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Spatial and Temporal Abundance of the reef gastropod *Tectus niloticus* (Gastropoda: Tegulidae) in Marine Protected Areas in Palawan, Philippines: Prospects for Conservation

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A B S T R A C T

The unsustainable harvesting of the reef gastropod *Tectus niloticus* or 'trochus' for the production of 'mother of pearl' buttons have led to the collapse of its population and closure of its fishery in some countries. With the costly conservation measure involving the restocking of hatchery produced juveniles in partly protected reefs in the Philippines, this study assessed the abundance of trochus in three types of habitats of three Marine Protected Areas (MPAs) in Palawan, Philippines to document the status of its populations and to propose a more relevant conservation measure. Unguarded and continuously exploited MPAs in the mainland Palawan harboured the least numbers of trochus. By contrast, in effectively protected areas of the Tubbataha Reefs Natural Park (TRNP), densities were quite high with large trochus being abundant in three types of habitats. However, the densities declined the farther the site from the Ranger Station of TRNP. In permanent monitoring sites in TRNP, the abundance declined between 2006 and 2008, with slight recovering trends toward 2010. Sizes of sampled trochus at TRNP in 2008-2010 were significantly larger than in 2006. The presence of recruits at constantly fished MPAs at Palawan on the mainland could lead to population recovery if these areas are effectively spared from fishing for a longer period of time. Restored biodiversity in networks of MPAs could be highly beneficial to the ecosystem, the fisheries and economic sectors.

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INTRODUCTION

The Commercial top (*Tectus niloticus,* Tegulidae*)*, commonly called 'trochus', is an ecologically important but overly exploited large reef gastropod with patchy distribution in the Indo-Pacific Region [1, 2]. Trochus as grazers can help maintain a balanced reef ecosystem. Their short larval period [3] and the isolation of many reefs were considered reasons for their inability to colonise suitable offshore reef habitats [4, 5], unless they are translocated. In more than 6 decades, trochus translocation to about 60 places within the Indo-Pacific Region has expanded its distribution, eventually becoming an important fishery resource at many of the locations to which it has been introduced [6, 7]. Harvesting of trochus started in prehistoric times [8, 9], but when commercial harvest of its shells for the mother-of-pearl button industry started in the early 1900s, its populations began to decline [4, 5] and eventually declared as threatened species in some countries [10-13].

Stock assessment provides a wide array of biological data [7, 14-17]. It is an important step to determine the effectiveness of management intervention, and in providing a basis for effective conservation [18, 19]. Assessment of trochus population in India following a 10-year ban on harvest have led to open the fisheries for three years [11]. Periodic population monitoring of density and standing stock of the introduced trochus in the Cook Islands was conducted to assess population

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recovery from the previous harvest and to estimate catch quota for the next harvest [20-22]. Results of assessment of trochus in Tongatapu Lagoon, Kingdon of Tonga 12 years after its introduction, suggest successful recruitment and establishment of a population but harvesting was held for another 8 years to allow an increase in population size [7]. Size measurement along with abundance surveys are essential to assess recruitment overfishing, which can be detected if populations are dominated by sizes smaller than the allowed harvestable sizes, or sizes that are less likely to be searched or exploited [5]. Population assessment and the implementation of varied conservation measures have taken place in most trochus producing countries only after harvests have begun to fall [5, 23, 24].

In the Philippines, no comprehensive study about trochus exploitation has been conducted in spite of the fact that the country is one of the world's top trochus producers [25] with the highest quality [14, 26]. As early as 1980, trochus had already been overharvested in the Philippines [3], and now only forming a small part of fishermen's harvest [27-29].

A number of conventional methods has been suggested to manage the trochus populations [4, 5]. Deciding on which one to use requires prior knowledge about the current status of trochus population. In this study, the spatial and temporal abundance of trochus in exploited and unexploited marine protected areas (MPAs) in Palawan, Philippines were assessed.

MATERIALS AND METHODS

Study sites

The study sites in Palawan, Philippines included the Tubbataha Reefs Natural Park (TRNP) in the middle of the Sulu Sea (Sites 1 – 4); Rasa Island (Site 5) in the southern part of Palawan (Site 5), and Binduyan (Site 6), a northern village in the city of Puerto Princesa (Figure 1).

Tubbataha Reefs Natural Park is a United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Heritage Site (8°43'– 8°57' N and 119°48'–120°3' E), about 150 km southeast of Puerto Princesa City, Palawan. It covers a total area of 97,030 ha of which roughly 10,000 ha are coral reefs [30]. The park was subdivided into four study sites based on the perceived level of poaching: (Site 1) Unexploited North Atoll, composed of three stations near the Ranger Station; (Site 2) Moderately Exploited North Atoll, composed of five stations that are about 9 km away from the Ranger Station; (Site 3) Heavily Exploited South Atoll, composed of five stations around the South Atoll Reef (about 14 km from the Ranger Station); and (Site 4) the distantly located Jessie Beazley Reef situated 24 km north of the Ranger Station.

