the night.

After spawning, some eggs were collected and observed under the microscope to ensure that fertilisation had taken place, which is indicated by the first cell division that normally occurs within five minutes after fertilisation. Fertilised eggs were then filtered through 60  $\mu$ m mesh size sieve and rinsed with clean filtered seawater; their numbers were estimated. The eggs were then divided and transferred into one 2.25-tonne rectangular and two 2.0-tonne cylindro-conical fibreglass tanks.

Soon after the eggs hatched into free swimming trochophore larvae, the density of the larvae in each tank was estimated. The larvae together with its medium were poured into similar size tanks containing cultured sessile microalgae, *Navicula* spp. Cultured algae consisted of the mix-

ture of three microalgae species belonging to the genus *Navicula* which had been isolated from Ambon Bay (Makatipu et al. 1996). The growth of the algae was enhanced by adding "Okinawa" culture medium (Dwiono et al. 1995).

In the laboratory, the juveniles were fed on the sessile microalgae. In order to increase the surface area for algal growth, substrates in the form of dead corals and empty shells were added to provide additional surfaces for the growth of diatom species. Faeces and other sediments were siphoned out daily and fresh filtered seawater was added to replace the lost water. Total seawater changes were done only when there were phytoplankton contaminations (which may compete with sessile diatoms in nutrient uptake) or the quantity of remaining benthic microalgae was insufficient and juveniles had to be moved to another tank containing newly cultured microalgae. Growth rates were estimated fortnightly by measuring 50 eggs or juvenile shells selected randomly for measurements.

## Results

No spawning activity was observed during the first night although the animals were active and moved around the tank bottom. In the morning, spawning induction was repeated by providing similar aeration 'stimuli' to the animals throughout the day. In the evening they were transferred into a spawning tank containing freshly prepared UV-treated filtered seawater. After this second treatment, the broodstocks were observed to be more active compared to the previous night, and the first spawning was observed in one female and two males that evening (Table 1).

The first male initiated spawning by releasing white clouds (sperm) directly into the water at 9.30 pm. The sperm were expelled through its siphon by alternate contraction-relaxation movement of the soft part of the body. Sperm were intermittently released every 5 to 10 minutes. At 10.30 pm, two-thirds of the seawater in the spawning tank was drained to reduce the high sperm concentration in the water, and fresh UV-treated filtered seawater was added as replacement. The change of water induced the first male to intensify its spawning; it also induced the second male to spawn followed by the spawning of the female.

The spawning episode in the female was very short (~ 30 minutes) but intense. No further spawning was observed after 11.10 pm; the female remained inactive at the bottom of the tank. Consequently, at 0.30 am (29 October), observation was stopped as no further indication of

**Table 1. Induced spawning of the green snail (*Turbo marmoratus* L.) under laboratory conditions at the Experimental Mariculture Laboratory (28 October 1996).**

No.	Shell diameter (cm)	Sex	Remark
1	14.35	Male	Spawnd from 21.30 pm to 00.30 am
2	12.40	Unknown	No spawning
3	12.00	Female	Spawnd from 10.40 pm to 11.10 pm
4	11.35	Male	Spawnd from 10.39 pm to 00.30 am
5	10.25	Unknown	No spawning

spawning activities was observed, and all spawners were transferred to the recovery tank.

On release, the eggs were round and dark green in colour, measuring  $0.24 \pm 0.02$  mm in diameter. The egg underwent the first cell division within 5 minutes after fertilisation. Four, eight and 16 cells stages were achieved 10 minutes, 20 minutes and 45 minutes after fertilisation, respectively. After the 16-cells stage the eggs were collected with a 60  $\mu$ m mesh size sieve, rinsed with filtered seawater, and their numbers estimated. The total number of eggs spawned from the female was esti-

mated at 1,825,750. The eggs were transferred into three hatching tanks.

Fourteen hours after fertilisation, the eggs hatched into free-swimming trochophore larvae. Estimation from the three hatching tanks gave an average hatching rate of 66.7%. Approximately 22 hours later (36 hours after fertilisation), most of the larvae had their first shell torsion and metamorphosed into veliger larvae. At 60 hours old, these larvae

reached the pediveliger stage with distinctive velum and foot. Pediveliger with fully developed foot tested and moved on the substrate before finally metamorphosing into benthic living juveniles without their velum. The juveniles fed by scraping sessile benthic microalgae that grew on substrate and on the tank's surfaces.

The growth rate of the green snail juveniles are presented in Table 2. The table shows that the instantaneous growth rate of an animal was not constant, but increased with the age and size of the animal. Up to the 14th week, the instantaneous

**Table 2. Early development and growth of green snail (*Turbo marmoratus* L.) in the laboratory.**

Age (weeks)	Stage	Shell diameter (mm)				Instantaneous growth rate
		Min	Max	Mean	SD	
0	Eggs	0.21	0.27	0.24	0.02	–
2	Juvenile	0.40	0.55	0.49	0.05	–
4	Juvenile	0.55	0.85	0.70	0.07	0.10
6	Juvenile	0.82	1.18	0.95	0.09	0.12
8	Juvenile	1.00	1.88	1.21	0.16	0.13
10	Juvenile	1.39	1.64	1.48	0.13	0.13
12	Juvenile	1.27	1.91	1.77	0.16	0.14
14	Juvenile	1.54	3.36	2.10	0.34	0.16
16	Juvenile	1.73	3.54	2.54	0.42	0.22
18	Juvenile	2.00	4.27	3.05	0.65	0.25
20	Juvenile	2.18	5.64	3.34	0.76	0.14
24	Juvenile	2.43	6.37	4.89	1.01	0.39
26	Young snail	2.17	9.64	5.75	1.64	0.44
28	Young snail	3.56	11.31	6.62	1.82	0.43
30	Young snail	4.69	12.62	7.07	2.03	0.22

Values are obtained from random measurements of 50 individuals and presented for minimum (Min), maximum (Max), means (Mean) and standard deviation (SD). Instantaneous growth rate is the average shell growth between two successive measurements.

growth rate ranged from 0.10 mm to 0.16 mm per week. It varied from 0.22 mm to 0.25 mm per week afterwards.

Between the 18th and 20th and the 28th and 30th weeks, the instantaneous growth rate decreased due to the depletion of diatoms (*Navicula* spp.) in the tank. The growth rate picked up again after the juveniles were transferred to another tank containing dense cultured microalgae; the instantaneous growth rate increased up to 0.39–0.44 mm per week.

However, the abundant cultured food in the tank was quickly depleted within a short time (less than eight weeks) and the instantaneous growth rate dropped. This short period to depletion showed that the consumption rate of green snail juveniles was already too high and it was predicted that the consumption rate of the juveniles in the tank would exceed the growth rate of cultured *Navicula* spp. Therefore, another rearing method has to be considered.

## Discussion and conclusion

The green snail (*T. marmoratus*) is dioecious (male and female sexes are separate). In nature, the proportion of male and female individuals is equal (Komatsu et al. 1995). The gonad (whitish in males and dark green in females) is located at the posterior extremity of the soft body part, close to digestive glands. Natural spawning of green snails in subtropical areas occurs during warmer months from June to September in the Northern Hemisphere (Murakoshi et al. 1993; Yamaguchi 1993), but in tropical waters, the spawning may occur several times throughout the year.

Research on reproductive biology or spawning of green snails has never been conducted previously in tropical water. The present paper outlines the first attempt at green snail spawning in Indonesia.

The spawning trial in October 1996, produced a total of 1,875,750 eggs from a single female. Subsequent spawning trials conducted on the same female and four males resulted in 583,300 eggs and 1,575,000 eggs in April and June 1997, respectively (unpublished data). Murakoshi et al. (1993) in Okinawa reported that female individuals measuring from 16 to 20 cm in diameter produced from 850,000 to 6,000,000 eggs.

In the present study, spawning occurred during no or new moon periods starting after dusk. Male spawned first, followed by the female. This spawning behaviour is similar to topshells that spawned from 9.00 pm to 12.00 pm (Pradina et al.

1996). However, work at Yaeyama islands (24°–25° North), concluded that the correlation between moon cycles and green snail spawning was not clear (Komatsu et al. 1995).

In Okinawa, green snail eggs hatched into trochophore about 22 hours after fertilisation at water temperatures ranging from 21–23 °C, while in warmer water (~ 25 °C) the hatching period shortened to only 12 hours (Yamaguchi 1993). In the present study, the hatching period was 14 hours with 66.7% hatching rate at 26 °C. Hatching rates of green snail eggs in Okinawa varied from one spawning to another and ranged from 14.6–100% (Murakoshi et al. 1993).

Pediveliger larvae require suitable substrate for settlement, i.e. solid substrate covered with abundant sessile diatoms. This requirement was observed during the study, where one of the three fibreglass tanks used for larval rearing was not sufficiently covered by sessile diatoms. In this tank, the pediveliger were still swimming in the water column, while in the other two tanks the pediveligers were already settled on the third and fourth day. In order to induce the larvae to settle, the pediveliger larvae were transferred to another tank containing more abundant sessile diatom. Three hours after the transfer, the density of swimming pediveliger larvae decreased and three hours later no swimming pediveliger were observed in the water column. This phenomenon was different from observations conducted on topshells (*Trochus niloticus*), where pediveligers required less abundant sessile diatoms in the rearing tank compared to green snail pediveliger (pers. obs.).

