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

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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 reseeding 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 reseeding. In addition, such information 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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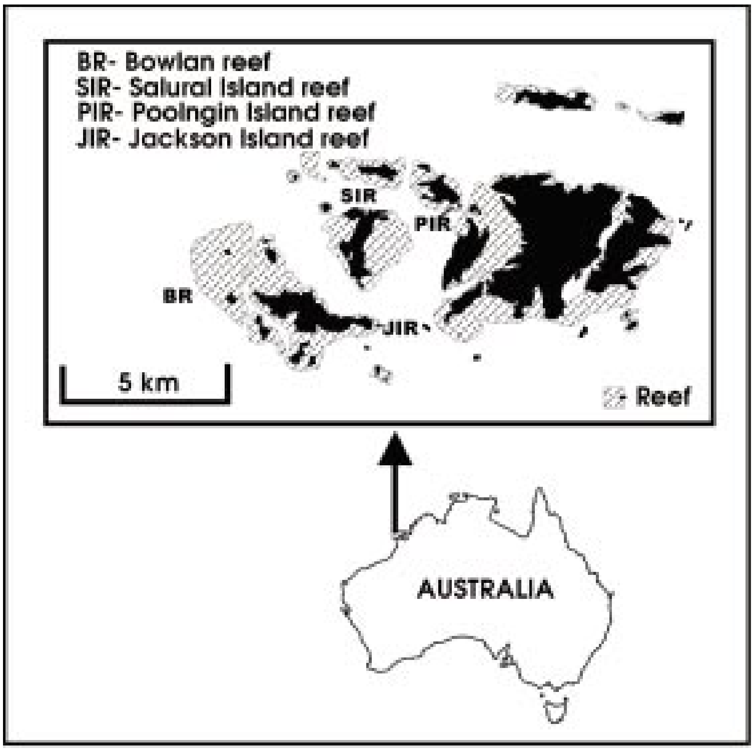

Figure 1. **Study area and reef locations at the mouth of King Sound, WA.**

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 surveys 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

