Notes on common macrobenthic reef invertebrates of Tubbataha Reefs Natural Park, Philippines

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ABSTRACT

Macrobenthic reef invertebrates are important reef health indicators and fishery resources but are not very well documented in Tubbataha Reefs Natural Park. To provide notes on the species composition and the abundance and size of commonly encountered macrobenthic reef invertebrates, belt transects survey in intertidal, shallow, and deep subtidal reef habitats were conducted. In total, 18 species were recorded, six of which were echinoderms and 12 were mollusks, which include the rare giant clam *Hippopus porcellanus*. Only the giant clam *Tridacna crocea* and the top shell *Trochus niloticus* occurred in all seven permanent monitoring sites but the two species varied in densities across depths. There was also an outbreak of crown-of-thorns (COTs) sea stars in some sites. The large variation in the density of each species across sites and depths suggests niche differences, overharvesting, or their recovery from having been overly exploited. Separate monitoring areas for each commercially important species are suggested to determine how their populations respond to poaching and their implications on the park's long term management.

Key words: Macrobenthic invertebrates, marine protected area, Tubbataha Reefs Natural Park

INTRODUCTION

Situated within the Coral Triangle, the Tubbataha Reefs Natural Park (TRNP) harbors some of the richest marine ecosystems in the world (White and Cruz-Trinidad 1998, Arquiza and White 1999, White and Vogt 2000). Covering an area of 96,828 ha, TRNP is the country's largest Marine Protected Area (MPA) and the sole, pure marine World Heritage Site in Southeast Asia (Songco and Jack 2009). The North and South Atolls and Jessie Beazley Reef that comprise it feature spectacular reef formations teeming with marine life (Dygico 2006). Its strategic location in the middle of the Sulu Sea makes it an important source of fish and coral larvae that enrich the fisheries of eastern coast of Palawan (see White and Vogt 2000). But like many other reefs, TRNP has always been a target of illegal fishermen before and even after its declaration as a national park in 1988 (TMO unpublished data, Arquiza and White 1999, Dygico 2006, Dolorosa and others 2010, Jontila and others 2011). Such is a challenge to the management in preserving the globally significant biological diversity and ecological processes of TRNP.

To efficiently manage the park, monitoring efforts were conducted as early as the 1990s, but it was only in 1997 that monitoring and evaluation were undertaken more systematically. Seven permanent monitoring sites for fish and corals at 10 m depths were established then and in 2002, replicates at depths of 5 m were added in the same sites (Ledesma and others 2008). Between 1997 and 2005, studies on seabirds, seagrass, planktons, large predators including sharks and cetaceans, and focal benthic mollusks species were conducted sporadically. A survey of focal benthic mollusks in 2005 followed the transect lines for coral monitoring, which was at 5 m and 10 m depths, with one additional transect in the intertidal area (Dolorosa and Schoppe 2005). With the incidence of illegal collection of the reef gastropod topshell *Trochus niloticus* or 'trochus' in 2006, the management immediately facilitated the gathering of baseline data. Seven permanent monitoring stations in the shallow subtidal areas (~1 m deep during low tide) were established and marked with cement blocks (see Dolorosa and others 2010). During the second trochus monitoring in 2008, efforts were exerted at noting other macrobenthic invertebrates occurring within the trochus habitat in terms of species composition, abundance and size. Information on such is necessary to aid the management in safeguarding the species against illegal collectors. Knowing where these species abound would help the management maximize their resources by focusing more on "hot spot" areas that need greater protection.

METHODS

The study was conducted in the South and North Atolls of TRNP (8°43'-8°57' N latitude and 119°48'-120°3' E longitude). The park is located amidst Sulu Sea, some 150 km southeast of Puerto Princesa City, Palawan and 130 km south of Cagayancillo, the municipality where the park belongs (Figure 1).