Mean shell growth of the green snail recorded in the present study were  $0.70 \pm 0.07$  mm,  $1.21 \pm 0.16$  mm,  $1.77 \pm 0.16$  mm,  $2.54 \pm 0.42$  mm and  $3.34 \pm 0.76$  mm for 1 month, 2 month, 3 month, 4 month and 5 month old juveniles, respectively. This growth rate was slightly lower than that reported for early juveniles in Okinawa reared in experimental aquaria. The green snail juveniles in Okinawa reached mean sizes of 0.5 mm, 2.0 mm and 4.0 mm after 1 month, 3 month and 4.5 month of rearing, respectively (Yamaguchi 1993). In another study, with mass rearing using a running water rearing system, juveniles measuring  $0.9 \pm 0.1$  mm after 1.5 month and juveniles with sizes ranging from 1.3 mm to 4.1 mm were obtained after 3 to 4 month (Murakoshi et al. 1993). These results suggested that the growth of juveniles in the present study was lower than those obtained in experimental aquarium (small scale) in Okinawa, but was higher than those obtained from mass culture.

The difference in growth rates reported in the above studies may be a function of food availability. In small-scale rearing, food supply was easier and more controlled, while in mass culture food supply, juveniles handling and rearing were more complicated.

When the shell diameter was about 7 mm (30 weeks old), the grazing rate of juveniles was very high and almost exceeded the capacity of the laboratory to supply sessile diatoms. In Japan, laboratory rearing was limited until 3 to 4 months when juveniles reached 1.3–4.1 mm shell diameter. These juveniles were then transferred into concrete tanks built in intertidal areas for further on-growing. The success of this rearing technique was unknown since growth and survival data were not available.

Rearing in concrete tanks or cages built in intertidal areas is a possible solution to the problem of food limitation in the laboratory for herbivorous benthic grazing gastropods. The grow-out of other gastropods belonging to superfamily Trochoidea (*Trochus niloticus* and *Turbo chrysostomus*) in cages built in intertidal areas were feasible (Dwiono et al. 1995, 1997, 1998). This ocean nursery technique resulted in a higher growth rate compared to those reared in the laboratory. The minimum size (shell diameter) used in the ocean nursery was 10 mm for *T. niloticus*, while for slow-growing gastropods, such as *T. chrysostomus*, the minimum size was 9.0 mm. Assuming that green snail (*T. marmoratus* L.) juveniles have a similar feeding behaviour to those two gastropods, an ocean nursery for green snail may be expected to yield similar encouraging results.

## References

- Abbott, R.T and S.P. Dance. 1986. Compendium of seashells. American Malacologist. Florida. 412 p.
- Arifin, Z. and D.E.D. Setyono. 1992. Potency of mollusc resources and their development prospect in Maluku. Proceeding of Workshop on Fisheries Resources in Maluku. Ambon 2–3 March (1992). Badan Penelitian dan Pengembangan Pertanian, Balai Penelitian Perikanan Budidaya Pantai, Maros. 77–86 (in Indonesian).
- Dwiono, S.A.P., E. Danakusumah, Pradina and P.C. Makatipu. 1995. Hatchery of topshell (*Trochus niloticus* L.) in laboratory. National Seminar on Biology XI, University of Indonesia, Depok. 23–27 July 1995. 11 p. (in Indonesian).
- Dwiono, S.A.P., P.C. Makatipu and Pradina. 1997. A hatchery for the topshell (*T. niloticus*) in Eastern Indonesia. In: Trochus: status, hatchery practice and nutrition. ACIAR Proceeding no. 79. 33–37.
- Dwiono, S.A.P. and P.C. Makatipu. 1998. Experimental hatchery of *Turbo chrysostomus* L. (Mollusca: Gastropoda). Proceeding of the first LIPI – Hasanuddin University Joint Seminar on Marine Sciences, R&D Center for Oceanology, Ambon – Indonesia. 115–120 (in Indonesian).
- Eisenberg, J.M. 1981. A collector's guide to seashells of the world. New York: Crescent Books. 239 p.
- Komatsu, T., M. Murakoshi and R. Nakamura. 1995. A study on the reproduction of the green snail, *Turbo marmoratus*, in the Ryukyu Islands, southern Japan. Suisanzoshoku 43(3):297–304.
- Kubo, H. 1991. Topshell (*Trochus niloticus*), green snail (*Turbo marmoratus*) and turban snail (*Turbo argyrostomus*). In: Shokita et al. (eds). Aquaculture in Tropical Areas. Midori Shobo, Tokyo. Hal 276–287.
- Makatipu, P.C., S.A.P. Dwiono and Pradina. 1996. Growth pattern of *Navicula* spp. in various culture media. Perairan Maluku dan Sekitarnya 11:57–65 (in Indonesian).
- Murakoshi, M., T. Komatsu and R. Nakamura. 1993. Development of mass seed production techniques for green snail, *Turbo marmoratus* in Okinawan water. Suisanzoshoku 41(3):299–309.
- Pradina, S.A.P. Dwiono, P.C. Makatipu and E. Danakusumah. 1996. Spawning experiment in the topshell *Trochus niloticus* (Gastropoda) in laboratory. Perairan Maluku dan Sekitarnya 10:59–69 (in Indonesian).
- Usher, G. F. 1984. Coral reef invertebrates in Indonesia: their exploitation and conservation needs. IUCN/WWF Project Report no. 1688. 97 p.
- Wilson, B. 1993. Australian marine shells. Volume 1. Kallaroo, Western Australia: Odyssey Publishing. 408 p.
- Yamaguchi, M. 1993. Green snail. In: A. Wright and L. Hill. (eds). Nearshore marine resources of the South Pacific. Institute for Pacific Studies, Suva, 497–511.





## Habitat preferences of juvenile trochus in Western Australia: implications for stock enhancement and assessment

Jamie R. Colquhoun

### Introduction

Restocking of trochus (*Trochus niloticus*) populations commenced with the translocation of adults in the South Pacific region in the 1920s (Crowe et al. 1997). The development of simplified hatchery culture methods has allowed easy production of mass numbers of juvenile trochus (Heslinga et al. 1983; Lee 1997), and release of these 'seeds' is now a viable option for stock enhancement. However, strategies for release of cultured juveniles are still in their infancy and information is needed, such as the appropriateness of reef habitats for seeding.

The principal problems in reseeded programs seem to be predation, fitness of juveniles and suitability of seeding habitats (Yamaguchi 1990; Nash 1993; Castell 1997). On Orpheus Island, Great Barrier Reef, Castell (1997) showed that juvenile trochus were abundant chiefly on the reef flat habitat while adults were more common on the reef crest and slope. However, regional differences in the ecology of trochus are inherent (Amos 1991; Nash 1993) and reefs in other regions can have different gross structure and habitats. The lack of knowledge on habitats preferred by juvenile trochus, in regions of interest, compromises the success of restocking programs.

A small commercial trochus fishery exists at the mouth of King Sound off the northern coast of Western Australia (WA). The Aboriginal communities of the region intend to restock depleted reefs with hatchery produced juveniles. While some information on juvenile distribution, abundance and habitat preferences is available from other regions, little is known about the ecology of juveniles on reefs in WA. Suitable seeding habitats, which have naturally high abundance of juvenile trochus, need to be identified. Information on habitat preferences, size distribution and abundance within and among reefs will increase the potential of reseeded. In addition, such informa-

tion would aid the development of effective methods for accurate stock assessment and monitoring. The aims of this study were to determine which reef habitats are preferred by wild juveniles on coral reefs in King Sound and whether these are different to the habitats preferred by adults.

### Study area

Surveys were carried out from May to June 2000 on the intertidal sections of four fringing reefs at the mouth of King Sound in WA (16°25'S, 123°07'E) (Fig. 1). The reefs appear to be constructed dominantly by encrusting coralline algae and are algae-dominated reefs (Brooke 1995).

Two reef types are common: one characterised by seaward intertidal terraces and the other by a gently sloping reef front. Intertidal terraces have a stepped seaward margin causing a damming effect landward.

The reefs chosen for this study are among a number of reefs in the region currently being used for research into stock enhancement. The four study reefs vary in size, are representative of reefs in the region and have natural stocks of juvenile and adult trochus. The intertidal areas of the reefs were partitioned into four habitats: coral rubble platform (platform), patch reef (patch), sand/seagrass (sand), and rocky/boulder (rock). A subtidal live coral habitat at the seaward edge of the reefs was not examined due to water depth.

### Characteristics of reef habitats

The reef platform habitat generally occurs on the seaward margin of the reefs and forms part of the reef slope and reef flat. A diverse algal community dominates the surface cover on the reef platform while interspersed low massive hard corals, soft corals, sponges, ascidians and zoanthids are less abundant.

