INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 20, No. 2, p. 106-115, 2022
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Diversity and abundance of Coral Reefs in Palaui Island protected landscape and seascape, San Vicente Sta. Ana, Cagayan, Philippines

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Article published on February 20, 2022

Key words: Diversity, PIPLS, Coral reef

Abstract

Palaui Island Protected Landscape and Seascape (PIPLS) is one of the Marine Key Biodiversity Areas (KBA's) in Philippines and it is noted for its enormous coral reef. The study was conducted to assess the health of PIPLS coral reef ecosystem and its diversity. Point Intercept Transect (PIT) method was used to monitor the coral reef condition, diversity, and the supporting fauna of coral reef ecosystem. The overall coral reef percentage cover was 70% which is in good condition. New recruits were found on the area which demonstrate a recovery process. There was a high percentage of live hard corals (42.2%) dominated by *Acropora* and *Porites* species, live soft corals (27.2%) dominated by *Lobophytum* species, and white dead corals (1.2%). Hard and soft corals with the highest density is *Porites lobota* (12.15%) and *Lobophytum pauciflorum* (8.41%), respectively. The overall species richness of PIPLS was 89 and a diversity index of 3.6 which means that PIPLS harbours different species belonging to different families but only occur in few numbers. The Simpson index value for all the observation sites indicates that all taxa were equally present. There are six (6) coral life corms thriving in PIPLS, these includes the tabular, branching, solitary, massive, encrusting and digitate corals. The health status of coral reef depends on environmental and human intervention. In order to determine if there are changes on the status and condition of coral reefs in the area and conservation programs being implemented are successful, yearly monitoring should be conducted.

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Introduction

Coral reefs are the most biologically diverse and economically valuable ecosystems on earth and the Philippines is one of the countries being blessed with great biodiversity of coral reefs due to its archipelagic nature. However, the destructive fishing practices and poor land management leading to sedimentation and poor water quality (Licuanan and Gomez, 2000) adversely affect the ecological balance of the ecosystem (White and Crus-Trinidad, 1998).

According to Gomez *et al.* (1994), the overall condition of the coral reefs in the country is not good which most of the reef areas have been adversely affected by human activities and only less than 5% are considered to be in excellent condition.

Being located on the Pacific belt of fire which several typhoons often hit the northern part of Cagayan Province, coral reefs in Palaui Island Protected Landscape and Seascape (PIPLS) often experience stress from strong waves coupled with other stressors like cyanide fishing and other destructive fishing practices. In order to address the depleting resource, PIPLS was one of the identified and established Marine Key Biodiversity Areas (KBA-11) for biodiversity conservation in the Philippines (CI, Philippines, 2006) and to date coastal development in the area is still growing along with sewage outfalls, runoffs and other environmental stressors caused by increasing number of visitors going to the island.

The estimated total reef area of the island is about 50 ha. (DENR, 2001 cited by DENR-PAMB, 2010 unpublished) and published information of the status of the reef ecosystem is still limited and not easy to accessed. There are studies already conducted in the area but it only focuses on other habitats like seagrass, mangroves, ecotourism and valuation. However, studies on coral reef ecosystem particularly on the status and diversity is still lacking which is very vital information that will be needed by resource managers and policy makers for monitoring and evaluation purposes and serve as basis in decision making with regards to its management, protection, and conservation. This will also serve as baseline information for future coral reef activities and projects to be conducted in the area.

Materials and methods

Location and Background of the study area

This study was conducted at PIPLS in San Vicente, Sta. Ana, Cagayan. It lies between 18° 30' to 18° 35' North latitude and 122° 05' to 122° 10' East longitude. It is bounded on the East by the Pacific Ocean, on the North and West by the West Philippine Sea, and on the South by the San Vicente Strait (Fig. 1) with a total area of 7, 415.48 ha (land and water). Coral reef assessment conducted in the month of May 2017 because of good weather condition and slow current movement.

