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Economically Important Benthic Macroinvertebrates in the Reefs of West Sulu Sea, Palawan, Philippines

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Benthic macroinvertebrates are essential components of the marine ecosystem and a source of food and livelihood in many coastal communities. However, a lack of knowledge about their status has resulted in their overexploitation in many areas where they are openly harvested. In this paper, we assessed the species composition, population density, uses, and conservation status of economically important benthic macroinvertebrates in the coral reefs of the West Sulu Sea, Palawan, Philippines. A total of 100 transects from six sites (3–10-m depth) covering a reef area of 25,000 m^2 were assessed using scuba diving. There were 15 species belonging to 11 families found in the surveyed sites, with the Crocus giant clam *Tridacna crocea* Lamarck 1819 encountered in all sites. The mean population density of each species ranged between 0.8–306.4 individuals ha^{-1}. Based on the IUCN Red List, most of the species encountered have "Least Concern" and "Not Evaluated status," whereas two species are listed as "Lower Risk/ Conservation Dependent." Mostly, these organisms are harvested as a source of food, souvenirs, decorations, and jewelry. The absence of some high-value and threatened species may indicate over-harvesting of these species. The results of this study can be used as a basis for formulating a long-term management plan for these benthic macroinvertebrates and their coastal habitats.

Keywords: conservation status, economic use, population density, reef invertebrates, species composition, species conservation

INTRODUCTION

Benthic macroinvertebrates are common inhabitants of shallow-water marine habitats, where they provide various ecosystem services (*e.g.* aeration of sediments, nutrient recycling). They are essential components of marine food chains, as they support many organisms vital to the marine ecosystem (Wildsmith *et al*. 2011). The presence or absence of some species (*e.g.* giant clams) may also indicate the reef's health, level of exploitation, and environmental deterioration, and also affect the abundance of reef fish populations (Wildsmith *et al*. 2011; Neo *et al.* 2015). Benthic macroinvertebrates can occur in significant numbers in well-protected areas where their exploitation is prohibited, particularly the threatened species (Andrefouet *et al.* 2005; Conales *et al*. 2015; Dolorosa *et al*. 2016).

Benthic macroinvertebrates are traditionally harvested on coral reefs and other shallow-water habitats, significantly contributing to the daily food supply and income of small-scale fishers in coastal communities (del Norte-Campos *et al.* 2005; Szabo and Amesbury 2011; de Guzman *et al.* 2019). Among this group, sea cucumbers, bivalves, gastropods, and crustaceans are commonly observed in these habitats (Jontila *et al*. 2014; Dolorosa *et al*. 2015;

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Furkon *et al*. 2019). They are also primarily targeted in gleaning fisheries, mostly undertaken by women and children (de Guzman 2019; Furkon *et al*. 2019). Most of the species collected are utilized primarily as food, whereas others are collected as souvenir items, components of handicrafts and decorations, jewelry, carving tools, and other non-traditional uses (Floren 2003; Jontila *et al.* 2014; Gomez 2015; Mecha and Dolorosa 2020).

Because of their limited mobility or slow-moving nature in highly accessible habitats, benthic macroinvertebrates are prone to human threats such as overexploitation (Szabo and Amesbury 2011). In contrast, their limited mobility is an advantage in the monitoring aspect of stock enhancement initiatives (Gonzales 2005). Some large species of reef gastropods – such as the triton shell *Charonia tritonis* (Linnaeus 1758), top shell *Rochia nilotica* (Linnaeus 1758), horned helmet *Cassis cornuta* Linnaeus 1758, and green turban snail *Turbo marmoratus* Linnaeus 1758 – are already overfished, and calls for their protection have already been made in many parts of their geographical distribution range (Dolorosa *et al*. 2013a, 2015; Hall *et al*. 2017). Similarly, a number of high-value sea cucumber species are becoming rare because of high market demand, forcing the fishery to shift to undersized and low-valued species (Purcell *et al.* 2012). In addition to overexploitation, illegal, unreported, and unregulated fishing also threatens the existence of a number of macroinvertebrate species that may lead to the collapse of their populations, including the species that depend on them (Wildsmith *et al.* 2011; Neo *et al.* 2015). In fact, the population of many species (*e.g.* giant clams, top shells, sea urchins, *etc.*) has already declined in many parts of the country, and efforts to enhance their population in depleted reefs have already been made in the past (Juinio-Meñez 2004; Gonzales 2005; Gonzales *et al.* 2006; Gomez and Mingoa-Licuanan 2006; Cabaitan *et al.* 2008; Dolorosa *et al.* 2016).

Overexploitation of natural resources is linked to a growing human population and the need for food, a widespread problem in developing countries (Maya and Ayano 2021). In the Philippines, a lack of access to alternative skills and sources of livelihood, as well as lucrative prices offered on the black market for some macroinvertebrates (*e.g.* top shells, giant clams), often drive small-scale fishers to overexploit marine resources (Knudsen 2016). In response to this problem, the government is formulating policies and strategies to lessen poverty incidence and hunger in the country through the sustainable use of marine resources. This is also part of the country's contribution to the United Nations' Sustainable Development Goals (SGD) (*i.e.* SDGs 1, 2, and 14), which aim to end poverty and hunger by achieving food security, improving nutrition, promoting sustainable agriculture, and the sustainable use of marine resources (UN 2018). Sustainable utilization of marine and fisheries resources is necessary to help achieve food security, as these are major sources of food and livelihood in coastal communities (DA-BFAR 2020). Thus, when the populations of benthic macroinvertebrates are protected from overharvesting, the sources of food and livelihood are also protected.

The West Sulu Sea on the eastern side of the island province of Palawan is an invaluable fishing ground for artisanal and commercial fishers (DA-BFAR 2020). However, most of the studies conducted in this area are limited only to the finfish fisheries and biodiversity assessment of reef fishes (Candelario *et al.* 2018; Balisco and Dolorosa 2019), and very few tackled benthic macroinvertebrates. However, studies related to macroinvertebrates focused mainly on a few species groups (*e.g.* sea cucumbers, top shells) (Gonzales *et al.* 2006, 2014b; Dolorosa *et al.* 2017; Jontila *et al*. 2017), and little information is available on their population status, particularly those with economic relevance. Establishing knowledge of their biology, ecology, and distribution is a critical step in proposing measures for their management and conservation. Thus, this study aimed to determine the species composition, population density, uses, and conservation status of economically important benthic macroinvertebrates in selected sites of the West Sulu Sea, Palawan, Philippines. In addition to providing scientific information, this study also aims to inform local governments and policymakers about management measures to implement. These measures may be applied to the sustainable utilization of these economically critical reef resources in the province.

MATERIALS AND METHODS

Sampling Sites

The West Sulu Sea in the eastern part of Palawan, Philippines (latitude 7°42′ – 12°7′ N, longitude 117°3′ – 120°31′ E) covers an area of 29,993 km^2, serving as an invaluable fishing ground for artisanal and commercial fishers (DA-BFAR 2020). The study stations involved reefs generally adjacent (fringing) to mainland Palawan, forming part of the proposed or existing marine protected areas in the municipalities of Roxas, Narra, Sofronio Española, Brooke's Point, Bataraza, and Puerto Princesa City (Figure 1). We surveyed a total of 22 reef stations comprised of 100 transects covering a reef area of 25,000 m^2. The sampling depths ranged between 3–10 m, with the shallowest reef found in Bataraza (3–6 m) and the deepest reef in Sofronio Española (5–10 m). Water visibility ranged between 5–20 m. The geographical information of each site is described in Appendix I.

