Experiments on using hatchery-reared *Trochus niloticus* juveniles for stock enhancement in Vietnam

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Abstract

The topshell (*Trochus niloticus* Linnaeus, 1767) is a commercially exploited mollusc that is commonly found on Indo-Pacific coral reefs. One effective method of replenishing natural populations of trochus is artificial breeding and the release of larvae and juveniles into the wild. Artificial breeding has been successful at the Institute of Oceanography, Nha Trang, in Vietnam. Artificially reared trochus seeds were used for restocking, based on community management at Chao Reef (12°22′39″S; 109°18′18″E). Results on trochus growth rates at different culture densities in cages showed that appropriate densities were: 100 ind m^{-2} for specimens measuring 10–22 mm in shell diameter, <50 ind m^{-2} for individuals measuring 25–40 mm and <10 ind m^{-2} for individuals of 40–50 mm. The latter should be released to the reef for natural development in the wild. Suitable culture sites are coral reefs, with limited wave action, high water transparency, and availability of rubble or rocks covered with algae. Cage culture is the most effective culture method because it is easily managed and cages can protect topshells from waves, wind and predators. The preliminary results presented here are from the first study on this species in Vietnam, thus providing the basis for topshell stock enhancement in this country.

Introduction

Trochus, or topshell (*Trochus niloticus* Linne, 1767), is a mollusc that is found on coral reefs of the Indo–Pacific. It can reach up to 13 cm in shell height, and the shell diameter ranges from 50–60 mm at two years of age. This species is economically valuable in terms of food, and the shell is used to produce crafts and cosmetics. The main topshell exporting countries are Indonesia, the Philippines and Thailand, with Japan, Hong Kong and Europe being the biggest consumers. Production of trochus in the Andaman Sea (Thailand) was 1955 kg in 1994–1995; this number decreased to 450 kg in 1995–1996 and rose again to 4382 kg in 1996–1997.

In Vietnam, *Trochus niloticus* has been exploited for its meat and shell. Current market prices are between 40,000 and 70,000 Vietnamese dongs (VND)[2] per shell sold as handicraft, and VND 150,000 kg^{-1} for the meat. Nowadays, due to high demand for the shell, overexploitation of trochus has resulted in resource exhaustion. *T. niloticus* is one of the protected species listed within Vietnam's Red Book (MOST 2000) and by CITES. The habitat of topshell and other marine species has been destroyed. Hence, resource rehabilitation and stock enhancement are necessary, both locally and globally. One effective solution for recovering trochus resources is artificial breeding and the release of larvae and juveniles back into the field (Amos 1992; Ponia 2000; Lee 2000).

Studies on the biology and ecology of *T. niloticus* have been conducted in Indonesia, Thailand, Japan, Micronesia and Australia. Some of the results of these studies can be applied to rearing trochus (Bour 1988; Shokita et al. 1991; Dobson and Lee 1996). The main diet of trochus consists of seaweeds that are easily collected in tidal areas. Rehabilitation and stock enhancement of trochus do not require high financial investment, as they can be conducted in the natural environment.

The specific objective of this project was to artificially breed *Trochus niloticus* for stock enhancement. This paper presents preliminary results of experiments on using hatchery-reared juveniles to enhance stocks of the topshell, *T. niloticus*, in Vietnam.

Materials and methods

Study area

This study was carried out at Chao Reef (12°22′39″S, 109°18′18″E), in the Dam Van hamlet, Ninh Van commune, Ninh Hoa district, Khanh Hoa province

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2. VND 10,000 = USD 0.62 (July 2007)

