Original Article

Status of coral reefs, butterflyfishes, and benthic macro-invertebrates in Araceli and Dumaran, Palawan, Philippines

Russell B. Climaco[1,*], Geofrey M. Aludia[1], Niño Jess Mar F. Mecha[2], Anton Rey B. Cornel[1], Ace Niño Andrew M. Acebuque[1], Jomil F. Rodriguez[1], Jona A. Miguel[1], Ian D. Menardo[1], and Roger G. Dolorosa[2]

[1]*WWF-Philippines, Puerto Princesa City, Palawan*
[2]*Western Philippines University-Puerto Princesa Campus, Sta. Monica, Puerto Princesa City*

*Correspondence: rclimaco@wwwf.org.ph

Received: 10 Mar. 2022 || Revised: 13 Oct. 2022 || Accepted: 18 Nov. 2022

ISSN: 1656-4707
E-ISSN: 2467-5903
Homepage: www.palawanscientist.org

How to cite:
Climaco RB, Aludia GM, Mecha NJMF, Cornel ARB, Acebuque ANAM, Rodriguez JF, Miguel JA, Menardo ID and Dolorosa RG. 2022. Status of coral reefs, butterflyfishes, and benthic macro-invertebrates in Araceli and Dumaran, Palawan, Philippines. The Palawan Scientist, 14(2): xx-xx.

ABSTRACT

As a major fishing ground in Palawan, the reefs in the municipal waters of Araceli and Dumaran are continuously facing anthropogenic and climate-related threats. Hence, to provide information about the reef conditions, surveys were undertaken in three sites of each municipality as the basis for management. Data collection used the C30 method where a 75 m × 25 m sampling area was established at the upper reef slope (2-5 m deep) of each site. Substrates were photo-documented at predetermined random positions and the photos were processed using Coral Point Count with excel extension software (CPCe) to determine the percent substrate categories. Identification and counting of butterflyfishes and benthic macro-invertebrates were also undertaken. The hard-coral cover (HCC) ranged between 27.10 and 53.88% (fair to very good) for Araceli and 22.66 and 48.62% (fair to good) for Dumaran. The number of species and density of butterflyfishes largely varied across reefs. The benthic macro-invertebrates only included the blue *Linckia* starfish and giant clams. The current reef condition calls for urgent management actions.

Keywords: C30 methods, *Chaetodon baronessa*, *Chaetodon melannotus*, giant clams, island reefs

INTRODUCTION

Coral reefs provide various ecological and economic goods and services, including shoreline defense against storm surges, essential sources of food and shelter for various organisms, serving as important fishing grounds, and venues for recreation (Burke et al. 2011; Maulil et al. 2014). The total net benefits of the world's coral reefs are about US$29.8 billion, wherein tourism and recreational activities accounted for US$9.6 billion, US$9 billion for coastal protection, US$5.7 billion for fisheries, and US$5.5 billion for its biodiversity (Burke et al. 2002; 2011). In the Philippines, coral reefs have total economic value of about US$4 billion per year arising from reef fisheries, tourism and biodiversity (Tamayo et al. 2018).

Despite the promising benefits of coral reefs, its status continues to decline globally (Gardner et al. 2003). The degradation of these reef areas are mainly brought by anthropogenic threats and pressures (Alcala and Russ 2002; Licuanan et al. 2019). As of 2019, hard coral cover (HCC) for Philippine reefs falls under Category C (22-33% HCC) which is lower than the average of Tubattaha Reefs Natural Park- a well-protected marine area in the country (Licuanan et al. 2019; Licuanan 2020).

The island province of Palawan is located between the West Philippines Sea and the Sulu Sea – this region has the highest remaining hard coral cover in the Philippines (Licuanan et al. 2019) and making it known as the apex of marine biodiversity (ADB 20 14). Further, the area is also home to 505 species of coral (WWF-Philippines 2019) and more than a thousand reef fishes (Allen and Erdmand 2009; Gonzales 2013; Balisco and Dolorosa 2019) and benthic macro-invertebrates species (Ardines et al. 2020; Balisco et al. 2020).

Reef monitoring is vital to measure the management effectiveness and early warnings of threats to coral ecosystems (Licuanan et al. 2021). Its information could be used in formulating sound management strategies for coral reef conservation (WWF-Philippines 2019). Practical reef conservation actions can help realize the Sustainable Goal Development (SGD) 14 or life below the water of the United Nation's 17 SGDs (UN 2015). In Palawan, reef monitoring surveys have been done in many localities (i.e. WWF-Philippines 2012, 2013; Dolorosa et al. 2015a; Dolorosa 2016; Balisco et al. 2017); however, little has been done in Araceli and Dumaran.

The reefs within the municipal waters of Araceli and Dumaran are among the richest fishing grounds in Palawan (WWF-Philippines 2010). However, according to local communities anthropogenic activities such as illegal fishing and illegal entry from nearby municipality continues to threaten the reefs of these two areas. This study provides the latest data on the reefs' condition in the two municipalities in terms of coral cover, species richness and density of butterflyfishes, and abundance of benthic macro-invertebrates. The findings may serve as the basis for local policymakers to formulate management systems and prioritize areas for conservation.

METHODS

Study Sites

The survey was conducted in November 2021 in the municipalities of Araceli and Dumaran, Palawan. These municipalities are known for the relatively good coral covers compared to other areas (pers. obs.). Survey sites in Araceli included the Cambari, Cotad, and Langoy, while Camangyan, Mayabaka, and Syed for Dumaran (Figure 1).