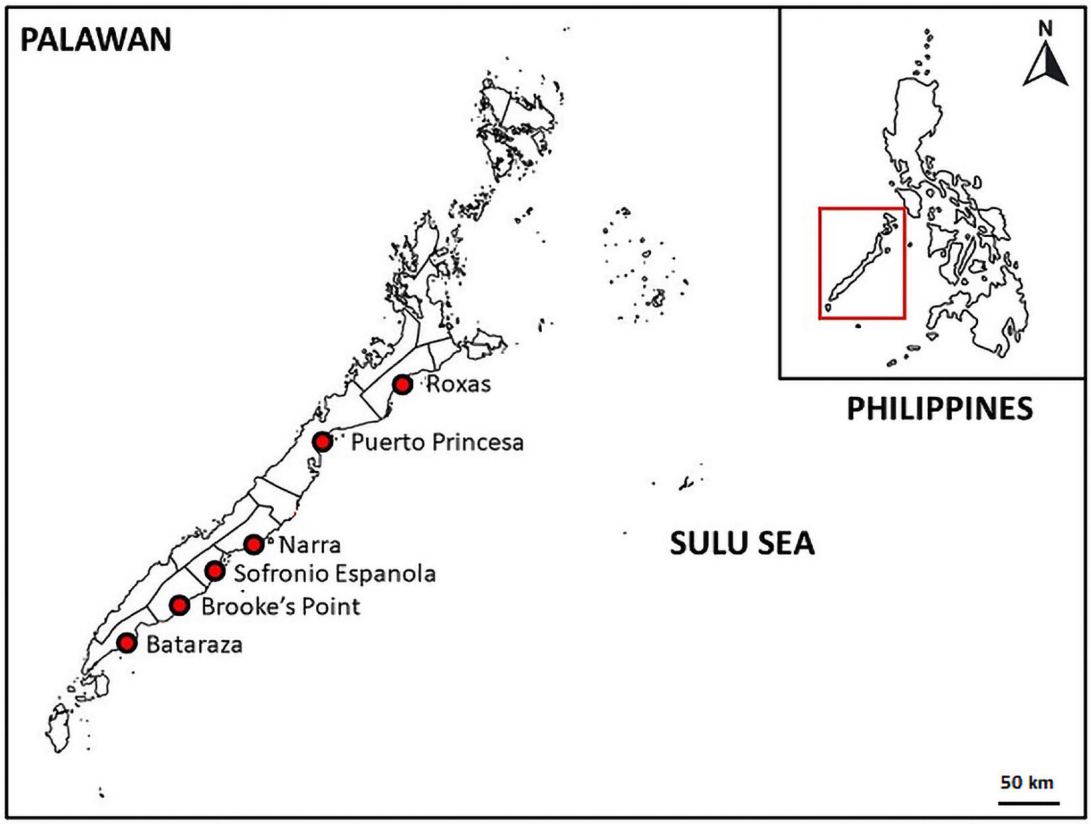

Figure 1. Location of six sampling sites for economically important benthic macroinvertebrate assessments in the reefs of West Sulu Sea, Palawan, Philippines.

Sampling Procedure

The study was conducted between May 2016–July 2017 during the southwest monsoon (*habagat*) (Table 1). This was carried out in conjunction with coral and fish visual census surveys using scuba diving. All assessments were conducted between 08:00 AM–03:00 PM.

We selected reef areas that are large enough (*i.e.* > 1,000 m^2) to cover at least two transects per station, with depths not more than 10 m, and avoided stations with patchy reefs and too much rubble. In each station, 2–8 belt transects (50 m x 5 m) (depending on reef size) were laid at a relatively uniform depth that is parallel to the shoreline. Each belt transect covers an area of 250 m^2 and was carefully examined for the presence of economically important benthic macroinvertebrates in the substrates and crevices. We limit the survey to "economically important" species, which are harvested because of their economic use, such as food, souvenir item, components of handicrafts and decorations, jewelry, and other non-traditional uses. Species found within the belt transects were listed on a slate board and only a few representative individuals per species were photographed *in situ* using an underwater camera. No specimens were collected throughout the survey. We identified the species encountered based on their morphological features – following the works of Schoppe (2000), Jontila *et al.* (2014), and Dolorosa *et al*. (2015). The valid scientific names and taxonomic authorities were verified using the WoRMS (World Register of Marine Species) (Horton *et al.* 2021) and Sea Life Base (Palomares and Pauly 2021).

We computed the overall population and mean species densities (individual ha^{-1}) per site. The works of Schoppe (2000), Floren (2003), Purcell *et al.* (2012), and Jontila *et al.* (2014) were used as the basis for determining the economic uses of each species. We also determined the conservation status of each species identified using the Red List of Threatened Species by the International Union for Conservation of Nature (IUCN 2021).

RESULTS

Species Composition

We encountered a total of 15 economically important benthic macroinvertebrate species belonging to 11 families during the different surveys: one crustacean species

(Phylum Arthropoda), five sea cucumbers and sea urchins (Phylum Echinodermata), and nine gastropods and bivalve species (Phylum Mollusca) (Figures 2 and 3; Table 1).

Among the sites surveyed, Bataraza stations had the highest number of species with 10; followed by Narra and Puerto Princesa with five species each; and Roxas (four species), Brooke's Point (three species), and Sofronio Española (two species). Across sites, the most common species was *Tridacna crocea,* being noted in all sites. *Holothuria edulis*, *T. rubralineata*, *T. maxima*, *C. miles*, *C. tigris*, *P. margaritifera*, *A. pectinata*, and *L. lambis* occurred only in one site (Table 2)

Population Density

The overall mean (± SD) population density of benthic macroinvertebrates was computed at 25.1 (± 78.1) individuals ha^{-1}. Among the sites surveyed, Bataraza stations had the highest mean (± SD) population density at 178.0 (± 505.2) individuals ha^{-1}, followed by Roxas with 59.6 (± 84.5) individuals ha^{-1}, Sofronio Española (26.7 ± 9.4 individuals ha^{-1}), Brooke's Point (15.6 ± 10.2 individuals ha^{-1}), Narra (14.6 ± 15.1 individuals ha^{-1}), and Puerto Princesa City (10.7 ± 15.8 individuals ha^{-1}) (Table 3).

Among the species, the three species with the highest mean (± SD) population density were *D. setosum* (306.4 ± 645.1 individuals ha^{-1}), *T. crocea* (25.6 ± 9.8 individuals ha^{-1}), and *E. calamaris* (13.2 ± 23.6 individuals ha^{-1}). The rest of the species had densities of less than 10 individuals ha^{-1} each (Table 3).

Economic Uses

In terms of economic use, 12 species are utilized as "food", six species are sold as "souvenir items," two species are used in making "jewelry," and three species are harvested both as "food" and "souvenir or jewelry." The pearl from *P. margaritifera* is used as a component of jewelry, whereas the shell of *R. nilotica* is used both for making shell buttons and traditional jewelry. Species collected as souvenir items include *C. tigris*, *L. lambis*, *T. maxima*, *T. squamosa*, and *T. crocea*. The rest are usually consumed as food (Table 4).

Conservation Status

Based on the IUCN Red List, five of the economically important species encountered in this study have "Least Concern" status (*i.e. P. versicolor*, *H. edulis*, *P. graeffei*, *C. miles*, and *T. crocea*), two species have "Lower Risk/ Conservation Dependent" status (*i.e. T. maxima* and *T. squamosa*), one species has a "Data Deficient" status (*i.e. T. rubralineata*), and the rest have a "Not Evaluated" status (Table 4).