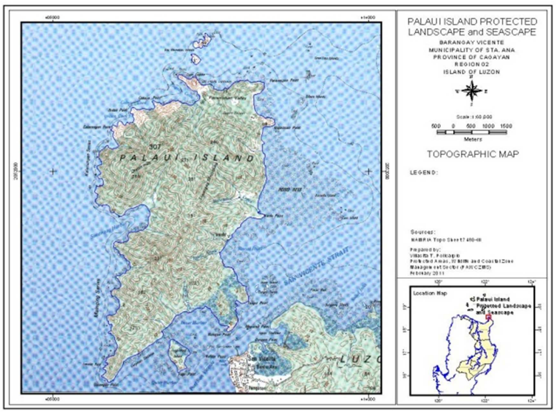

Fig. 1. Map of Palaui Island Protected Landscape and Seascape where the study was conducted.

The island was chosen as one of the Coastal Environmental Project (CEP) sites in 1993 due to its biological and ecological significance. Not long after, it was declared as a Marine Reserve in August 1994 under the category of Protected Landscape and Seascape based on Republic Act (R.A.) 7586 known as the National Integrated and Protected Area System (NIPAS) Law. In February 14, 1995, it became a part of Cagayan Economic Zone Development Authority (CEZA) when the entire municipality of Sta. Ana fell under the management of CEZA by virtue of R.A. 7922 (CEZA Act) and it was selected as a priority site for tourism development in 2005. Out from the total area of the island, 200 hectares were declared as Military Reserved under Presidential Proclamation (PP) No. 201 in which this area is being managed by the Philippine Navy. There were 14 institutional stakeholders composing the Protected Area Management Board (PAMB) of the island (DENR-PAMB, 2010 unpublished).

Palaui Island has four puroks: Racat, Malham, Alicoco and Mabulbul. Other significant sites in the area includes Langaoan series, Tallag, Pantalan, Hapon, Batayan, Tangol Point, Ramak ng Mati, Paradungan, Baratubot, Palanas, Baritoy, Susudan, Kannagan, Hoyo, Pasto, and Panamahan on the east; Popok on the north, Gosangan Point on the south, and Kampanaryo, Maing-ing, Pog, Agwab, Siwangag, Calacongan, Order Point and the well-known historical site, the Cape Engaño on the west (DENR-PAMB, 2010 unpublished). The area is generally sloping with relatively low hills and dominant moderate slopes. The west coast of the island has high cliffs while the eastern portion has extensive reef flat with rock islets. Bandera Mountain is the highest elevated area in the island while the second is Bantay Kali located near Siwangag cove followed by Siwangag and Agwab. The lowest elevation is found on the eastern side of the island along the shores near Langaoan Shallows and Robo Reef near Baratubot (DENR-PAMB, 2010 unpublished).

Data collection

Coral reef assessment was conducted using the Point Intercept Transect (PIT) method of English *et al.* (1997). Using Self Contained Underwater Breathing Apparatus (SCUBA) equipment's, percentage coral relative to other benthos, species identification and photo-documentation was collected. Three observation sites were randomly selected in the area where a 50-meter transect line was deployed over the coral reef areas following the procedure of English *et al.* (1997). The three (3) collection sites in the study area were Snake Island, Punta Verde, and Cape Engaňo. Recordings were taken at every 25 centimeters along the line from the end to the other. Each 50 meter transect line contains 200 sampling points and there were three sampling stations during the assessment. Hence, a total of 600 sampling points were established during the conduct of the study. Coral species intercepted by the transect line within the established sampling points were identified and recorded. Total enumeration and identification of coral species were conducted. Sponges, coral rubbles, sand/silt, dead corals with algae, micro-algae, and rocks that occur in the transect line were recorded. Soft corals and hard corals were also identified using field guides (Bright *et al.* 2013; Tracey *et al.* 2014).

Data analysis

Data were presented in tables, graphs, and percentages. Percentage coral cover was calculated using the following formula (Uychiaoco *et al.* 2001).