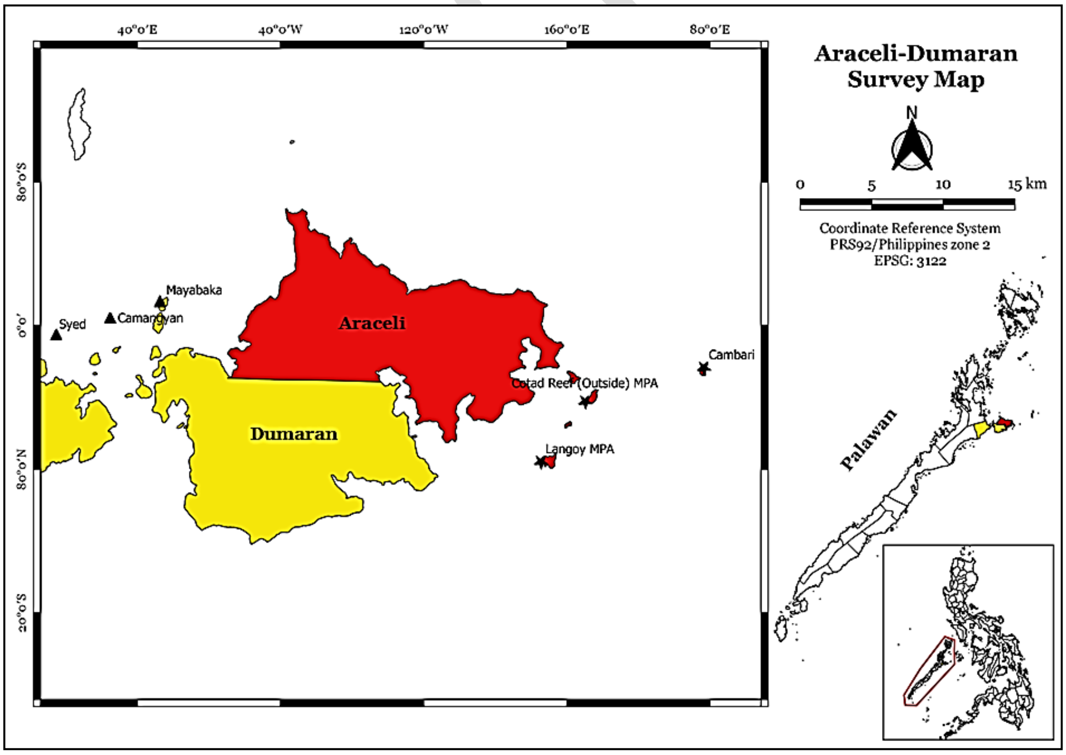

Figure 1. Map of the Philippines and Palawan (inset) and the locations of sampling sites in the municipalities of Araceli (★) and Dumaran (▲), Palawan.

Cambari island. This is located about 11 km away from Barangay Poblacion, Araceli. A fringing reef between 2-9 m deep (Figure 2A), which harbored numerous coral species and marine fauna. Water is relatively clear during sampling with up to 10 m horizontal visibility. The sightings of adult and juvenile manta rays, makes the waters of Cambari a potential diving destination.

Cotad island. This is located in the southeastern portion of Araceli and is approximately 4 km away from the town center. Water is relatively clear with good visibility (Figure 2B). The reef harbored a diverse species of marine flora and fauna.

Langoy island. This is located in the southern part of the town center and about 6 km away from Bgy. Poblacion of Araceli. Corals flourished near the shoreline at depths ranging between 3 to 8 m (Figure 2C). Water is relatively clear with high visibility.

Camangyan reef. This reef flat is within the jurisdiction of Dumaran, and approximately 5 km from Barangay Danleg. Corals generally *Acropora* spp. flourished at about 4-5 m deep with good visibility (Figure 2D). Some portions of the reef exhibited damage possibly due to the outbreak of crown-of-thorn starfish and boat anchorage.

Mayabaka reef. This is located about 400-500 m off Mayabaka Island, Barangay Poblacion, Dumaran. The reef is about 4-5 m deep (Figure 2E).

Syed reef. This is located east of Barangay Culasian, Dumaran. This shallow reef (4-5 m deep) dominated with *Acropora* spp. is approximately 80 m away from the shoreline (Figure 2F). Water is relatively clear with a visibility of 5-10 m.

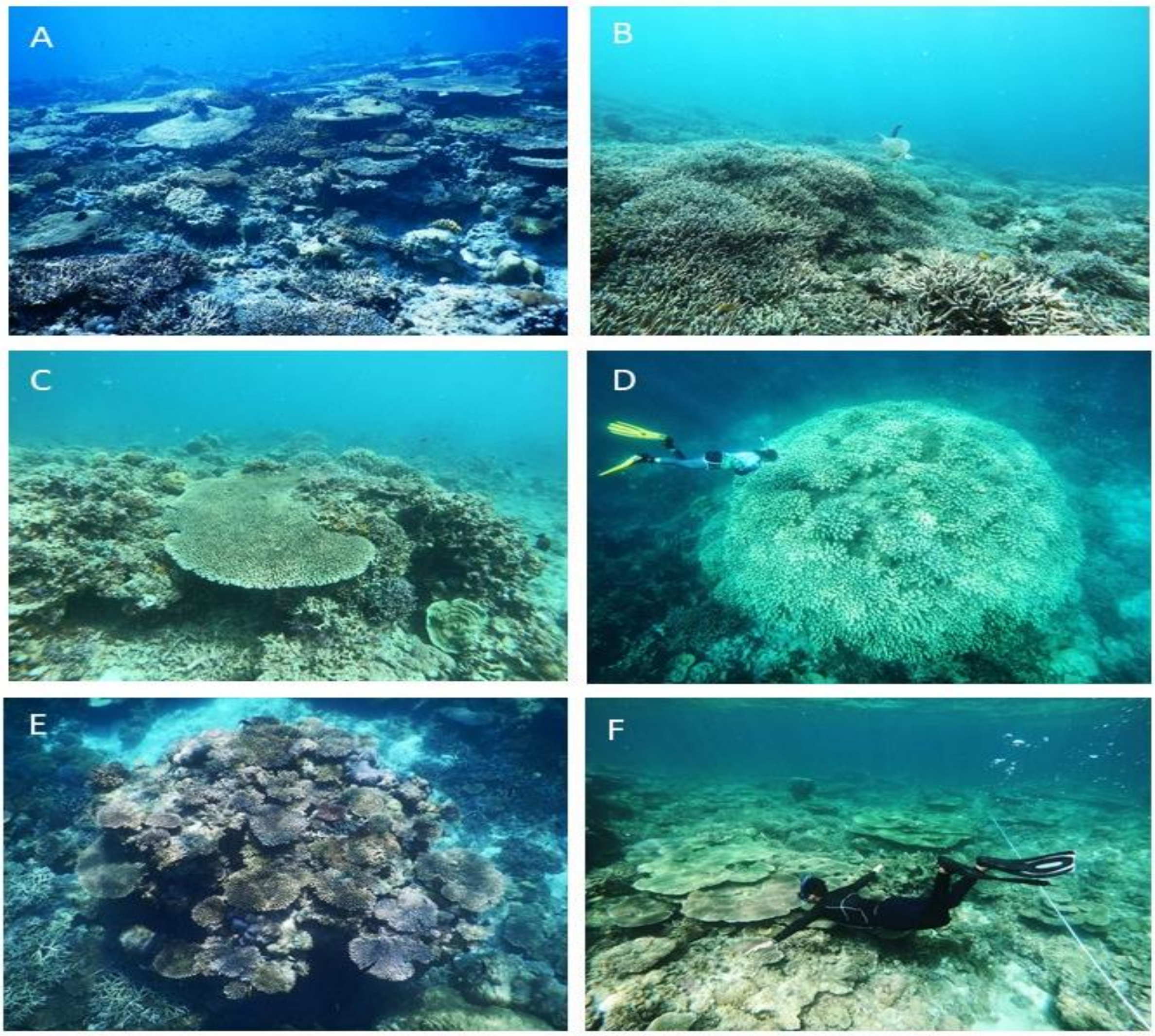

Figure 2. The reefs in Cambari (A), Cotad (B), Langoy (C), Camangyan (D), Mayabaka (E) and Syed (F).