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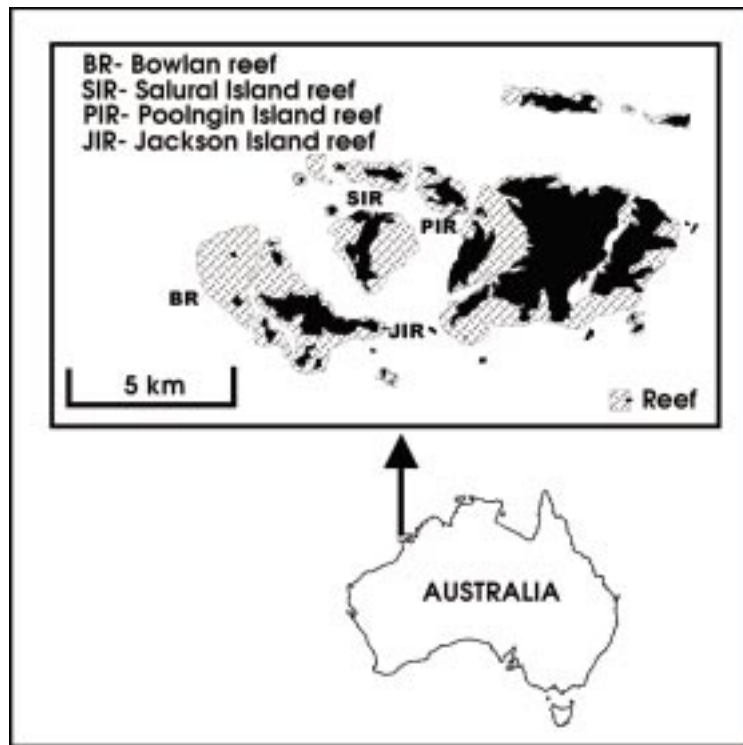


Figure 1. Study area and reef locations at the mouth of King Sound, WA.

The patch reef habitat occupies most of the area on these reefs and occurs behind or at the sides of the coral rubble platform habitat and extends to the back sand and seagrass habitat. It is a network of pools, sand, coral rock and rubble overlying a hard siltstone or quartz base. Standing water at low tide is generally less than a metre in depth with a dominant over story of *Sargassum* sp. and *Turbinaria* sp.

The sand and seagrass habitat is situated mainly on, but not isolated to, the back of reefs. It is dominated by sand with isolated patches of coral rock or rubble. Seagrasses (e.g. *Thalassia hemprichii*, *Enhalus acoroides* and *Halophila ovalis*) are the most common biota.

The rock and boulder habitat is composed of siliceous quartz-gneiss and granite boulders. It forms the sides of fringing reefs extending from the subtidal live coral habitat back into the intertidal sand and seagrass habitats.

## Materials and methods

The density of trochus within each habitat was determined by surveying randomly positioned 50 m x 2 m strip transects, approximately 50 m apart, in each habitat and perpendicular to the

shoreline. For the larger reefs, representative areas of each habitat were identified. Six transects were surveyed in each habitat on each reef except in the sand habitat on Jackson Island Reef where only two transects were surveyed due to lack of habitat area. Surveys were conducted by walking slowly along the center of the 50 m tape while holding a 2m-wide 'T' bar delineating 1 m either side of the tape. All trochus sighted within each transect were counted, shell basal width (SW) measured and recorded into 10 mm size classes. Surveys were restricted to approximately two hours before and after low tide, depending on reef height and tide.

Data of size class distribution were graphed and density scaled to individuals per hectare. Mean precision (S.E./mean) of abundance was calculated for each habitat in the study. For the benefit of future sampling, the mean required sampling effort (n) for each habitat was calculated for three levels of precision: 0.1, 0.2, 0.3. For analyses of juveniles, data on individuals < 50 mm were used. Adults were considered > 50 mm as the minimum size at commencement of sexual maturity is ~50 mm (Gimin and Lee 1997). Cochran's test was used to determine homogeneity of variances amongst reefs and habitats. A 2-factor ANOVA was used to analyse the density of juvenile trochus among reefs and habitats. The total areas of each

reef and habitats within reefs were estimated from aerial photos and distances estimated during field surveys.

### Results

The surveys showed that no single habitat could be identified as exclusively preferred by either juvenile or adult trochus. Juvenile and adult trochus were found commonly in three of the four intertidal habitats on these reefs (Fig. 2): reef platform, patch reef and rock. Juveniles in the rock habitat were large (40–50 mm) (Fig. 2). The sur-

veys confirmed that juvenile trochus do not prefer habitats dominated by sand. Only two juvenile trochus were recorded in the sand habitat on one reef. Juvenile trochus <30 mm SW and adults >100 mm SW were not encountered in the surveys. The distribution of trochus among habitats on different reefs was broadly similar and no size class was dominant (Fig. 2).

While juvenile and adult trochus occur commonly on platform, patch reef and rock habitats, their distribution within these habitats was highly patchy. This is shown by estimates of the precision

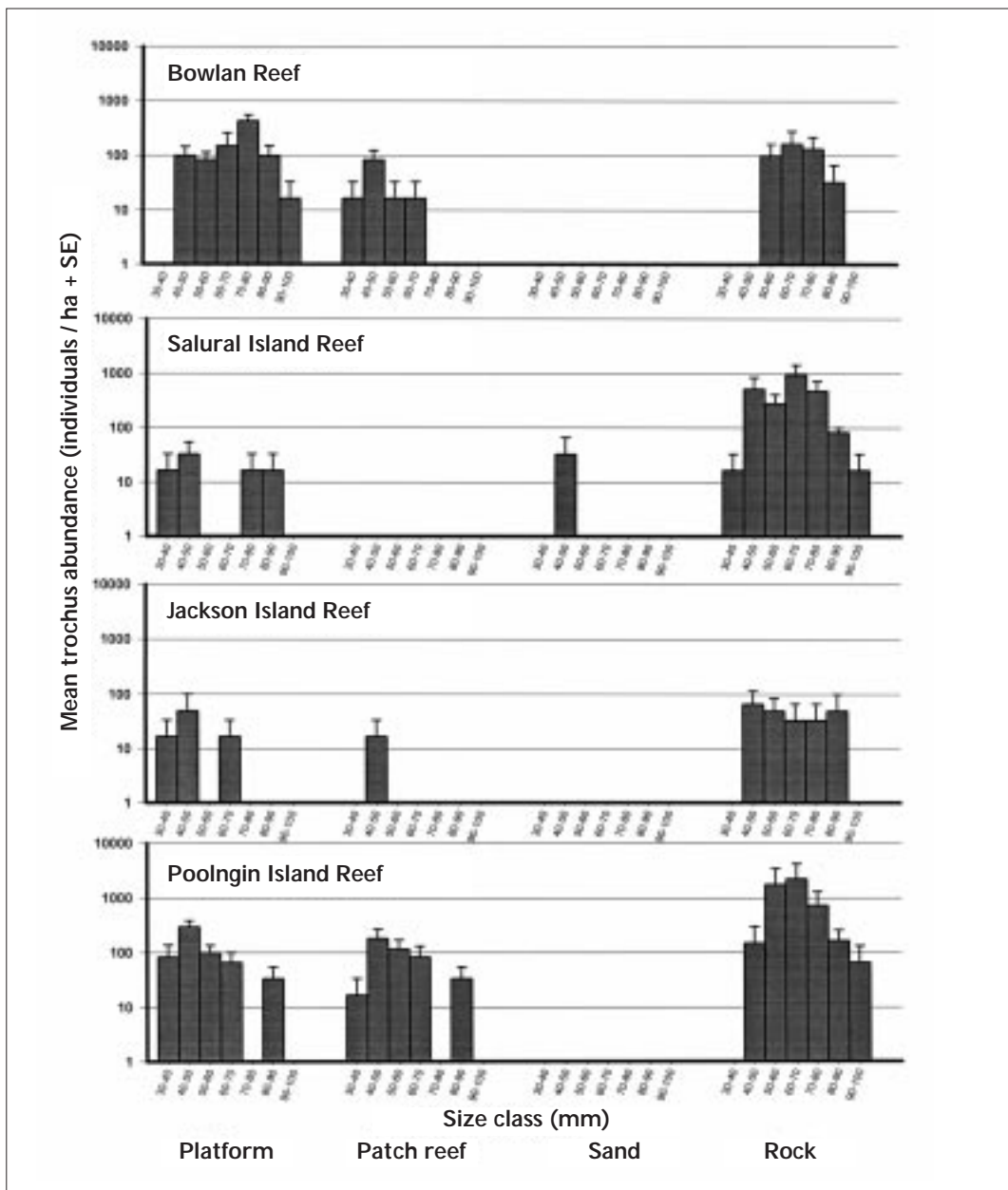


Figure 2. Size class distribution of *T. niloticus* within habitats on the four study reefs. Y-axis is on a log scale and abundance data scaled from 100 m<sup>2</sup> to hectare<sup>1</sup>



(S.E./mean) of mean abundance values within habitats, which ranged from 0.39 to 0.42. Considerably more sampling effort is required to increase precision to a more acceptable level (Table 1). Each recorder can position and census approximately six transects (50 m x 2 m) per hour.

More than half of the surveyed transects on reef platform, patch reef and rock habitats did not contain juvenile trochus. Juveniles were not found in the rock habitat on Bowlan Reef and the patch habitat on Salural Reef (Fig. 3).

Although juvenile trochus occurred in high numbers in the rock habitat, this habitat occupied a small proportion of area on all four reefs (Table 2). The reef platform was the only habitat in which juvenile trochus were found for all four reefs. The patch habitat generally covered the largest area of the reefs (Table 2).