Percentage cover

$$= \frac{Totalnumberofhardcorals}{Totalnumberofobservationpoints} x\ 100$$

Diversity (H'), evenness index (J), and Simpson's dominance index (1-D), were calculated using the Shannon-Wiener (1948), Pielou (1966), and Simpson (1949) with the following formulas:

Shannor-Wiener species diversity (H')

$$H' = -\sum_{t=1}^{s} p = ni \ln ni$$

Simpson's dominance index

$$\lambda = \sum_{i=1}^{S} \frac{ni(ni-1)}{N(N-1)}$$

where:

n_i– is the proportion of S made up of the ith species

S – total number of species in the community (species richness)

Ln n_i– natural logarithm of the proportion (ln ni)

N – total number of individuals

Pielou's evenness index (J')

$$J' = H'/\ln S$$

where: S = number of species

Coral reef condition (Table 1) was determined using the coral reef rating of English *et al.* (1997).

Table 1. Criteria in the determination of coral reef condition of PIPLS.

Condition	Criteria
Excellent	76-100% coverage
Good	51-75% coverage
Fair	26-50% coverage
Poor	0-25% coverage

Result and discussion

Out of 535 coral individuals, a total of 89 coral species (belonging to 27 genera) were recorded during the assessment (Fig. 2). Among these are hard corals (belonging to 23 genera, 12 families) and 18 species (belonging to 4 genera, 2 families) are soft corals. In 2002, Alinio *et al.* reported that there are 35 genera of corals with genus *Porites* as the most dominant in PIPLS.

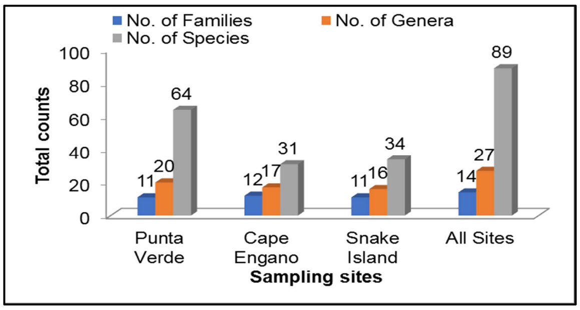

Fig. 2. Total families, genera and species per observation site.

Coral reef condition

Out of 488 species of corals present in the Philippines (Nemenzo, 1981), 18% of it were known to exist in PIPLS. Using the criteria of percentage coral cover (hard and soft corals). Notably, Punta Verde is in excellent condition with 81% coral cover while Cape Engaňo and Snake Island exhibited good condition with a coral cover of 65% and 65.5%, respectively (Fig. 3). As observed, most of the coral area in Cape Engaňo was covered with turf algae where hard corals seldom occur in the transect line and corals in Snake Island were dominated by live soft corals and macro-algae.

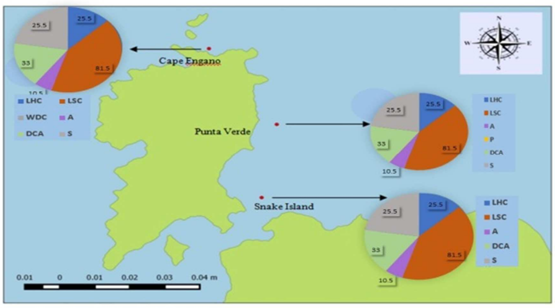

Fig. 3. Percentage coral cover of PIPLS coral reef ecosystem.

Legend: LHC– Live Hard Coral, LSC - Live Soft Coral, WDC– White Dead Coral, DCA- Dead Coral with Algae, A- Algae (Turf and Freshly macro-algae), P - Poriferans, S– Substrate

The overall percentage coral cover of the three (3) observation site (Table 2) was 70.5% which is in good condition. While white dead corals had an average cover of 1.2%, dead corals with algae had 3.5%, algae had 11% (turf algae 7.2% and fleshy macro-algae 3.8%), sponges had 0.3%, and substrate constitute 14.7%. The highest coral cover was observed in Punta Verde could be due to the establishment of marine sanctuary in the area where it was characterized by the dominance of *Acropora* species with large portion of table corals (*Acropora cytherea*) observed. Likewise, there are presence of massive and sub-massive *Porites* on the shallow depths of the transect line.

