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

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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^2, 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).

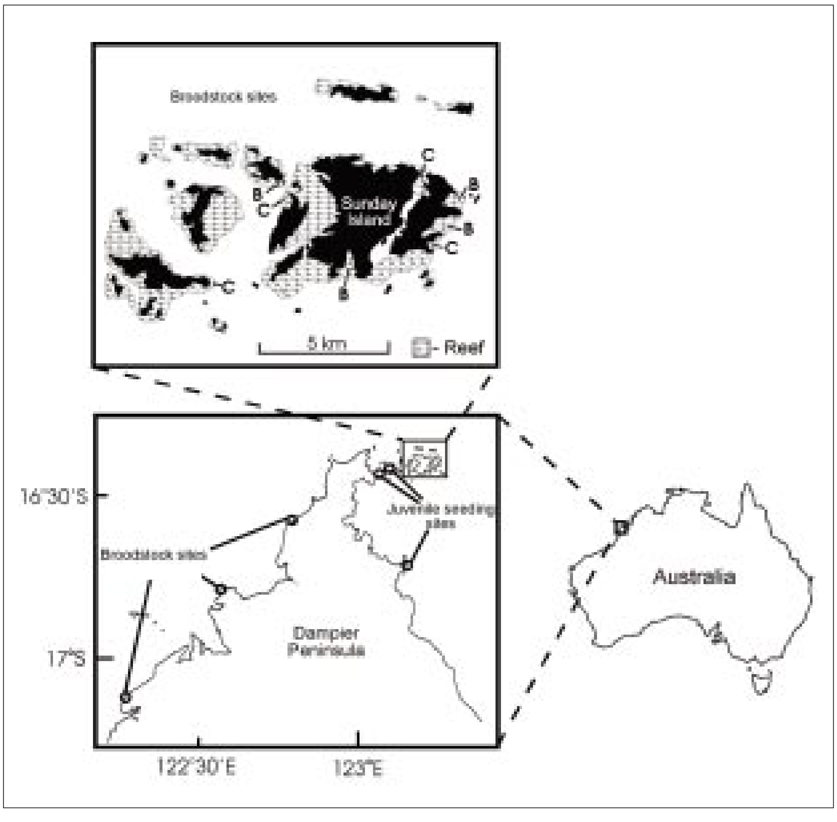

Figure 1. Study sites for broodstock translocation and juvenile seeding experiments in WA. Reef sites in upper inset denoted as: C - control; and B - broodstock transplanted.

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 population 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.

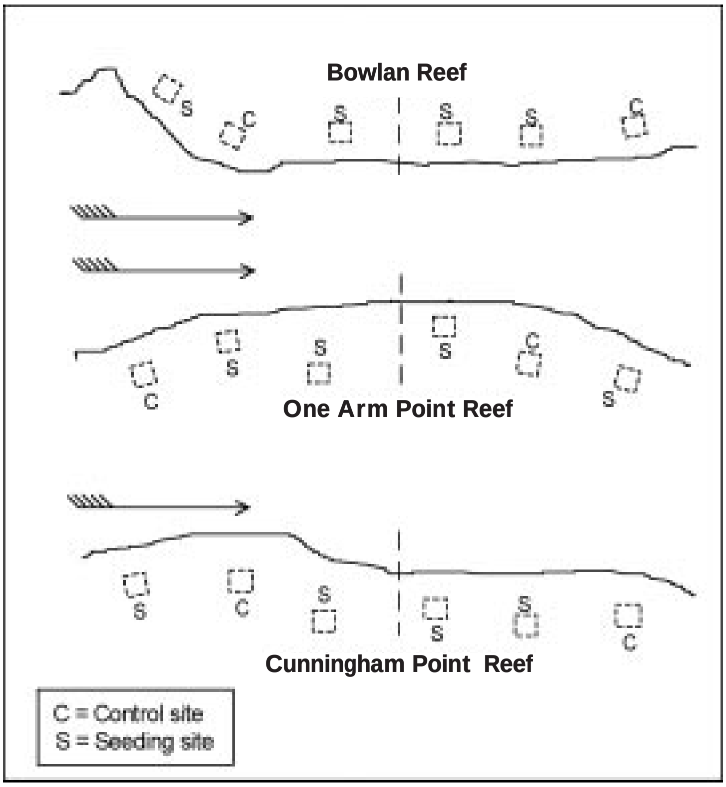

Figure 2. **Schematic diagram of layout of sites (dashed boxes) for control and juvenile seeding treatments in the mass-seeding experiment. Arrows denote direction of flooding tidal currents. Dashed lines represent the reef split for the design.**

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 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^2) 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 methods 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.