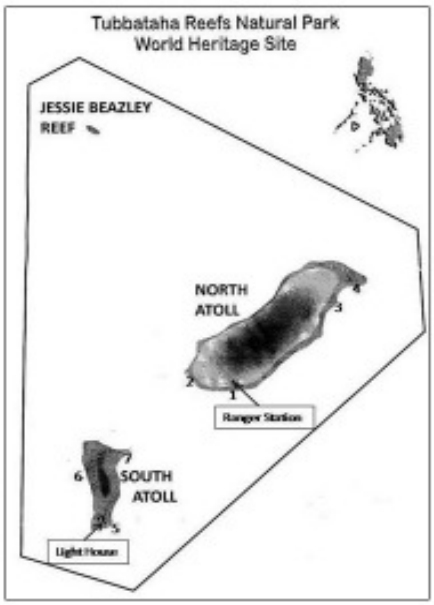

Figure 1. Tubbataha Reefs Natural Park Map showing its location in the Philippines (upper right) and the permanent monitoring sites (modified after Tubbataha Management Office Brochure)

Between May 27 and June 3, 2008, the seven permanent monitoring sites established in 2006 (see Dolorosa and others 2010) at the shallow subtidal (~1.0 m deep at low tide) areas were revisited (Figure 1) and replicates in intertidal (exposed at low tide) areas and at ~5 m deep reef slope were added. The selected areas were generally composed of rock substrates that favor the abundance of trochus. Belt

transects (100 m x 2 m) positioned parallel to the shoreline to record the abundance of echinoderms and macrobenthic mollusks were surveyed with the use of SCUBA gears. In total, 21 transects were surveyed covering 4,200 m^2. The sizes of reef gastropods were measured either with a plastic ruler glued on a slate board or with calipers. The relaxed lengths of sea cucumbers were measured with a tape measure. Noteworthy macrobenthic reef invertebrates encountered outside but along the transect lines were noted. Field identification of mollusks were based on the works of Poutiers (1998a, 1998b) and Springsteen and Leobrera (1986), while for echinoderms, the works of Conand (1998) and Schoppe (2000) were used.

RESULTS

Species composition

In total, 18 species were recorded, six of which were echinoderms and the rests were mollusks. The echinoderms were composed of Crown-of-thorns (COTs) sea star, *Acanthaster planci*, and five species of sea cucumbers. The 12 macrobenthic mollusks were composed of eight gastropods and four bivalves, all of which were giant clams. All, except the three sea cucumber species (*Bohadscia argus, Stichopus chloronotus*, and *Thelenota ananas*) and three mollusk species (*Bursa bubo, Chiragra chiragra*, and *Tridacna squamosa*), occurred within the belt transects (Table 1).

Abundance and size

There was a large variation in the abundance of species across sites (Table 2) and depths (Table 3). The COTs were only noted in deep reef slopes of Sites 1 and 4 (Tables 2 and 3). No size measurement was taken for the COTs but their approximate diameter ranged between 20 and 40 cm.

Of the five sea cucumber species noted during the survey, only *Holothuria atra* and *Pearsonothuria graeffei* occurred within the shallow and deep subtidal

Table 1. Species of echinoderms and mollusks encountered during the 2008 survey

Family	Species
Echinodermata (Asteroidea)	
Acanthasteridae	*Acanthaster planci*
Echinodermata (Holothuroidea)	
Holothuriidae	*Bohadscia argus**
	Holothuria atra
	Pearsonothuria graeffei
Stichopodidae	*Stichopus chloronotus**
	*Thelenota ananas**
Mollusca (Gastropoda)	
Bursidae	*Bursa bubo**
Conidae	*Conus lividus*
Cypraeacidae	*Cypraea tigris*
Strombidae	*Chiragra chiragra**
	Strombus luhuanus
Trochidae	*Tectus pyramis*
	Trochus niloticus
Turbinidae	*Turbo chrysostomus*
Mollusca (Bivalvia)	
Tridacnidae	*Hipoppus porcellanus*
	Tridacna crocea
	T. maxima
	*T. squamosa**

**Noted outside the transect*

habitats at relatively too low densities (Tables 2 and 3). The two largest sea cucumbers found were *Thelenota ananas,* each measuring 60 cm in length. The mean sizes of other species ranged between 24 and 33 cm (Fig. 2, Table 4).