Table 2. Estimated percentage coral cover and other benthic forms of PIPLS, 2017.

Taxa	Coral Cover (%)				
	Punta Verde	Cape Engaňo	Snake Island	Total	Average
Corals					
Live hard corals	58.0	43.0	25.5	126.5	42.2
Live soft corals	23.0	18.5	40.0	81.5	27.2
White dead corals	0	3.5	0	3.5	1.2
Total	81	65	65.5	211.5	70.5
Algae					
Dead corals with algae	5.5	2.5	2.5	10.5	3.5
Turf algae	0	16.5	5	21.5	7.2
Fleshy macro-algae	1.5	8.5	1.5	11.5	3.8
Poriferans					
Sponges	1.0	0	0	1.0	0.3
Substrate					
Rubble	0.5	0.5	3.5	4.5	1.5
Rock	10.5	1.0	14.5	26	8.7
Sand/Silt	0	6.0	7.5	13.5	4.5

Notably, the strip of the reefs that tends to be located near or close to the shoreline could be attributed to siltation occurring in the area when heavy downpour occurs or this could be due to the presence of recruitment substrate. There were also segments where rocks, dead corals with algae, and soft corals (*Sarcophyton, Eleutherobia,* and *Lobophytum*) were observed. Meanwhile, Cape Engaňo (Table 3) has higher percentage cover of hard corals than soft corals which were dominated by genus *Porites* and genus *Lobophytum*, respectively. However, it can be noted that some of the areas were dominated by turf algae and fleshy macro-algae. The observed presence of encrusting corals and deep canals in the area could be an indication that the area is exposed to high energy wave action during the northeast monsoon. Though, Cape Engaňo is no longer a part of the marine sanctuary, the distance of the site from the fishing communities on the mainland may have contributed to the preservation of coral cover.

Table 3. Relative density and frequency of hard coral species in PIPLS, 2017.