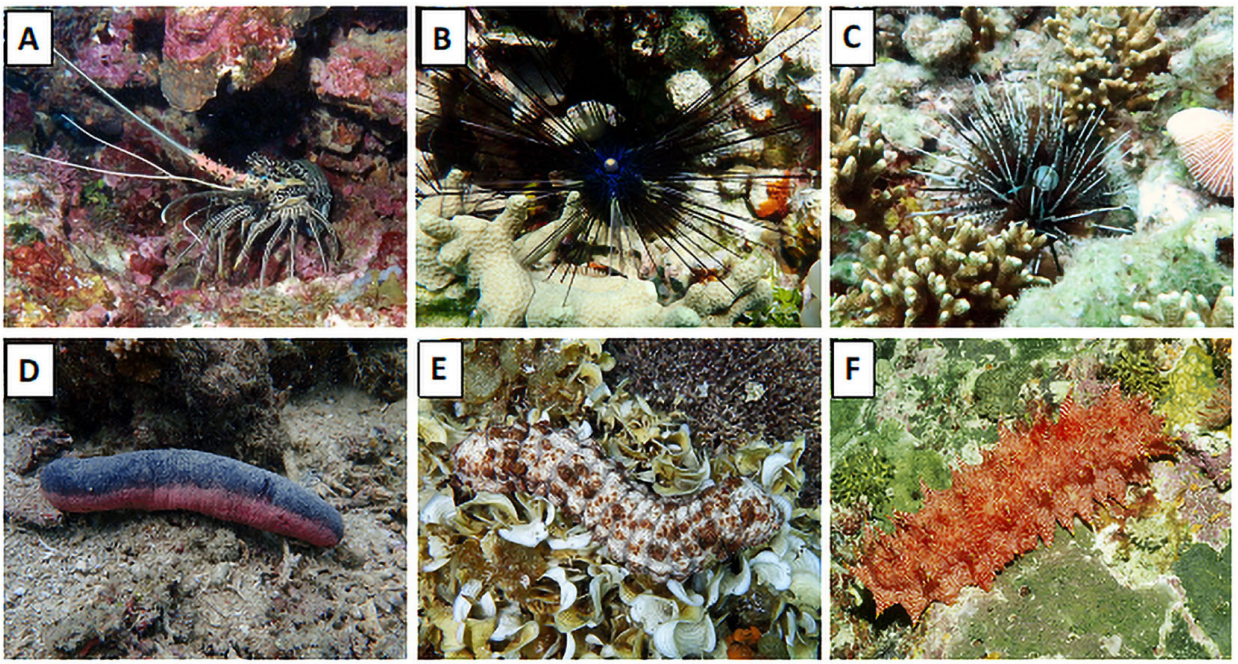

Figure 2. Some of the economically important benthic macroinvertebrates encountered in the surveyed sites of West Sulu Sea, Palawan, Philippines: painted spiny lobster *Panulirus versicolor* (A), long-spined sea urchin *Diadema setosum* (B), banded sea urchin *Echinothrix diadema* (C), pinkfish *Holothuria edulis* (D), Graeffei's sea cucumber *Pearsonothuria graeffei* (E), and striped sea cucumber *Thelenota rubralineata* (F). Photo credits: D.G. Tabaranza (A) and F.R. MacConnaughey (F).

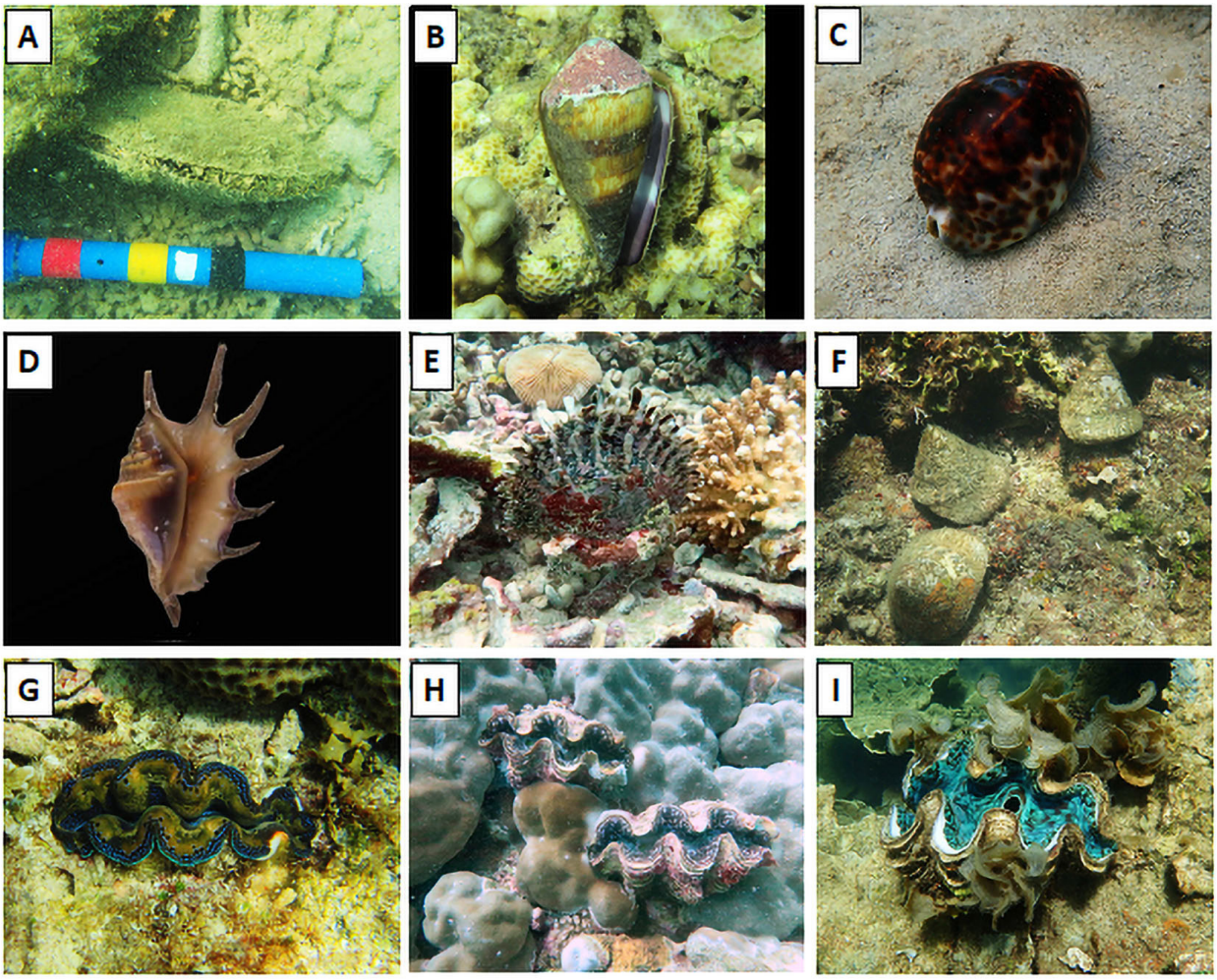

Figure 3. Some of the economically important benthic macroinvertebrates encountered in the surveyed sites of West Sulu Sea, Palawan, Philippines: comb pen shell *Atrina pectinata* (A), soldier cone *Conus miles* (B), tiger cowrie *Cypraea tigris* (C), spider conch *Lambis lambis* (D), black-lip pearl oyster *Pinctada margaritifera* (E), commercial top shell *Rochia nilotica* (F), crocus giant clam *Tridacna crocea* (G), elongate giant clam *Tridacna maxima* (H), and fluted giant clam *Tridacna squamosa* (I).

Table 1. Family, scientific, common, and local names of economically important benthic macroinvertebrates encountered in the surveyed reefs of West Sulu Sea, Palawan, Philippines.

Family name	Scientific names and author	Common name	Local name
Phylum Arthropoda			
Palinuridae	1. *Panulirus versicolor* (Latreille 1804)	Painted spiny lobster	*Banagan*
Phylum Echinodermata			
Diadematidae	2. *Diadema setosum* (Leske 1778)	Porcupine sea urchin	*Tayong*, *tayom*
Diadematidae	3. *Echinothrix calamaris* (Pallas 1774)	Banded sea urchin	*Tayong*, *tayom*
Holothuriidae	4. *Holothuria edulis* Lesson 1830	Pinkfish	Hotdog
Holothuriidae	5. *Pearsonothuria graeffei* (Semper 1868)	Graeffei's sea cucumber	Flower, *balat*
Stichopodidae	6. *Thelenota rubralineata* Massin and Lane 1991	Striped sea cucumber	Legs
Phylum Mollusca			

Table 1. Family, scientific, common, and local names of economically important benthic macroinvertebrates encountered in the surveyed reefs of West Sulu Sea, Palawan, Philippines.