Rasa Island (9°13'21.25" N and 118°26'38.06" E) is an 834 ha wildlife sanctuary situated about 1 km offshore of the Municipality of Narra, Palawan. The island has 175 ha of coastal forest, 560 ha mangrove, 39 ha coconut plantation and 60 ha barren or sparsely vegetated sand and coral outcrops [31]. Fishing and gleaning remained unregulated in this protected site.

Binduyan (10° 00'46.78" N and 119° 04'14.92" E) is the second northernmost village of Puerto Princesa City. The two small adjacent reefs called Sabang Reef – a 40 ha village sanctuary and a seeding site for hatchery produced trochus; and Bitauran Reef - an open-accessed area. The exposed area (~14 ha) of Sabang Reef at low tide is nearly twice larger than that of Bitauran Reef (~8.5 ha). Both reefs were frequented with gleaners during low tide.

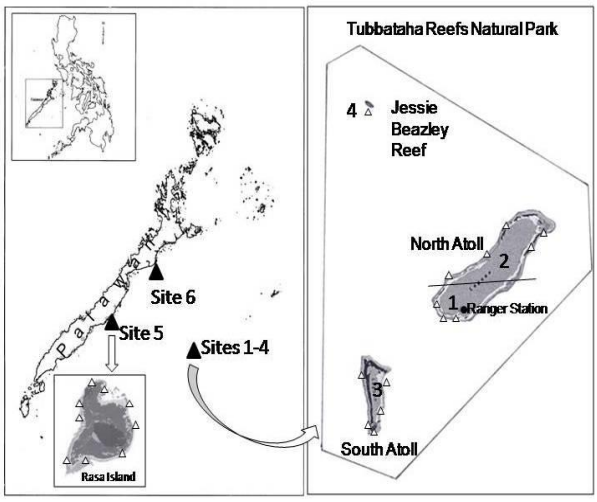

Figure 1. The six study sites.1 – Unexploited North Atoll; 2 – Moderately Exploited North Atoll; 3- Overexploited South Atoll; 4 – Overexploited Jessie Beazley Reef; 5 – Overexploited Rasa Island; 6 – Overexploited Binduyan and part of Green Island Bay. Sampling stations are indicated by small triangles (i.e. around Rasa Island and in Atolls at TRNP).

Sampling methods

Three types of habitats such as flat, boulder and complex were surveyed at each site (Table 1). Flat habitats, generally composed of rubble and flat rocks, are the highest part of the reef and firstly exposed at low tide. Boulder habitats, only exposed at lowest low tide,are composed of coral rocks, mostly larger than 20 cm in diameter forming a narrow strip along the edge of the reef flat. Complex habitats are mixture of rock and hard corals at the seaward reef slope which were always submerged at 3 – 5 m deep (Figure 2). To determine the habitat

complexity or rugosity index [32] of the reef, a weighted 20-m rope (10 mm diameter) which follows the contour of the reef was placed in parallel with the 20-m transect line (Figure 2).

TABLE 1. Numbers of 2 x 20 m transect lines per study site and types of habitat surveyed. A – flat, B – boulder, C – complex, UE – unexploited, ME – moderately exploited, OE-overexploited.

Site Number	Site Name	Status	Number of	Habitat Type			Total Transects
				A	B	C	
1	North Atoll, TRNP	UE	3	20	16	20	56
2	North Atoll, TRNP	ME	5	16	36	36	88
3	South Atoll, TRNP	OE	5	8	32	16	56
4	Jessie Beazley Reef, TRNP	OE	1	0	4	4	8
5	Rasa Island, Narra, Palawan	OE	9	44	48	36	128
6	Binduyan, Puerto Princesa City	OE	2	8	20	12	40
Total			25	96	156	124	376

Spatial abundance and size structure

Reef check method in assessing reef invertebrates [33] were used to measure the abundance and size structure of trochus. The suggested 5 m width of belt transect was reduced into 2 m to increase the number of stations and to exhaustively search the snails. Substrate types (e.g. hard coral, rock, rubble and sand) were recorded at 0.5 m intervals of transect lines, following the substrate criteria and point intercept method described by Hodgson et al. [33]. In TRNP, seven permanent monitoring stations established in 2006 [34] and seven additional stations were surveyed. Surveys in TRNP were conducted between November 2009 and July 2010; and between March and July 2010 in Rasa Island and Binduyan, respectively (Figure 1, Table 1).