Family Name	English Name	Species	N	n/N	Rel. Den. (%)	Rel. Freq. (%)
Poritidae	Lobe coral	*Porites lobata* (Dana)	65	0.121	12.15	11.28
Pocilloporidae	Thin Birds nest coral	*Seriatopora hystrix* (Dana)	61	0.114	11.4	9.02
Poritidae	Lichen coral	*Porites lichen* (Dana)	35	0.065	6.54	7.27
Poritidae	Branching flowerpot	*Alveopora spongiosa* (Dana)	11	0.021	2.06	2.51
Faviidae	Closed brain coral	*Goniastrea edwardsi*	9	0.017	1.68	2.01
Milleporidae	Fire Corals	*Millepora alcicornis* (Linnaeus)	9	0.017	1.68	1.25
Acroporidae	Staghorn coral	*Acropora caroliniana* (Nemenzo)	8	0.015	1.5	1.25
Acroporidae	Table coral	*Acropora Cytherea* (Dana)	8	0.015	1.5	1.5
Faviidae	Closed brain coral	*Goniastrea pectinata* (Ehrenberg)	8	0.015	1.5	1.5
Acroporidae	Staghorn coral	*Acropora cervicornis* (Lamarck)	7	0.013	1.31	1.75
Mussidae	Brain coral	*Favia* sp.	7	0.013	1.31	1.5
Montastraeidae	Brain coral	*Montastraea cavernosa* (Linnaeus)	7	0.013	1.31	1.5
Diploastreidae	Honeycomb coral	*Diploastrea heliopora* (Lamarck)	6	0.011	1.12	1.5
Acroporidae	Table coral	*Acropora digitifera* (Dana)	5	0.009	0.93	1
Mussidae	Brain coral	*Favia* sp. 1	5	0.009	0.93	1
Merulinidae	Brain coral	*Favites halicora* (Ehrenberg)	5	0.009	0.93	0.75
Fungiidae	Mushroom coral	*Fungia* sp.	5	0.009	0.93	0.75
Pocilloporidae	Birds nest coral	*Seriatopora stellate* (Quelch)	5	0.009	0.93	0.75
Fungiidae	Tongue coral	*Herpolitha limax* (Houttuyn)	4	0.007	0.75	1
Pocilloporidae	Birds nest coral	*Seriatopora aculeate* (Quelch)	4	0.007	0.75	0.75
Acroporidae	Robust staghorn coral	*Acropora robusta* (Dana)	3	0.006	0.56	0.5
Faviidae	Closed brain coral	*Goniastrea* sp.	3	0.006	0.56	0.75
Poritidae	Flowerpot coral	*Goniopora minor* (Crossland)	3	0.006	0.56	0.5
Montastraeidae	Star coral	*Montastraea faveolata* (Ellis &Solander)	3	0.006	0.56	0.25
Montastraeidae	Star coral	*Montastraea valencienesi* (Edwards & Haime)	3	0.006	0.56	0.75
Merulinidae	Lesser Valley Coral	*Platygyra* sp.	3	0.006	0.56	0.75
Poritidae	Jeweled finger coral	*Porites annae* (Crossland)	3	0.006	0.56	0.5
Poritidae	Finger coral	*Porites compressa* (Dana)	3	0.006	0.56	0.25
Poritidae	Plate and knob coral	*Porites monticulosa* (Dana)	3	0.006	0.56	0.5
Poritidae	Dome coral	*Porites nodifera* (Klunzinger)	3	0.006	0.56	0.5
Poritidae	Hump coral	*Porites* sp.	3	0.006	0.56	0.5
Acroporidae	Staghorn coral	*Acropora aspera* (Dana)	2	0.004	0.37	0.5
Acroporidae	Staghorn coral	*Acropora samentosa* (Brook)	2	0.004	0.37	0.25
Poritidae	Staghorn coral	*Alveopora* sp.	2	0.004	0.37	0.5
Merulinidae	Trumpet coral	*Caulastrea tumida* (Matthai)	2	0.004	0.37	0.5
Mussidae	Grooved brain coral	*Diploria labyrinthyformis* (Curacao)	2	0.004	0.37	0.5
Mussidae	Brain coral	*Diploria strigosa* (Dana)	2	0.004	0.37	0.5
Mussidae	Brain coral	*Favia* sp. 2	2	0.004	0.37	0.5
Fungiidae	Mushroom coral	*Fungia* sp. 2	2	0.004	0.37	0.5
Oculinidae	Star coral	*Galaxea* sp.	2	0.004	0.37	0.5
Helioporidae	Blue coral	*Heliopora coerulea* (Pallas)	2	0.004	0.37	0.5
Montastraeidae	Star coral	*Montastraea* sp.	2	0.004	0.37	0.5
Pocilloporidae	Cauliflower coral	*Pocillopora damicornis* (Linnaeus)	2	0.004	0.37	0.5
Acroporidae	Staghorn coral	*Acropora elegans* (Edwards and Haime)	1	0.002	0.19	0.25
Acroporidae	Staghorn coral	*Acropora gemmifera* (Brook)	1	0.002	0.19	0.25
Acroporidae	Finger coral	*Acropora humilis* (Dana)	1	0.002	0.19	0.25
Acroporidae	Staghorn corals	*Acropora muricata* (Linnaeus)	1	0.002	0.19	0.25
Acroporidae	Fuzzy table coral	*Acropora paniculata* (Verrill)	1	0.002	0.19	0.25
Acroporidae	Staghorn coral	*Acropora* sp.	1	0.002	0.19	0.25
Poritidae	Branching flowerpot	*Alveopora tizardi* (Basset-Smith)	1	0.002	0.19	0.25
Merulinidae	Candycane coral	*Caulastrea* sp.	1	0.002	0.19	0.25