Family name	Scientific names and author	Common name	Local name
Cardiidae	7. *Tridacna crocea* Lamarck 1819	Crocus giant clam	*Manlit*
Cardiidae	8. *Tridacna maxima* (Röding 1798)	Elongate giant clam	*Taklobo*
Cardiidae	9. *Tridacna squamosa* Lamarck 1819	Fluted giant clam	*Taklobo*
Conidae	10. *Conus miles* Linnaeus 1758	Soldier cone	–
Cypraeidae	11. *Cypraea tigris* Linnaeus 1758	Tiger cowrie	–
Margaritidae	12. *Pinctada margaritifera* (Linnaeus 1758)	Black-lip pearl oyster	–
Pinnidae	13. *Atrina pectinata* (Linnaeus 1767)	Comb pen shell	–
Strombidae	14. *Lambis lambis* Linnaeus 1758	Spider conch	*Saang*, *lambis*
Tegulidae	15. *Rochia nilotica* (Linnaeus 1758)	Commercial top shell	*Samong*

Table 2. Occurrence of economically important benthic macroinvertebrates in the reefs of surveyed sites in the West Sulu Sea, Palawan, Philippines. Note: positive (+) sign means the presence of such benthic macroinvertebrates in the surveyed site. Abbreviation used: ROX – Roxas, PPC – Puerto Princesa City, NAR – Narra, SES – Sofronio Española, BRP – Brooke's Point, and BAT – Bataraza.

Family name		ROX	PPC	NAR	SES	BRP	BAT
Phylum Arthropoda							
Palinuridae	1. *Panulirus versicolor*	+					+
Phylum Echinodermata							
Diadematidae	2. *Diadema setosum*	+	+		+		+
Diadematidae	3. *Echinothrix calamaris*	+	+				+
Holothuriidae	4. *Holothuria edulis*		+				
Holothuriidae	5. *Pearsonothuria graeffei*			+			+
Stichopodidae	6. *Thelenota rubralineata*			+			
Phylum Mollusca							
Cardiidae	7. *Tridacna crocea*	+	+	+	+	+	+
Cardiidae	8. *Tridacna maxima*						+
Cardiidae	9. *Tridacna squamosa*		+	+			+
Conidae	10. *Conus miles*					+	
Cypraeidae	11. *Cypraea tigris*						+
Margaritidae	12. *Pinctada margaritifera*						+
Pinnidae	13. *Atrina pectinata*						+
Strombidae	14. *Lambis lambis*					+	
Tegulidae	15. *Rochia nilotica*			+			
Total		**4**	**5**	**5**	**2**	**3**	**10**

Table 3. Estimated mean (± SD) population densities (individuals ha^{-1}) of economically important benthic macroinvertebrates encountered in the reefs of surveyed sites in the West Sulu Sea, Palawan, Philippines. Abbreviation used: ROX – Roxas, PPC – Puerto Princesa City, NAR – Narra, SES – Sofronio Española, BRP – Brooke's Point, and BAT – Bataraza.

Family name		ROX	PPC	NAR	SES	BRP	BAT	Mean (± SD)
Phylum Arthropoda								
Palinuridae	1. *Panulirus versicolor*	7.3 (± 10.1)	0	0	0	0	5.0 (± 10.0)	**2.1 (± 3.3)**
Phylum Echinodermata								
Diadematidae	2. *Diadema setosum*	185.5 (± 383.1)	4.4 (± 13.3)	0	33.3 (± 81.7)	0	1,615 (± 1,897.6)	**306.4 (± 645.0)**
Diadematidae	3. *Echinothrix calamaris*	14.5 (±48.2)	4.4 (± 13.3)	0	0	0	60.0 (± 120)	**13.2 (± 23.6)**
Holothuriidae	4. *Holothuria edulis*	0	13.3 (± 33.2)	0	0	0	0	**2.2 (± 5.4)**
Holothuriidae	5. *Pearsonothuria graeffei*	0	0	2.1 (±6.3)	0	0	25 (± 37.9)	**4.5 (± 10.1)**
Stichopodidae	6. *Thelenota rubralineata*	0	0	5.0 (± 10.0)	0	0	0	**0.8 (± 2.0)**
Phylum Mollusca								
Cardiidae	7. *Tridacna crocea*	30.9 (± 49.3)	40.0 (± 42.4)	10.9 (± 27.0)	20.0 (± 31.0)	26.7 (± 30.6)	25.0 (± 25.2)	**25.6 (± 9.8)**
Cardiidae	8. *Tridacna maxima*	0	0	0	0	0	10.0 (± 20.0)	**1.7 (± 4.1)**
Cardiidae	9. *Tridacna squamosa*	0	2.2 (± 6.7)	15.2 (± 52.5)	0	0	10.0 (± 20.0)	**4.6 (± 5.9)**
Conidae	10. *Conus miles*	0	0	0	0	13.3 (± 23.1)	0	**2.2 (± 5.4)**
Cypraeidae	11. *Cypraea tigris*	0	0	0	0	0	15.0 (± 19.1)	**2.5 (± 6.1)**
Margaritidae	12. *Pinctada margaritifera*	0	0	0	0	0	5.0 (± 10.0)	**0.8 (± 2.0)**
Pinnidae	13. *Atrina pectinata*	0	0	0	0	0	10.0 (± 20.0)	**1.7 (± 4.1)**
Strombidae	14. *Lambis lambis*	0	0	0	0	6.7 (± 11.5)	0	**1.1 (± 2.7)**
Tegulidae	15. *Rochia nilotica*	0	0	40 (± 28.3)	0	0	0	**6.7 (± 16.3)**
Mean (±SD)		**59.6 (± 84.5)**	**10.7 (± 15.8)**	**14.6 (± 15.1)**	**26.7 (± 9.4)**	**15.6 (± 10.2)**	**178.0 (± 505.2)**	**25.1 (± 78.1)**

Table 4. Economic uses and conservation status of economically important benthic macroinvertebrates encountered in the surveyed reefs of West Sulu Sea, Palawan, Philippines. The conservation status was based on the International Union for Conservation of Nature Red List (IUCN 2021).

Species	Economic use	Conservation status (IUCN Red List)
Phylum Arthropoda		
Panulirus versicolor	Food	Least Concern
Phylum Echinodermata		
Diadema setosum	Food	Not Evaluated
Echinothrix calamaris	Food	Not Evaluated
Holothuria edulis	Food	Least Concern
Pearsonothuria graeffei	Food	Least Concern
Thelenota rubralineata	Food	Data Deficient
Phylum Mollusca		
Atrina pectinata	Food	Not Evaluated
Conus miles	Food	Least Concern
Cypraea tigris	Souvenir	Not Evaluated
Lambis lambis	Food, souvenir	Not Evaluated
Pinctada margaritifera	Food, for jewelry	Not Evaluated
Rochia nilotica	Food, for jewelry	Not Evaluated
Tridacna crocea	Food, souvenir	Least Concern
Tridacna maxima	Food, souvenir	Lower Risk/ Conservation Dependent
Tridacna squamosa	Food, souvenir	Lower Risk/ Conservation Dependent

DISCUSSION

Species Composition

The number of economically important benthic macroinvertebrate species encountered in the surveyed sites is considered "low" in comparison with other studies. This low number of species may be explained by the time of sampling, environmental parameters, and the level of exploitation in the area. Due to the limited sampling time, most of the species recorded are diurnal (*i.e.* active during the daytime), and nocturnal species may not have been detected as the surveys were conducted between 08:00 AM–03:00 PM). Water visibility (*i.e.* a measure of the clarity of water) was also a factor in observing some species since some of the sampling sites have poor visibility (< 10 m), making it very difficult to spot cryptic species. Additionally, the West Sulu Sea is a traditional fishing ground for many artisanal fishermen, and the catch trend has significantly decreased over the past years, including macroinvertebrates (Candelario *et al.* 2018).

Several gastropod species (*e.g. R. nilotica*), which are abundant on well-protected reefs (*e.g.* Tubbataha Reefs Natural Park, TRNP) (Dolorosa 2015; Dolorosa *et al*. 2016) were only found on a reef of Narra. This species was once abundant in many reefs but became so rare in most of its distribution range due to overharvesting of its shell used in the manufacture of shell buttons (Dolorosa *et al.* 2016). The horned helmet conch *C. cornuta*, which is also abundant in TRNP (Dolorosa *et al*. 2013a; Dolorosa 2015), was not noted in this study. This species prefers sandy and rubble patches within the reef, tends to hide under the sand during the day, and actively feeds at night (Poutiers 1998), making them difficult to notice during the day surveys.