Data Collection

Before the data collection, a reconnaissance survey was conducted on all sites to identify sampling stations that fall under the C30 criteria (Licuanan et al. 2021) for site establishment. At each site during the survey, a 75 m × 25 m transect line was laid parallel to the shoreline. Each corner was marked with floating buoys serving as the parameter of the station. Each sampling station was established at the upper reef slope at 2-5 m deep (Licuanan et al. 2021).

The HCC and other substrates were quantified using the C30 method (Licuanan et al. 2021). This method involved two skin divers: 1) the navigator who holds the buoy marker and guides the photographer on where to take a photo of the substrate, and 2) the photographer who takes photos of the substrate using a monopod (Figure 3) at predetermined random positions or imaging spots in the sampling stations. The random positions were generated through MS excel using the formula =randbetween (1,8) for directions and =randbetween (1,10) for the distance. The directions were guided by a compass (e.g. 1 = north, 2 = Northeast, 3 = East, etc.), while the distances (in meters) were calibrated to several flipper kicks (1 flipper kick =1-meter distance). The direction and distance of each swim were relative to starting position at the center of the reef sampling station facing the shore/mainland. Each substrate spot was photographed with the base of the monopod facing the shore/mainland. When the random number led the divers to the outer boundary, the diver swam back to the original direction until the remaining distance is completed. These randomization steps were repeated until 50 pictures were captured within each station.

The species and density of butterflyfishes and target benthic macro-invertebrates (i.e. *Linckia*, *Protoreaster*, crown of thorns, feather star, and giant clam) were noted and counted within the 75 m × 25 m sampling station. The counting of butterflyfishes was done by dividing the width (25 m) of the sampling station into two segments (12.5 m). Three (3) skin divers then swam along the length of the first segment up to the endpoint, the second segment then continued back to the starting point. All butterflyfishes observed were counted and identified to species level using the laminated identification field guide containing photos of 37 species of butterfly fishes (Licuanan 2021). Butterfly fishes are reef health indicators and can be used to describe the health of the reef (Reese 1981), without taking into account the other reef fishes. Giant clam size classification was determined using the A4 laminated field guide wherein one-half the width of the field guide is considered as small (<10.5 cm), (medium 10.6 cm to 29.7 cm − full width) while an individual that is larger than the full width is considered as large (29.7>).

Figure 3. The navigator (left) and photographer (right) researchers while photo-documenting the substrate using the C30 method.

Data Analysis

For HCC, all captured images of the substrate were processed using the CPCe software (Kohler and Gill 2006), which helped determine the HCC from relative frequencies of ten randomly-positioned scoring points per image. The averages (±sd) were determined using MS Excel. Graphs were generated to visually compare the data among sites.

RESULTS

Coral Cover

Both municipalities HCC were generally variable, but the averages only differed by about 4%. For Araceli, the HCC ranged between 27.10 and 53.88% with an average (±sd) of 37.25 ± 14.52%, while in Dumaran, the HCC ranged between 22.66 and 48.62% with an average of 33.39 ± 13.55%. Cotad in Araceli and Syed in Dumaran had the highest HCC of 53.88% and 48.62%, respectively. However, algal assemblages (AA) for Araceli and Dumaran were higher than HCC. In Araceli, AA ranged between 41.56 and 59.47% (mean: 47.79 ± 0.12%), while it is between 34.44 and 56.56% (mean: 44.83 ± 11.12%) in Dumaran. Other abiotic components were relatively low compared to HCC and AA (Figure 4).

Species Richness and Density of Butterflyfishes

Out of the 37 species of butterflyfishes included in the datasheet, only ten species were recorded. Seven species were observed in Araceli, while five species in Dumaran (Figure 5). Only *Chaetodon baronessa* and *Chaetodon melannotus* occurred in both municipalities. Among the seven species encountered in Araceli, *C. baronessa, Chaetodon vagabundus* and *Chaetodon lunulatus* were more common than the other species observed in all three sites (Cambari, Cotad, and Langoy). Cambari had the highest number of species (6), followed by Cotad (5). Langoy only registered three species.

Among the three sites in Dumaran, Syed registered the highest density and number of butterflyfishes. *Chaetodon octofasciatus* had the highest density among the five species, with the same species that occurred in all three sites (Kamangyan, Mayabaka, and Syed) whileonly two species (*C. octofasciatus* and *Chelmon rostratus*) appeared in Kamangyan.

Benthic Macro-Invertebrates

The recorded benthic macro-invertebrates only included the blue *Linckia* starfish and giant clams for Dumaran, while only blue *Linckia* starfish were noted in Araceli. Giant clams in Kamangyan recorded the highest density with 88.5 individuals per 1,875 m^{2,} further, it was observed that most of the giant clams in Dumaran are relatively small in size. Other species of interest, such as crown-of-thorns (COT) starfish, chocolate chip sea star *Protoreaster nodosus*, and feather stars, were only noted outside the established 75 m × 25 m sampling areas.