Family Name	English Name	Species	N	n/N	Rel. Den. (%)	Rel. Freq. (%)
Faviidae	Meteor shower coral	*Cyphastrea* sp.	1	0.002	0.19	0.25
Mussidae	Brain coral	*Diploria* sp.	1	0.002	0.19	0.25
Merulinidae	Hedgehog coral	*Echinopora* sp.	1	0.002	0.19	0.25
Mussidae	Brain coral	*Favia rotundata* (Veron, Pichon, & Wijsman Best)	1	0.002	0.19	0.25
Mussidae	Brain coral	*Favia* sp. 3	1	0.002	0.19	0.25
Fungiidae	Mushroom coral	*Fungia* sp. 3	1	0.002	0.19	0.25
Oculinidae	Star coral	*Galaxea fasicularis* (Linnaeus)	1	0.002	0.19	0.25
Faviidae	Closed brain coral	*Goniastrea* sp. 1	1	0.002	0.19	0.25
Poritidae	Flowerpot coral	*Goniopora lobota* (Edwards &Haime)	1	0.002	0.19	0.25
Fungiidae	Slipper coral	*Herpolitha* sp.	1	0.002	0.19	0.25
Merulinidae	Brain coral	*Leptoria* sp.	1	0.002	0.19	0.25
Pocilloporidae	Cauliflower coral	*Pocillopora verrucosa* (Elis & Solander)	1	0.002	0.19	0.25
Poritidae	Mustard hill coral	*Porites asteroids* (Lamarck)	1	0.002	0.19	0.25
Poritidae	Brighams coral	*Porites brighami* (Vaughan)	1	0.002	0.19	0.25
Poritidae	Hump coral	*Porites cylindrical* (Dana)	1	0.002	0.19	0.25
Poritidae	Hump coral	*Porites desilveri* (Veron)	1	0.002	0.19	0.25
Poritidae	Knobby finger coral	*Porites duerdeni* (Fenner)	1	0.002	0.19	0.5
Poritidae	Column coral	*Porites rus* (Forskal)	1	0.002	0.19	0.25
Pocilloporidae	Birds nest coral	*Seriatopora* sp.	1	0.002	0.19	0.25
Mussidae	Closed brain coral	*Symphyllia* sp.	1	0.002	0.19	0.25
Total			359	0.679	67.13	68.59

On the contrary, Snake Island were dominated by soft coral species than hard corals. Soft corals were dominated by *Lobophytum* species and hard corals were dominated by *Porites* species. The area is nearly close to the mainland of San Vicente where high coastal development (buildings, hotels, and resorts) and increasing population within the coastal area was observed. Hence, runoff and sedimentation are often observed. Therefore, the dominance of soft corals and fleshly macro-algae in the area could be attributed to the effect of sedimentation and runoff. According to Golbuu *et al.* (2003), benthic communities are easily smothered by sedimentation which reduces photosynthetic yields in corals. The excess sediments cover the corals, blocking the light necessary for their symbiotic zooxanthellae and smothering polyps and in this case, nutrients disrupt the balance between fast growing macro-algae and corals thereby macro-algae take over and smother corals (Philipp and Fabricius, 2003).

Generally, new recruits were found to grow on the dead coral substrate in Punta Verde and Cape Engaňo which is an indication that some of the coral species are recovering. The distribution of coral species in the three observation sites were patchy and most of the species were confined near the shoreline.

These patches were observed in the sandy areas and gradually sloping reefs. Large *Tridacna* species were also observed in the area. Coral rubbles were present in all the observation sites since the area is being used as navigation area for motorboats ferrying visitors and tourists going to Punta Verde, Cape Engaňo, and Snake Island. These rubbles are the result of dropping of anchors and use of "tikin" or bamboo poles which cause physical damage to corals. Corals might also scrape by boats that attempt to approach during receding tide. Presence of white dead corals was also observed particularly *Favites* and *Seriatopora* species. The cause of whitening is still not clear since there are no coral predators observed in the area during the assessment. However, it was claimed by the fishers that cyanide fishing or use of obnoxious substances are being used in the area to stun or capture ornamental fish for marine aquarium and live fish trade.

Coral reef density

As observed, hard corals with the highest relative density and relative frequency were *Porites lobata, Seriatopora hystrix,* and *Porites lichens* with relative density of 12.15%, 11.40%, and 6.54%, and a relative frequency of 11.28%, 9.02%, and 7.27%, respectively (Table 3).