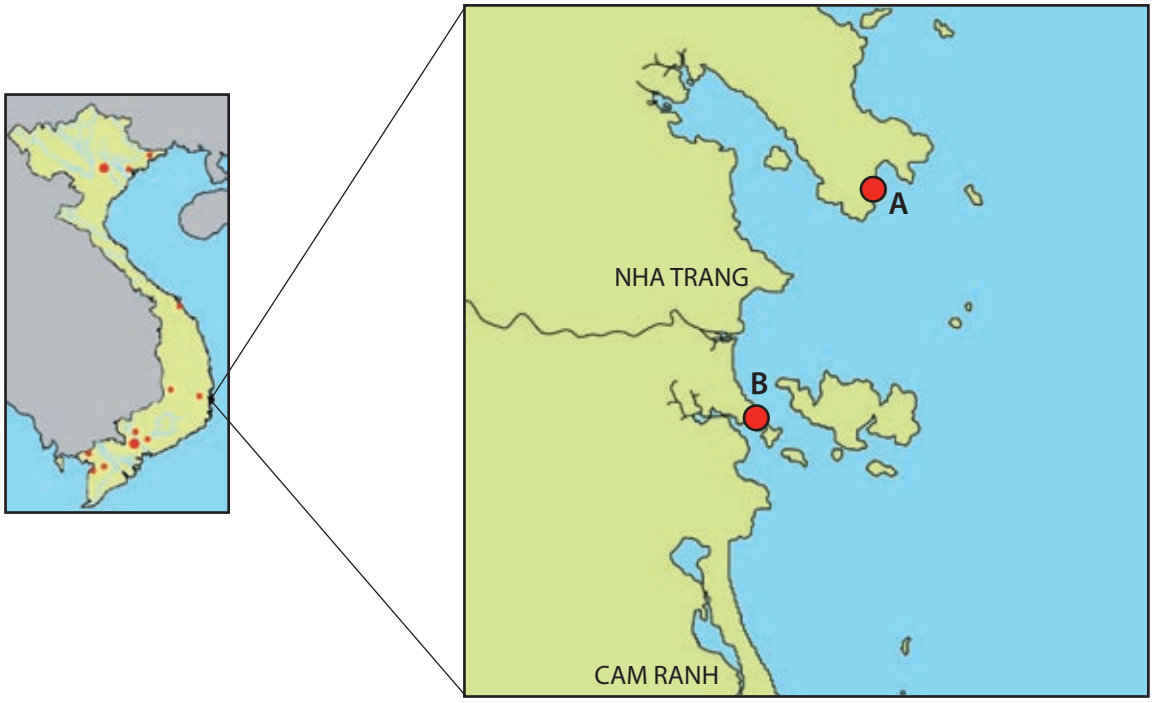

Figure 1. Vietnam and a closeup of the study area.
A: Ran Chao Reef, where restocking experiment took place;
B: Institute of Oceanography, where trochus were bred.

of Vietnam (Fig. 1). The site is approximately eight hectares. In recent years, trochus were present at Chao Reef, but they have since completely disappeared due to overexploitation.

Trochus culture cages were placed on the northern side of Chao Reef on the sand and rubble bottom, at the reef base where there is less wave action.

The seaweed and algal composition of Chao Reef includes: *Lyngbya aestuarii*, *Lyngbya lutea*, *Ocillatoria* sp., *Acanthophora spicifera*, *Galaxaura arborea*, *Gelidium pusillum*, *Gracilaria edulis*, *Hypnea pannosa*, *Lorencia composita*, *Feldmannia* sp., *Dictyota dichotoma*, *Dictyota bartayresii*, *Padina australis*, *Enteromorpha* sp., *Amphiroa foliacea*, *Galaxaura ablongata*, *Laurencia composita*, *Padina japonica*, *Sargassum* spp., *Caulerpa racemosa*, *Enteromorpha* sp., *Halimeda opuntia*.

Experimental research

Trochus niloticus juveniles were obtained from artificial breeding in the laboratory at the Institute of Oceanography. They were transported by boat to the site (around 2 h).

Cage culture at different densities

Trochus were cultured in cages (1 x 1 x 0.6 m) consisting of iron bars (14 mm in diameter). Each cage was surrounded by a nylon net (4 mm mesh size).

Seaweed and algae growing on dead corals or rocks were used as food. The dead coral and rocks were collected in adjacent areas and placed inside the culture cages to cover about 70–85% of the bottom area. Food was changed and cages cleaned three times a month.

Experiment 1 (17 August to 4 October 2003)
The three culture densities tested were 50 ind m^{-2}, 100 ind m^{-2} and 250 ind m^{-2}, beginning with an initial size of 8–12.5 mm shell diameter. The mean diameter (DK) was 10.59 ± 1.30 mm (S.D.) and body weight was 0.37 ± 0.14 g (S.D).

Experiment 2 (4 November 2003 to 10 June 2004)
Culture densities were 50 ind m^{-2} and 100 ind m^{-2}. The initial size (shell diameter) of the trochus was 22.90 ± 1.74 mm and 22.28 ± 2.44 mm (S.D.), respectively for each treatment.

