Focal benthic mollusks (Mollusca: Bivalvia and Gastropoda) of selected sites in Tubbataha Reef National Marine Park, Palawan, Philippines

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ABSTRACT

The study was conducted at Tubbataha Reef National Marine Park from May 6-11, 2005. Seven pre-established stations with survey sites at 5 and 10 m depth and one intertidal area were assessed using 150 m permanent belt transects. Focal benthic mollusks found one meter to the left and right of transects were identified and counted. A total of 19 species belonging to eight families were recorded, of which 15 species are univalves. In the intertidal area a total of 12 species were noted, 13 species at the shallow (5 m) and five species at deeper (10 m) areas. Species belonging to the family Tridacnidae and Trochidae were the most abundant. Among the subtidal stations, the highest number of individuals was noted at a shallow reef flat (station VI). In terms of density, the intertidal area had the highest (213,310 ind. km^{-2}) followed by the shallow (72,870 ind. km^{-2}) and the deep with 5,720 ind. km^{-2}.

The densities of *Tridacna crocea* (133,330 ind. km^{-2}) and *Hippopus hippopus* (3,330 ind. km^{-2}) at the intertidal area were found to be higher than in most other survey sites in Palawan but previous density records at the park indicate a stiff decline. On the contrary, the first record on the density of *T. squamosa* (950 ind. km^{-2}) at the park is much lower compared to that from other parts of Palawan. Large and commercially valuable gastropods like, *Trochus niloticus, Tectus maculatus* and *T. pyramis* that are rarely encountered at the intertidal areas were abundant at the TRNMP. Other important species like *Tridacna gigas, Charonia tritonis* and *Cassis cornuta* were not encountered at the study sites. To fully assess the abundance of focal mollusks, permanent transects should be established in the same seven sites but in shallow reef flat of about 2 m deep, in the lagoon and in the intertidal of North and South Islets where species composition, density and growth could be monitored on an annual basis which could be used to evaluate the management effectiveness at the TRNMP.

Key words: bivalves, focal species, gastropods, Palawan, Philippines, Tubbataha Reef

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INTRODUCTION

Coral reefs are the most biologically diverse of shallow water marine ecosystems but are being degraded worldwide by human activities and climate warming (Roberts et al., 2002). They are critically important for the ecosystem goods and services they provide to maritime tropical and subtropical nations (Souter & Linden, 2000). Yet reefs are in serious decline; an estimated 30% are already severely damaged, and close to 60% may be lost by 2030 (Wilkinson, 2000). There are no pristine reefs left (Jackson et al., 2001). Local successes at protecting coral reefs over the past 30 years have failed to reverse regional scale declines, and global management of reefs must undergo a radical change in emphasis and implementation if it is to make a real difference (Hughes et al., 2003).

In the 1980s, the previously pristine and unique Tubbataha Reef of Palawan started to show evidence of serious destruction and over-exploitation that has continued even after its declaration as a Natural Marine Park in 1988 (Arquiza & White, 1999). With the creation of the Tubbataha Management Foundation in 1990, the declaration as World Heritage Site in 1993, and finally the establishment of the Protected Area Management Board in 1999, conditions did improve under the impact of resource management strategies with national and international support. The current Tubbataha Reef National Marine Park (TRNMP) Management has the goal to preserve the globally significant biological diversity and ecological processes of Tubbataha and to manage them and the surrounding areas on a sustainable basis. While regular monitoring of coral reef conditions and associated fish fauna, has been conducted for the past eight years (Sabater et al., 2004), the assessment of focal species was only in November 2003 during the TRNMP Management Effectiveness Workshop recognized as a gap. Focal species are organisms of ecological importance and/or human value that are of priority interest for management through the marine protected area. Aside from top predators, benthic mollusks were identified as important indicators of habitat health and proper resource management and protection. Since species abundance of focal species is one of the most widely used biological ‘ success’ measures of management effectiveness (Pomeroy et al., 2003) the present study intended for