The result of the assessment corroborates to the result of the assessment conducted by Aliňo *et al.* (2002) where *Porites* species are the most dominant species in PIPLS. The soft corals on the other hand, with the highest observed percentage relative density are *Lobophytum pauciflorum* (8.41%), *Lobophytum crassum* (7.66%), and *Sacrophyton elegans* (3.18%) with a relative frequency of 7.27%, 9.02%, and 2.76%, respectively (Table 4).

Table 4. Relative density and frequency of soft coral species in PIPLS, 2017.

Family Name	English Name	Species	n	n/N	Rel. Den. (%)	Rel. Freq. (%)
Stichodactylidae	Sebae anemone	*Heteractis crispa* (Hemprich & Ehrenberg)	45	0.084	8.41	7.27
Alcyoniidae	Devils hand coral	*Lobophytum* sp. 4	41	0.077	7.66	9.02
Alcyoniidae	Devils hand coral	*Lobophytum* sp. 5	17	0.032	3.18	2.76
Alcyoniidae	Sea soft leather coral	*Sarcophyton mililatensis* (Verseveldt & Tursch)	13	0.024	2.43	2.26
Alcyoniidae	Devils hand coral	*Lobophytum depressum* (Tixier-Durivault)	12	0.022	2.24	1.75
Alcyoniidae	Rough leather coral	*Sarcophyton glaucum*	10	0.019	1.87	1.25
Alcyoniidae	Leather coral	*Sarcophyton* sp. 2	10	0.019	1.87	1.75
Alcyoniidae	Leather coral	*Sarcophyton* sp. 1	9	0.017	1.68	1.5
Alcyoniidae	Devils hand coral	*Lobophytum sarcophytoides*	5	0.009	0.93	1
Alcyoniidae	Slimy leather coral	*Sarcophyton trocheliophorum* (von Marenzeller)	3	0.006	0.56	0.25
Alcyoniidae	Devils hand coral	*Lobophytum* sp.	2	0.004	0.37	0.5
Alcyoniidae	Devils hand coral	*Lobophytum* sp. 2	2	0.004	0.37	0.5
Alcyoniidae	Devils hand coral	*Lobophytum* sp. 3	2	0.004	0.37	0.25
Alcyoniidae	Soft corals	*Eleutherobia* sp.	1	0.002	0.19	0.25
Alcyoniidae	Devils hand coral	*Lobophytum* sp. 1	1	0.002	0.19	0.25
Alcyoniidae	Large yellow leather	*Sarcophyton elegans* (Moser)	1	0.002	0.19	0.25
Alcyoniidae	Cabbage Leather coral	*Lobophytum crassum* (von Marenzeller)	1	0.002	0.19	0.25
Alcyoniidae	Devils hand coral	*Lobophytumpauciflorum* (Ehrenberg)	1	0.002	0.19	0.25
Total			176	0.331	32.89	31.31

Table 5. Diversity index per observation sites in PIPLS, San Vicente, Sta. Ana, Cagayan, 2017.

Diversity Index	Observation Sites			
	Punta Verde	Cape Engaňo	Snake Island	All sites
Species richness	64	31	34	89
Average population	3.35	4.81	4.73	6.01
Total number of individuals (N)	220	154	161	535
Natural log of species	4.16	3.43	3.53	4.49
Natural log of individuals (ln N)	5.39	5.04	5.08	6.28
Simpson's dominance index (1-D)	0.95	0.88	0.91	0.8
Pielou's evenness index (J)	0.88	0.81	0.81	0.80
Shannon-Weiner diversity index (H')	3.70	2.80	2.80	3.60

These are the species of hard and soft corals that were common and abundant in the observation sites. *Porites* species could be more adaptable in the environment because the area is exposed to high wave action wherein the species is known as a very common genus of coral and are found in the widest area of the world's coral reefs (Manogar *et al.*, 2019).

Coral reef diversity

Cape Engaňo has the most observed genera (10 genera) of corals belonging to eight families followed by Punta Verde with nine genera and Snake Island with seven genera.

Species richness was 64, 31, and 34 for Punta Verde, Cape Engaňo, and Snake Island, respectively, and has an overall species richness of 89 (Table 5).