Of the eight giant clam species that are known to occur in the Philippines and Palawan in particular (Ecube *et al*. 2019; Dolorosa *et al*. 2015), only three species were noted in this study, suggesting a decline in the population of other species in many areas. A few living individuals of true giant clam *Tridacna gigas* (Linnaeus 1758) could be found even in shallow waters in well-managed areas (Mecha and Dolorosa 2020). However, this study did not find even an empty shell of this endangered species among the surveyed sites.

Among the sea cucumbers, only three species were encountered in this study: *H. edulis*, *P. graeffei*, and *T. rubralineata*. There are about 32 reef-inhabiting economically important sea cucumber species recorded in Palawan (Jontila *et al*. 2014), 13 each in Tubbataha (Dolorosa 2015) and Arreceffi Island in Puerto Princesa City (Jontila *et al.* 2017), and only four in Pag-asa Island of the Kalayaan Island Group (Balisco *et al.* 2020). The low number of sea cucumber species found in this study could be related to sampling strategies, types of habitats surveyed, and level of exploitation. Sampling activities were conducted during the day, preventing the documentation of nocturnal species. In addition, the survey was only limited to reef areas and did not cover other known sea cucumber habitats such as seagrass and sandy areas. Similarly, sea cucumbers are one of the most heavily harvested commodities in Palawan and previous studies showed signs of overfishing of this species group, including the shift in the capture of undersized individuals and low-value species (Jontila *et al.* 2014; Dolorosa *et al*. 2017; Jontila *et al.* 2017). Being found in easily accessible habitats (*e.g.* seagrass beds and coral reefs), their slow movement and growth made them highly susceptible to overharvesting. They have been locally extinct in many places and there is already a need to include their habitats as part of protected areas (Anderson *et al.* 2010; Jontila *et al*. 2014). These circumstances make the sea cucumber

species a good candidate species for responsible stock enhancement programs (Gonzales 2005).

Lobsters are nocturnal creatures but we observed them hiding in reef crevices during the day sampling in some reefs of Bataraza and Roxas. Five lobster species are recorded from Palawan (*Panulirus ornatus* (Fabricius 1798), *Panulirus longipes longipes* (Milne-Edwards 1868), *Panulirus penicillatus* (Olivier 1791), *P. versicolor*, and *Thenus orientalis* (Lund 1793) (Gonzales and Taniguchi 1995), but only *P. versicolor* was encountered in this study. Lobsters are also one of the most exploited invertebrates because of high market demand, but their populations have already dwindled in many parts of Southeast Asia (particularly the Philippines) due to overexploitation and destruction of their natural habitat (Gonzales and Tanaguchi 1995; Juinio-Meñez and Gotanco 2004). The increased grow-out activities of lobsters in Palawan and other provinces resulted in the heavy collection of lobsters from the wild to supply the industry's grow-out and export demand (Gonzales and Taniguchi 1995; Juinio-Meñez and Gotanco 2004; Baguinbin *et al*. 2015).

Population Density

The differences in population density of each species across sites surveyed can be attributed to habitat differences, transect depths, rate of exploitation, and level of management (Dolorosa and Jontila 2012). The mean density of giant clams in this study is estimated at 31.8 individuals ha^{-1}, which is mainly comprised of the smallest species *T. crocea* (25.6 individuals ha^{-1}), which has been also recorded in all surveyed sites. The presence of empty giant clam shells from at least one species was noted in a few stations which is a sign of continued exploitation. The mean giant clam density in this study is lower compared to other studied reefs in Palawan. Giant clams abound in well-managed reef areas (*e.g.* TRNP, Apulit Island) (Gonzales *et al.* 2014a; Conales *et al*. 2015), but are less abundant in open access areas such as the reefs of Pag-asa Island of the Kalayaan Island Group (Balisco *et al*. 2020) (Table 5).

In undisturbed habitats, giant clams can occur in substantial numbers. In the Eastern Tuamotus in the South Pacific and Dongsha Atoll in the South China Sea, enormous populations of *T. maxima* were documented although the species is considered endangered in most of its range (Andrefouet *et al.* 2005; PCSD 2010; Neo *et al.* 2018). Aside from being a source of food, giant clams have tremendous ecological importance and, thus, the decline of their population can cause ecological imbalance and could affect the lives of coastal fishers (Cabaitan *et al.* 2008; Neo *et al.* 2015; Mecha and Dolorosa 2020). There have been success stories in restoring giant clam populations in areas with limited access to any forms of extractions (*e.g.* resorts, marine protected areas) (Gomez and Mingoa-Licuanan 2006; Gonzales *et al*. 2014a; Jontila *et al*. 2017). However, the success of any restoration activity in open access areas highly depends on the cooperation of local stakeholders and political will. Hence, collaborative efforts among different sectors involved are critical to protect and revive the populations of these species.

The population density of sea cucumbers in this study was considered "low" (7.6 individuals ha^{-1}) compared to other parts of Palawan (Arreceffi Island, 359 individuals ha^{-1}; Pag-asa Island, 175 individuals ha^{-1}; TRNP, 42 individuals ha^{-1}), but higher than in Apulit Island (7 individuals ha^{-1}) (Table 6). This low population density suggests that these species are overharvested on many parts of the West Sulu Sea (Jontila *et al.* 2014; Dolorosa *et al.* 2017) and was also observed by some gatherers operating in the said area (pers. comm.). Sea cucumbers are slow-moving marine organisms that are found in easily accessible habitats (*e.g.* seagrass beds and coral reefs). They are one of the most exploited macroinvertebrates in Palawan and most of the populations have already declined in the wild (Dolorosa and Jontila 2012; Jontila *et al*. 2014). Similarly, if the health of the reefs declines, reef-associated sea cucumbers are also in peril. They are already overharvested in many countries, and some are even on the brink of local extinction, which is usually irreversible in nature (Jontila *et al*. 2014). Its high market demand and lucrative price have led to the collection of undersized sea cucumbers, some of which fetch lower prices due to their smaller sizes when dried. With the declining population of highly valued species in the wild, low-valued species are now being harvested to cater to the increasing demand for dried products in international markets (Purcell *et al.* 2012; Dolorosa *et al*. 2017).

Table 5. Comparison of the mean population densities (individuals ha^{-1}) of giant clams (*Tridacna* spp., *Hippopus* spp.) in the different reef sites of Palawan, Philippines.

Location	Site/reef	Density	Sources
Cayancillo	Tubbataha Reefs Natural Park	22,000	Conales *et al.* (2015)
Kalayaan	Pag-asa Island	175	Balisco *et al.* (2020)
Taytay	Apulit Island	681	Gonzales *et al.* (2014a)
West Sulu Sea	**Various reefs**	**31.8**	**This study**

Table 6. Comparison of the mean population densities (individuals ha^{-1}) of sea cucumbers in different reef sites of Palawan, Philippines.

Location	Site/reef	Density	Source
Puerto Princesa City	Arreceffi Island	359	Jontila *et al.* (2017)
Cagayancillo	Tubbataha Reefs Natural Park	42	Dolorosa (2015)
Kalayaan	Pag-asa Island	175	Balisco *et al*. (2020)
Taytay	Apulit Island	7	Gonzales *et al.* (2014b)
West Sulu Sea	**Various reefs**	**7.6**	**This study**

Economic Uses

The economic uses of benthic macroinvertebrates from the West Sulu Sea varied across localities. A majority of sea cucumbers, mollusks, and lobsters are consumed locally as food, whereas few are collected for jewelry or souvenir items (Gonzales and Taniguchi 1995; Floren 2003; Jontila *et al.* 2014; Dolorosa *et al.* 2015). These macroinvertebrates are either sold to a local buyer, wet markets, peddled in the streets or nearby neighborhoods, or sold to souvenir shops (Floren 2003; del Norte-Campos *et al.* 2005). On the other hand, sea cucumbers are usually brought directly to a local processor, where they are processed into a dried form (internationally known as *trepang* or *beche-de-mer*) before being sold to a local middleman or to a buyer in Puerto Princesa City (Jontila *et al.* 2014). In general, the buyer sets the price for dried products based on the species, quality, and size (Purcell *et al.* 2012; Jontila *et al.* 2014). *Holothuria edulis* is considered a low-value species, whereas *P. graeffei* and *T. rubralineata* are considered medium-valued species (Purcell *et al.* 2012). Other high-valued sea cucumber species usually encountered in coral reefs of Palawan (*e.g. Holothuria scabra, Holothuria whitmaei, Holothuria fuscogilva, Stichopus* spp.) (Jontila *et al.* 2014; Dolorosa 2015) were not noted in the present study. The Philippines exported 429 tons of dried sea cucumbers valued at PHP 355 million in 2019, and the collapse of this fishery would, therefore, affect the country's revenue and fishers highly dependent on this resource (DA-BFAR 2020).