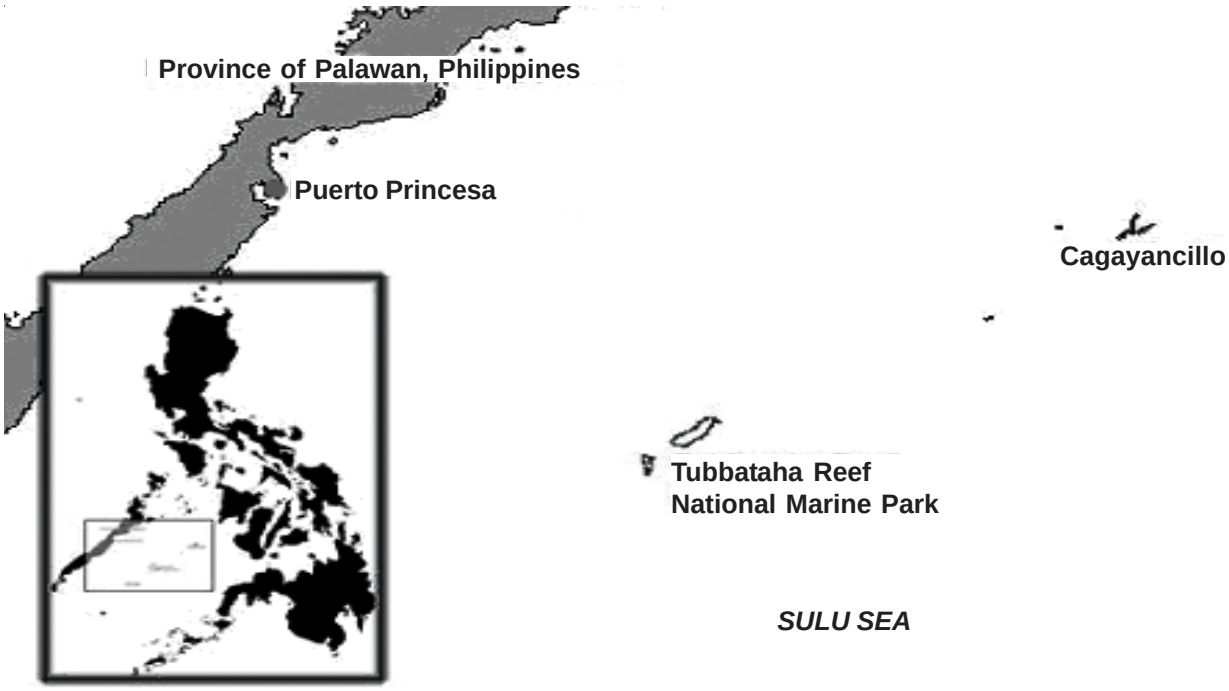

Fig. 1. Map showing Tubbataha Reef National Marine Park. TRNMP is part of the municipality of Cagayancillo, an oceanic island in the Philippines (inset). (Source: Sabater et al., 2004).