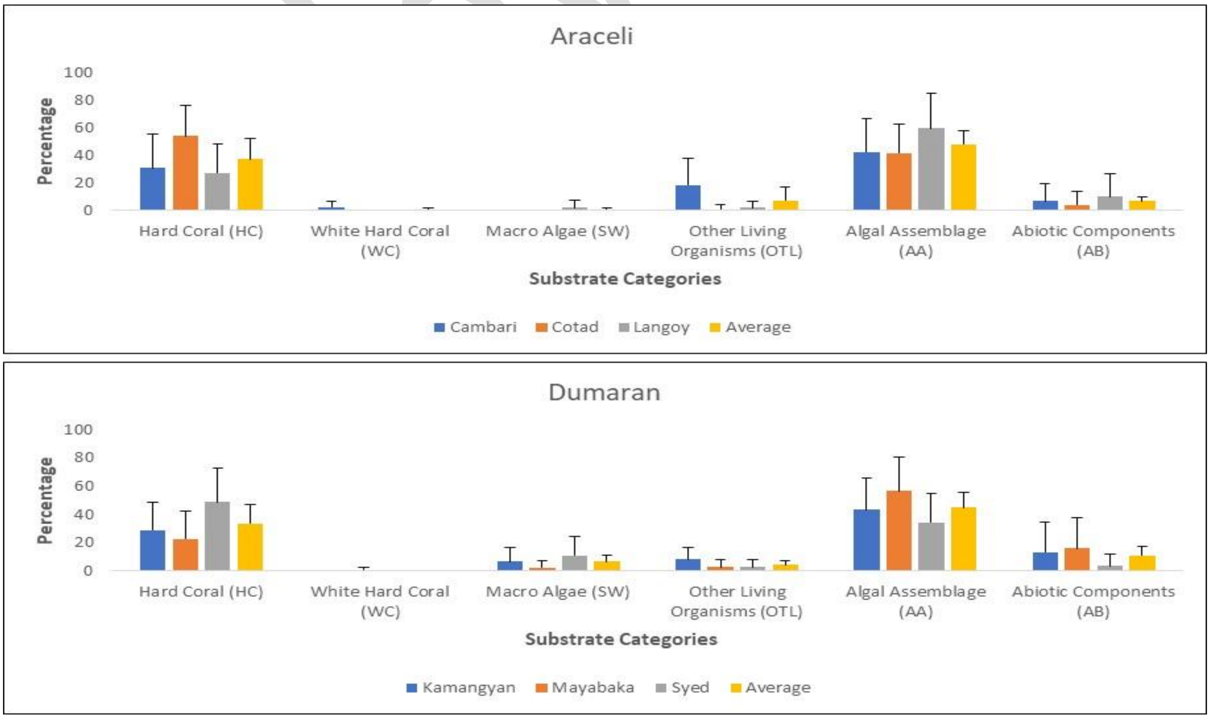

Figure 4. Percent substrate cover in Araceli and Dumaran, Palawan.

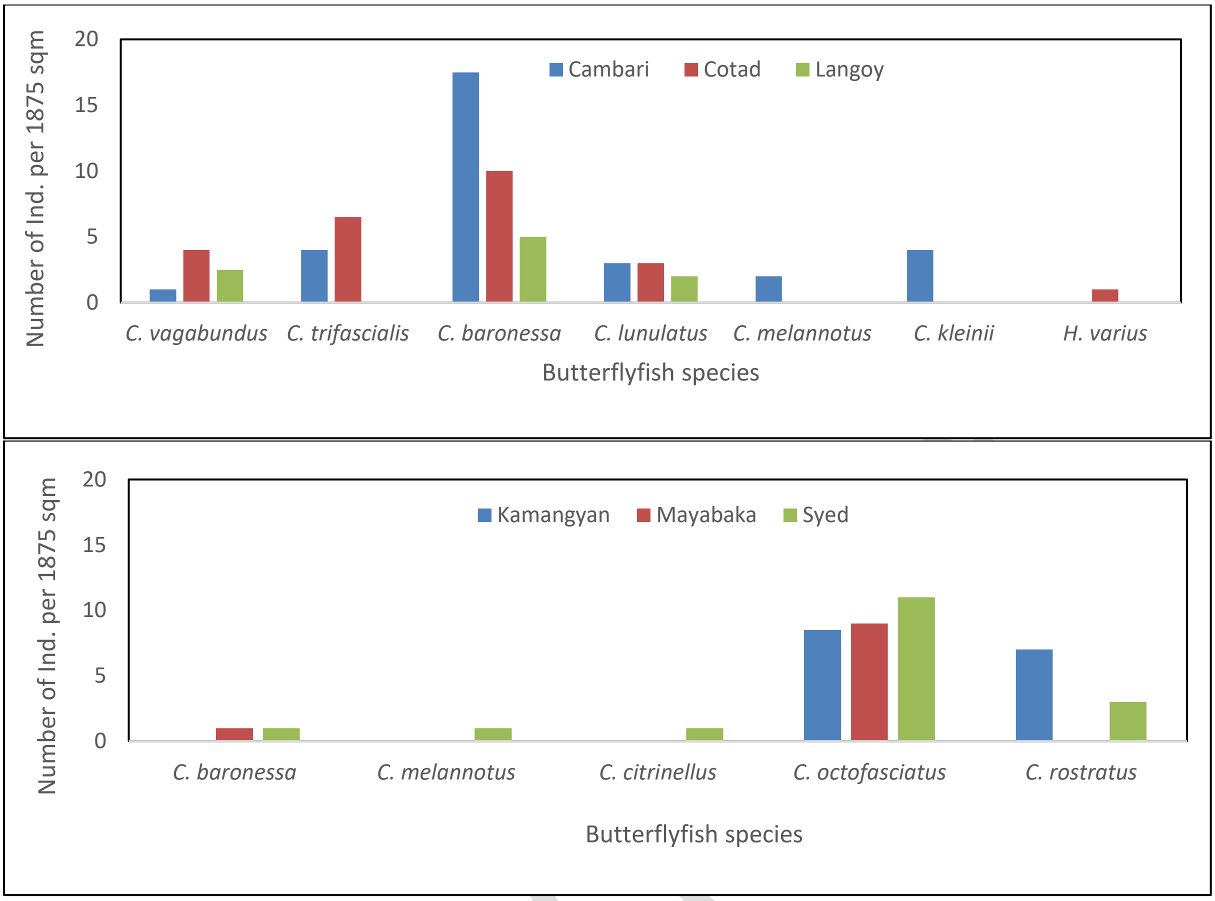

Figure 5. Species richness and density of butterflyfish species (individuals per 1875 m^2) in Araceli (top) and Dumaran (bottom), Palawan.

Table 1. Density (individuals per 1,875 m^2) of targeted benthic macro-invertebrates in surveyed sites in Araceli and Dumaran, Palawan.

Species	**Araceli**			**Dumaran**		
	Cambari	Cotad	Langoy	Kamangyan	Mayabaka	Syed
Blue *Linckia* starfish	4.50 (±2.12)	2.50 (±0.71)	1.00 (±1.41)			
Giant Clam *Tridacna* spp.						
Small (<21 cm)	1.00 (±0.00)	1.00 (±0.00)	3.50 (±2.12)	88.50 (±27.58)	41.50 (±37.48)	18.67 (±19.14)
Medium (22 to 29.7 cm)				2.00 (±1.41)	3.00 (±2.12)	1.33 (±2.31)