The majority of the species encountered in this study (except for *C. tigris*) are utilized as food by the nearby local communities. The spines of *D. setosum* and *E. calamaris* are removed to open the body, revealing the gonads which are consumed raw or flavored with vinegar. The commonly consumed and exported sea urchin species, *Tripneustes gratilla,* was not encountered in this study, although they are also known to inhabit reef areas. *Atrina pectinata, C. miles, L. lambis, P. margaritifera,* and *R. nilotica* are also consumed locally and are sometimes sold in the wet markets together with other mollusks. Aside from food, *P. margaritifera* is also harvested for its occasional pearls, whereas *R. nilotica* is exploited for its lustrous mother-of-pearl layer used to produce shell buttons. Both pearls and mother of pearls are used as key components of traditional and sophisticated jewelry.

The gathering of giant clams is prohibited by existing laws (*e.g.* Republic Act No. 9147, Republic Act No. 10654), but anecdotal evidence from local communities proved that they are still harvested as food. Their shells are valuable souvenir items and are used as decoration in churches, houses, restaurants, *etc.* (Mecha and Dolorosa 2020). Giant clam shells have recently been used as an alternative material for ivory in carvings, thus, the demand for their shells has increased in recent years (Gomez 2015). As such, hundreds of tons of giant clam shells have been traded from Palawan (Floren 2003), and the confiscation of 200 tons of giant clam shells in 2021 amounting to PHP 1.2 billion are manifestations of a once abundant giant clam population (Miranda 2021). When giant clams are protected, they can be potential candidate components of a sustainable ecotourism and aquarium industry (Rabiyanti *et al.* 2020).

Other high-value species previously recorded in Palawan reefs (*e.g. C. cornuta, C. tritonis,* and *T. marmoratus*) were absent in this study. These species are protected under Philippine laws and local legislation (*i.e.* Republic Act No. 9147, Republic Act No. 10654, PCSD Resolution No. 10-413) and have been actively conserved in areas where their population can potentially recover. Their shells are common items in many souvenir shops (Floren 2003), but they are now difficult to find in most reefs of Palawan, except in TRNP where they are strictly protected (Dolorosa *et al*. 2013a, 2015). Stock enhancement efforts for these mollusks are important as they are vital components of a balanced reef ecosystem (Hall *et al.* 2017) and fisheries. Shell export substantially contributed to the national economy in 2019 as 4,499 metric tons (valued at PHP 180.1 million) were exported during that period (DA-BFAR 2020).

Conservation Status

Five species were listed as "Least Concern" species under IUCN Red List: *P. versicolor*, *H. edulis*, *P. graffei*, *C. miles*, and *T. crocea. Panulirus versicolor* is one of the most expensive marine commodities in the world due to its high international demand (Juinio-Meñez and Gotanco 2004). The unregulated heavy collection of baby and gravid lobsters from the wild proliferates in the country resulted in their overexploitation (Gonzales and Taniguchi 1995; Juinio-Meñez and Gotanco 2004).

Both *H. edulis* and *P. graeffei* are among the conspicuous macroinvertebrates on coral reefs because of their striking features and colorations. However, even though they have "Least Concern" status, there are indications that their populations have already declined in many parts of Palawan waters (Jontila *et al*. 2017). Due to declining populations of high-value species, many fishers target species of "low" to "medium" value, even if they are undersized (Anderson *et al.* 2010; Dolorosa *et al*. 2017). If this situation continues, it may lead to the eventual collapse of this lucrative fishery. Thus, including known sea cucumber habitats as part of marine protected areas is an important step in their conservation and restoration.

Although *T. crocea* is a "Least Concern," and *T. maxima* and *T. squamosa* have Lower Risk/ Conservation Dependent status based on IUCN Red List, they are protected by existing Philippine laws (Republic Act No. 9147; Republic Act No. 10654). A few empty giant clam shells in some sampling sites suggest that they are still consumed locally despite the prohibition on the gathering and trading of these resources. Thus, to further strengthen their protection, giant clams, top shells, turban snails, and many other large reef invertebrates in Palawan are legally protected through Resolution No. 10-413 (PCSD 2010). Other efforts were also made to increase the wild populations of these important species, including the establishment of hatcheries for top shell (*R. nolitica*) and giant clams (*Hippopus* spp., *Tridacna* spp.) for stock enhancement and restocking purposes in a project collaboration between the Malampaya Foundation, Inc., Western Philippines University, and other institutions (Dolorosa *et al.* 2013b; MFI 2020).

The population of other species with "Not Evaluated" status may already have decreased in many localities before they can be assessed. Thus, it is imperative to assess their status so that their management and protection can be improved. Efforts must be undertaken to revive the dwindling wild populations of these benthic macroinvertebrates so that the organisms dependent on them will be able to reap the benefits of many ecosystem services they offer.

CONCLUSION AND RECOMMENDATIONS

The number of benthic macroinvertebrate species in surveyed sites in the West Sulu Sea, Palawan is relatively "low" compared with other studies. The low density of *T. maxima* and *T. squamosa* and the absence of some giant clam species (*e.g. T. gigas*, *T. noae*), including some economically important large gastropods (*e.g. C. tritonis*, *C. cornuta*, and *T. marmoratus*) implies overexploitation of these species. The individual conservation status of these species additionally supports the scarcity of some species in the surveyed sites. Most of the species encountered have "Least Concern" and "Not Evaluated" status, whereas endangered species that were recorded before are already difficult to find in the surveyed sites. A long-term management plan (*e.g.* setting up of harvest quotas, regulating the harvesting of juvenile and gravid individuals, responsible stock enhancement, *etc.*) must be well-crafted to sustain the marine ecosystem and the utilization of these critical marine resources. Their potential as commodities for sustainable ecotourism may likewise be given attention.

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STATEMENT OF CONFLICT OF INTEREST

There is no conflict of interest among the authors.

NOTES ON APPENDICES

The complete appendices section of the study is accessible at https://philjournsci.dost.gov.ph

REFERENCES

ANDERSON SC, FLEMMING JM, WATSON R, LOTZE HK. 2010. Serial exploitation of global sea cucumber fisheries. Fish and Fisheries 12(3): 317–339. https://doi.org/10.1111/j.14672979.2010.00397.x

ANDREFOUET S, GILBERT A, YAN L, REMOISSENET G, PAYRI C, CHANCERELLE Y. 2005. The remarkable population size of the endangered clam *Tridacna maxima* assessed in Fangatau Atoll (Eastern Tuamotu, French Polynesia) using *in situ* and remote sensing data. ICES J Mar Sci 62: 1037–1048.

BAGUINBIN DM, DOLOROSA RG, BALISCO RAT, BAACO AT. 2015. Profitability of live lobster trading in Araceli, Palawan, Philippines. In: Science, Technology, & Innovation. Matula JLS, Cabrestante MP, Palon MP, Regoniel PA, Gonzales BJ, Devanadera NP eds. Proceedings of the 2nd Palawan Research Symposium 2015, National Research Forum on Palawan Sustainable Development; 09–10 Dec 2015; Puerto Princesa City, Palawan, Philippines. p. 113–117.

BALISCO RAT, DOLOROSA RG. 2019. The reef-associated fishes of West Sulu Sea, Palawan, Philippines: A checklist and trophic structure. AACL Bioflux 12(1): 1260–1299.