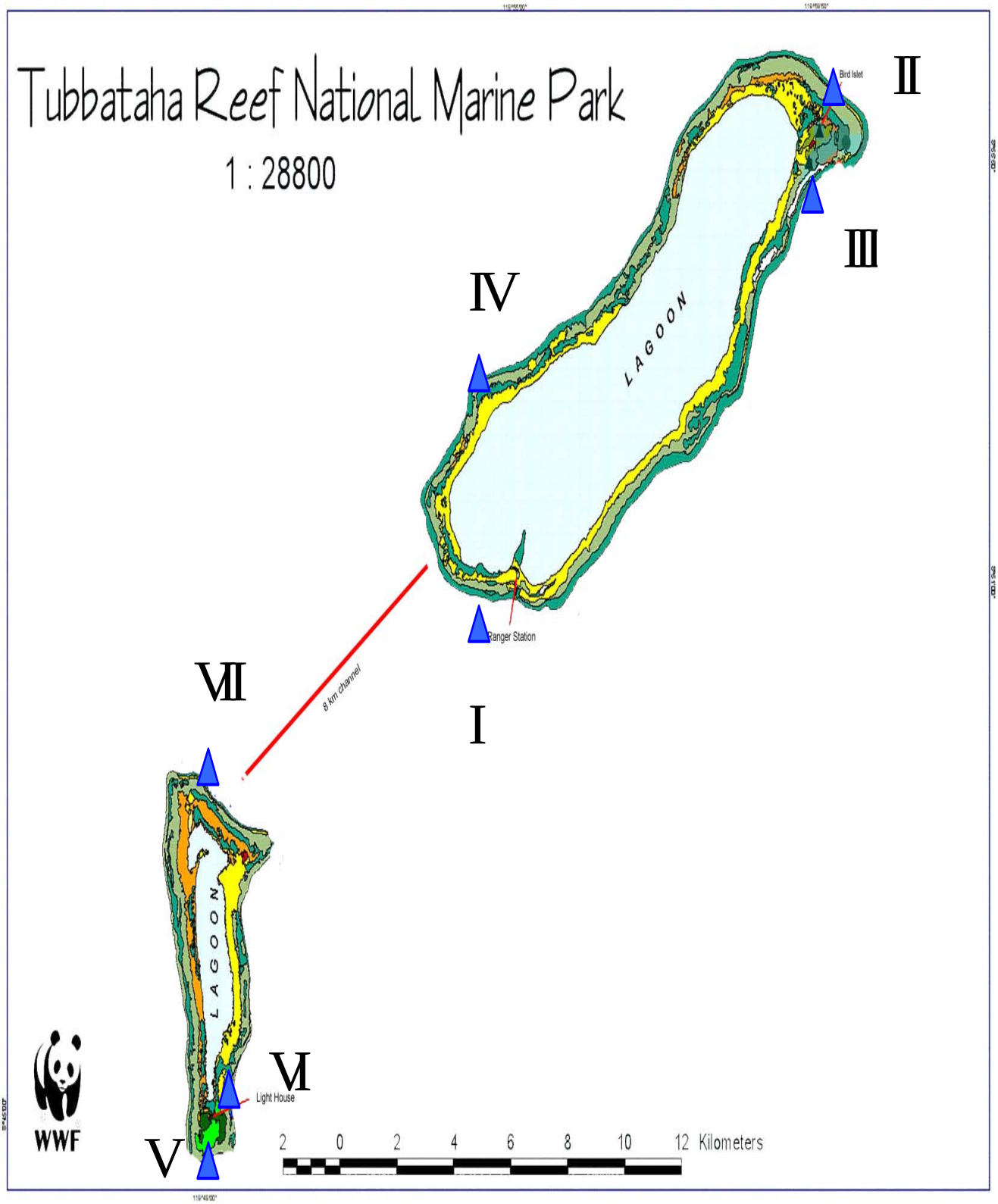

Fig. 2. Location of the seven monitoring stations (triangles) in Tubbataha Reef National Marine Park. (Source, Sabater et al., 2004).

the first time to determine the species composition and density of focal benthic mollusk species in TRNMP.

MATERIALS AND METHODS

Tubbataha Reef is located in the Sulu Sea, 150 km southeast of Puerto Princesa City, Palawan. It is under the political boundaries of the municipality of Cagayancillo, located about 80 km northeast of Tubbataha (Fig. 1).

Seven sites were surveyed within the reef area. Geographic locations of the sites are provided in Sabater et al. (2004). Four sites (1-4) are in the north atoll, and three sites (5-7) in the south atoll (Fig. 2). Site selection around the atoll is based on the various coral reef structures found representative of the monsoonal exposure effects. The reef structure ranges from monospecific stands of *Acropora brueggemanni* and sand-reef patch areas located at the sheltered reef areas to spur-and-groove habitats with mixed coral assemblage dominated by robust corals located at the exposed areas (Sabater et al., 2004).