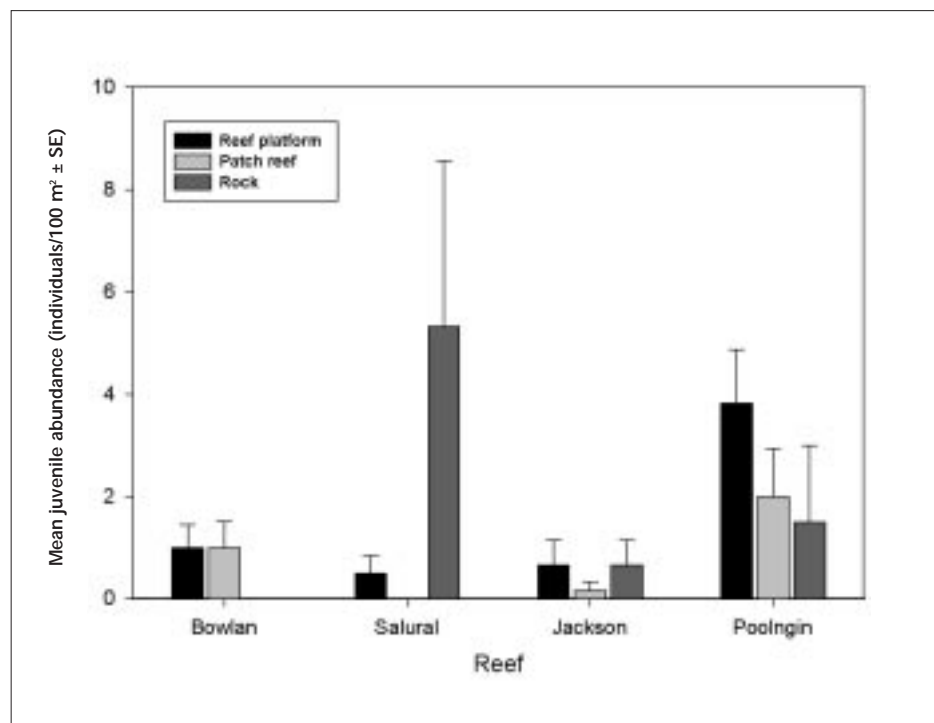
Notable during the surveys was that trochus were present in the rock habitat only where it was bordered by platform or patch habitat, but not where it was adjacent to sand habitat. There is a very distinct narrow intertidal zone within the rock habitat in which trochus were found. This zone offers considerably more protection from desiccation than the platform or patch habitats with an abundance of racks, crevices and shade.

**Table 1. Mean number of (50 m x 2 m) transects (n) (± SE) required for precision = 0.1, 0.2 and 0.3 for each habitat.**

Precision	Habitat		
	Platform	Rock	Patch
0.1	30 (± 7)	29 (± 3)	31 (± 15)
0.2	15 (± 4)	15 (± 2)	15 (± 7)
0.3	10 (± 2)	10 (± 1)	10 (± 5)

**Table 2. Estimates of total intertidal reef area and percentage area coverage of each habitat out of the total reef area for each reef.**

Reef name	Total intertidal reef area (ha)	%Reef platform	%Patch reef	%Sand	%Rock
Bowlan	238	31	48	18	3
Salural	66	21	62	9	8
Jackson	9	16	67	12	5
Poolngin	13	49	39	9	3
<b>Mean area</b>		29.3	54.0	12.0	4.8



**Figure 3. Mean abundance of juvenile trochus (30-50 mm SW) within platform, patch reef and rock habitats of the four study reefs.**

Cochran's test indicated that variances of mean abundance of juvenile trochus were significantly heterogeneous, even after (x transformations (Cochran's C:  $P = .019$ ). Moreover, Figure 3 shows clearly that the abundance of juveniles varied significantly among habitats and reefs. Therefore, a 2 factor ANOVA was used in an exploratory sense only to determine the percentage of variance for all the terms in the model. Variability in abundance of juvenile trochus among transects accounted for the majority of the overall variation (63%). The interaction between reef and habitat accounted for 25% of the variability in abundance. Variability among levels within the main effects, reef and habitat, explained a relatively small percentage of the overall variability in the data (9% and 3%, respectively). These results show that the distribution of juvenile trochus on these reefs was highly patchy at scales within habitats (predominantly), among habitats and among reefs (Fig. 3).

## Discussion

The findings reiterate that regional differences in trochus ecology are inherent. The scope of this study limits the ability to detect spatial patterns in juvenile abundance to a broad resolution. Nevertheless, large juvenile trochus (30–50 mm SW) were found to inhabit three macro-habitats on reefs surveyed in King Sound. Variation in density and distribution of juvenile and adult trochus was particularly high within habitats on a reef, which demonstrates that their distribution was clumped or patchy. Densities of trochus populations are thought to be influenced by reef orientation, degree of exposure to surf or current, substrate type, food availability and water depth (Heslinga et al. 1983).

The high densities of trochus that were found in the rock habitat demonstrates this is one of their preferred habitats. Sims (1985) found that trochus on reefs in the Cook Islands had extremely clumped distributions in high energy zones with animals clustered upon the bare rock walls of the deeper surge channels. Surveys at Dead Henoat, Indonesia found an abundance of juvenile trochus underneath rocks and boulders throughout the entire shore (Dangeubun and Latuihamalo 1998). This preferred habitat has previously been overlooked in trochus studies in WA.

Juvenile trochus have been found in rock habitats in many regions because of substrate stability, an abundance of food and less accumulation of silt (Sims 1985; Hahn 1989; McGowan 1990; Nash 1993). The intertidal part of the rock habitat adjacent to platform or patch reefs seems to offer suit-

able habitat for large juvenile and adult trochus and different physical and biological features from the platform and patch habitats. The rocks are usually smooth and covered with short filamentous and turfing algae.

The high densities of juvenile and adult trochus found in the rock habitat suggests that this habitat may also be suitable for the translocation of large juveniles and adults. The edges of boulders may offer increased protection from desiccation, currents and predation and have accessible food resources, therefore increasing survivorship of trochus. But, the rock habitat lacks the reef matrix and small-scale refuges present in the platform habitat so it may not be suitable for transplanting small hatchery reared juveniles. Habitats with large numbers of naturally occurring juveniles should be the most suitable habitats for hatchery produced 'seed'.

Areas of the platform or patch habitat that are topographically complex, at the scale of tens of centimetres, with holes and crevices for refuge are likely to be the preferred habitat for reseeding small juveniles. It is assumed that juveniles <30 mm SW inhabit such cavities (Nash 1993). Juveniles of shell basal width <30 mm are found rarely in surveys and little is known of their ecology (Heslinga et al. 1984; Arifin and Purwate 1993; Nash 1993; Castell 1997; Purcell and Colquhoun pers. obs.). Castell (1997) suggested that small-scale variations in habitat may greatly affect the survival of juveniles and consequently should be considered in reseeding experiments.

Adult trochus >100 mm are also very rarely found on reefs in King Sound (Magro 1997). This may be due to longevity of the species in this region or to fishing pressure. Until further studies can be done on a broader spatial scale, perhaps on reefs that incur little or no fishing pressure, the maximum size of trochus will be unknown.

A different approach to previous studies needs to be taken when estimating population size or potential reseeding and translocation sites in this region. Due to the variation in size and position of the different trochus habitats on reefs, it is important that all the potential habitats are identified and surveyed and the total area each habitat covers is estimated for each reef. Previous studies have concentrated on dividing reefs into zones (Magro and Black 1995; Castell 1997; Magro 1997); each zone representing a section of the reef defined by a certain distance from the reef edge or shore. Few studies have divided a reef into habitats defined by physical and biological characteristics, regardless of distance from the reef edge or shore.

Without adequate levels of temporal and spatial sampling effort, patterns of distribution and abundance are difficult to distinguish with clumped distributions. More extensive monitoring of the three preferred habitats on more reefs would minimise variation and increase the accuracy of population size.

Sufficient survey effort will sample more of the population and provide acceptable confidence limits to reliably detect declines in abundance from overfishing and success from reseeded or translocation experiments (Nash 1993). An average of 15 transects per habitat would increase precision notably to a desirable level of 0.2. This combined information will contribute to the protocol required for future surveys of trochus in WA.

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### References

- Amos, M. 1991. Experiences in trochus resource assessment and field survey: Workshop on trochus resource assessment, development and management (Port Vila, Vanuatu, 13 May – 02 June 1991). ICFMaP Technical Document 13, SPC, Noumea. pp. 9.
- Arifin, Z. and P. Purwati. 1993. Conservation and sustainable use of lola gastropod (*Trochus niloticus*) in Banda Islands, Indonesia. Report to MAB-UNESCO and EMDI-Canada. pp. 54.
- Brooke, B. 1995. Geomorphology. In: F.E. Wells, J.R. Hanley and D.I. Walker (eds), Marine biological survey of the southern Kimberley, Western Australia. Western Australian Museum, Perth. 21–57.
- Castell, L. 1997. Population studies of juvenile *Trochus niloticus* on a reef flat on the north-eastern Queensland coast, Australia. Marine Freshwater Research 48:211–217.
- Crowe, T., M. Amos and C. Lee. 1997. The potential of reseeded with juveniles as a tool for the management of trochus fisheries. In: C.L. Lee and P.W. Lynch (eds), Trochus: status, hatchery practice and nutrition. ACIAR Proceedings No. 79. Australian Centre for International Agricultural Research, Canberra, Australia. 170–177.
- Dangeubun, J. and M. Latuihamalo. 1998. Density, abundance, and distribution of juvenile molluscs with emphasis on Trochus, Kei Besar Island, Indonesia. Phuket Marine Biological Center Special Publication 18(1):59–62.
- Gimin, R. and C. Lee. 1997. The reproductive cycle of *Trochus niloticus* in King Sound, Western Australia. In: C.L. Lee and P.W. Lynch (eds), Trochus: status, hatchery practice and nutrition. ACIAR Proceedings No. 79. Australian Centre for International Agricultural Research, Canberra, Australia. 52–59.
- Hahn, K. 1989. Culture of the tropical top shell, *Trochus niloticus*. In: CRC Handbook of culture of abalone and other marine gastropods. Boca Raton, Florida: CRC Press, Inc. 301–315.
- Heslinga, G., Orak, O. and M. Ngiramengior. 1983. Trochus reseeded for commercial exploitation - Republic of Palau. Annual Report Submitted to the Pacific Tuna Development Foundation. Division of Marine Resources, Koror, Republic of Palau. 105 p.
- Heslinga, G., Orak, O. and M. Ngiramengior. 1984. Coral Reef Sanctuaries for Trochus Shells. Marine Fisheries Review 46(4): 73–80.
- Lee, C. 1997. ACIAR trochus reef reseeded research: a simplified method of induced spawning in trochus. SPC Trochus Information Bulletin 5:37–39.
- Magro, K. 1997. Estimating the total habitat and biomass of trochus in King Sound, north-western Australia. In: C.L. Lee and P.W. Lynch (eds), Trochus: status, hatchery practice and nutrition. ACIAR Proceedings No. 79. Australian Centre for International Agricultural Research, Canberra, Australia. 22–24.
- Magro, K. and R. Black. 1995. A preliminary assessment of the standing stock and biomass of trochus in King Sound, northwestern Australia. Final report to the Fisheries Research and Development Corporation. Canberra. pp. 29.