In total, 376 transect lines (2 x 20 m) were surveyed in 25 stations within six sites covering an area of 15,040 m^2. Flat and boulder habitats were surveyed by reef walking while complex habitats were surveyed by snorkelling during low tide. All trochus found along each transect were counted and measured for their maximum basal diameter to the nearest millimetre with the aid of a ruler glued on a slate board.

Figure 2. The three types of surveyed *T. niloticus* habitat in MPAs in Palawan, Philippines. Flat habitat at TRNP (top), and boulder (middle) and complex (bottom) habitats at Rasa Island.

Catch per unit effort

Catch per unit effort (CPUE), is treated as the number of trochus captured per fishermanper hour (ind h^{-1}). At TRNP (Sites 1, 2 and 3), the estimated area covered during the collection was determined from the distance covered using the Global Positioning System (GPS) coordinates and the approximate width (5 m) of the reef each person can survey visually while snorkelling in calm water. At Site 5, CPUE was based on the catches of 5 – 9 fishermen who participated during the 4-day collection. At Site 6, CPUE was based from the catch of five fishermen in Green Island Bay (also an area with several village MPAs).

Temporal abundance in TRNP. Abundance data from the seven permanent monitoring stations at TRNP between 2006 [34, 35] and 2010 were compiled. The numbers and areas covered by transect surveys between 2006 and 2010 are shown in Table 2.

Data analyses

The substrate composition at each habitat type per site was compared with analysis of variance and Scheffé post hoc tests. In the analysis, rugosity index, hard corals, rock, rubble and sand were used as dependent variables while types of habitat (flat, boulder, complex) were used as fixed independent variables. Transect lines with >10% sand were deselected so that percentage of sand did not significantly vary among habitats ($F_{(2,312)}$ = 1.7, P> 0.05). Rugosity index ($F_{(2,312)}$ = 315.42, P < 0.001), and percentages of hard coral ($F_{(2,312)}$ = 56.15; P< 0.001), rock ($F_{(2,312)}$ = 112.77, P < 0.001) and rubble ($F_{(2,312)}$ =185.47, P< 0.001) significantly differed among habitats. Highest rugosity index (1.22) and percentage of hard corals (20.5%) occurred in complex habitat; the highest percentage of rock (82.22%) and rubble (58.36%) occurred in boulder and flat habitats respectively.

TABLE 2. Length of transect lines and area covered during the survey at seven permanent monitoring stations in TRNP from 2006 – 2010. *In 2010, there were eight transects in six stations and 16 transects in one station.

Year	Width and length of transect per site	Number of transects per site	Area covered (m^2) per site	Total Area Surveyed (m^2)	Depth of surveyed area
2006	2 x 150	1	300	2,100	Shallow subtidal area
2008	2 x 100	1	200	1,400	Shallow subtidal area
2009	2 x 25	4	100	700	Shallow subtidal area
2010*	2 x 20	8 or 16	320 or 640	2,560	Intertidal and shallow subtidal area

The abundance of trochus in three types of habitat within each site and among all sites was compared with Poisson log linear model. The abundance (ind 40 m^{-2}) was treated as dependent variable, with habitat or both habitat and status (Unexploited Site or Exploited Site) as factors. Rugosity index and percentages of rock and rubble were added as covariates.

To analyse the size structure, 280 (21% of the total) additional samples of trochus collected by octopus fishermen from the complex habitats at Sites 5 and 6 were added to two trochus individuals encountered along the transect line at the complex habitats at each site. In total, 1,446 individuals were measured, of which six percent were from flat habitats, 40% from boulder habitats and 54% from complex habitats. More than 70% of the samples were from Sites 1 and 2 (Table 3).

The mean sizes of trochus at each type of habitat across sites and between habitats within each site were compared with univariate analysis of variance and post hoc Scheffé tests. The sizes of trochus were treated as dependent variable and either site or habitat as independent variable.

The sizes of trochus from the seven permanent monitoring stations at TRNP obtained in 2006, 2008 and 2009 [34, 35] and during the recent survey were compared using univariate analysis of variance. In 2007, there was no survey of the site so the sizes of trochus confiscated from illegal fishermen at TRNP in that year [34] were included in the analysis. All statistical comparisons were performed using the SPSS version 16 [36].