Each site has two permanent transects of 150 m length; one at about 5 m and one at about 10 m depth. These transects have been established since 1997 for the regular monitoring of benthic communities (especially corals) and reef-associated fishes. Shallow transects are typically along slightly sloping parts of the reef characterized by branching corals while deep transects are located along steep slopes (walls). In the present study, focal bivalve and gastropod species were assessed alongside these transects. Transect width was limited to 1-m belts right and left of each transect. All except two transects were assessed during day time. The number of species abundance of each focal species such as flagship, indicator (e.g. triton shell), keystone, target (commercially valuable) and threatened species (according to IUCN 2004) were assessed. In addition to the shallow and deep transects, the intertidal area near Stn. V at the South Islet was assessed.

The intertidal was characterized by few live corals at the seaward margin followed by massive coral rocks and rubble intercepted by sandy-muddy substratum. A 150 m transect line was laid during low tide from the exposed reef margin towards the light house.

The shells were identified using the following references: Carpenter & Niem (1998), Knop (1996), Allen & Steen (1994), Sabelli (1991), Garcia (1986), Springsteen & Leobrera (1986) and Oliver (1975).

Diversity and abundance data were analyzed per site, with intertidal transects separated from shallow and deep transects. Density per square meter was obtained by dividing the number of individuals recorded with the area (300 m^2) surveyed per transect, then it was extrapolated into number of individuals per square kilometers (ind. km^{-2}).

RESULTS

Species Composition

A total of 19 species belonging to eight families were recorded, of which 15 species are univalves. Of these, Tridacnidae and Conidae had the highest number of species comprising 21 % for each family. This was followed by Trochidae and Cypraeacide (both with 16 %). Lowest percent share belong to families Fasciolariidae, Mitridae and Turbinidae (Fig. 3).

Density

A total of 12 focal species belonging to six families were recorded at the intertidal area at the South Islet. Bivalves were only represented by the family Tridacnidae. Among all species *Tridacna crocea* was the most abundant and dense (133,330 ind. km^{-2}) followed by *Conus lividus* (20,000 ind. km^{-2}) and *Trochus niloticus* (166,670 ind. km^{-2}). The calculated density of focal mollusks within that intertidal area was 213,310 ind. km^{-2} (Table 1).

At the shallow area, a total of 13 focal species under eight families were recorded. Gastropods dominated with seven families and 10 species. In terms of abundance, *T. crocea* ranked first with an average of 30,480 ind. km^{-2}, followed by *Tectus pyramis* (15,710 ind. km^{-2}), and *T. maxima* (12,860 ind. km^{-2}) (Table 1). *Tridacna squamosa* was so rare (950 ind. km^{-2}) that it was only encountered in stations IV and VI. The calculated density of all focal mollusks in shallow areas was 72,870 ind. km^{-2}. Highest abundance was recorded at Stn. VI which is a reef flat dominated by massive