DISCUSSION

Coral Cover

The average percentage HCC in Araceli (37.25 ± 14.52%) and Dumaran (33.39 ± 13.55%) falls within the Category B conditions (>33-44% HCC) which is higher than the average HCC in Tubattaha Reefs Natural Park (see Licuanan et al. 2019; Licuanan 2020). However, a previous survey in 2017 (Figure 6) indicated a decline of more than 10% in both Cambari and Langoy (WWF-Philippines 2017). A similar condition was also observed in other areas in Palawan (WWF-Philippines 2012, Gonzales et al. 2014a, Gonzales et al. 2014b, Dolorosa et al. 2015a, WWF-Philippines 2017) However, the comparison should be treated with caution due to variation in survey methods and the surveyed sites, the general trend for coral reefs is declining, globally, 20% of coral reefs have already been destroyed, and 50% are in danger of being destroyed in the near future (van der Meer et al. 2013). The key drivers of coral loss include anthropogenic and changes in climatic conditions, which cause portions of otherwise connected reefs to die, fragmenting reef growth, and causing a decrease in the continuity of shelter for fish (Pratchett et al. 2013; van der Meer et al. 2013). The reefs in Langoy, Araceli showed numerous marks of boat anchorage, which, if left uncontrolled could bring further damage to the reef ecosystem. A study conducted by Palaganas V. (1991) on the impacts of boat anchors on the coral reef in Sombrero Island, Batangas Philippines revealed that a total of 15.4164 m^2 of corals were damaged by a boat anchor, 13.4164 m^2 of which was caused by anchor droppings and 2.3370 m^2 from anchor retrieval. If left unchecked, this activity would lead to the further decline of reef productivity. In a similar study conducted in the British Virgin Islands, hard coral colonies in highly anchored sites were 40% smaller in surface area and ~60% less dense than areas with little boat anchorage incidence. Furthermore, highly anchored sites supported only ~60% of the species richness of little anchored areas, ~60% as structurally complex, and supported less than half fish biomass with those rarely anchored (Flynn and Forrester 2019).

The percent HCC in Dumaran was comparable to the reef conditions in other areas of Palawan which have been monitored six or seven years ago (WWF unpublished data; Figure 4). The three-dimensional coral cover can be almost 100% when undisturbed, as observed in some reef slopes in the Green Island Bay in the municipality of Roxas and Tubattaha Reefs Natural Park, Cagayancillo Palawan (pers. obs.) When fully protected from all forms of human disturbance, damaged coral reefs may take decades to fully recover (Burke et al. 2002). Thus, restoring damaged reefs requires strengthened and effective enforcement mechanisms. Regular monitoring of the reef is crucial in detecting changes in the reef's condition and as a measure of management success (Uychiaoco et al. 2010). Regular patrolling can help deter illegal fishers, thus allowing marine resources to recover over time.

The higher percent composition of AA (44.83-47.79%) than HCC (33.39-37.25%) in the reefs of Araceli and Dumaran is an indication of disturbed reefs (Goatley and Bellwood 2013). It can be attributed to run-off and unsustainable fishing practices which affect the coral reef ecosystem in the area. According to River and Edmunds (2001), reef disturbances and run-offs provide suitable substrates for the attachment of algal species that hinders coral growth by shading and abrasion to coral polyps. In addition, a study conducted by McCook (1996), on the Great Barrier Reef revealed that the loss of herbivores due to overfishing can cause a shift from coral to algal-dominated reefs.

A drastic decline in coral cover can negatively affect fish biodiversity, both in protected and open-access areas. This can lead to permanent reef degradation and extinction of rare coral-specialist (Jones et al. 2004).

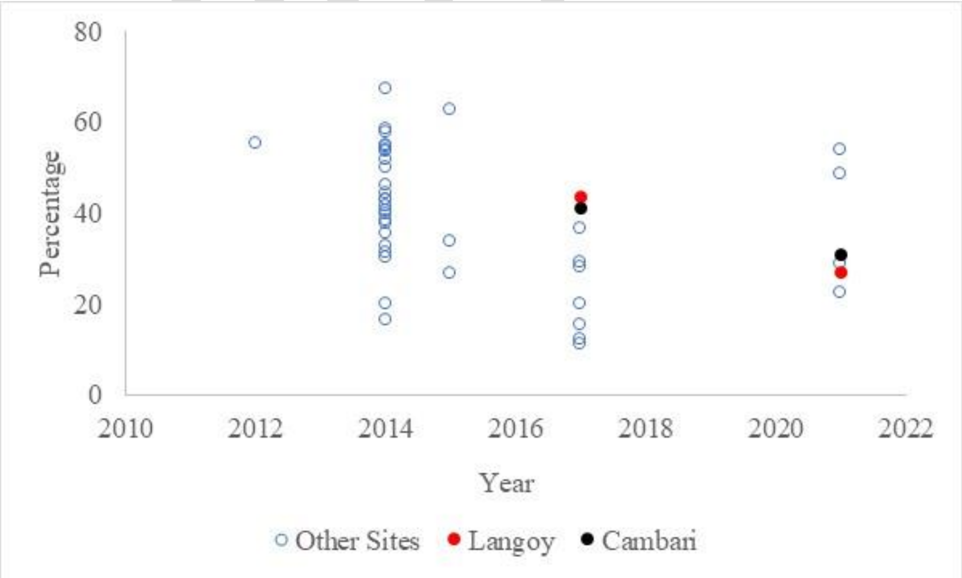

Figure 6. Percentage of hard coral cover (HCC) in some parts of Palawan in 2012, 2014, 2015, Araceli in 2017 (WWF unpublished data) and in Araceli and Dumaran in 2021.

Species Richness and Density of Butterflyfishes

The species richness of butterflyfishes in both study sites, Araceli (7 species) and Dumaran (5 species) was higher than in Coron, Culion, El Nido, Linapacan, and Taytay, which composed only of two species (Verdadero et al. 2017). However, the combined species richness (10 species) in Araceli and Dumaran was much lower than the species richness (17-20 species) reported in other areas (Table 2). In terms of density, the study recorded a total of 20 individuals 1000 m^2 which is relatively lower than the study conducted by Verdadero et al. 2017 with 40 individuals per 1000 m^2. The number of butterflyfish species may vary in accordance with the size of the reef and the available food. The recorded butterfly species were either obligate (restricted food/habitat) or facultative (wide range of food/habitat). *C. baronessa* is an obligate species, feeding exclusively on the polyps of the tubular *Acropora* corals (Berumen et al. 2005). This species occurred abundantly in the reefs of Araceli, but were seldom found in Dumaran. By contrast, the obligate *C. octofasciatus*, which exclusively feeds on coral polyps (Madduppa et al. 2014), occurred abundantly in all sites in Dumaran but not in Araceli. The uneven distribution of obligate and the low numbers of facultative species (*Chaetodon citrinellus*, *Chaetodon kleinii*, *Chaetodon vagabundus*, and *Heniochus varius*) need further investigation.