Experiment 3 (9 July to 10 September 2004)
Culture densities were 10 ind m^{-2}, 20 ind m^{-2}, and 40 ind m^{-2}. The initial size (shell diameter) of the trochus was 39.83 ± 3.61 mm, 39.92 ± 4.40 mm and 43 ± 5.32 mm (S.D.), respectively. Measurements of growth and survival were recorded monthly.

Effect of food quantity on growth rate

Experiment 4 (August to November 2004)
Initial size (shell diameter) was 15 mm and culture

density was 60 ind m^{-2}. Treatments consisted of no food, food covering 50% of the cage bottom, and food covering 100% of the bottom. Each treatment was represented in three replicates.

Experiment 5 (July to November 2004)
Initial size (shell diameter) was 40.18 ± 2.48 mm and culture density was 15 ind m^{-2}. Treatments consisted of no food and food covering 20%, 40%, 65% and 90% of the cage bottom.

Results

Data on the number of trochus remaining in the culture cages, basal diameter and weight were collected on a monthly basis. Results are expressed as mean ± S.D.

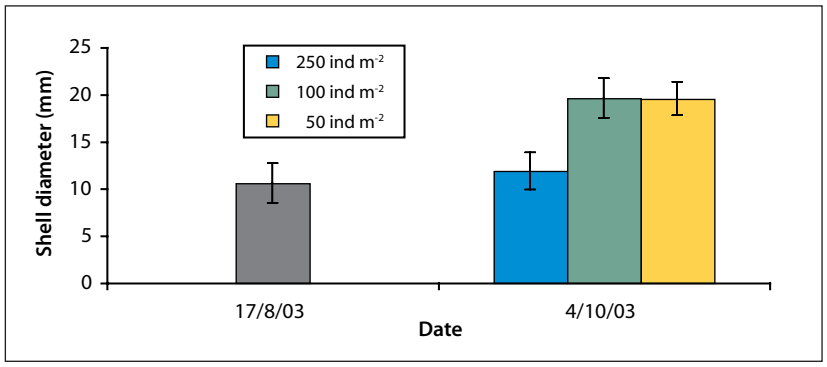

Figure 2. Initial size (17/8/03) and final sizes (4/10/03) of trochus cultured at different densities (50 ind m^{-2}, 100 ind m^{-2} and 250 ind m^{-2}).

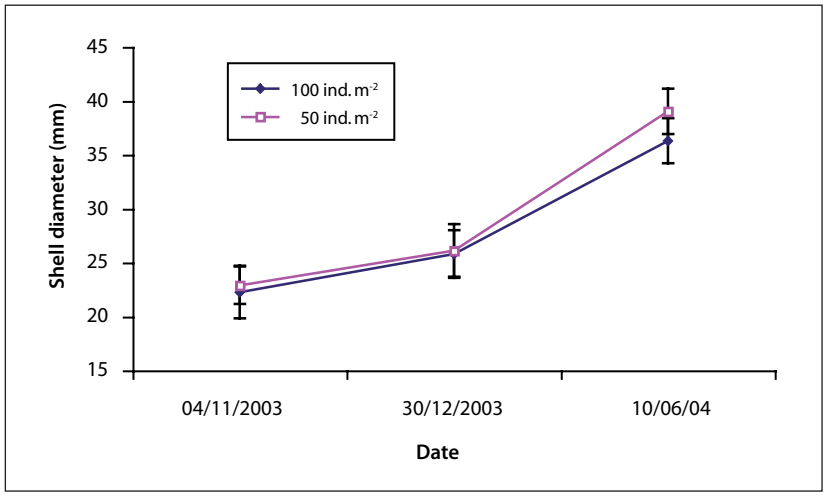

Figure 3. Growth of trochus cultured at different densities (50 and 100 ind m^{-2}).