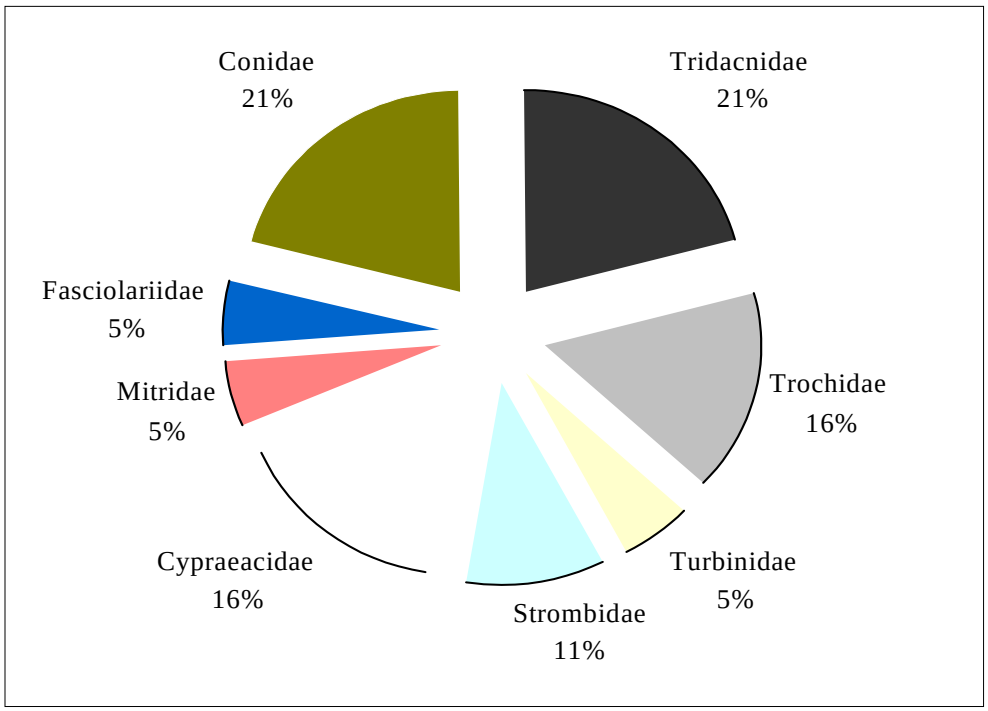

Fig. 3. Percent species composition of focal benthic mollusks at TRNMP.

Table 1. Density (ind. km^{-2}) of focal benthic mollusks at TRNMP.

Family	Species	Intertidal*	Shallow (5m)	Deep (10m)
Tridacnidae	*Hippopus hippopus*	33,330		
	Tridacna crocea	133,330	30,480	
	Tridacna maxima		12,860	950
	Tridacna squamosa		950	
Total no. of bivalve species		**2**	**3**	**1**
Trochidae	*Tectus pyramis*	3,330	15,710	1,910
	Trochus maculatus		3,810	1,430
	Trochus niloticus	16,670	3,330	
Turbinidae	*Turbo chrysostomus*	3,330	1,430	
Strombidae	*Lambis chiragra chiragra*		480	
	Lambis sp. (juvenile)	3,330		
Cypraeacidae	*Cypraea annulus*	13,330		
	Cypraea moneta	6,670		
	Cypraea tigris		1,430	950
Fasciolariidae	*Pleuroploca trapezium*		480	
Conidae	*Conus lividus*	20,000		
	Conus miles cf	3,330	950	
	Conus sp.	3,330		480
	Conus virgo	3,330	480	
Mitridae	*Mitra papalis*		480	
Total no. of gastropod species		**10**	**10**	**4**
Total density		**213,310**	**72,870**	**5,720**

*one transect only

corals. Other stations were covered with branching corals or were located at the drop off so that mollusk abundance was relatively lower compared to that in Stn. VI and the intertidal area. Broken shells of *Trochus* and *Turbo* were noted in many stations indicating the presence of mollusk predators. Large (<60 cm long) holothurians *(Bohadschia argus, Pearsonothuria graeffei, Holothuria* sp., *Thelenota ananas, Stichopus horrens, S. chloronotus)* were common along the shallow areas in Stn. III.

Very few focal mollusks were noted in the deep transects. They were represented by five species under four families. In terms of abundance, *T. pyramis* had a calculated density of 1,910 ind. km^{-2}, followed by *T. maculatus* (1,430 ind. km^{-2}). *Tridacna maxima* and *Cypraea tigris* both had a density of 950 ind. km^{-2} (Table 1). The density of all focal mollusks at 10 m depth was only 5720 ind. km^{-2}. Empty and or broken shells of *Trochus* and *Turbo* were noted in some stations.