Among the four giant clam species, only *Tridacna crocea* consistently occurred in seven sites (Table 2) with declining abundance as depth of habitat increased (Table 3). For other tridacnid species, abundance was very low (Tables 2 and 3). The average (± sd) shell length of *T. crocea* was 7.19±4.32 cm, while the *Hippopus porcellanus* measured 28.85±6.91 cm, and the *Tridacna maxima* was 13.12±5.64 cm (Figure 3).

Among the reef gastropods, only *Trochus niloticus* occured in all seven sampling sites, mainly concentrating in the shallow subtidal habitats (~1.0 m deep during low tide) of Sites 1 and 2 (Tables 2 and 3). The not-so-common trochid species *Tectus pyramis* appeared to favor deeper habitats. There was a high number of *Strombus luhuanus* in the intertidal area of Site 6 (Table

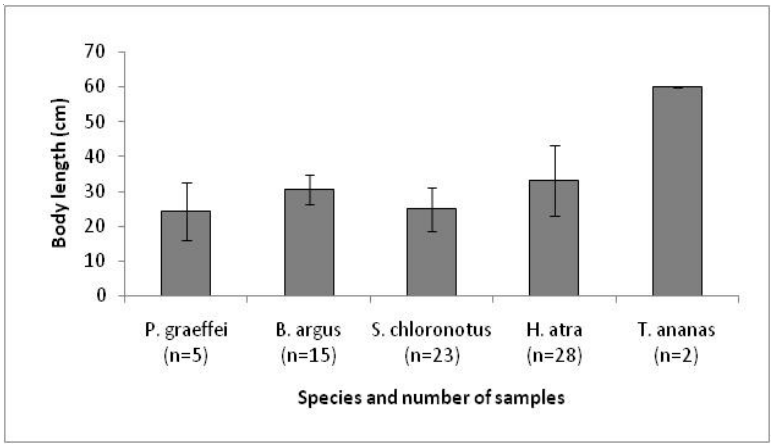

Figure 2. Mean (±sd) body length of sea cucumbers encountered at TRNP in 2008

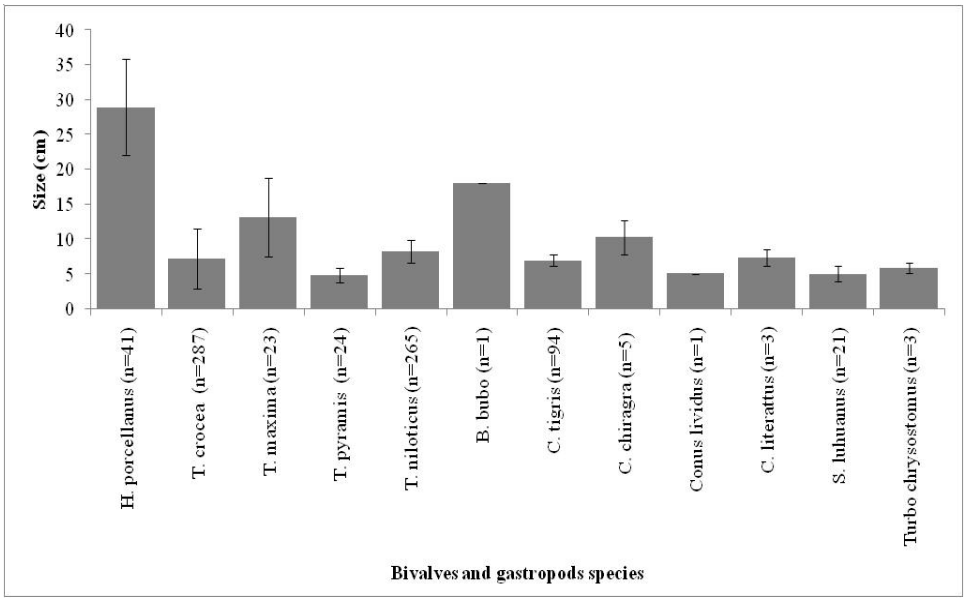

Figure 3. Mean (±sd) shell sizes of bivalves and gastropods encountered during the survey at the TRNP in 2008. All sizes were shell lengths except for maximum basal diameter for *T. niloticus* and *T. pyramis.*