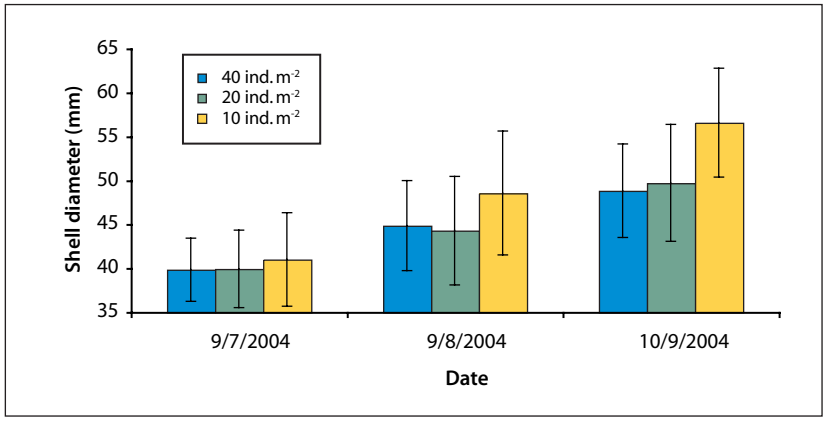

Figure 4. Growth of trochus cultured at different densities (10 ind m^{-2}, 20 ind m^{-2} and 40 ind m^{-2}).

Cage cultures at different densities

Experiment 1
Initial size (shell diameter) of the trochus was 10.59 ± 1.30 mm. After 1.5 months, growth rates of trochus cultured at a density of 100 ind m^{-2} were no different from those cultured at 50 ind m^{-2} and trochus in both treatments grew faster than trochus cultured at a density of 250 ind m^{-2} (ANOVA, $p < 0.001$) (Fig. 2). Furthermore, the survival rate at 50 ind m^{-2} was the highest (100%), followed by 73% at 100 ind m^{-2} and nearly 20% at a density of 250 ind m^{-2}.

Experiment 2
After seven months, trochus at densities of 100 ind m^{-2} and 50 ind m^{-2} grew from an initial size of about 22 mm to 36.31 ± 2.08 mm and 39.04 ± 2.11 mm, respectively, with no significant difference between the two treatments (*t*-test, $p > 0.18$) (Fig. 3). Survival was 79% and 100% for trochus cultured at 50 ind m^{-2} and 100 ind m^{-2}, respectively.

Experiment 3
After two months, the final sizes measured were 48.82 ± 5.33 mm at a density of 40 ind m^{-2}, 49.72 ± 6.66 mm at 20 ind m^{-2}, and 56.57 ± 6.2 mm at 10 ind m^{-2}. Survival was greater than 90% for all three treatments. No significant difference in growth rate was found between densities of 20 ind m^{-2} and 40 ind m^{-2}, but significant differences were observed between 10 ind m^{-2} and the two other densities (Fig. 4).

Effect of food quantity on growth rate

Experiment 4
The trochus in this trial had an initial size of 15 mm and reached about 26 mm in four months. There was no significant difference in growth rate between the treatments (i.e. 0%, 50% and 100% food covering on the cage bottom) (ANOVA, p> 0.05) (Fig. 5).

The animals grew well but the mortality rate was higher in the cages without any food compared with the others. The reason may be a lack of food in the initial growth stage. There was no significant difference in the survival rate of the trochus in cages with 50% and 100% cover, but both groups showed significant differences in comparison to the survival of trochus in the treatment with no substratum (Fig. 6).

Experiment 5
This experiment was conducted at a density of 15 ind m^{-2} with all individuals having a shell diameter of 40.18 ± 2.48 mm and a weight of 20.08 ± 3.96 g. In cages with no food, trochus fed on seaweed attached to the walls. In other cages, trochus were further supplied with different amounts of seaweed attached to dead corals. Survival rates were greater than 90% in all treatments. Trochus cultured with more food grew faster (Fig. 7).

There were significant differences among the growth rates of trochus cultured with different covers of food/substrata: 90% > 65% > 40% > 20% > no substrata (ANOVA, p < 0.02). Results showed that trochus cultured in cages supplied with food covering 90% of the bottom yielded the greatest sizes, weight and growth rates. In contrast, trochus in cages with no rocks or additional food showed the slow-