Generally, mollusks in TRNMP were more abundant in shallow waters, and had the highest density along the intertidal transect (Fig. 4).

DISCUSSION

Among the 19 focal species, only the giant clams are listed under the IUCN Red List of Threatened Species (IUCN, 2004). *Tridacna squamosa, T. maxima* and *H. hippopus* are under Lower Risk/Conservation Dependent (LR/cd ver 2.3 1994) while *T. crocea* falls under the Lower Risk/Least Concern (LR/lc ver 2.3 1994) category. However, under the Fisheries Administrative Order No. 208 series of 2001, all seven species of giant clams are listed as endangered. *Trochus niloticus* is also listed as threatened (BFAR, 2006). For a World Heritage Site like TRNMP, the recorded number of threatened and endangered mollusks is quite low.

The observed pattern of increasing density of focal mollusks from subtidal to intertidal sites is substrate- and depth-related. Deep transects were either along steep reef walls or on reef slopes dominated by branching corals. In most of the sites surveyed, the reef starts sloping at about 3 m, hence most shallow transects were on sloping areas, too often covered with branching coral formations. Only shallow reef platforms dominated by massive corals (such as Stn. VI,) as well

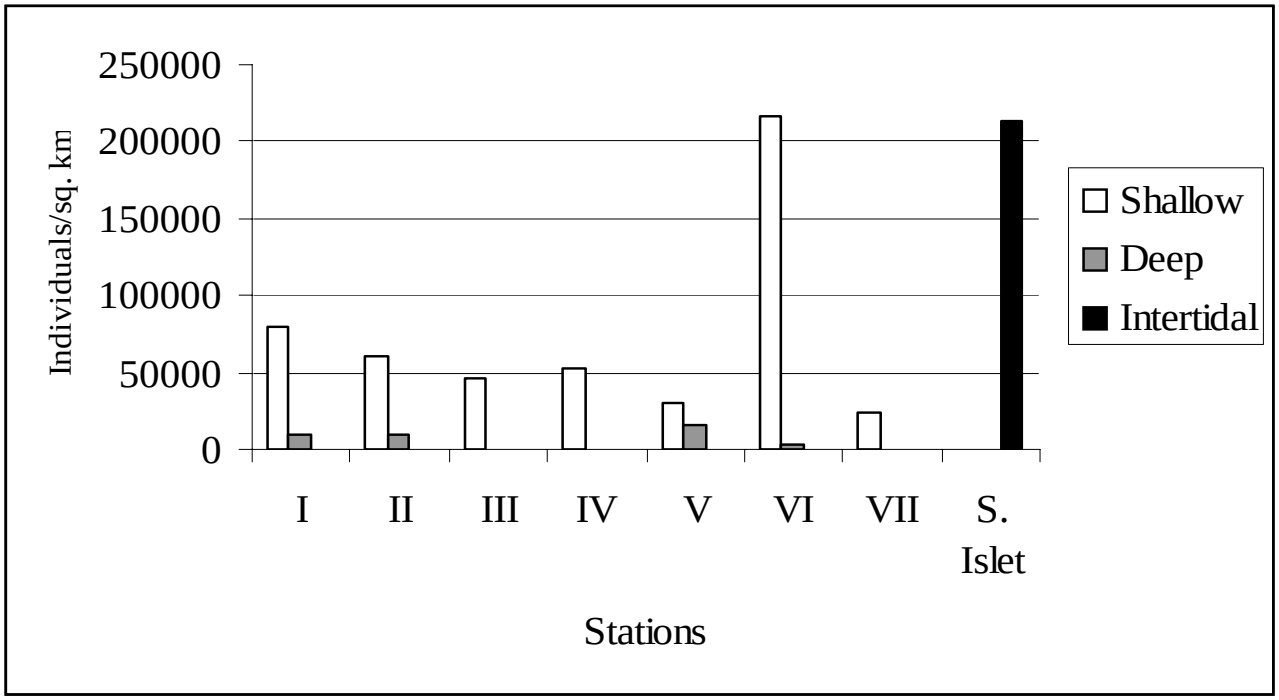

Fig. 4. Density (ind. km^{-2}) of focal mollusks in the different stations.