McGowan, J. 1990. Trochus and you. Marine Resources Division, Department of Resources and Development, Saipan, Mariana Islands. pp. 20

Nash, W. 1993. Trochus. In: A. Wright and L. Hill (eds), Nearshore Marine Resources of the South Pacific. ICOD, Canada. 451–495.

Sims, N. 1985. The abundance, distribution and exploitation of *Trochus niloticus* L. in the Cook Islands. Proceedings of the Fifth International Coral Reef Congress, Tahiti 5: 539–544.

Yamaguchi, M. 1988. Transplantation and marine ranching/farming of inshore resources on coral reefs. SPC Fisheries Newsletter 46:37–4



## Recent surveys of transplanted green snail (*Turbo marmoratus*) and trochus (*Trochus niloticus*) on Tongatapu, Tonga

Ulunga Fa`anunu<sup>1</sup>, Siosaia Niumeitolu<sup>1</sup>, Mosese Mateaki<sup>1</sup> and Kenichi Kikutani<sup>2</sup>

### Introduction

The former Japan International Cooperation Agency (JICA)/ Tonga Aquaculture Research and Development Project (a five-year project with two years of follow up) concentrated on developing the techniques of hatchery trochus and green snail seed production. It was done with the aim of releasing the juveniles to accelerate establishment and enhancement of both species in the wild. JICA dispatched a short-term expert to assist the shellfish seed restocking and recovery survey. The expert developed the optimum size for restocking and releasing including a study on predation and its control and established a recapture technique and monitoring method. His expertise and assistance were also needed in the renovation of the seawater intake system under an aid grant from Japan, which started in August 1999.

As a consequence of the many demands placed on the expert JICA dispatched another short-term expert to assist in the resource survey, management of shellfish, and hatchery management during construction of the seawater intake system, and assist in the TCTP.

### Present status of the Ministry of Fisheries Sopus Mariculture Center in Tongatapu

Most facilities of the Sopus Mariculture Center (SMC) that had been damaged by Cyclone Isaac in 1982 were rebuilt during the seven-year JICA project. However, the poor seawater supply system remained the main problem for the hatchery. In late 1999 a new pump house and a new awning house were constructed (Figs. 1 and 2). The project was completed in March 2000.

The SMC facilities now consist of 50 rearing tanks in the hatchery, three seawater intake pumps, four blower air pumps, one generator, a control panel and other necessary intake equipment in the newly constructed pump house. An elevated tank has been installed on the top of the pump house (Fig. 1). Outside the pump house there are two filtration units for seawater and a fuel tank for the generator. A seawater intake strainer was set up at the reef margin.

After changing to the new seawater intake system, the growth rate of green snails (*Turbo marmoratus* L.) became faster than previously recorded. It

1. Ministry of Fisheries, Tonga

2. Japan International Cooperation Agency (JICA)

is obvious that the better growth rate was due to a good supply of stable, quality seawater (Fig. 3).

The current number of green snails reared in the hatchery is about 12,550 individuals (270 spawners, 780 from 1996 and 1997 spawning, 2900 from 1998 spawning and 8600 from 1999 spawning). The intermediate culture phase 1 for juveniles from the first spawning in the new millennium starts on July. At present, 900 juveniles have been collected from the settlement tank.

**Surveys of introduced green snail (*Turbo marmoratus* L.) and trochus (*Trochus niloticus*)**

*Surveys of green snail at `Euaiki Island*

The surveys of released green snail at `Euaiki Island (Fig. 4) were conducted in May 1999 and April 2000.

In May 1999, a total of 11 green snails were recaptured, all of which were animals released in May and June 1998 (Niumeitolu et. al 1999). Most of the recaptured shells were found in holes, caves or under ledges. Only a few individuals were found at the coral reef dents.

In April 2000, we recaptured 35 green snails on the same site we surveyed in May 1999. Once again, most of the recaptured shells were found in holes, caves or under the ledges, and only a few individuals at the coral reef dents. Of these 35 recovered shells, 2 had been released in August 1994, 25 in May and June 1998, 5 in May 1999 and 3 in February 2000.

From this survey, we believe that the first introduced group (August 1994) still survives and contributes to natural recruitment. Also, the groups released in 1998 and 1999 have reached mature sizes. We collected many of them in a quite small area, therefore it is conceivable that those green snails had already established a spawning group.

In this report we will only consider green snails released in 1998, because we need more data for green snails released in 1994, 1999 and 2000.



Aymeric Desurmont

**Figure 1. The new SMC seawater intake pump house.**



Aymeric Desurmont

**Figure 2. The new SMC fiberglass tanks and awning house.**



Aymeric Desurmont

**Figure 3. Ulunga Fa'anunu proudly presenting green snails born and raised at SMC. The new seawater intake system has allowed better growth rates.**

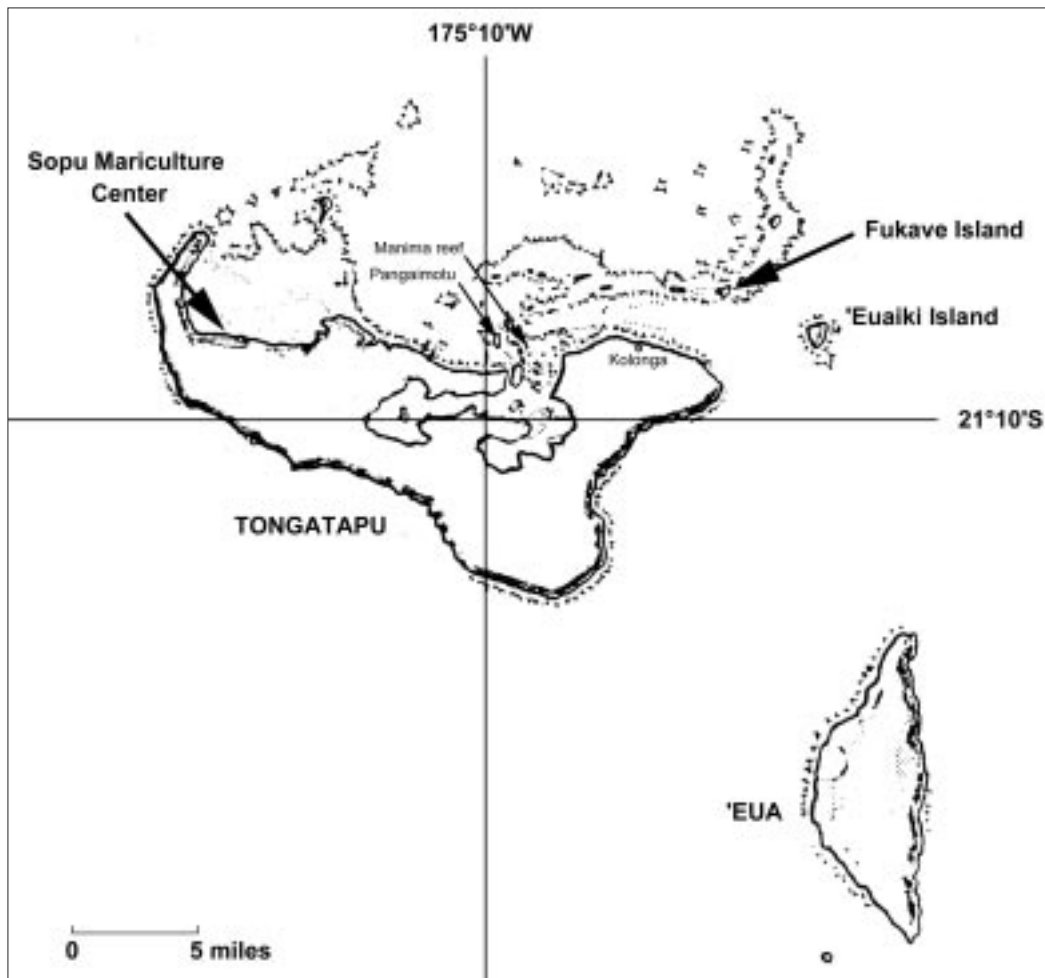


Figure 4. Green snail and trochus survey sites on Tongatapu.