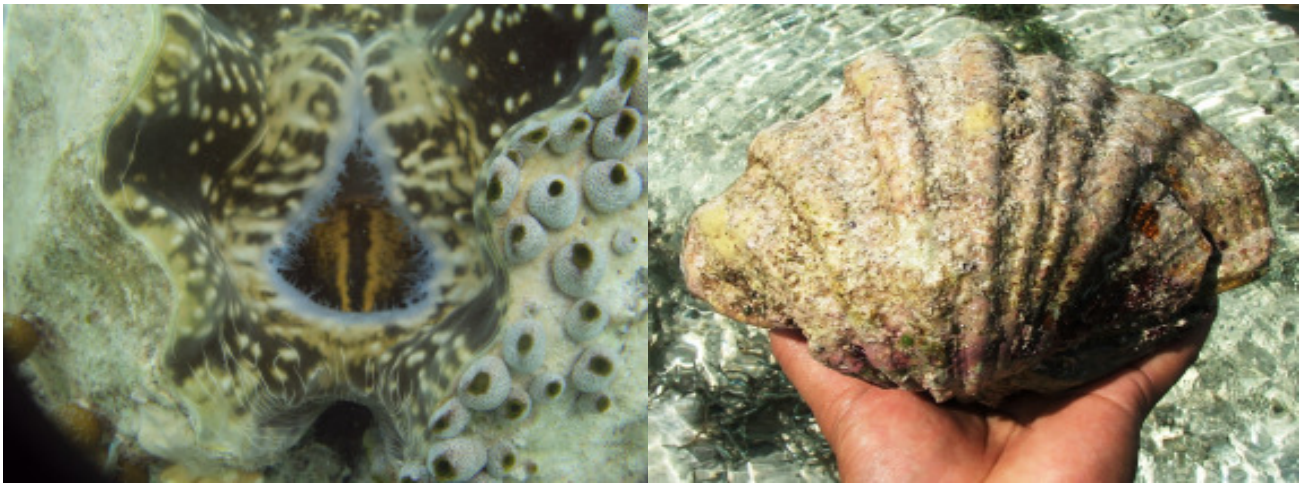

Figure 4. The *Hippopus porcellanus* in Tubbataha Reefs Natural Park. Note the fringing tentacles on the inhalant siphon (left) and the shell that is globose in shape and semicircular in outline with smooth and regularly shaped dorsal margin (right).

2). In terms of average size (±sd), *T. niloticus* measured (8.2±1.6 cm) while *T. pyramis* was about 4.8±1.1 cm in diameter. The sizes of other mollusks species are shown in Figure 3.

DISCUSSION

The limited number of species encountered in this study could be site-related. Transects were established in rocky areas suitable for the trochid species, but possibly not for others. The surveyed sites were only at the seaward reef flat and slope and did not include other important habitats within the lagoon. Sea cucumbers generally favor sandy-muddy grounds with rubble (Conand 1998, Schoppe 2000) instead of seaward rocky habitats, which are preferred by the trochus (Nash 1993). Some species are nocturnal (Kerr and others 2006) making them difficult to spot during the day. There are over 170 sea cucumber species in the Philippines (see Olavides and others 2010), thus further surveys on other potential habitats within the park may yield additional species.

All five sea cucumber species recorded in TRNP are harvested and sold as *bêche-de-mer* with varying demands (Conand 1998, Akamine 2002, Olavides and others 2010). Among these five species, *Pearsonothuria graeffei* is of pharmacological importance because it contains substances with anti-cancer properties (Zhao and others 2011). However, the indiscriminate harvesting of sea cucumbers has caused their populations to decline, forcing fishermen to venture to deeper and offshore reefs (Anderson and others 2011), which may include marine protected areas (Choo 2008).