as intertidal areas with coral rocks and partly sand-muddy substrate (such as the one in South Islet) provide the habitat preferred by the mollusks under study. This was especially obvious for *T. crocea* which needs hard substrate to bore into and sunlight for photosynthesis. The niche of *T. crocea,* living embedded in massive corals, had been observed by various authors (see Alcala, 1986; Juinio et al., 1988; Bolen, 2005), and explains its high density in the intertidal and shallow reef flat areas in this study. Yamaguchi (1996) also found *T. crocea* and *T. maxima* to be common in coral rocks around seagrass beds in the North Reef of Tubbataha.

In terms of *T. crocea* density, TRNMP ranks second after survey sites in Northern Palawan (Alcala, 1986), followed by Snake Island, Honda Bay (Bolen, 2005), Binaluan Bay, Taytay (Sayson, 2003) and Roxas (Condesa, 2005) (Table 2). Density patterns among those sites are not expected to be related to resource management and protection of giant clams since *T. crocea* is little if at all exploited. High density of *T. crocea* seems solely substratum related, reflecting the availability of coral heads into which the species burrows. In the intertidal areas of Roxas surveyed by Condesa (2005) e.g. such coral heads were almost completely absent, resulting in only 7,000 and 15,000 ind. km^{-2} (Table 2). Although density of tridacnids, especially *T. crocea* in TRNMP was found to be higher than in most other survey sites in Palawan, previous density records of *T. crocea* and *T. maxima* from TRNMP in 1993-1995 indicate a stiff decline (Calumpong & Cadiz, 1993; Ozoa, 1995). *Tridacna crocea* for example decreased from 2,200,000 ind. km^{-2} in 1993 (Calumpong & Cadiz, 1993) to 1,000,000 in 1995 (Ozoa, 1995), and to 133,330 in 2005 (Table 2). The much lower density at intertidal area at South Islet, however, is not enough to conclude that there is a continuous decline of tridacnids, considering that the present data were only taken from a single transect. Hence, permanent mollusk transects should be established in the same seven sites but in shallow reef flats of about 2 m deep. In addition, permanent transects should be established in the lagoon and in the intertidal of North and South Islets where species composition, density and growth could be monitored along these transects on an annual basis.

Unlike *T. crocea* which was still relatively abundant, the other giant clam species, especially non-boring and heavily exploited giant clam were rather rare. Very low numbers of *T. squamosa* and *H. hippopus* were noted during the present study, as well as earlier by Yamaguchi (1996). Although Yamaguchi (1996) reports dead shells of *H. hippopus* in seagrass beds, he believes that this was not necessarily attributed to harvesting by fishermen. In Papua New Guinea, however, fishermen, as well as poachers, collect giant clams by extracting the meat leaving the shell behind (Kinch, 2002). White et al. (2003) affirms that large scale extraction of precious and common shells and giant clams has been done in the past in the Tubbataha Reef. And still, recently, hundreds of giant clams were confiscated from Chinese fishermen who poached in TRNMP. Records by Ticke (2002) state 200 confiscated *T. gigas* while Benavent-Villena & Pido (2004) are referring to 30 sacks of dried giant clams confiscated that time. Although no *T. gigas* was encountered during the present study, Tubbataha park rangers mentioned that there are still some *T. gigas* in the park. The current status of the giant clams in TRNMP might lead to similar conditions as in the Mu Ko Surin Marine National Park in Thailand where *T. crocea* is abundant, *T. maxima* is rare, *T. squamosa* is nearing extinction, and *T. gigas* and *H. hippopus* are considered extinct (Talaythai 2001). According to Kinch (2002) giant clams are highly vulnerable to stock depletion, for the stocks will become non-sustaining when densities fall below the critical mass. Aside from that, the low settlement, survival and growth of *T. squamosa* on live coral substrate (Calumpong et al., 2003) would take hundreds of years for the re-establishment of a stock particularly in isolated areas (Munro, 1993 in Kinch, 2002). These may be the reasons that despite protecting TRNMP for more than a decade, populations of commercially valuable giant clam species at the seven established stations remain low. This condition requires the establishment of specific sites for non-boring tridacnid species to ensure fertilization and larval recruitment. The stability or an increase in the population of the focal benthic mollusks especially the following giant clam species: *T. gigas, T. squamosa* and *H. hippopus* over the next few years would indicate success of the conservation measures employed by the TRNMP.