BALISCO RAT, GONZALES BJ, DOLOROSA RG. 2020. Species composition, abundance, and conservation status of commercially important macrobenthic invertebrates in Pag-asa Island, Kalayaan, Palawan, Philippines. Asian Fisheries Science 33(4): 357–365. https://doi.org/10.33997/j.afs.2020.33.4.007

CABAITAN PC, GOMEZ ED, ALIÑO PM. 2008. Effects of coral transplantation and giant clam restocking on the structure of fish communities on degraded patch reefs. Journal of Experimental Marine Biology and Ecology 357(1): 85–98.

CANDELARIO MB, GONZALES LM, JARDIN JA. 2018. Status of fisheries resources of Honda Bay (2003-2013). The Philippine Journal of Fisheries 25(1): 52–61.

CONALES SF, BUNDAL NA, DOLOROSA RG. 2015. High density of *Tridacna crocea* in exposed massive corals proximate the Ranger Station of Tubbataha Reefs Natural Park, Cagayancillo, Palawan, Philippines. The Palawan Scientist 7: 36–39.

[DA-BFAR] Department of Agriculture – Bureau of Fisheries and Aquatic Resources. 2020. Philippines Fisheries Profile (2019). Department of Agriculture – Bureau of Fisheries and Aquatic Resources, PCA Compound, Elliptical Road, Quezon City. 76p.

DE GUZMAN AB. 2019. Women in subsistence fisheries in the Philippines: The undervalued contribution of reef gleaning to food and nutrition security of coastal households. SPC Women Fisheries Bulletin 29: 34–40.

DE GUZMAN AB, SUMALDE ZM, RANCE GMS, COLANCE MDB, PONCE MFV. 2019. Contribution of gleaning fisheries to food security and nutrition of poor coastal communities in the Philippines. Journal of Environmental Science and Management SI(1): 58–71.

DEL NORTE-CAMPOS AGC, CAMPOS WL, VILLARTA KA. 2005. A survey of macro-invertebrate gleaning in the Banate Bay intertidal area, Eastern Panay Island. Science Diliman 17(2): 11–20.

DOLOROSA RG. 2015. The sea cucumbers (Echinodermata: Holothuroidea) of Tubbataha Reefs Natural Park, Philippines. SPC Bêche-de-mer Information Bulletin 35: 10–18.

DOLOROSA RG, JONTILA JBS. 2012. Notes on common macrobenthic reef invertebrates of Tubbataha Reefs Natural Park, Philippines. Science Diliman 24(2): 1–11.

DOLOROSA RG, CONALES SF, BUNDAL NA. 2013a. Status of horned helmet *Cassis cornuta* in Tubbataha Reefs Natural Park, and its trade in Puerto Princesa City, Philippines. Atoll Research Bulletin 595: 1–17. https://doi.org/10.5479/si.00775630.595

DOLOROSA RG, GRANT A, GILL JA, AVILLANOSA AL, GONZALES BJ. 2013b. Indoor and deep sub-tidal intermediate culture of *Trochus niloticus* for restocking. Reviews in Fisheries Science 21 (3–4): 414–423.

DOLOROSA RG, PICARDAL RM, CONALES SF. 2015. Bivalves and gastropods of Tubbataha Reefs Natural Park, Philippines. Checklist 11(1): 1–12. https://doi.org/10.15560/11.1.1506

DOLOROSA RG, GRANT A, GILL JA. 2016. Spatial and temporal abundance of the reef gastropod *Tectus niloticus* (Gastropoda: Tegulidae) in Marine Protected Areas in Palawan, Philippines: prospects for conservation. Iranica Journal of Energy and Environment 7(2): 193–202. 10.5829/idosi.ijee.2016.07.02.16

DOLOROSA RG, SALAZAR CB, DELFIN MTV, PADUGA JR, BALISCO RAT. 2017. Sea cucumber fisheries in Rasa Island Wildlife Sanctuary, Narra, Palawan, Philippines. SPC Beche-de-mer Information Bulletin 37: 9–20.

ECUBE KMA, VILLANUEVA EG, DOLOROSA RG, CABAITAN RC. 2019. Notes on the first record of *Tridacna noae* (Röding 1798) (Cardiidae: Tridacninae) in Palawan, Philippines. The Palawan Scientist 11: 112–115.

FLOREN AS. 2003. The Philippine shell industry with special focus on Mactan, Cebu. Coastal Resource Management Project. Department of Environment and Natural Resources, Manila, Philippines. 50p.

FURKON, NESSA MN, AMBO-RAPPE R. 2019. Invertebrate gleaning: forgotten fisheries. IOP Conf. Series: Earth and Environmental Studies 253: 012029. 10.1088/1755-1315/253/1/012029

GOMEZ ED. 2015. Rehabilitation of biological resources: coral reefs and giant clam populations need to be enhanced for a sustainable marginal sea in the Western Pacific. Journal of International Wildlife Law & Policy 18(2): 20–127. 10.1080/13880292.2015.1044795

GOMEZ ED, MINGOA-LICUANAN SS. 2006. Achievements and lessons learned in restocking giant clams in the Philippines. Fisheries Research 80(1): 46–52. https://doi.org/10.1016/j.fishres.2006.03.017

GONZALES BJ, GALON WM, BECIRA JG. 2006. Community-based stock enhancement of top shell in Honda Bay, Palawan, Philippines. In: Proceedings of the Regional Technical Consultation on Stock Enhancement for Threatened Species of International Concern; 13–15 Jul 2005; Iloilo City, Philippines. Primavera JH, Quinitio ET, Eguia MRR eds. Aquaculture Department, Southeast Asian Fisheries Development Center, Tigbauan, Iloilo, Philippines. p. 49–59.

GONZALES BJ. 2005. A guide to species selection and principles of marine stock enhancement in the Philippines. Fisheries Resource Management Project. Department of Agriculture-Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines. 27p.

GONZALES BJ, TANIGUCHI N. 1995. Spiny lobster (*Panulirus ornatus, P. versicolor* and *P. longipes longipes*) fishery in Palawan, Philippines: with considerations of its conservation and management. Bulletin of Marine Science and Fisheries – Kochi University 15: 121–130.

GONZALES BJ, DOLOROSA RG, PAGLIAWAN HB, GONZALES MMG. 2014a. Marine resource assessment for sustainable management of Apulit Island, West Sulu Sea, Palawan, Philippines. International Journal of Fisheries and Aquatic Studies 2(2): 130–136.

GONZALES BJ, PAGLIAWAN HB, BECIRA JG, GONZALES MMG. 2014b. Marine resource assessment for sustainable utilization of Snake Island, Palawan, Philippines. AACL Bioflux 7(5): 372–385. http://www.bioflux.com.ro/aacl

HALL MR, MOTTI CA, KROON F. 2017. The potential role of the giant triton snail, *Charonia tritonis* (Gastropoda: Ranellidae) in mitigating population outbreaks of the crown-of-thorns starfish. Integrated Pest Management of Crown-of-Thorns Starfish. Report to the National Environmental Science Programme. Reef and Rainforest Research Centre Limited, Cairns. 58p.

HORTON T, KROH A, AHYONG S, BAILLY N, BIELER R, BOYKO CB *et al.* 2021. World Register of Marine Species. Retrieved on 25 Jul 2021 from https://www.marinespecies.org

via doi:10.14284/170

[IUCN] International Union for Conservation of Nature. 2021. The IUCN Red List of Threatened Species. Version 2021-3. Retrieved on 26 Jul 2021 from https://www.iucnredlist.org

JONTILA JBS, BALISCO RAT, MATILLANO JA. 2014. The sea cucumbers (Holothuroidea) of Palawan, Philippines. AACL Bioflux 7(3): 194–206.

JONTILA JBS, BALISCO RAT, BATIN GT. 2017. Species composition, density, and distribution of sea cucumbers (Holothuroidea) at Arreceffi Island, Honda Bay, Palawan, Philippines. SPC Beche-de-mer Information Bulletin 37: 21–29.