To date, all the seven giant clam species in the Philippines have been recorded in the TRNP. Species of giant clams noted during the survey include: *Tridacna crocea, Tridacna maxima, Tridacna squamosa*, and *Hippopus porcellanus*. In 2009, *Tridacna derasa* and empty shells of the *Tridacna gigas* were noted (Dolorosa unpublished data) and the presence of the *Hippopus hippopus* has been previously reported (Yamaguchi 1996, Dolorosa and Schoppe 2005). However, it can be that the finding of the *H. hippopus* was a misidentification of *H. porcellanus* (Fig. 4), although the possibility that these two species can co-exist cannot be disregarded.

The densities of commonly encountered macrobenthic reef invertebrates in the TRNP appear to vary among sampling sites and depths. Considerable numbers of the *A. planci* in the deep subtidal (~5 m) reef slope of Sites 1 and 4, with densities at 28 and 37 ind/200 m^2, can be noted. These species can be seen aggregating,

often on top of each other, while actively feeding during the day. As early as 2007, *A. planci* had been commonly sighted in some reefs within the TRNP and in many reef areas in the mainland Palawan (pers. obs.). In 2008, researchers collected more than 3,000 individual COTs in the Northwestern part of the North Atoll, which measures about 2 h (Ledesma and others 2008). In the Great Barrier Reef, outbreaks of COTs have been thought to be a natural phenomenon but have also been linked with the overexploitation of their predators and the influx of nutrients (Harriott and others 2003). In TRNP, the reported COTs predators, such as the giant reef gastropods *Charonia tritonis* and *Cassis cornuta*, were not noted during the survey, but in January 2010, two *C. tritonis* on the reef slope and six *C. cornuta* partly buried in exposed sand during low tides (Dolorosa unpublished data) were noted, suggesting a variation in habitats between the two species.

The densities of sea cucumbers in the TRNP are quite low compared with some reported densities in the Pacific (see Conand 1998), but their sizes appear larger or comparable with the maximum and common sizes (Table 4) as reported by Conand (1998) and Kerr and others (2006). Shiell (2004) and Eriksson (2012) report that adult and juvenile sea cucumbers have separate distinct habitats; this survey was only conducted at the seaward reefs, which could be one of the reasons for having low densities and limited but large-sized samples.

The density of *T. crocea*, which declined with depth, could also be substrate and site related. In an inner reef surrounding the Ranger Station of the TRNP, high numbers of *T. crocea* aggregated in coral heads, exposed at low tide (pers. obs.), make this area a potential monitoring site for the said species. Hammer and Jones (1976) show that the density of the *T. crocea* on top and underside of coral boulders varies with distance from the shore, writing that the highest density occurs at habitats 140 m (24.1 ind m^{-2}) from shore compared with those found at 90 m (7.6 ind m^{-2}) and 160 m (14.4 ind m^{-2}) from shore. In the TRNP, the density of the giant clam *T. crocea* is higher than reported densities from other parts of the country and in many areas in the Pacific (see Othman and others 2010). Based on the previous studies conducted in the Park, it appears that the population of *T. crocea* has declined considerably from 440 ind/200 m^2 in 1993 to 200 ind/200 m^2 in 1995, down to 27 ind/200 m^2 in 2005 (see Dolorosa and Schoppe 2005). These figures provide a snapshot of information on the general status of the species in the TRNP. However, sites covered by each survey differ and results cannot be compared directly and would be insufficient to say that population of *T. crocea* has indeed declined over the years. To have a reliable data trend, there should be a representative number of sites and regular monitoring over the years. Data should be site-specific rather than generalized, for it is important to take into account the inherent differences of each site.