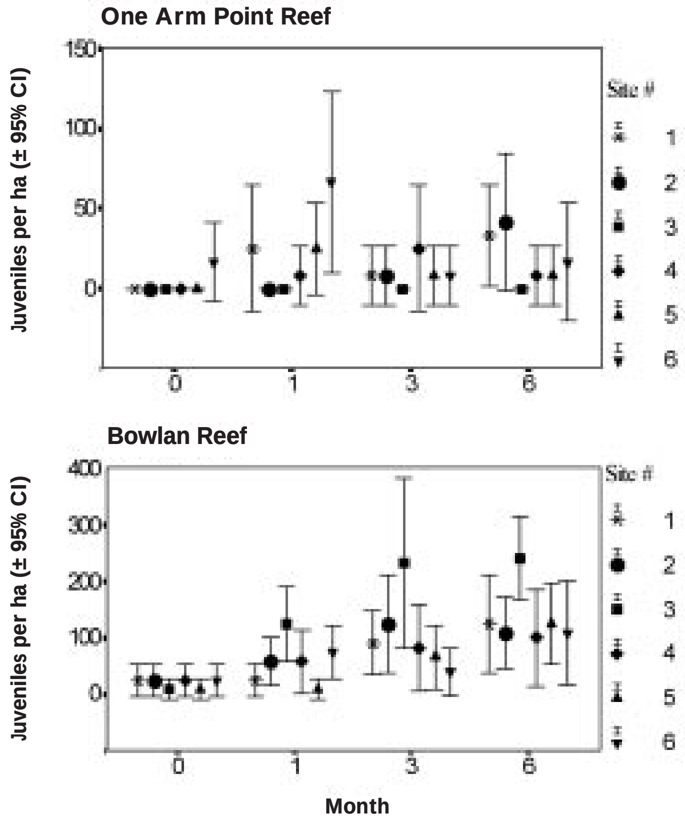

Figure 3. **Error-bar plots for mean abundance of 20–50 mm juveniles at each of six sites on two study reefs over a six-month period. Note change in scale between graphs.**

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).

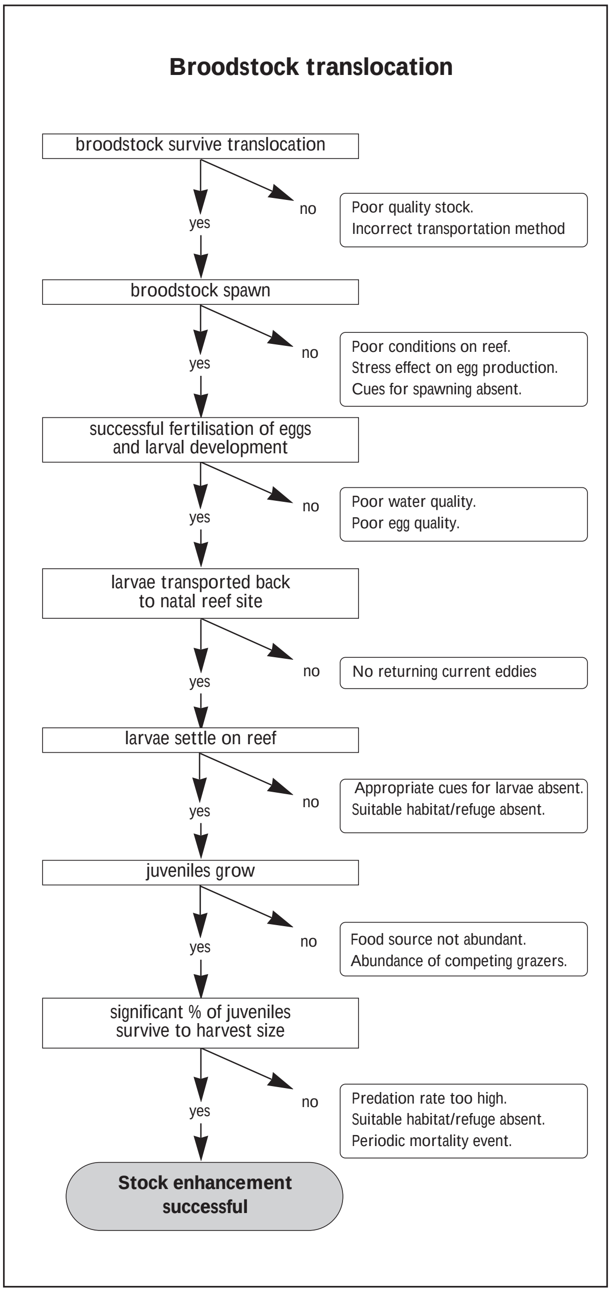

Figure 4. **Broodstock translocation: flow-chart of critical steps during the process of stock enhancement. Likely causes for failure during successive steps are provided in boxes on right.**

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.

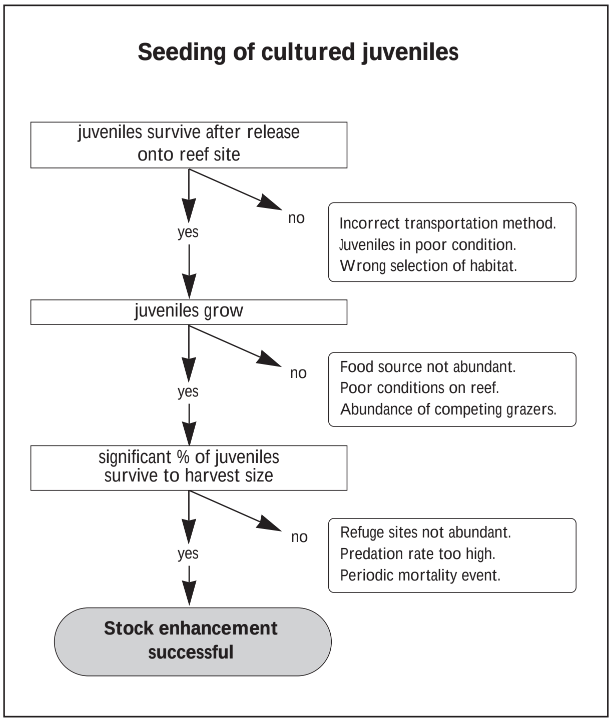

Figure 5. **Juvenile seeding: flow-chart of critical steps during the process of stock enhancement using hatchery produced juveniles. Likely causes for failure during successive steps provided in boxes on right.**

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