Butterflyfishes are considered reef health indicators (Crosby and Reese 1996; Pratchett et al. 2006; Leahy 2016). They are sensitive to the change in their habitats, particularly those species under obligate corallivores (Crosby and Reese 1996; Brooker et al. 2013). The absence of these species in coral reefs indicates an early warning that changes are coming (Crosby and Reese 1996). In the Southern Great Barrier Reef, the populations of butterflyfishes decreased by 50% when live coral cover declined by only 12% (Andrews and Kownacki 2021). Specialized coral-dependent fishes are highly vulnerable to coral loss caused by climate-induced coral bleaching. Moreover, the structural collapse of dead coral colonies may have significant but more variable impacts across a wide range of fishes (Graham et al. 2009).

Benthic Macro-Invertebrates

Following the global trends for shellfish harvesting, giant clams – the largest living bivalves, are highly prized (Shang et al. 1991; Lucas 1994) for their meat and shells (Gomez and Mingoa-Licuanan 2006; Neo et al. 2017). They occur in nearshore habitats, especially in coral reef and seagrass ecosystems, making them highly vulnerable to harvesting (Newman and Gomez 2000; Mecha and Dolorosa 2020). Many livelihood activities, especially in developing countries like the Philippines, depend on artisanal fisheries, including the harvesting of giant clams (Juinio et al. 1987). These speciesserve as a cheap source of protein, especially for offshore small island inhabitants (Ardinez et al 2020).

Table 2. Species richness and density of butterflyfishes in various localities in Palawan in comparison to this study sites.

Location	Species Richness	Fish Density (ind/ 1000 m^{-2})	Sources
Pagasa Island, Kalayaan	20	4	Pagliawan et al. 2008
Snake island, Honda Bay, PPC	17	19	Gonzales et al. (2014a)
Apulit island, Taytay,Palawan	5	5	Gonzales et al. (2014b)
Coron, Culion, El nido Linapacan, Taytay	2	40	Verdadero et al. (2017)
Roxas	18	3	Balisco et al. (2017)
Araceli	7	20	This study
Dumaran	5		

The presence of giant clams in the reefs of Dumaran makes the areas suitable for resource conservation, by providing a substrate for colonization for epibionts, increasing the topographic heterogeneity of the reef, and acting as a reservoir of zooxanthellae (Neo et al. 2014). Meanwhile, the absence of medium and large size giant clams in Araceli may be attributed to the local collection of giant clams in the area.

There has been a surge in collecting fossilized giant clam shells in Palawan in recent years. Between 2019 and 2021, the government has confiscated thousands of tons of shells valued at PHP2.7 billion (BBC News 2021; Magdayao 2021; Noriega 2021). Giant clam shells are in high demand in the carving industry and substitute for elephant ivory (Larson 2016; Neo 2017). Unearthing these fossilized giant clam shells can destabilize the substrate and cause disturbance to the ecosystem (Bale 2016). While the government prohibits the collection and trade of giant clams (DA 2001, RA 10654), illegal trade continues to threaten the last remaining populations thus requiring an effective surveillance and monitoring system. However, considering the value of giant clam shells, it is sad to note some allegations regarding the involvement of government officials in the activity (Fabro 2021).

Apart from vigorous monitoring of macrobenthic invertebrates such as giant clams, establishing Marine Protected Areas (MPA) is viewed as an effective strategy for protecting the remaining populations of macrobenthic organisms, coral reefs, and other marine life. Further, Cabaitan et al. (2008) claimed that an increase in the density of giant clams can influence fish biomass, thus benefiting fishing communities.

On the other hand, target benthic macro-invertebrates such as blue *Linckia* starfish were only observed in the Araceli, while the rest of the target macroinvertebrates such as COT, feather star, and chocolate chip sea stars were not noted in both areas. According to Scheibling and Metaxas (2008), chocolate chip sea star *P. nodosus* are less frequent on the reef as they are more abundant in the seagrass bed areas. There is no known ongoing local collection and market for the blue *Linkia* and chocolate chip sea star; hence it is improbable that the observed low density is due to exploitation. The absence of COT is a good sign but continued monitoring is needed to detect early signs of COT outbreak.

The findings of this study suggest that the coral reefs in Araceli and Dumaran are still in good condition as it has a higher average HCC compared to the baseline HCC in various bioregions in the Philippines (see Licuanan et al. 2019; Licuanan 2020). Therefore, a sound management approach should be available and implemented to protect and manage these areas. With this, the natural restoration of coral reefs from its recruit would continue and save a lot of investment and mortality of corals from coral transplantation/gardening (Reyes et al. 2017). In addition, effective marine resource management strategies will also help replenish the fish population and other macro-benthic invertebrates in the area. Moreover, information and education campaigns on proper boat anchorage for coastal fishers and boat operators of fishing boats and in tourism could help minimize coral damage.

ACKNOWLEDGMENTS

This study was funded by the WWF-Philippines in partnership with the local government of Araceli and Dumaran. We are thankful to the two anonymous reviewers for their constructive comments and suggestions.

REFERENCES

ADB (Asian Development Bank). 2014. State of the Coral Triangle: Philippines. Mandaluyong City, Philippines. 128pp.

Alcala A and Russ G. 2002. Status of Philippine coral reef fisheries. Asian Fisheries Science, 15: 177-192. https://doi.org/10.33997/j.afs.2002.15.2.009

Allen GR and Erdmann MV. 2009. Reef fishes of El Nido, Palawan, Philippines. Primex Printers Inc., El Nido Foundation Inc.

Andrews BM and Kownacki AKS. 2021. Quantification of the effect of coral reef degradation on butterflyfish populations in the Southern Great Barrier Reef. Journal of Marine Science Research and Oceanography, 4: 154-158.

Ardines RB, Mecha NJMF and Dolorosa RG. 2020. Commonly gleaned macrobenthic invertebrates in a small offshore island of Cawili, Cayagancillo, Palawan, Philippines. The Palawan Scientist, 12: 102-125.

Bale R. 2016. Critical reefs destroyed in poachers' quest for world's biggest clams. National Geographic. https://www.nationalgeographic.com/animals/article/wildlife-giant-clam-poaching-south-china-sea-destruction. Accessed on 21 August 2022.

Balisco RAT and Dolorosa RG. 2019. The reef-associated fishes of West Sulu Sea, Palawan, Philippines: a checklist and trophic structure. AACL Bioflux, 12(4): 1260-1299.

Balisco RAT, Gonzales BJ and Dolorosa RG. 2020. Species composition, density, and conservation status of some economically important macrobenthic invertebrates in Pag-asa Island, Kalayaan, Palawan, Philippines. Asian Fisheries Science, 33: 357-365. https://doi.org/10.33997/j.afs.2020.33.4.007

Balisco RAT, Gonzales JG, Matillano JA and Gonzales BJ. 2017. Mapping and assessment of 1,700 ha coral reefs in Roxas, Palawan. Technical Report. Department of Environment and Natural Resources (DENR)–Provincial Environment and Natural Resources Office (PENRO). 30pp.