Other large and commercially valuable species such as the gastropods, *Trochus niloticus, Tectus maculatus* and *T. pyramis* which are nowadays rarely encountered in intertidal areas were abundant at the TRNMP. Intertidal areas near coastal residents of Palawan are usually overexploited as density data indicate. Condesa (2005) for example recorded a mean density of only 1,000 ind. km^{-2} of *T. niloticus* in Green Island, Roxas. Still lower is the density of the species in the Cartier Reef, Australia where it only ranged from 133-333 ind. km^{-2} (Smith et al., 2002). It is expected that Tubbataha' s previously overexploited gastropods stocks have recovered under the past years of protection. Since gastropods mate, fertilization and therewith recruitment and increase of stocks are easier achieved compared to broadcast spawning in bivalve species, whose gametes are easily dispersed in water by currents.

The very low number of other commercially important gastropods like *Lambis* spp. and the absence of *Charonia tritonis tritonis* and *Cassis cornuta* both in shallow and deeper areas may again be attributed to the substrata of the survey sites. *Cassis cornuta* for example is common on sandy substrate between coral formations (Carpenter & Niem 1998) which was rarely encountered along the surveyed transects. Over exploitation in previous years might also have led to the absence of the species in the survey sites, which were easily accessible to poachers before. Park Rangers claimed that *C. cornuta* and *C. tritonis* are still present in the lagoon, an area that was always difficult to access by poachers.

Therefore, it is recommend that in order to better assess the species composition and density of focal species in the TRNMP, more survey transects per site need to be established at the intertidal and shallow reef flats.

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Table 2. Density (ind. km^{-2}) of commercially exploited benthic mollusks at TRNMP in comparison with other studies.

Author & Location / Species	Palawan, Philippines										
	Condesa (2005)		Bolen (2005)	Sayson (2003)	Alcala (1986)		Calumpong and Cadiz (1993)		Ozoa (1995)	This study (2005)	
	Green Island, Roxas, Intertidal	Caramay, Roxas, Intertidal	Snake Island, PPC, 1-5m	Binaluan Bay, Taytay, 1.5-3.5m	Cagayan Island, 0.5-5m	Northern Palawan, 0.5-5m	TRNMP North Islet, 6-10 m	TRNMP South Islet, Intertidal	TRNMP Intertidal	TRNMP Intertidal	TRNMP Reef slope, 5m
Tridacna crocea	15,000	7,000	120,000	55,833	18,069	328,619	1,400,000	2,200,000	1,000,000	133,330	30,480
T. maxima			100,000		25,509	2,667	500,000	200,000	333,300		12,860
T. squamosa			20,000	3,050	1,240	2,714					950
T. gigas											
Hippopus hippopus			300	1,110					111,100	3,330	
All giant clam spp.	**15,000**	**7,000**	**240,300**	**59,993**	**44,818**	**344,000**	**1,900,000**	**2,400,000**	**1,444,400**	**136,660**	**44,290**

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