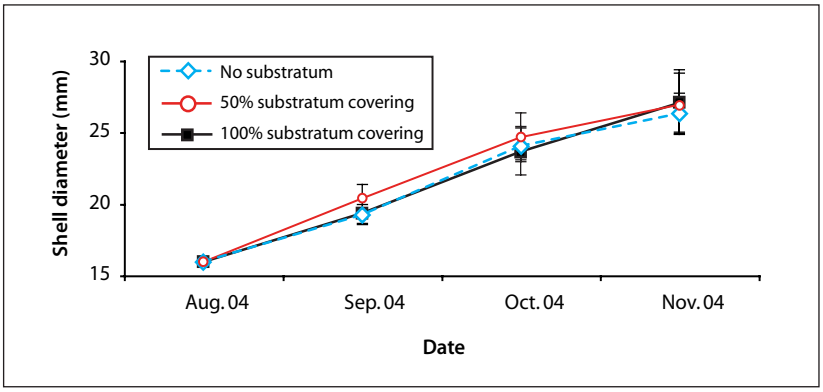

Figure 5. Growth of trochus with different amounts of food supplied.

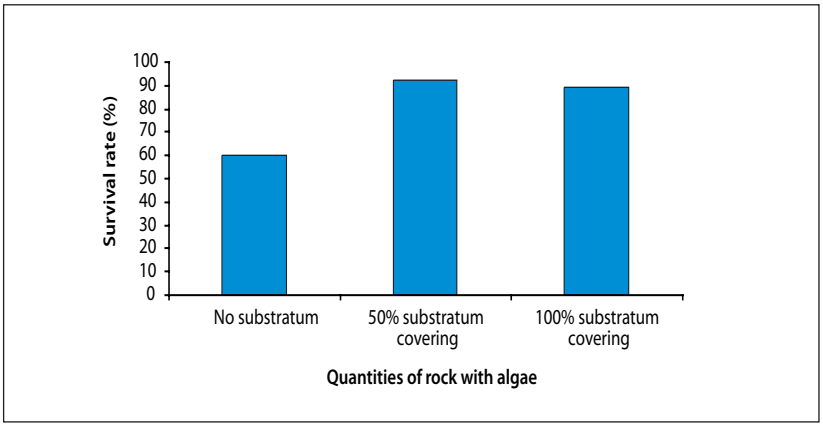

Figure 6. Survival rate of trochus with different amounts of food supplied.

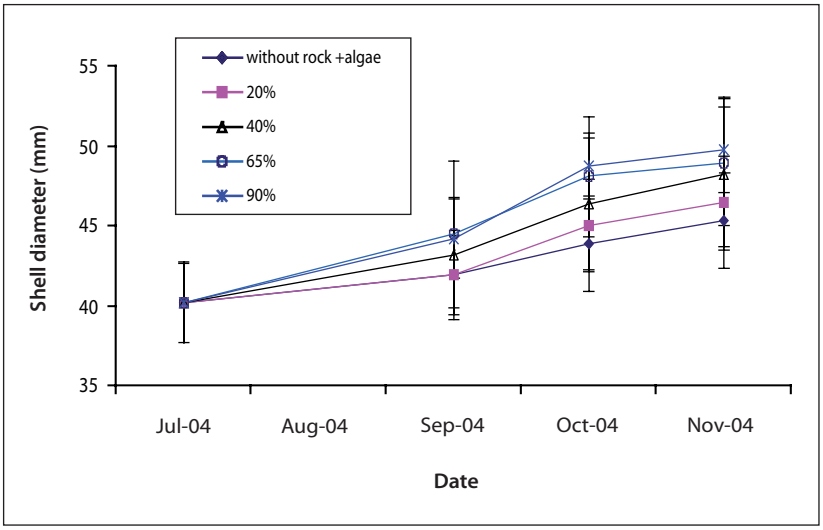

Figure 7. Growth of trochus with different amounts of food supplied.

est growth rate. Survival rates were also higher in cages with additional substrata. The results suggest that a sufficient amount of food supply is essential when trochus are larger than 40 mm (Fig. 7).

Discussion

Trochus generally occur from the littoral zone to depths of less than 5 m, although they have been found at 20 m (Shokita et al. 1991). They usually colonize the windward margins of coral reefs where small seaweeds are abundant around rubble in the littoral zone (Trochus cannot survive on sandy and muddy bottoms (Nash 1985)). The study area at Chao Reef was a rocky reef flat with algae present, and the results of the culture experiments indicate that this is an appropriate site for trochus restocking.

Our data show that small trochus grew faster than larger ones. The growth rate of trochus was higher in the dry season (March to October) than in the rainy season (November to March) when low temperatures, windy conditions, and increased wave action yielded lower survival rates.