Table 1 shows the increment shell height of each year's group. The average shell height increment for one and two years after release was 54.2 mm and 89.6 mm, respectively. Average shell height for each year was 111.2 mm and 146.6 mm, respectively (Table 1). These results indicate that the growth rate of green snail seeds after release in the wild was considerably faster than when captive. The green snail juveniles had an average shell height of 57 mm when they were released. After two years in the wild, they grew to an average of 146.6 mm and had reached maturity and commercial size.

The number of shells recovered in this year's survey increased by 14 from last year's study. We assume one of the reasons for the increase was the shell growth made them more prominent and easier to find in the field. The increase in shell height from last year was about 40 mm.

Two green snails from the group released in 1994 were found. However, it is difficult to estimate the overall survival number of this group since they probably spread out around 'Euaiki Island.

#### *Survey of released trochus at Fukave Island*

Recover surveys of the introduced trochus in Fukave Island have been realised since 1994 (Numeitolu et al. 1999). Table 2 shows the recaptured number and rate of trochus. From the 400 trochus released in 1994, we recaptured 125 individuals during our survey in June 2000. The recovery rate was 31.1% compared to 28.2% last year. The increase may be attributed to the survey team observing seven habitats this year, compared to only six last year. From the results of this year's survey, we could say that the first introduced trochus from 1994, are still an important spawner group.

#### *New recruitment surveys of trochus*

Due to some unexpected circumstances experienced in previous years, we were unable to conduct enough surveys. In February 2000 we conducted a survey on the reef around Pangaimotu Island (Fig. 4). Five trochus were recovered in the one-hour survey. The shell diameter sizes of recaptured trochus were 100.5, 96.9, 71.6, 73.7, and 63.7 mm.

In June 2000, we surveyed the Manima reef flats and found two juvenile trochus at 0.5 m depth on the reef flat area. The shell diameter of both shells was 50 mm.

A fisherman found one trochus on the reef adjacent to Kolonga village. Since the specimen looked new to him he took it home and informed the Ministry. We then interviewed him and explained the importance of this species for Tongans in the near future. We also kept the shell, whose diameter was 124.8 mm.

The sizes of recaptured trochus indicate that new recruitment has probably occurred every year since 1994, and new generations of trochus are spreading out.

#### *Status of green snail new recruitment*

We were not able to carry out a survey for green snail new recruitment, because there was not enough time to cover this survey. However, we obtained important information from *The Taimi Tonga*, one of the local newspapers. A diver found one large green snail at night around the fore reef slope area on 'Eua Island (Fig. 4). From the newspapers picture, the green snail was estimated to be over 16 cm in shell height and 3 or 4 years old. 'Eua island is about 20 km to the south-southeast of 'Euaiki Island where green snail were introduced.

#### Seed production of green snail

We conducted seed production using natural spawning of eggs in April 2000. We obtained 100,000 settlement stage larvae from the 900,000 fertilised eggs. The larvae were divided and transferred to two 4-ton settlement tanks. The Intermediate Culture Phase 1 (ICP1) started on 29 June. About 700 juveniles of 2.5 to 3.0 mm in shell width were already transferred for ICP1. The final production number for Phase 1 will be confirmed in three months' time. According to its present

**Table 1: Recaptured green snail growth rate at 'Euaiki Island.**

No.	Initial shell height (mm)*	Shell height (mm) at time of recapture	Shell height increment (mm)
<b>Recaptured in May 1999</b>			
1	57.0	95.0	38.0
2	57.0	110.0	53.0
3	57.0	116.8	59.8
4	57.0	104.4	47.4
5	57.0	99.8	42.8
6	57.0	104.0	47.0
7	57.0	120.0	63.0
8	57.0	120.0	63.0
9	57.0	128.0	71.0
10	57.0	110.5	53.5
11	57.0	115.0	58.0
<b>Average</b>		<b>111.2</b>	<b>54.2</b>
<b>Recaptured in June 2000</b>			
1	57.0	143.5	86.5
2	57.0	145.5	88.5
3	57.0	147.5	90.5
4	57.0	154.4	97.4
5	57.0	152.5	95.5
6	57.0	150.0	93.0
7	57.0	152.5	95.5
8	57.0	145.0	88.0
9	57.0	132.5	75.5
10	57.0	150.5	93.5
11	57.0	145.8	88.8
12	57.0	157.5	100.5
13	57.0	152.0	95.0
14	57.0	140.2	83.2
15	57.0	131.2	74.2
16	57.0	147.7	90.7
17	57.0	143.2	86.2
18	57.0	149.5	92.5
19	57.0	146.0	89.0
20	57.0	145.0	88.0
21	57.0	153.7	96.7
22	57.0	149.4	92.4
23	57.0	138.6	81.6
24	57.0	144.0	87.0
<b>Average</b>		<b>146.6</b>	<b>89.6</b>

\* Average initial shell height when released on May and June 1998

**Table 2: Number of recaptured trochus and recapture rate at Fukave Island site.**

Year	No. of recaptured trochus	Recapture rate
1994	91	22.8%
1995	57	14.3%
1996	78	19.5%
1998	96	24.0%
1999	113	28.2%
2000	125	31.3%

condition, this year's production should contribute a good stock for future releases.

### Other activities

Some public awareness campaigns on trochus and green snail transplantation were aired from Radio Tonga from December 1999 to July 2000. The public was urged to protect these important resources until they reached harvestable size. The program released information on their new recruitment and SMC activities.

### Future direction

Future direction for both species, as recommended by Nuimeitolu et al. (1999), was proposed for implementation by the MOF. However, for the time being MOF should concentrate on seed pro-

duction of the green snail, seed release for establishment of spawners' groups, and recruitment surveys. Also the MOF should impose a continuous ban on the harvest of green snails and trochus until their populations are sufficient to support a sustainable commercial fishery.

### References

- Japan International Cooperation Agency. 1999. Basic design study report on the project for renovation of seawater supply system in the Kingdom of Tonga. GRT CR (2) 99-046:86 p.
- Nuimeitolu S., M. Mateaki and K. Kikutani. 1999. Report on the seed releasing and restocking survey of trochus and green snail. In: Technical report of the JICA short term expert: 11 p.



## Protecting the trochus bounty

Keith Saunders<sup>1</sup>

The coral reef flats of the inner islands of King Sound number in the hundreds. These environments present almost idyllic conditions for a much-underestimated species of mollusc commonly known as the trochus or topshell. The trochus (*Trochus niloticus*) once existed in these tidal zones in huge numbers. These zones are in pristine condition with no negative impacts from run-off from settled or industrial areas. However, a combination of overharvesting over the last 20 years and, to a lesser extent, poaching by illegal foreign fishers, has seen trochus populations plummet. From a maximum recorded harvest in the 1980s of 135 tonnes, the current level of harvest is less than 15 tonnes.

Modern fisheries management ensures that sustainable harvesting practices are applied through innovative aquaculture programs and education of local fishers. The impact of illegal foreign fishers collecting the shell is addressed in a more proactive, hands-on approach.

The International Operations Section (IOS) of Fisheries Western Australia is a dedicated and expe-

rienced team of professional compliance officers who undertake a wide variety of demanding tasks on behalf of the Australian Fisheries Management Authority (AFMA), Australia's federal fisheries management agency. They operate in all environments and extremes: from the tropical areas of Cocos and Christmas Islands in the Indian Ocean, to the Antarctic waters of Heard Island in the Southern Ocean, their role in providing monitoring, control and surveillance services is state of the art. For IOS officers based in Broome, Western Australia, keeping an eye on the trochus stocks of King Sound is just one of their various fisheries compliance tasks.

The trochus of King Sound are sought after by Indonesian fishers, who have a small window of opportunity to seek their bounty. The usual practice is to make their way from Indonesia to the north and to enter King Sound under the cover of darkness. The maze of mangroves and tidal ranges of 10 metres allow them to conceal their vessels during the day.

Typically, the vessels used are around 10 to 15 metres with a crew of anywhere from 12 to 30. A

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large crew ensure a brief period of exposure when collecting the shell. Low tide exposes the trochus for a speedy harvest, sometimes in broad daylight. A moving frontal line of poachers edges across the reef zone, ensuring no shell of any size escapes capture.

Once the fishing vessel is full to capacity or time and tide dash their efforts, the poachers make their escape. In order to go undetected, the fishers may again hide their vessel among the thick mangroves fringing any one of the myriad of islands in the Sound. When darkness approaches, the poachers motor out of the Sound to open water and run for home. The closest island in Indonesia is only 360 nautical miles to the north of King Sound.

Although the majority of Indonesian vessels used are motor powered, occasionally traditional sailing vessels are used.

A Memorandum of Understanding (MOU) was developed in 1974 between Australia and Indonesia. Australia agreed to permit Indonesian traditional fishers to exploit an area of more than 1500 square nautical miles inside the Australian Fishing Zone (AFZ). The MOU area is Australia's gesture to Indonesia to support limited efforts of traditional fishing practices. The view being that Indonesians may have used the region historically and since no Australian effort of significance was applied to the area, there was room for Indonesian fishers.

Under normal circumstances Indonesian fishers are allowed to operate in the MOU area using only traditional means. The definition of traditional is quite specific – a traditional vessel is made of wood, is sail-powered, and does not have an engine. Any fishing methods used must also be traditional. Such a traditional sailing vessel observed in the MOU area would not cause concern if sighted by surveillance aircraft.

A sailing vessel intending to take trochus from King Sound can travel from Indonesia through the MOU area to its most southerly border. From this border to the entrance to King Sound is only 120 nautical miles. Thus, the poachers' exposure to detection is reduced to 20 hours instead of 60 by transiting the MOU area and by appearing from the air, to be a traditional sailing vessel. The run home is equally assisted by the area's safe waters.