TABLE 3. Number of trochus sampled per site per type of habitat in six study sites in Palawan, Philippines. A – flat, B – boulder, C – complex, UE – unexploited, ME – moderately exploited, OE - overexploited

Site Number	Site Name	Status	Habitat Type			Total
			A	B	C	
1	North Atoll, TRNP	UE	20	312	285	617
2	North Atoll, TRNP	ME	58	209	162	429
3	South Atoll, TRNP	OE	NT	26	46	72
4	Jessie (Beazley Reef, TRNP	OE	NT	0	0	0
5	Rasa Island, Narra, Palawan	OE	11	14	155*	180
6	Binduyan, Puerto Princesa City & part of Green Island Bay, Palawan	OE	5	16	127*	148
Total			94	577	775	1 446

Where * = mostly collected by octopus fishers for 1 – 2 days, NT – no transect.

RESULTS AND DISCUSSION

Abundance

The overall pattern of abundance of trohus at six study sites was characterised by a declining trend with increasing site's distance from the Ranger Station (as for the case of study sites at TRNP), with loss of large

trochus from the flat habitat first, then from boulder habitats, but with large individuals remaining in complex habitats in sites that are relatively far from the Ranger Station or the sites that are close to coastal communities. The densities of trochus in boulder and complex habitats at Site 1 were considerably higher than at other sites (Figure 3).

In the boulder habitat at Site 1, the abundance was nearly twice as high as that in the complex habitat, but the difference was not so pronounced in Site 2. In Site 3, the trend changed, with abundance in the complex habitat higher than in boulder habitat. Only empty trochus shells were found at Site 4, while extremely low trochus abundances occurred in all habitats at Sites 5 and 6.

In general, the abundances of trochus in three types of habitat were more variable and significantly higher in unexploited than exploited sites. The boulder habitats in unexploited site (Site 1) have the highest trochus abundance, while abundance was higher in complex habitats of heavily exploited sites.

Comparison of abundance at each type of habitat per site revealed a significant variation in abundance at Site 1 (χ^2 = 11.20, *df* = 2, *P*< 0.01), but not at Site 2 (χ^2 = 0.93, *df* = 2, *P*> 0.05), Site 3 (χ^2 = 0.64, *df* = 3, *P*> 0.05), Site 5 (χ^2 = 51, *df* = 2, *P* > 0.05) and Site 6 (χ^2 = 0.35, *df* = 2, *P*> 0.05). Multiple comparison of all sites revealed significant variation in abundance among sites (χ^2 = 143.08, *df* = 4, *P* < 0.001).

The density of trochus and CPUE was much higher in unexploited and moderately exploited sites compared to heavily exploited sites. At Sites 5 and 6, catches were extremely low, with each fisherman only able to collect about 1 – 2 trochus per hour, compared with the high CPUE of nearly 200 ind hr^{-1} at unexploited site. The area covered during the collection increased as the density and CPUE of trochus decreases. The large confidence intervals recorded in unexploited (Site 1) and moderately exploited site (Site 2) suggested a high variation in abundance within the complex habitats. At Site 4, only empty shells of trochus were found, indicating that they have occurred in the past on the reef (Figure 4).

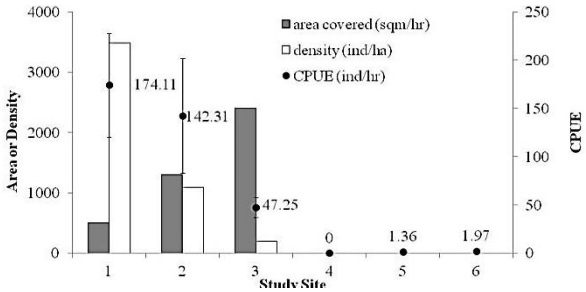

Figure 4. CPUE for trochus in complex habitats of six study sites in Palawan, Philippines. Error bars are 95% confidence intervals. Area covered (m^2 hr^{-1}) during the collection and estimated density (ind ha^{-1}) were only for Sites 1 – 3

The findings of the study showing that trochus density was higher and size structure dominated by large individuals in fully protected areas than in exploited areas are to be expected as shown by many studies on various marine species on coral reefs [37-40]. Generally, the greatest abundance of adults occurred at the intertidal area with decreasing abundance towards the deep [5], while the juveniles are restricted in the intertidal flats [41, 42]. The absence of juveniles (< 50 mm shell diameter) at the subtidal area could be a result of predation on individuals that settled on the subtidal habitats [5], the difficulty in finding them because of their small size and cryptic nature [43], and their nocturnal habit [5]. Trochus juveniles encountered during the study were all found under the rocks while large individuals were either clustered on reef crevices or simply exposed on open spaces. Trochus juveniles raised in cages installed on the reef crest can grow as fast as those at the intertidal area [44]. This suggests that conditions in deeper parts of the reef are suitable for growth but they cannot survive because of predation or they are difficult to find because of their small size and cryptic behaviour.