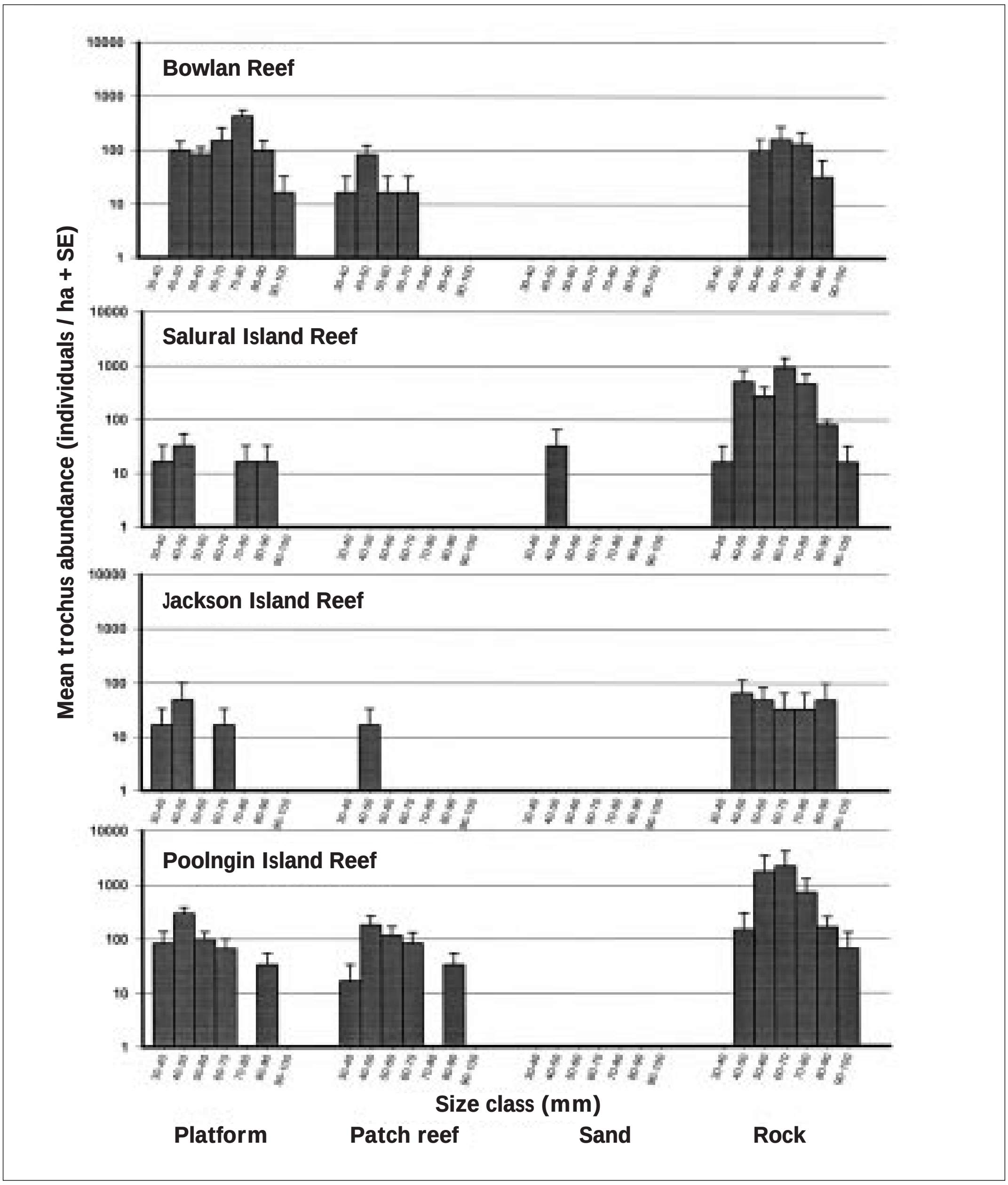

Figure 2. **Size class distribution of *T. niloticus* within habitats on the four study reefs. Y-axis is on a log scale and abundance data scaled from 100 m^{-2} to $hectare^{-1}$**

(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.

	Habitat		
Precision	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
	Mean area	29.3	54.0	12.0	4.8

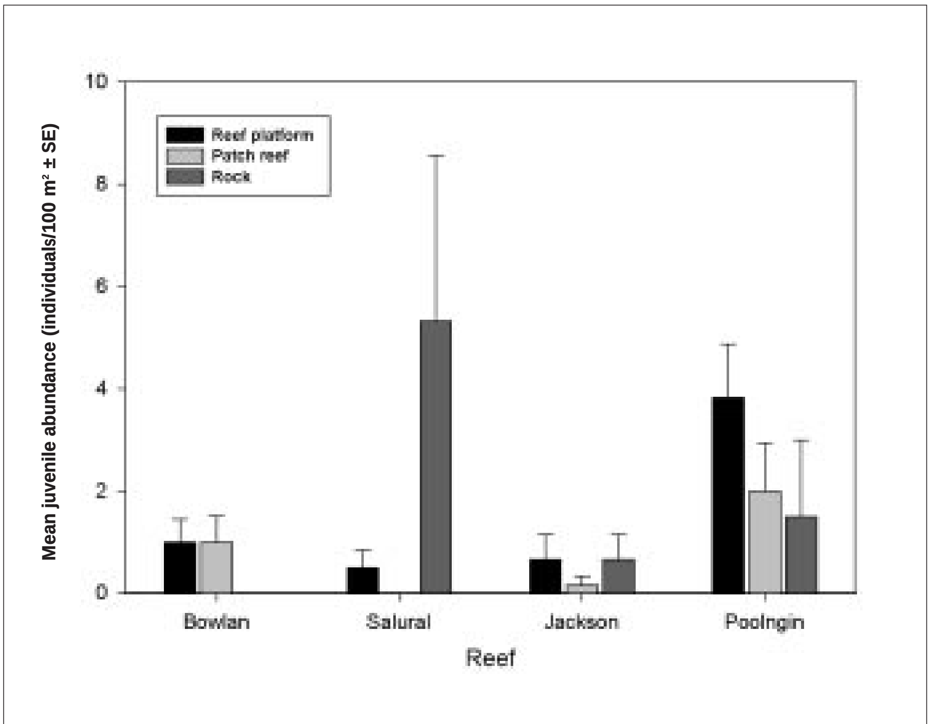

Figure 3. Mean abundance of juvenile trochus (30–50 mm SW) within platform, patch reef and rock habitats of the four study reefs.

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

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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 Sopu Mariculture Center in Tongatapu

Most facilities of the Sopu 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

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