The density of *Tridacna maxima* in some sites at the TRNP is much higher than the reported densities from other parts of the country (Othman and others 2010), but comparable with the densities in fished (0.6 ind/200 m^2) and unfished (0.8 ind/200 m^2) reefs in the Maldives (Basker 1991). The *T. maxima*, however, can reach an extremely high density of 88.3 million clams in 11.46 km^{-2} (Gilbert and others 2006), equivalent to 1,541 ind/200 m^{-2}. In the Reao Atoll, the density can be as high as 244 ind m^{-2} or 48,800 ind/200 m^{-2} (Salvat 1971 in Gilbert and others 2006). Conversely, the *Hippopus porcellanus* appears to be very rare in the Philippines as its density is only reported in El Nido, Palawan at 0.0008 ind/200 m^2 (see Othman and others 2010). However, the high number of *H. porcellanus* in Site 6 indicates a recovering population. It may also suggest that it is not a current target species compared to trochus whose population declined sharply in Site 6 due to poaching (Dolorosa and others 2010, Jontila and others 2011). The mean sizes of tridacnid species recorded in the TRNP, which were much smaller than their common sizes as reported by Poutiers (1998a), also suggest that most individuals have yet to reach their maximum sizes.

The locally threatened reef gastropod *T. niloticus* (DA 2001) in the TRNP had its mean density in 2006 (about 6,000 ind ha^{-1}) (Dolorosa and others 2010) reduced to 1,714 ind ha^{-1} or 34 ind/200 m^2 in only two years of exploitation (Jontila and others 2011). Results of this

study further show that only sites close to the Ranger Station (Sites 1 and 2) contained considerable populations (Table 2). Despite this, the population of trochus in the TRNP is exceptionally higher than at any other sites in the country (see Dolorosa and others 2010) and even in some Pacific Islands (Smith and others 2002, Lasi 2010). Conversely, the mean size of trochus (82 mm) is smaller than in the Cartier Reef (Smith and others 2002), in Tongavera, Cook Islands (Chambers 2007), and in Aitutaki (Ponia and others 1997). The other trochid species *Tectus pyramis* appear to prefer deeper areas although few individuals occur in the intertidal and shallow subtidal sites. Its average density (2 ind/200 m^2) and size (4.8±1.1 cm) are comparable with the previous report (2.38 ind/200 m^2; 4.7±0.5 cm) of Dolorosa and others (2010), suggesting the absence of exploitation. Unlike the trochus, the shells of *T. pyramis* have low commmercial value (Gillespie 1997) and their inclusion in the confiscated trochus collected by poachers from the TRNP in 2007 (Dolorosa and others 2010) is rather accidental and because the poaching happened at night.

The other invertebrates in the TRNP are sparsely distributed with no distinct pattern, oftentimes noted in intertidal and shallow subtidal sites. It is only *Strombus luhuanus* that has a considerable number recorded in the intertidal areas of Site 6 (70 ind/200 m^2) and fewer in the intertidal and deep areas of Site 5. The species seems not at all exploited because of its small size or may have quickly recovered given the similarities in mean sizes between the recent (Fig. 3) and previous studies. Yamaguchi (1996) reports an average size of 5.03 cm, while a common size of 5 cm is reported by Poutiers (1998b).

Aside from the possible effects of harvesting, the low numbers of macrobenthic reef invertebrates might be related to slow recovery. Overfishing of sea cucumbers (Uthicke and Conand 2005) and giant clams (Gomez and Mingoa-Licuanan 2006, Othman and others 2010) are common problems in the Philippines and in most parts of their habitat range. Once overfished, these organisms are difficult to revive because of their large size, slow growth, mode of reproduction (broadcast spawner), low fecundity, and late maturity (Bruckner 2006, Anderson and others 2011). It is important to note that prior to having been declared as a National Park in 1988, the Tubbataha Reefs had already been overexploited (Arquiza and White 1999) and possibly, many slow growing reef species (e.g. *T. gigas*) are still in the process of recovering. It is estimated that after harvesting closure, decades are required for sea cucumber populations to recover; recovery for other large macro invertebrates require a much longer time (see Anderson and others 2011).

To fully understand the status of sea cucumbers, giant clams, and other important reef invertebrates like crustaceans, there is a need to establish separate survey sites for each species for regular monitoring. Assessment is suggested in areas dominated by sand, rubble, and sea grass at the seaward and leeward parts of the South and North Atolls. Different survey methods (e.g. traps) may be needed to study the crustacean resources in the TRNP.