JUINIO-MEÑEZ MA. 2004. Invertebrate stock enhancement. In: In turbulent seas: the status of Philippine marine fisheries, Department of Agriculture, Bureau of Fisheries and Aquatic Resources, Cebu City: Coastal Resources Management Project of the Department of Environment and Natural Resources. p. 241–245.

JUINIO-MEÑEZ MA, GOTANCO RR. 2004. Status of spiny lobster resources in the Philippines. In: Spiny lobster ecology and exploitation in the South China Sea region. Williams KC ed. Proceedings of a workshop held at the Institute of Oceanography; 2004 July; Nha Trang, Vietnam; ACIAR Proceedings 120: 3–6.

KNUDSEN M. 2016. Poverty and beyond: small-scale fishing in overexploited marine environments. Hum Ecol 44: 341–352. https://doi.org/10.1007/s10745-016-9824-y

MAYA MM, AYANO SF. 2021. The impact of population growth on natural resources and farmers' capacity to adapt to climate change in low-income countries. Earth Syst Environ 5: 271–283. https://doi.org/10.1007/s41748-021-00209-6

MECHA NJMF, DOLOROSA RG. 2020. Searching the virtually extinct *Tridacna gigas* (Linnaeus, 1758) in the reefs of Palawan, Philippines. The Philippine Journal of Fisheries 27(1): 1–18. 10.31398/tpjf/27.1.2019-0005

[MFI] Malampaya Foundation, Inc. 2020. 2018–2019 Report. Malampaya Foundation, Inc. p. 18–19. Retrieved on 27 Mar 2022 from https://www.malampayafounda-

tion.org/news/mfi-wpu-closes-year-2020-with-over-132-million-philippines-true-native-tridacna-gigas-spawned

MIRANDA R. 2021. P 1.2-B worth of giant clam shells seized in Palawan; 4 nabbed Retrieved on 14 Feb 2022 from https://newsinfo.inquirer.net/1420452/p-1-2-b-giant-clam-shells-seized-in-palawan-4-nabbed#ixzz7KqTBUFHQ

NEO ML, ECKMAN W, VICENTUAN K, TEO SLM, TODD PA. 2015. The ecological significance of giant clams in coral reef ecosystems. Biological Conservation 181: 111–123. https://doi.org/10.1016/j.biocon.2014.11.004

NEO ML, LIU LL, HUANG DW, SOONG K. 2018. Thriving populations with low genetic diversity in giant clam species, Tridacna maxima and Tridacna noae, at Dongsha Atoll, South China Sea. Regional Studies in Marine Science 24: 278–287.

PALOMARES MLD, PAULY D eds. 2021. SeaLifeBase. World Wide Web electronic publication. www.sealifebase.org, version (12/2021). Accessed on 24–26 Dec 2021.

[PCSD] Palawan Council for Sustainable Development. 2010. Approving the 2010 updated list of terrestrial and marine wildlife in Palawan and their categories pursuant to Republic Act 9147, otherwise known as the Wildlife Resources Conservation and Protection Act" (PCSD Resolution No. 10-413). 13p.

POUTIERS JM. 1998. Gastropods. In: FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific, Volume 1: seaweeds, corals, bivalves, and gastropods. Carpenter KE, Niem VH. eds. FAO, Rome. p. 363–648.

PURCELL SW, SAMYN Y, CONAND C. 2012. Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes No. 6. Rome. 223p.

RABIYANTI I, YULIANDA F, IMRAN Z. 2020. Study of giant clam resources for potential marine tourism in Morella Waters, Central Maluku. IOP Conference Series: Earth and Environmental Sciences 420: 012023. doi:10.1088/1755-1315/420/1/012023

REPUBLIC ACT NO. 9147. 2001. An act providing for the conservation and protection of wildlife resources and their habitats, appropriating funds therefore and for other purposes. Retrieved on 12 Oct 2021 from https://www.officialgazette.gov.ph/2001/07/30/republic-act-no-9417/

REPUBLIC ACT NO. 10654. 2015. An act to prevent, deter and eliminate illegal, unreported, and unregulated fishing, amending Republic Act No. 8550, otherwise known as "The Philippine Fisheries Code of 1998," and for other purposes. Retrieved on 12 Oct 2021 from https://www.officialgazette.gov.ph/2015/02/27/republic-act-no-10654/

SCHOPPE S. 2000. Echinoderms of the Philippines: a guide to common shallow water sea stars, brittle stars, sea urchins, sea cucumbers and feather stars. VISCA-GTZ Program on Applied Tropical Ecology, Visayas State College of Agriculture. 144p.

SZABO K, AMESBURY JR. 2011. Molluscs in a word of islands: the use of shellfish as a food resource in the tropical island Asia-Pacific region. Quaternary International 239: 8–18. https://doi.org/10.1016/j.quaint.2011.02.033

[UN] United Nations. 2018. The 2030 Agenda and the Sustainable Development Goals: an opportunity for Latin America and the Caribbean (LC/G.2681-P/Rev.3), Santiago. 94p.

WILDSMITH MD, ROSE TH, POTTER IC, WARWICK RM, CLARKE KR. 2011. Benthic macroinvertebrates as indicators of environmental deterioration in a large microtidal estuary. Marine Pollution Bulletin 62(3): 525–538. https://doi.org/10.1016/j.marpolbul.2010.11.031

APPENDIX

Appendix I. Geographical information of the stations and reefs surveyed per site in the West Sulu Sea, Palawan, Philippines between May 2016–Jul 2017.

Site	Stations/ reefs	No. of transects	Area covered (m^2)	Depth Range (m)	Water visibility (m)	Coordinates	Date of sampling
Roxas	Johnson Island	8	2,000	5–9	5–15	10°14.334'N/ 119°22.398'E	May 2017
	Green Island	8	2,000	5–9	5–15	10°15.516'N/ 119°26.519'E	May 2017
	Modessa Island	6	1,500	4–8	5–15	10°17.289'N/ 119°25.946'E	June 2017
Puerto Princesa	Panglima	2	500	4–7	5–15	9°55.863' N/ 119°04.012' E	April 2017
	Sabang	2	500	6–10	10–20	10°00.354' N/ 119°03.881' E	April 2017
	BMRS	2	500	3–7	10–15	10°01.329' N/ 119°06.360' E	April 2017
	Nagpawikan	2	500	5–7	10–15	10°01.269' N/ 119°06.987' E	April 2017
	Lacson	2	500	5–7	5–10	9°58.882' N/ 118°59.235' E	April 2017
	San Rafael	2	500	4–7	5–10	9°58.638' N/ 118°58.065' E	April 2017
	Pungtod Elis	2	500	5–8	5–10	9°58.064' N/ 118°55.733' E	April 2017
	Santos	2	500	4–7	5–10	9°57.547' N/ 118°55.941' E	April 2017
	Manalo	2	500	5–6	5–10	9°56.646' N/ 118°51.571' E	April 2017
Narra	Rasa Island	22	5,500	5–8	5–10	9°13'36.26"N/ 118°25'47.62"E	May 2016
	Temple Island	12	3,000	5–8	5–10	9° 7'59.59" N/ 118°10'4.92" E	May 2016
Sofronio Española	Site	4	1,000	5–8	10–15	8˚56.176’ N/ 118˚06.032’ E	July 2017
	Malanap	4	1,000	5–7	10–15	8˚58.853’ N/ 118˚04.505’ E	July 2017
	Barracuda	4	1,000	6–10	15–20	8˚53.644’ N / 118˚07.633’ E	July 2017
Brooke’s Point	Mainit	6	1,500	4–7	5–10	8˚51.638’ N/ 117˚57.726’ E	July 2017
Bataraza	Buliluyan	2	500	3–6	5–15	8°19'52.69"N/ 117°12'14.92"E	July 2017
	Rio Tuba	2	500	5–8	5–10	8°29'23.31"N/ 117°25'55.52"E	July 2017
	Sebentahan	2	500	6–9	5–10	8˚37.234’ N / 117˚34.733’ E	July 2017
	Gusong Maliit	2	500	5–8	10–15	8˚36.935’ N / 117˚33.791’ E	July 2017
Total		**100**	**25,000**				