Motor vessels are not permitted in the MOU area. Their voyage from Indonesian waters (at the outer edge of the Australian Fishing Zone) to King Sound is approximately 250 nautical miles. At an average speed of 6 to 12 knots they are exposed to

detection for around 30 to 40 hours. The return voyage to the safety of Indonesian waters may be considerably slower, a moderate-sized trochus boat can carry 1 to 2 tonnes of trochus.

To combat these poachers and to ensure that *T. niloticus* has a chance for survival, Australian Fisheries Officers call upon the resources of the Royal Australian Navy and the aircraft of the Australian Customs Coastwatch surveillance service. Coastwatch carries out almost daily aerial patrols of the King Sound area, which assists in the detection of poachers. The fishers, however, are well versed in the best ways to avoid such detection. International Operations Section Fisheries Officers patrol the waters of the Sound aboard Royal Australian Naval Patrol Boats. This enables them to actually investigate the shores and beaches of the islands. These experienced officers are extremely familiar with the poachers' activities and can easily identify if poachers have been in the area.

Apprehension of trochus poachers by Fisheries Officers is usually generated by either a sighting by surveillance aircraft, or as a result of a report from local fishers of an unusual noise or vessel on the horizon. On the still and magical Kimberley nights, the putt-putt noise of an Indonesian single-cylinder diesel motor is extremely distinct and carries for miles and miles. There is usually no mistaking the sound as most local fishing vessels use high speed modern marine diesels.

Once apprehended, sail or motor vessels are towed or escorted to the WA town of Broome. Situated some 150 nautical miles south of the entrance to King Sound, Broome is the base for one of the world's richest pearl operations. Poachers are held at a site 10 miles north of the Broome townsite, in a creek that serves as an immigration and fisheries detention centre. There, the poachers are monitored until their case comes to court. Typically, they may wait a week or so, and a guilty verdict means one of two options. First offenders are usually served a Good Behaviour Bond and previous offenders are guaranteed a gaol sentence.

Over the past few years the number of poachers to King Sound has dropped slightly. One can hope this is due to the presence of Australian authorities and not as a result of low stocks of trochus.





## Differentiating between juvenile *Trochus niloticus* and *Trochus histrio* in the field

Graeme Dobson<sup>1</sup>

Searching for small juvenile *Trochus niloticus* in complex coral structures is a difficult task at the best of times, but it is made even more difficult by the presence of other similar juvenile gastropods. Differentiating between small juvenile *Trochus* spp. in the field is often hard and can lead to the unnecessary collection of specimens for later examination.

During surveys on reefs of northwestern Australia, the principal confusion lay between *Trochus niloticus* and *Trochus histrio*. A reliable character to differentiate between the two in the field was found to be the number of parallel ridges on the base of the shell (Fig. 1). *T. histrio* has six or seven distinct and strongly nodulous ridges, whereas *T. niloticus* has 13–16 weak ridges becoming less distinct toward the outer edge of the shell. The ridges were easily checked by running a thumb nail across the shell base.

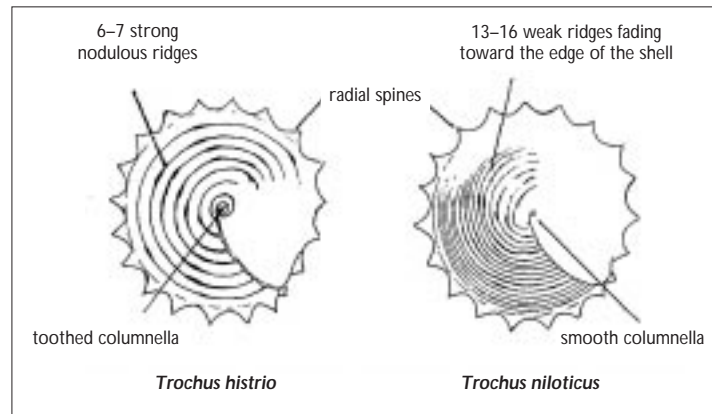


Figure 1. The number and strength of ridges differentiate *Trochus niloticus* from *T. histrio*.

When juvenile *T. niloticus* grow to about 20 mm shell width, the ridging is lost; however, at this size they can be readily and reliably identified by colouration and patterning.



## Using underwater metal detectors for research into trochus reseedling

Tasman Crowe<sup>1</sup>

Researchers involved in stock enhancement, fisheries and ecology must use a range of techniques to recapture tagged animals effectively. One of the more challenging situations is when a comparatively small and cryptic animal must be recaptured in a complex habitat, particularly when the animal is mobile and may range over a wide area. As part of the Australian Centre for International Agricultural Research (ACIAR) Trochus Reseeding Research Project, it was necessary to mark juvenile trochus in the size range of 16–25 mm and recapture them over wide areas of

complex coral reef in Australia, Indonesia and Vanuatu (Crowe et al. in review). After release, the animals often moved into and under the substratum (e.g. live coral or coral rubble) and could not be reliably found using visual searches (see also Castell et al. 1996).

To solve this problem, we used underwater metal detectors to locate metal tags fixed to the animals. The metal detector used was a *Pulse 8X* with a 7.5 inch detecting coil, supplied by JW Fishers Mfg (1953 County St., E. Taunton, MA 02718, USA). This

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detector is of the pulse induction type. It works in fresh or saltwater and is not sensitive to either the salt in the water or minerals in the substratum. The unit is contained in a housing, waterproof to 30 m depth and can be charged from a 12 V battery, making it suitable for research in remote areas.

We found the smallest tag that could fit on a juvenile trochus and still be reliably detected was a piece of 0.3 g aluminium. Tags were detectable within a range of 8 cm of the coil, regardless of the intervening medium (e.g. air, water, rock, sand or coral) and could be pin-pointed to within 1–2 cm. Each tag was made from a 30 x 300 mm sheet of domestic aluminium foil folded into a 15 x 15 mm square. Tags were stuck to the shells of juvenile trochus using cyanoacrylate glue. Folded foil tags were used because they were flexible enough to be conformed to the surfaces of the shells of the trochus, which greatly improved the strength of the bond.

The effectiveness of the system was investigated in a series of pilot trials that tested: (i) the percentage of tagged trochus recaptured in a typical habitat using a standard search pattern; (ii) the effects of the tags on the short-term survival of the trochus; and (iii) the effective life of the tags (rate of loss, long-term detectability). The trials used juveniles reared at the hatchery at the Northern Territory University, Australia. The field sites were on the coral reef at Cunningham Point on the east coast of the Dampier Peninsula, northeast of Broome, Western Australia.

Results indicated that the tagging system was an effective method for finding trochus in the complex habitat provided by coral reefs. Over 85% of a known number of juveniles were consistently recaptured (Crowe et al. in press). This information has since been used to adjust estimates of survival made using the technique in a large experiment to test stock enhancement of trochus (Crowe et al. in review; Castell et al. 1996). A variety of other visual tags have been used in research into stock enhancement with trochus, but tests of their effectiveness have rarely been reported (Crowe et al. 1997).

Contrary to expectation, the folded foil tags had no measurable effect on the short-term survival of juvenile trochus (Crowe et al. in press). The tags we used, however, have a limited operational life. After 1.5 months in the hatchery, all tags tested remained attached to the snails, but after four months many had become loose and would probably have been dislodged on the reef. Although in our laboratory study there was little loss of detectability of tags over a six-month period, many of the tags deployed on reefs as part of a larger study could not be detected after three months. On

reefs, the tags were exposed to alternating combinations of salt water, air and sun that may have corroded the foil, making it hard to detect. Similar problems may not necessarily arise in subtidal research. The tags can be used reliably on intertidal reefs for at least one month. Recapture is less certain after two to three months and should not be attempted at all after three months.

Performance could potentially be improved by using solid pieces of metal that would not corrode as easily. These could not be attached with cyanoacrylate glue because cyanoacrylates will only bond surfaces that are in direct contact (i.e. they cannot fill gaps). Epoxy putty (Milliput® or Sea Goin' Poxy Putty®) may be suited to this task and may result in a more durable bond. If numbers were stamped into solid metal tags, individuals could be identified. Aluminium is one of the most easily detected metals. Metal detectors do not easily detect stainless steel.

The trials were done in a coral rubble habitat, where trochus were able to live up to 3 or 4 cm below the 'surface'. The complexity of this habitat was about average for the reseeding research that we undertook. The 7.5 inch coil could not detect trochus that lived deep within more complex habitats (e.g. live branching corals, such as *Acropora* spp.).

It would be possible, but time-consuming, to use a smaller (1 inch) probe to search for tagged animals in such habitat. Larger targets can be detected at greater ranges (to a maximum of 2 m with a 7.5 inch coil). Larger coils (up to 18 inches) are also available for use with the detector. These can detect larger targets over greater distances, but are no more sensitive to the small targets we were using than 7.5 inch coils. The value of the technique would be limited in areas with large amounts of metal debris because there would be many spurious signals.

In summary, we found the use of a metal detector to recapture animals tagged with appropriate metal tags to be effective. It is relatively inexpensive (the detector costs less than USD 1500, tag costs are negligible), convenient, uses small harmless tags, and has potential to be adapted for many applications in stock enhancement, fisheries and ecological research. Further details are available in a forthcoming article in *Aquaculture* (Crowe et al. in press).