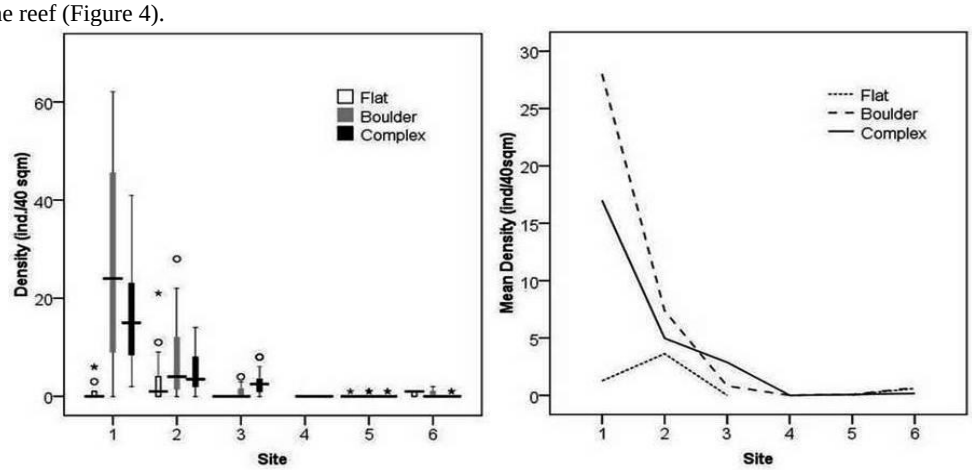

Figure 3. Box plot (left) and line graph (right) showing the density (ind./40 sqm) of trochus per type of habitat per site. Site 1 was unexploited and Sites 2 – 6 were exploited at varying degrees.

The importance of habitat in enhancing survival has been reported for other species. The association of juvenile abalone with crustose coralline algae is believed to be important for food and as a refuge from predators like wrasses which prey only on abalone juveniles larger than 5 mm long [45]. In TRNP, trochus juveniles were found hiding under small rocks scattered on rubble dominated habitat. No juveniles were noted in an area with dense aggregations (at least 3 – 5 individuals per group) of medium sized (70 – 90 mm) adults. This was also the area with the highest abundance of nearly 2 ind m^{-2} in two 2 x 20 m transects.

Other factors affecting the variation of density and size distribution between habitats and sites could include: patterns of larval dispersal, water currents, habitat size and suitability, growth density dependence and degree of exploitation. Trochus have a short larval period, settling 50 – 60 h after fertilisation although some larvae could remain planktonic up to 10 days in the absence of suitable substrate [46]. It is not known how far a trochus larva can travel before settling on the reef, but their short larval period [46], patchy distribution [2] and ability to colonise offshore reef areas when translocated [6, 47] suggest that recruitment is within the parent population [5].

The highest adult density of 15,000 ind ha^{-1} or an average of 7,000 ind ha^{-1} at boulder habitats of the unexploited site at TRNP is lower than in pristine habitats in Cook Islands (66 ind m^{-2} or 66,000 ind ha^{-1}) [48] suggesting that trochus populations in TRNP is still recovering.

In overexploited sites, the abundances were extremely low and the patterns of distributions were altered depending on the size and location of the reef. In heavily exploited Cartier Reef in Australia, no trochus were recorded at the reef flat, 1.33 ind ha^{-1} at the reef crest (2 – 8 m deep), and 3.33 ind ha^{-1} at the reef slope (9 – 24 m deep). These densities from Cartier Reef were much lower than in flat, boulder and complex habitats in Rasa (9.5, 19.25 and 15.25 ind ha^{-1}) and Binduyan (150, 167.5 and 42.5 ind ha^{-1}), respectively.

The frequency of fishing at Jessie Beazley Reef (Site 4) could be lesser than in Rasa Island and Binduyan, but because of its small size, and possibly with the absence of currents connecting this site with sites having abundant population of trochus, the reef could have been easily overharvested. The low CPUEs in open-accessed areas and high market price may have forced fishermen to fish trochus in MPAs like TRNP [34] or even in Malaysian waters (pers. comm. with residents from southern Palawan).

Size structure

The size structure of trochus varied at each habitat with a general declining trend in sizes from unexploited to heavily exploited sites (Figure 5, Table 4). All sizes (small and large) of trochus occurred on flat habitats at unexploited site (Site 1, mean size: 87.47 mm), while only small sized individuals occurred on flat habitats of exploited sites (mean sizes ranged between 30.80 - 45.82 mm). Large individuals (mean: 87.39 mm) were common on boulder habitats at unexploited site (Site 1) and moderately exploited site (Site 2, mean: 95.85 mm), but were absent on boulder habitats at heavily exploited Sites 5 and 6. Large individuals occurred in all complex habitats except at site 4. In Sites 5 and 6, only two individuals occurred along the transect lines at complex habitat, so the catches of contracted fishermen intended for other studies were included.