During the rainy season, runoff from land carries sediment into the nearby seawater making it opaque. This sediment accumulates in the cages and may have an adverse effect on the growth of seaweed, resulting in a lack of food for cultured trochus. However, in the dry season, there is little runoff and the seawater is clear of sediments, allowing seaweeds to grow well on cages, and trochus to have access to sufficient food. It was easier to collect and change seaweed-covered rocks on a regular basis in the dry season so that trochus grew faster.

The very high survival rate (usually over 75%) in almost all the cage culture experiments, irrespective of density, indicates that trochus are able to adapt to the conditions at Chao Reef. On the other hand, the initial size of the trochus was a major factor affecting the survival rate. According to Isa et al. (1997) culturing trochus larger than 30 mm usually results in high survival rates because of the animal's increased resistance to predators and negative environmental conditions.

It is recommended that culture densities be adjusted depending on the initial size of the trochus (Table 1). At a shell diameter of 10–22 mm, trochus can be cultured at a maximum density of 100 ind m^{-2}. When trochus reach 25–40 mm, the density should be reduced to less than 50 ind m^{-2}. When trochus reach 40–50 mm, they should be cultured at densities lower than 20 ind m^{-2}, down to 4–7 ind m^{-2} for trochus larger than 50 mm.

Table 1. Size and density recommendations for trochus culture.

Basal diameter (mm)	Density in cages (ind m^{-2})
10–20	100
25–40	50
>40	<10

In cages which were not supplied with dead corals or rocks covered with algae, trochus grew quite well during the first stage of culture. In these cages, the food source was local seaweed and algae that naturally grew on the cage's walls. However, quantities of this kind of food are limited, so that the culture density is a critical factor that affects the growth and survival at later stages. Results from our experiments indicate that trochus less than 20 mm shell diameter can be cultured in cages at Ninh Van at densities less than 100 ind m^{-2} without adding food. When replacing substratum/food every 10 days, the cover of suggested substratum is about 50% at a density of 60 ind m^{-2} for trochus 15–25 mm.

Food plays an important role in the growth of cultured trochus. With smaller specimens (<30 mm), seaweed attached to rocks that cover more than 50% of the cage bottom need only be provided at the beginning of the culturing process. When trochus are larger than 30 mm, they need the food supply to be renewed two to three times a month by replacing the seaweed-covered rocks, and maintaining a cover of more than 50% of the bottom area.

In general, the commune governor, participants, and the local community positively supported the project and acted responsibly in working together with scientists during the course of the trochus culture experiments at Ninh Van. Interviews and meetings with local people revealed that the natural resources at Ninh Van have been degrading. People were interested in and ready to support research activities aimed at rehabilitating natural resources in general and trochus in particular. The hope is to develop a suitable culture model to improve living standards, manage coral reefs, and restore marine resources.

Cage culture appears to be an appropriate method because it is easy to manage and it reduces the

negative impact of predators. Trochus grew well when food in the form of seaweed-covered rocks was supplied. Results show that culture densities depend on the size of trochus, with lower densities suitable for larger animals (Table 1).

Predators, possibly crabs, killed some trochus during our experiments. The damaged shells are shown in Figure 8. According to Isa et al. (1997), predators are the principal factor affecting the survival rate of trochus. Main trochus predators include:

- crustaceans (e.g. crabs — *Mancinella tuberosa*, *Calappa hepatica*), mantis shrimp (*Gonodactylus chiragura*),
- molluscs,
- flatworms (e.g. common species are *Pericelis byerleyana* and *Planocera reticulata*), and
- fish (mainly porcupine fish, Diodontidae).

Diodontidae are the most dangerous threat to cultured trochus under laboratory conditions. However, in nature, Diodontidae are not abundant in areas where trochus occur or are cultured. Therefore, the threat that Diodontidae pose to cultured trochus is low. Flatworms, often found on rocks in the littoral zone, attack trochus at night. Therefore, removing flatworms from the substrata is a necessary precaution before starting a culture. Mantis shrimp and crabs can crush the shell and ingest trochus. They are common predators found in the littoral zone, in areas of trochus culture. Trochus are more susceptible to predators when they are young, especially when they are less than 10 mm in shell diameter. However, when the shell diameter exceeds 17 mm, the animal's defensive capabilities are much higher.

Figure 8. Trochus shells damaged by predators during experiments at Chao Reef.

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