Shannon-Weiner diversity index value was found to be high in Punta Verde (3.7) followed by Snake Island and Cape Engaňo with similar diversity value of 2.8. Comparing the diversity of the three sampling sites, Punta Verde is much more diverse than Cape Engaňo and Snake Island. There was a high diversity in Punta Verde because the area was dominated by different species of hard corals and the presence of soft coral species.

This was in contrast to the observation in Cape Engaño and Snake Island where the area was dominated more with soft corals belonging to two families.

The overall diversity index of PIPLS coral reef was high (3.6). According to Smith and Smith (2003), diversity is related to species richness and how individuals are evenly distributed among species in a community. Further, the authors concluded that a community with few individuals from many different species has higher diversity than that community of the same number of individuals with most of them belonging to few species. Values of the Shannon-Weiner diversity index for real communities typically fall between 1.5 and 3.5.

This statement is interestingly true in the case of Punta Verde since it harbours a lot of different species belonging to different families but only occurring in a few numbers. Cape Engaño is often exposed to high wave energy especially during southwest monsoon. Hence, new recruits were seldom found on the area. According to Orth and Colette (1996), the Shannon-Weiner diversity index has strong values for species with same importance and it takes low when some species have strong recoveries.

On the contrary, Simpson's dominance index value for Punta Verde was slightly higher (0.95) compared to Cape Engaño (0.88) and Snake Island (0.91). The value generated only indicates that all taxa in the observation sites were equally present. Ifo *et al.* (2016) stated that the value of equitability (evenness index) varied from 0 (all taxa are equally present) to 1 (taxon dominates the community completely).

The authors observed that, it is equal to 1 when all the species have the same abundance and tend towards 0 when the near total of floral and faunal is calculated to only one species. The study revealed that there is an existence of variability of coral diversity in all sampling areas. When there is a dissimilar abundance, the value of evenness decreases. The data showed that there are similar proportions of different species in the different observation sites as reflected by the evenness value which is nearly or close to 1.0.

Coral reef forms

The coral reef of PIPLS has six coral life forms recorded (Fig. 4). Most of the corals observed during the assessment was branching, massive, encrusting corals, and digitate corals. Only few tabular and solitary corals observed.

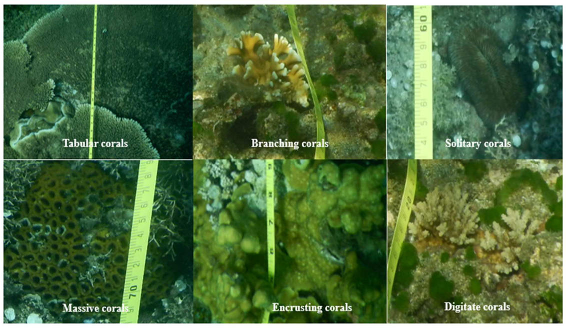

Fig. 4. Coral reef life forms present in PIPLS.

Coral reefs of Palaui Island are of fringing type and can be found on the Eastern and Southern part of the island. Reef flat between Palaui Island and mainland Luzon extend to about a kilometer eastward towards the Pacific Ocean. Corals are also found in Palaui Island particularly in Siwangag Cove, Aguab, and at Cape Engaño.

Conclusion

The topographic characteristic of Palaui Island Protected Landscape and Seascape and the complex interaction between biotic and abiotic factors in the area could be some of the factors that controls the differences in diversity, species richness of the coral reef species in the area. It can be inferred that the formation of corals, diversity, abundance and condition of coral reef in the area is affected by several factors like siltation, heavy downpour, wave action and the presence or absence of fishing communities in the area.

The dominance of soft corals and fleshy macro-algae in Snake Island could be attributed to sedimentation and run off. The presence of new recruits on dead corals in an indication of recovery process. Punta Verde has the highest diversity and species richness recorded wherein hard and soft corals were observed. To determine if there are changes on the status and condition of coral reefs in the area and conservation programs being implemented are successful, yearly monitoring should be conducted.

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