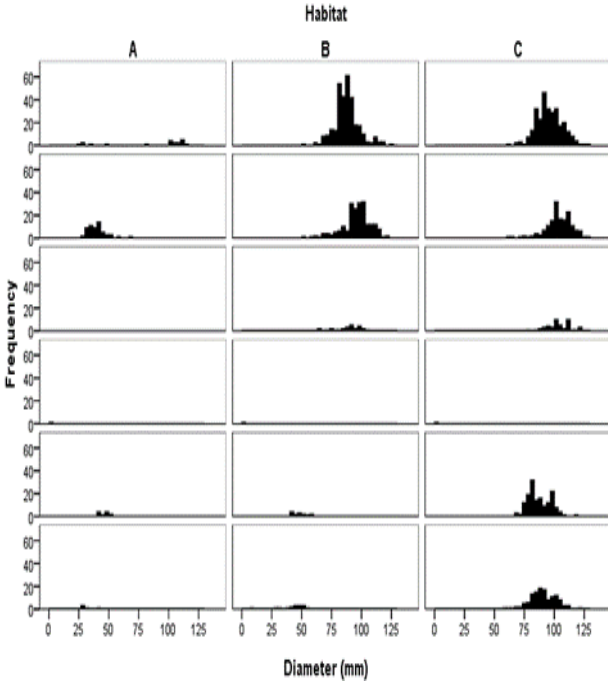

Figure 5. Frequency histogram of trochus per type of habitat at six study sites. A – flat habitat, B – boulder habitat, C – complex habitat. Trochus in complex habitat of Site 5 and Site 6 were from octopus fishermen

The overall mean sizes of trochus per type of habitat revealed that on complex habitats, trochus were significantly larger than those on boulder or flat habitats ($F_{(2,1443)} = 403.75$, $P < 0.001$, Table 4). In Site 1, trochus on flat habitats were significantly larger than those in flat habitats in other sites ($F_{(3,90)} = 44.74$, $P < 0.001$). In boulder habitats, trochus were of the same sizes among Sites 1, 2 and 3, but were significantly larger than in Sites 5 and 6 ($F_{(4,572)} = 141.74$, $P < 0.001$). However, in the complex habitat of Site 1, trochus was significantly smaller than in Sites 2 and 3 but not in Sites 5 and 6 ($F_{(4,770)} = 59.11$, $P < 0.001$). Comparison of sizes by habitat within each site revealed that in Sites 1 ($F_{(2,614)} = 36.91$, $P < 0.001$) and 5 ($F_{(2,177)} = 204.43$, $P < 0.001$), the average sizes of trochus in flat and

boulder habitats did not differ significantly but both were significantly smaller than in complex habitats. In other sites, the largest average size occurred on the complex habitats, followed by those on the boulder and flat habitats. The sizes of trochus in exploited sites which were either smaller or larger than in the unexploited site could be an effect of different levels of harvesting and faster growth at reduced density. In Sites 2 and 3, most trochus at intertidal and shallow subtidal areas could have been harvested; most samples constitute the large individuals from deeper parts of the reef; and reduction in density due to poaching could have favoured the growth of the remaining shells as reflected by the larger sized trochus found in boulder habitat at Site 2 than in Site 1 (Table 4, Figure 5). Nash [5] suggested that in the wild, growth rate increases with declining density. In Sites 5 and 6, although it is presumed that fast growth occurs because of low density, sizes of trochus were significantly smaller compared to other sites as harvesting may occur as soon as they emerge and become visible on the reef.

Temporal abundance in TRNP

Compiled data on abundance of trochus at the permanent monitoring stations in TRNP from 2006 [34] up to the present showed a massive decline at stations 3 – 4 (part of moderately exploited North Atoll) and stations 5 – 7 (part of heavily exploited South Atoll). Abundance was relatively stable in Sites 1 and 2 (Figure 6). The average mean sizes of trochus from 2006 to 2010 gradually increased (Figure 7). Univariate analysis of variance suggested a significant difference among the mean sizes of trochus at seven permanent monitoring stations at TRNP from 2006 – 2010 ($F_{(4, 3036)} = 442.27$; $P < 0.001$).

Post hoc Scheffé tests suggested that the sizes of trochus in 2006 (66.96 mm ± 17.39 sd) were not significantly different from the mean size of confiscated trochus in 2007 (68.51 mm ± 9.84 sd). Trochus sampled in 2008 (82.34 mm ± 13.81 sd) was significantly larger than in 2006 and 2007 but significantly smaller than in 2009 (93.50 ± 15.31 sd) and 2010 (89.38 ± 10.52 sd). Trochus sampled in 2009 were significantly larger than in 2010.The illegal exploitation of trochus at TRNP has greatly reduced its average density at the seven permanent monitoring stations of about 60 ind 100 m^{-2} in 2006 [34] by 70% in two years.