BBC News. 2021. Philippines: Giant clam shells worth $25m seized in raid. https://www.bbc.com/news/world-asia-56784215. Accessed on 21 August 2022.

Berumen ML, Pratchett MS and McCormick MI. 2005. Within-reef differences in diet and body condition of coral-feeding butterflyfishes (Chaetodontidae). Marine Ecology Progress Series, 287: 217-227. http://dx.doi.org/10.3354/meps287217

Brooker RM, Munday PL, Mcleod IM and Jones GP. 2013. Habitat preferences of a corallivorous reef fish: predation risk versus food quality. Coral Reefs, 32(3): 613-622. https://doi.org/10.1007/s00338-013-1057-6

Burke L, Selig E and Spalding M. 2002. Reefs at Risk in Southeast Asia. World Resources Institute (WRI), Washington, DC. 72pp.

Burke L, Reytar K, Spalding M and Perry A. 2011. Reefs at Risk Revisited. World Resources Institute. Washington. 86pp.

Cabaitan PC, Gomez ED and 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: 85-98. https://doi.org/10.1016/j.jembe.2008.01.001

Crosby MP and Reese ES. 1996. A Manual for Monitoring Coral Reefs with Indicator Species: Butterflyfishes as Indicators of Change on Indo-Pacific Reefs. Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, Silver Spring, MD. 45pp.

DA (Department of Agriculture). 2001. Conservation of rare, threatened and endangered fishery species. Philippines. Fisheries Administrative Order NO. 208, Series of 2001. http://www.bfar.da.gov.ph/LAW?fi=353#post. Accessed on 21 August 2022.

Dolorosa RG. 2016. Coral cover and density of reef associated macroinvertebrates and fishes in Rasa Island Wildlife Sanctuary, Narra, Palawan, Philippines. Technical report. 30pp.

Dolorosa RG, Balisco RAT, Bundal NA and Magbanua RM. 2015a. Reef assessment of Cagayancillo, Palawan, Philippines. World Wildlife Fund for Nature Philippines. 25pp.

Fabro KA. 2021. Surge in seizures of giant clam shells has Philippine conservationists wary. Mongabay News and Inspiration from Nature 's Frontline. https://news.mongabay.com/2021/03/surge-in-seizures-of-giant-clam-shells-has-philippine-conservationists-wary/. Accessed on 21 August 2022.

Flynn RL and Forrester GE. 2019. Boat anchoring contributes substantially to coral reef degradation in the British Virgin Islands. PeerJ, 7: e7010 https://doi.org/10.7717/peerj.7010

Gardner TA, Côté IM, Gill JA, Grant A and Watkinson AR. 2003. Long-term region-wide declines in Caribbean corals. Science, 301(5635): 958-960. https://doi.org/10.1126/science.1086050

Goatley CHR and Bellwood DR. 2013. Ecological consequences of sediment on high-energy coral reefs. Plos One, 8(10): e77737. https://doi.org/10.1371/journal.pone.0077737

Gomez ED and Mingoa-Licuanan SS. 2006. Achievements and lessons learned in restocking giant clams in the Philippines. Fisheries Research, 80:46-52. https://doi.org/10.1016/j.fishres.2006.03.017

Gonzales BJ. 2013 Field Guide to Coastal Fishes of Palawan. Coral Triangle Initiatives on Corals, Fisheries, and Food Security. USAID-WWF. 208pp.

Gonzales BJ, Pagliawan HB, Becira JG and Gonzales MMG. 2014a. Marine resource assessment for sustainable utilization of Snake Island, Palawan, Philippines. AACL Bioflux, 7(5): 372-385.

Gonzales BJ, Dolorosa RG, Pagliawan HB and Gonzales MMG. 2014b. Marine resource assessment for sustainable management of Apulit Island, West Sulu Sea, Palawan, Philippines. International Journal of Fisheries and Aquatic Science, 2(2): 130-136.

Graham NAJ, Wilson SK, Pratchett MS, Polunin NVC and Spalding MD. 2009. Coral mortality versus structural collapse as drivers of corallivorous butterflyfish decline. Biodiversity Conservation, 18: 3325-3336. https://doi.org/10.1007/s10531-009-9633-3

Jones GP, McCormick MI, Srinivasan M and Eagle JV. 2004. Coral decline threatens fish biodiversity in marine reserves. Proceedings of the National Academy of Sciences, 101(21): 8251-8253. https://doi.org/10.1073/pnas.0401277101

Juinio MAR, Meñez LAB and Villanoy CL. 1987. Use of giant clams resources in the Philippines. Naga, The ICLARM Quarterly 10(1): 7-8.

Larson C. 2016. Shell trade pushes giant clams to the brink. Science, 351(6271): 323-324. https://doi.org/10.1126/science.351.6271.323

Leahy SM. 2016. Habitat determinants of *Chaetodon* butterflyfish and fishery-targeted coral reef fish assemblages in the central Philippines. PhD Thesis, James Cook University. 184pp.

Licuanan WY. 2020. New scales to guide the assessment of hard coral cover and diversity in the Philippines. The Philippine Journal of Fisheries, 27(2): 121-126. https://10.31398/tpjf/27.2.2020-0008

Licuanan WY, Mordeno PZB and Go MV. 2021. C30—A simple, rapid, scientifically valid, and low-cost method for citizen-scientists to monitor coral reefs. Regional Studies in Marine Science, 47: 101961. https://doi.org/10.1016/j.rsma.2021.101961

Licuanan WY, Robles R and Reyes M. 2019. Status and recent trends in coral reefs of the Philippines. Marine Pollution Bulletin, 142: 544-540. https://doi.org/10.1016/j.marpolbul.2019.04.013

Lucas JS. 1994. The biology, exploitation, and mariculture of giant clams (Tridacnidae). Reviews in Fisheries Science, 2(3): 181-224. https://doi.org/10.1080/10641269409388557.

Madduppa HH, Zamani NP, Subhan B, Aktani U and Ferse SCA. 2014. Feeding behavior and diet of the eight-banded butterflyfish *Chaetodon octofasciatus* in the Thousand Islands, Indonesia. Environmental Biology of Fisheries, 97(2): 1353-1365. https://doi.org/10.1007/s10641-014-0225-z

Magdayao A. 2021. Endangered giant clams shells worth P57M confiscated in Palawan. Manila Bulletin. https://mb-com-ph.cdn.ampproject.org. Accessed on 21 August 2022.