## Acknowledgements

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## References

Castell, L., W. Naviti and F. Nguyen. 1996. Detectability of cryptic juvenile *Trochus niloticus* Linnaeus in stock enhancement experiments. *Aquaculture* 144:91–101.

Crowe, T.P., M.J. Amos and C.L. Lee. 1997. The potential of reseeding with juveniles as a tool for the management of trochus fisheries. In: C.L. Lee and P.W. Lynch (eds), *Trochus: status, hatchery practice and nutrition*. ACIAR Proceedings No. 79. Canberra: Australian Centre for International Agricultural Research. 170–177.

Crowe, T.P., C.L. Lee, K.A. McGuinness, M.J. Amos, J. Dangeubun, S.A.P. Dwiono, P.C. Makatipu, F. N'guyen, K. Pakoa and J. Tetelepta, J. (in review). Experimental evaluation of the use of hatchery-reared juveniles to enhance stocks of the topshell *Trochus niloticus* in Australia, Indonesia and Vanuatu. *Aquaculture*.

Crowe, T.P., G. Dobson and C.L. Lee. (in press). A novel method for tagging and recapturing animals in complex habitats and its use in research into stock enhancement of *Trochus niloticus*. *Aquaculture*.



## Harvesting the ra'ui<sup>1</sup>

Lisa Williams

Source: *Cook Island News*, 22 January 22 2000

Considering it's not legislated by law and there is no real way of enforcing it, the ra'ui which has existed in selected parts of the Rarotonga lagoon for the last two years has borne some magical fruit. Sure, it's Mother Nature's way of rewarding those who let her rest, but some would say te mana o te ra'ui (the power of the ra'ui) has indeed given hope for more than replenishing the food cupboard.

Imagine it happening in Nikao. Steaming mounds of fresh trochus meat, piled up by workers who gently work the delicacies out of boiled shells – this is one of the memories I have of trochus harvesting in Aitutaki. There is so much meat, you don't even think of eating it – you are simply overwhelmed by the sheer size of the thing. For hours, people boil water on open fires, in drums and cabin bread tins ready to blanch the sacks of trochus filled by others who have been collecting from the lagoon.

When it comes to trochus harvesting in Aitutaki, it's a united community effort – and the same

work effort is being called on to help with the Nikao community's first ever harvest of trochus with the lifting of the ra'ui in two weeks time.

Aitutaki has been harvesting trochus as a major source of income for the island for years. Rarotonga has never really done a trochus harvest on a commercial scale, and there are hopes that assistance in the form of advice from Aitutaki to run the first harvest in the Nikao ra'ui zone will come through.

Already the signs of inter-island cooperation are promising. Aitutaki will weigh in the Nikao consignment – expected to be around two tonnes or fifty flour sacks, when it exports its shells to New Zealand. The return to Nikao – expected to be around NZ\$ 30,000 – will go into the villages community fund. The trochus shells end up a Cook Islands export on the designer wear of fashion labels, or as components in jewellery.

There's also a demand for polished trochus, which can be dyed or sold as is. Sometimes you catch

1. Ra'ui: Rarotongan word for a seasonal closure or ban. In this case, it is effectively a marine protected area or reserve.

sight of them in paperweights, but you won't see tiny trochus shells leaving our shores. The plan for exporting trochus from here is not to take anything smaller than 8 cm or bigger than 11. The sizes outside that range are needed to replenish and maintain stocks for future harvesting. Ask Marine Resources, who conducted a pre-ra'ui 'audit' of the local lagoon before the ra'ui kicked in two years ago.

Before the ra'ui, the count for trochus was estimated at around 10,000. In its first year, the stocks jumped to 30,000. Now sitting on a plateau of around 40,000 in the Nikao ra'ui zone alone, marine officials suggest the zone has reached capacity because the rock areas that host the trochus are fairly well taken up. Harvest time, indeed, with only around 11,000 shells needed to fulfil the two tonne quota.

And while the two years of 'sleep and rest' offered by the ra'ui has allowed trochus stocks in the Nikao lagoon to literally shoot through the roof, it's the economic potential of the area that has the residents advocating caution and wise management rather than a free for all.

Many at a public meeting in Nikao this week want to see the thriving species in the area kept there as a living classroom of sorts for local schools. Not only has the Nikao ra'ui made a promise of economic revenue, it has yielded a promising diversity of sea life as well.

Kina, atuke, avake, vana (all different species of sea urchin), paua (giant clams), matu rori (sea cucumber gonads) rori matie, rori pua, rori puakatoro, rori toto (all different species of sea cucumber), trochus, trumpet shell, ariri, ungakoa, and poreo (all shellfish) are now species that can literally jump out off the pages of school books because classrooms can study them in their natural environs. It is humbling stuff for a lagoon that was overfished and under threat just two years ago. Even the corals are coming back, sporting life and colour while the ra'ui 'residents' take over.

"I don't want us to do what Arorangi did when they opened their ra'ui," a prominent Nikao resident says, "otherwise it's all been a waste of time. We've seen the tourism benefits and the ways schools can use the area and study the fish. We have to keep it that way."

At the meeting this week, Nikao MP and REAP member Ngamau Munokoa opened up consultation on how the ra'ui should be managed beyond 2000 – or its lifting date on February 5th. The results from residents have been gratifying: every-

one agrees the ra'ui has yielded more fish than ever in the Nikao area. Everyone agrees that the lifting of the ra'ui should be temporary – a few days, enough time to fish and gather trochus, and then closed. And the rules are simple. No net fishing. No night fishing and no gathering of shellfish apart from the trochus harvest.

The shellfish ban hasn't gone down too well with mamas who will be eyeing paua stocks in the lagoon as they scoop up trochus on the reefs. But the temptation will have to be dealt with – advice from marine studies of the area show that the paua replenishment of the area has not been as fast as the trochus. The paua are small and even, as the mamas say, if they look for the bigger ones, it would be difficult to resist the taste of a fresh-from-the sea morsel over fresh-off-the-plane from the outer islands.

Nikao alone is the only ra'ui area on the island to take on the trochus harvest. Takitumu vaka is eyeing the possibility of a harvest, but not in the ra'ui zone. But the temptations for those entering the seafood larder after a two-year absence is something all of Rarotonga is wrestling with.

Ngatangia held its meeting on the ra'ui area yesterday afternoon. Tikioki, which has seen an explosion in fish replenishment in the same way that Nikao has seen a shellfish boom, is to call another meeting for Monday night at the Kent Hall. In the meantime, Nikao continues preparing and will monitor its ra'ui with residents volunteering time to see that nobody takes forbidden fruit from the sea, or is fishing after 6 pm.

At the end of it all, there are lessons and rewards from the ra'ui that have become self-evident. Given enough time and a break from human impact, the lagoon cupboard will refill itself, and is able to be not just a source of food, but of education and money as well.

As one involved observer noted, those who supported the ra'ui merely to increase the catches of fish have noticed how short-term their benefits are. What the ra'ui does is provide a strong pointer in the right direction.

If properly managed, the ra'ui leads the way to a consensus for lagoon management that involves the community, strengthens our appreciation for the ui tupuna, and reaps economic benefits for Cook Islanders now while leaving a great environmental heritage for Cook Islanders to come. For those who've worked to make the ra'ui work, that's the real payoff.





## Pictorial view of the ACIAR Trochus Reseeding Research Project

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The Australian Centre for International Agriculture Research (ACIAR) funded a trochus reseedling research project that ran from 1995 to 1998. It was extended for another two years in 1999 and the project is to be completed in April 2001.

The research project involves three countries: Australia, Vanuatu and Indonesia. Additional information on the trochus extension project is given in the *Trochus Information Bulletin* No. 6, pages 16 and 17.

I believe this project is an excellent example of how ACIAR implements its projects and how it brings researchers together to solve a problem common to the countries or regions involved.

Enough has been said about the ACIAR trochus research project in the last couple of years. I hope this light-hearted pictorial presentation captures the essence of the project and the people involved with it.



**Tagging juvenile trochus  
with aluminium tags.**



**Graeme Dobson, a MSc student  
searching for tagged juveniles  
with a metal detector.**



No, they are not 'trochus predators' feeding on juvenile trochus; it is a group of university students helping with 'tethering' juveniles with fishing line prior to release in the field.

Trochus spawning in Vanuatu's hatchery. Dr C. Lee (left) and Moses Amos (right), project coordinator for Vanuatu .



Barney Smith, ACIAR Fisheries Program Coordinator presenting a certificate of appreciation to a traditional owner on Sunday Island, Australia for helping in the research project.

After a long day, the ACIAR project review team finally gave up and called it a day.





**ACIAR Trochus Reseeding Research Project review team visiting research site in Vanuatu.**

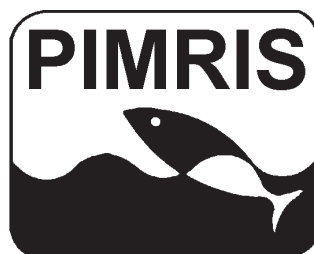
**Left to right:  
Dr Neil Andrew, project reviewer;  
Dr Putro Dwiono, Indonesia project coordinator;  
Felix N'guyen, Vanuatu researcher;  
Moses Amos, Project coordinator, Vanuatu; and  
Pakoa Kola, Vanuatu researcher.**

**Some trochus and mother of pearl ornaments on sale at Lombadina Aboriginal Community, Australia.**



**We all love 'stir-fried' trochus for dinner.**

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



Pacific Islands Marine Resources  
Information System

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.