The overall mean abundance in 2010 (23.64 ind 100 m^{-2}) was a little higher than in 2008 (17.14 ind 100 m^{-2}) but lower than in 2009 (29.50 ind 100m^{-2}) [35]. The decline in abundance between 2009 and 2010 could still be a possible effect of illegal fishing at the Park because there was not much increase in the number of samples although the area covered in 2010 (2,560 m^2) was three times higher than in 2009 (700 m^2) (Table 2, Figure 7). If poaching remained uncontrolled at TRNP even at a lesser degree, trochus population especially in sites distantly located from the Ranger Station would remain vulnerable and could be gradually depleted to a level beyond recovery. Localized extinction of trochus can both affect the ecosystem and the economy at an undetermined degree. Biomass of two commonly caught reef fish families (Acanthuridae and Carangidae) from Apo Island, Philippines, tripled in a well-protected no-take reserve over 18 years (1983-2001) while biomass of these families did not change significantly over the same period at a site open to fishing [49].

TABLE 4. Mean diameter (mm) of trochus per habitat per site. A – flat, B – boulder, C – complex. ns – no shells found along the transect lines or within the habitat; nt – no transect line was laid. The same superscript means no significant difference.

Site Number	Habitat across Sites			Habitats within Site			df	F value	P value
	A	B	C	A	B	C			
1	87.47^a	87.39^a	95.55^b	87.47^b	87.39^b	95.55^a	2; 614	36.91	<0.001
2	39.41^b	95.85^a	103.28^a	39.41^c	95.85^b	103.28^a	2; 246	735.58	<0.001
3	ns	88.19^a	102.93^a	ns	88.19^b	102.93^a	1; 70	35.37	<0.001
4	nt	ns	ns	nt	ns	ns			
5	45.82^b	48.58^b	87.35^c	45.82^b	48.58^b	87.35^a	2; 177	204.43	<0.001
6	30.80^b	42.50^b	90.28^c	30.80^c	42.50^b	90.28^a	2; 145	192.84	<0.001
Mean				49.93^c	88.30^b	95.10^a	2; 1443	403.75	<0.001
df	3; 90	4; 572	4; 770						
F value	44.74	141.74	59.11						
P value	<0.001	<0.001	<0.001						

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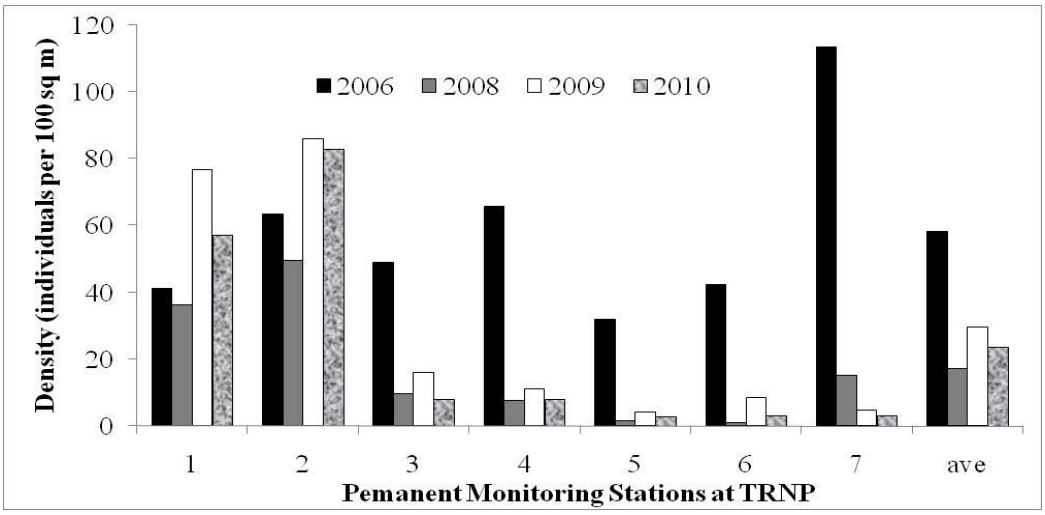

Figure 6. Temporal abundance of trochus at permanent monitoring stations in TRNP from 2006 – 2010. Number of samples: 2006 (n=1217), 2008 (n=240), 2009 (n=413), 2010 (n=509).