The TRNP is among the few MPAs in the country where protection and management really work. Over two decades of protection has made the fish population steadily increase and coral cover recovery relatively stable (Dygico 2006, Ledesma and others 2008). Fish population may be overwhelming but other resources, such as macrobenthic invertebrates, may already be dwindling as with the *T. niloticus*. The large scale extraction of reef invertebrates (Arquiza and White 1999) particularly giant clams (Ticke 2002, Benavente-Villena and Pido 2004) in the early 2000s could have seriously affected their populations, especially those of the *T. squamosa* and the *T. gigas.* All giant clam species are listed in Appendix II of CITES, suggesting that "these species are not necessarily threatened with extinction but that may become so unless trade so closely controlled" (CITES 2013). However, separate populations of species may have different conservation needs as some species may have become extinct in other areas (IUCN 2012). As the TRNP serves as a seed source for the heavily depleted reefs in mainland Palawan and the surrounding reef areas within the Sulu Sea (see White and Vogt 2000), the protection of the remaining populations of these reef invertebrates and other marine organisms in TRNP is deemed important.

Table 2. Mean (±sd) abundance (ind/200 m²) of echinoderms and mollusks per sampling site

Species	Sites						
	1	2	3	4	5	6	7
Echinoderms							
A. plancii	9.3±16.7			12.3±21.4			
H. atra			1.0±1.0	1.0±1.7			
P. graeffei		0.3±0.6					
Mollusks							
T. crocea	12.7±11.0	4.7±4.6	4.3±5.8	27.0±37.3	26.3±30.8	10.7±7.1	10.7±6.0
T. maxima		1.3±2.3					
H. porcellanus						3.7±5.5	0.3±0.6
T. niloticus	29.3±37.8	34.3±56.0	6.3±11.0	6.0±7.2	1.3±1.5	0.7±1.2	10.0±17.3
T. pyramis	3.3±5.8			2.3±4.0			
C. tigris			0.3±0.6				
C. lividus					18.0±31.2		
T. chrysostomus				0.3±0.6			
S. luhuanus		3.7±6.4			2.0±1.7	27.3±45.6	

Table 3. Mean (±sd) density (ind/200 m²) of reef invertebrates encountered during the 2008 survey at intertidal, shallow, and deep subtidal reef areas

Species	Intertidal	Shallow subtidal (~1m during low tide)	Deep Subtidal (~5 m)	Overall
Echinoderms				
A. plancii			9.3±16.1	3.1±9.9
H. atra		0.1±0.4	0.7±1.2	0.3±0.8
P. graeffei			0.1±0.4	0.1±0.2
Mollusks				
T. crocea	26.6±27.9	10.9±5.0	3.9±3.8	13.8±18.4
T. maxima		0.6±1.5		0.2±0.9
H. porcellanus	1.4±3.8	0.1±0.4	0.1±0.4	0.6±2.2
T. niloticus	2.6±6.0	34.1±37.2	1.0±1.5	12.6±25.9
T. pyramis			2.4±4.2	0.8±2.6
C. tigris		0.1±0.4		0.1±0.2
C. lividus		7.7±20.4		2.6±11.8
T. chrysostomus		0.1±0.4		0.1±0.2
S. luhuanus	13.0±30.2	0.7±1.2	0.4±1.1	4.7±17.4

Table 4. Maximum and mean lengths of sea cucumbers from TRNP and those from other studies

Species		Maximum (common) lengths (cm) in the Indo-Pacific Region (Conand 1998)	Maximum size (cm) in the Central Philippines (Kerr and others 2006)	Maximum (mean) lengths (cm) in this study
S. chloronotus	(n=23)	35 (18)		39 (25)
T. ananas	(n= 2)	80 (45)		60 (60)
B. argus	(n=15)	60 (36)	At least 50	37 (30)
H. atra	(n=28)	45 (20)	About 40	52 (33)
P. graeffei	(n= 5)	45 (35)	About 30	35 (24)

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