Maulil RN, Mamauag SS, Cabral RB, Celeste-Dizon EO and Aliño PM. 2014. Status, trends and challenges in the sustainability of small-scale fisheries in the Philippines: Insight from FISHDA (Fishing Industries' Support in Handling Decision Application) model. Marine Policy, 44: 212-221. https://doi.org/10.1016/j.marpol.2013.08.026

McCook LJ. 1996. Effects of herbivores and water quality on Sargassum distribution on the central Great Barrier Reef: cross-shelf transplants. Marine Ecology Progress Series, 139: 179-192. https://doi.org/10.3354/meps139179

Mecha N and Dolorosa R. 2020. Searching the virtually extinct Tridacna gigas (Linnaeus 1758) in the reefs of Palawan. The Philippine Journal of Fisheries, 27(1): 1-18. https://doi.org/10.31398/tpjf/27.1.2019-0005

Neo ML, Eckman W, Vicentuan K, Teo SLM and Todd PA.2014. 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. 2017. The story of shells – Part 1. https://meilin5giantclam.wordpress.com/2017/11/26/the-story-of-shells-part-1/. Accessed on 03 January 2021.

Neo ML, Wabnitz CCC, Braley RD, Heslinga GA, Fauvelot C, Wynsberge SV, Andréfouët S, Waters C, Tan A.-H, Gomez ED, et al. 2017. Giant clams (Bivalvia: Cardiidae: Tridacninae): a comprehensive update of species and their distribution, current threats and conservation status. Oceanography and Marine Biology: An Annual Review, 55, pp. 87-388.

Newman WA, Gomez ED. 2000. On the status of giant clams, relics of Tethys (Mollusca : Bivalvia : Tridacninae). Proclamation of 9th International Coral Reef Symposium. Bali, Indonesia, 2: 927-936.

Noriega R. 2021. Authorities seize P250M worth of giant clams shells in Palawan. Manila Bulletin. https://mb.com.ph/2021/07/01/authorities-seize-p250m-worth-of-giant-clam-shells-in-palawan/. Accessed on 21 August 2022.

Palaganas VP. 1991. Anchor damage on the coral reef of Sombrero Island, Batangas, Philippines. 7th Symposium on Coastal and Ocean Management, Long Beach, CA.

Pratchett MS, Hoey AS, Feary DA, Bauman AG, Burt JA and Riegl BM. 2013. Functional composition of Chaetodon butterflyfishes at a peripheral and extreme coral reef location, the Persian Gulf. Marine Pollution Bulletin, 72(2): 333-341. https://doi.org/10.1016/j.marpolbul.2012.10.014

Pratchett MS, Wilson SK and Baird AH. 2006. Declines in the density of Chaetodon butterflyfishes following extensive coral depletion. Journal of Fish Biology, 69: 1269-1280. https://doi.org/10.1111/j.1095-8649.2006.01161.x

Reyes MZ, Raymundo DJC, Rizwan SJ and Licuanan WY. 2017. Coral gardening: Issues and challenges. Policy Brief, XI(1): 1-4.

Republic Act No. 10654. 2015. Amendment of the Philippine Fisheries Code of 1968. https://www.officialgazette.gov.ph/2015/02/27/republic-act-no-10654/. Accessed on 21 August 2022.

River GF and Edmunds PJ. 2001. Mechanisms of interaction between macroalgae and scleractinians on coral reef in Jamaica. Journal of Experimental Marine Biology and Ecology, 261(2): 159-172. https://doi.org/10.1016/S0022-0981(01)00266-0

Scheibling RE and Metaxas A. 2008. Abundance, spatial distribution, and size structure of the sea star *Protoreaster nodosus* in Palau, with notes on feeding and reproduction. Bulletin of Marine Science, 82(2): 221-235.

Shang YC, Tisdell C and Leung PS. 1991. Report on a Market Survey of Giant Clam Products in Selected Countries. Publication No. 107. Waimanshaalo, Hawaii: Center for Tropical and Subtropical Aquaculture. 1pp.

Tamayo NCA, Anticamara JA and Acosta-Michlik L. 2018. National Estimates of Values of Philippine Reefs' Ecosystem Services. Ecological Economics, 146: 633-644. https://doi.org/10.1016/j.ecolecon.2017.12.005

UN (United Nations). 2015. Do you know all 17 SDGs? https://sdgs.un.org/goals. Accessed on 21 August 2022.

Uychiaoco AJ, Green SJ, dela Cruz PA, Gaite HO, Aliño PM and White AT. 2010. Coral Reef Monitoring for Management, 2nd Edition. University of the Philippines Marine Science Institute. United Nations Development Programme Global Environment Facility-Small Grants Program, Guiuan Development Foundation, Inc., Voluntary Service Overseas, University of the Philippines Center for Integrative and Development Studies, Coastal Resource Management Project, and Fisheries Resource Management Project. 120pp.

van der Meer MH, Horne JB, Gardner MG, Hobbs J-PA, Pratchett MS and van Herwerden L. 2013. Limited contemporary gene flow and high self-replenishment drives peripheral isolation in an endemic coral reef fish. Ecology and Evolution, 3(6): 1653–1666. https://doi.org/10.1002/ece3.584

Verdadero FXD, Licuanan WY, Escudero KC, Narida EJG, Cristobal ACC and España NB. 2017. Status of coral communities and reef-associated fish and invertebrates in Batangas and Northern Palawan. Manila Journal of Science, 10: 101-114.

WWF-Philippines (World Wildlife Fund). 2010. Annual report: 2010. Summary of reports of all activities and studies apropos to Live Reef Food Fish. Sustainability project of the coral triangle (Province of Palawan, Philippines). Initiative submitted to the Palawan Council for Sustainable Development Staff. World Wildlife Fund for Nature-Philippines. 364pp.

WWF-Philippines (World Wildlife Fund-Philippines). 2012. Hart reef marine protected area management plan. Unpublished report. World Wildlife Fund for Nature-Philippines. 13pp.

WWF-Philippines (World Wildlife Fund-Philippines). 2013. Dumaran marine protected area network management plan, Dumaran, Palawan. Unpublished report. World Wildlife Fund for Nature-Philippines. 15pp.

WWF-Philippines. 2017. Status of Coral Communities and Reef-Associated Fish and invertebrates in the Municipality of Araceli, Palawan. Technical Report. 13pp.

WWF-Philippines (World Wildlife Fund-Philippines). 2019. Reef monitoring system vital for reef conservation and management. Coral Reef Resilience and Fisheries Sustainability.

ROLE OF AUTHORS: *RBC – gathered and analyzed the data and co-wrote the manuscript; GMA – gathered and analyzed the data; NJMFM – analyzed the data and co-wrote the paper; ARBC – gathered and analyzed the data; ANAMA – gathered and analyzed the data; JFR – gathered and analyzed the data; JAM – gathered and analyzed the data; IDM – gathered and analyzed the data; RGD – analyzed the data and co-wrote the paper.*