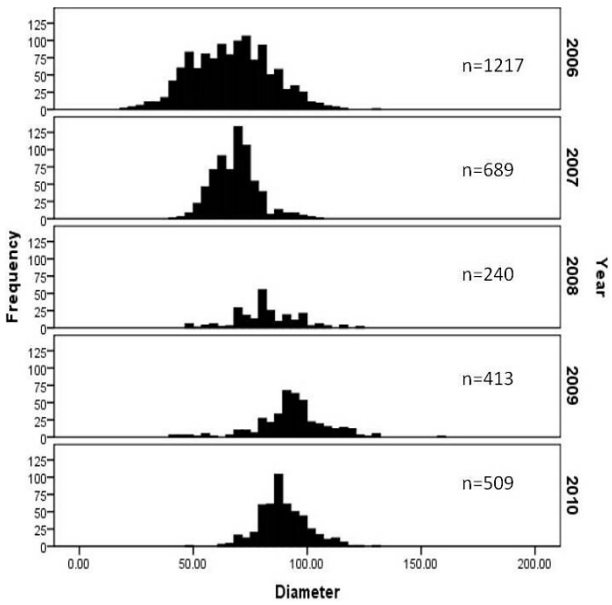

Figure 7. Frequency histogram of trochus at seven permanent monitoring stations at TRNP from 2006 – 2010. The data in 2007 were the sizes of confiscated trochus from illegal fishermen at the park.

CONCLUSIONS

These findings suggest that except in Jessie Beazley Reef, the remaining populations of trochus in other surveyed sites were still capable of successful reproduction as reflected by the presence of recruits in shallow habitats. Such further suggests that these populations could recover if fishing is effectively controlled as what has been achieved in other localities [21, 50].

However, population recovery in distantly located Jessie Beazley Reef could be very slow. There might be lesser chances for recruits coming from the North and South Atolls to settle in Jessie Beazley Reef because of lack of connectivities in TRNP [51] and short larval stages [5]. The translocation of breeding adults [4, 6] along with effective surveillance to arrest all forms of extractive activities could be the best option in restoring its extinguished population. The presence of recruits in overfished Rasa Island and Binduyan could be due the greater number of islands in the mainland Palawan which create more heterogeneous microhabitats for larval settlement as what has been observed for corals [50]. Effective law enforcement on fishing and trading, information and education campaign, provision of alternative livelihood, effective MPA management among others could help revive the lost populations. Continued monitoring of these sites, efforts to revive the lost reef biodiversity and effective sustainable utilization of these resources are suggested. Restored biodiversity in a network of MPAs could increase resilience to climate change and provide varied ecological and economic benefits.

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Persian Abstract

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چکیده

بهره برداری نادرست از گونه دریایی Tectus niloticus (گونه‌ای از نرم تنان صدف دار) برای تولید دانه‌های مروارید منجر به کاهش جمعیت آن‌ها و کم رونق شدن صنعت ماهیگیری در برخی کشورها شده است که در این راستا حفاظت‌های پرهزینه از این گونه‌ها که شامل ذخیره سازی نوزادهای این گونه می‌باشد، در بخش‌هایی از جزیره‌های محافظت شده فیلیپین صورت می گیرد. در این تحقیق فراوانی نرم تنان صدف دار در سه نوع زیستگاه از سه حوزه دریایی حفاظت شده (MPAs) در پالاوان فیلیپین تعیین و جمعیت آنها بطور مستند بیان شد و همچنین اقدام حفاظتی مناسب پیشنهاد شد. بهره برداری بدون حفاظت و بطور پیوسته در MPAsپالاوان باعث پناه گرفتن کمترین تعداد از این گونه نرم تنان شد. درمقابل در منطقه‌های محافظت شده پارک طبیعی صخره‌ای Tubbataha (TRNP) تراکم جمعیت این نرم تنان صدف دار در سه نوع زیستگاه بالا بوده است. اگرچه، تراکم آن‌ها در گستره‌های مکانی دورتر از ایستگاه TRNP کاهش یافت. در سایت‌های نظارتی دائمی در TRNP فراوانی بین سال‌های دو هزار و شش و دو هزار و هشت کاهش پیدا کرد و تا سال دو هزار و ده روند بهبود کمی را نشان داده است. اندازه‌های گونه Tectus niloticus نمونه برداری شده در TRNP در سال‌های دو هزار و هشت تا دو هزار و ده به طور چشمگیری نسبت به سال دو هزار و شش افزایش داشت. حضور پیوسته و موثر کارمندها برای مدت طولانی در هنگام صید در MPAs پالاوان منجر به بهبود جمعیت شد. تنوع زیستی در شبکه‌های MPAs توانسته برای اکوسیستم، شیلات و بخش های اقتصادی مفید واقع شود.