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Research Article

Status of benthic cover in Carbin Reef, Sagay Marine Reserve, Western Visayas, the Philippines

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ABSTRACT

This study determined the status of Carbin Reef benthic cover, Sagay Marine Reserve, Negros Occidental. The underwater benthic assessment was conducted on March 2019 by laying eight 50-meter transect lines at the depths of 6 meters (crest) and 12 meters (slope). Photo-quadrat method was used in obtaining still benthic images for every 1-m across eight 50-meter transect lines. A total of 400 still images were acquired and analyzed using Coral Point Count with Excel Extension (CPCe). The sedimentation rate was also determined by deploying sediment collectors. Results showed that Carbin Reef is characterized by 26.09% live coral cover and 43.25% abiotic structure such as rocks, sand, and coral rubbles. Fifty-five (55) coral species belonging to thirty-three (33) genera were identified, dominated by *Porites*, *Fungia*, and *Goniastrea*. Throughout the area, *Porites lobata* was the most dominant coral species. The overall hard coral cover seemed to have decreased since 2014. Further analysis showed the prevalence of bleached corals and diseases such as white syndrome, and white band disease. Similarly, two signs of compromised health including sediment damage and competition overgrowth were also present. The sedimentation rate per day was below the maximum tolerable levels by most corals during dry season. Overall, this study presents the first extensive study of coral diversity in Carbin Reef–characterized by a moderately diverse area and considered as a moderately stressed habitat.

Keywords: Live coral cover, CPCe, Transect images, Species diversity, Sedimentation

Introduction

The Philippines, lying at the apex of Coral Triangle, has an estimated coral reef area of 26,000 km^2 and considered as the second largest in Southeast Asia (Spalding, 2001; Burke et al., 2002; Burke et al., 2011; Carpenter et al., 2011). There are approximately 500 species of scleractinian or stony corals in the country, with 12 of them considered as endemic (ADB 2014). However, an average of 15% decline on coral reefs globally happens caused by climate change, typhoons, diseases, pollution, overfishing, etc. (Hughes et al., 2017). Philippine coral reefs suffer the same, which is in a declining state. Based from 1976-1981 nationwide coral reefs assessment, only 5.5% of the Philippine coral reefs are in excellent condition, while 70.1% are considered fair to poor (Gomez et. al., 1981). Subsequent studies were conducted between 1987-1994 and revealed a decline in excellent live coral cover from 5.5% to 2.4%, with 75.3% categorized as poor or fair (Gomez et. al., 1994). Similarly, a nationwide survey from 1990 to 1999 found that 4.3% of the coral reef area is in excellent condition (Licuanan and Gomez, 2000). With the declining state of the Philippine coral reefs and increasing environmental pressures, continuous monitoring of their conditions is important for proper management and protection.

Due to increased coral reef declines, the Philippine Coral Reef Information Network (PhilReefs) produced a series of publications serving a venue to monitor the status of Philippines coral reefs. These publications were cascaded from national to local levels (from province to barangay) providing specific information on coral reef status (Aliño et. al., 2002; PHILREEFS, 2010). The country's coral reef monitoring sites were divided into six biogeographic regions: the West Philippine Sea, North Philippine Sea, South Philippine Sea, Sulu Sea, Celebes Sea, and Visayan Sea (Aliño and Gomez, 1994) represented with 61 municipalities/cities (PHILREEFS, 2010). In the Visayan region, particularly in the province of Negros Occidental, three municipalities/cities (6 stations) were included in the survey between January 2015 and January 2017 (Licuanan et al., 2017). The results revealed 33% hard coral cover (HCC) present in Northern Negros, ranking as the 6th highest percentage of HCC in the country. While majority of the reefs surveyed in Visayas are categorized as poor, excellent conditions are found in protected areas reiterating the importance of marine reserves in coral reef protection.

Negros Occidental is known for its largest marine reserve in the Philippines the Sagay Marine Reserve (SMR). Being the largest marine reserve in the country, SMR is an important management initiative for national and international sustainability and food security. It is also known for its rich marine ecosystem diversity (Maliao et al., 2004; Manejar et al., 2019; Albarico et al., 2020). SMR was established in 1983 and was previously known as Sagay Marine Sanctuary. The Department of Environment and Natural Resources (DENR), recognized the potential of Sagay's coast to contribute to the preservation of Philippine biodiversity and advocated its inclusion in the National Integrated Protected Areas System (NIPAS) (Surtida, 2001; NIPAS 1992). The Presidential Proclamation 592 declared the 32,000 ha Sagay's coastal waters on June 10, 1995 as protected seascape (NIPAS, 1992). The Sagay Marine Reserve Law was then strengthened through Republic Act No. 9106, enacted on April 1, 2001 (Proclamation No. 592) to include the islands of Molocaboc Daku, Molocaboc Diut, Matabas, and Suyac, as well as their surrounding reefs such as Carbin, Molocaboc, and Panal, and the coastal waters of Himo-gaan Baybay, Old Sagay, Taba-ao, Bulanon, Molocaboc, and Vito in the 32,000 ha SMR (NIPAS 1992; Proc. 592; R.A 9106).

Carbin Reef is one of the reef components inside SMR, and the nearest to the mainland (about 5.4 km), and an estimated area of 200 hectares. This was first proclaimed through Municipal Ordinance No. 2 as a marine sanctuary in 1983, hence, it became an important biodiversity conservation model locally and internationally (Alcala, 1988; Webb et al., 2004). A previous study recorded twenty-eight (28) genera of scleractinian corals dominated with massive species *Porites* spp., and sub-massive types (*Favia stelligera*) in Carbin Reef (Maliao et al. 2004). The area was assessed to evaluate its effectiveness on the restoration and conservation of donkey's ear abalone stocks considering the reef's protected status. While the reserve is monitored by SMR Office, scientific reports and published diversity studies are important to provide scientifically sound literatures. Currently, there is a lack of up-to-date information on the status of Carbin Reef. Species-level data is also lacking. Therefore, the aim of this study was to determine the benthic cover, coral diversity, and health status of corals in Carbin Reef in order to establish an in-depth diversity background and to strengthen its management.

Material and Methods

Sampling

Sampling was done in March 2019 in Carbin Reef, Sagay City, Negros Occidental (Figure 1); one of the major reefs within the 32,000 hectares' SMR. Carbin reef covers about 200 hectares and is characterized as a sand cay at the southern end. The most common substrate are dead corals, found in the north, east, and west of the cay. A sandy bottom characterizes the area in the south. On the northern extremity of the reef, a dense growth of *Sargassum* spp. are found. In 1983, a reef watch tower was built in Carbin reef and is still in use by the local government unit's *bantay dagat* or local deputized fisheries enforcers (Maliao et al., 2004). The Philippines' *bantay dagat* or sea guardian program is a community-based law enforcement that uses volunteers from coastal villages or barangays to help detect and apprehend illegal fishing in municipal waters (Maderazo and Advisors, 2016).

Carbin reef is within the Strict Protection Zone of SMR wherein fishing activities are prohibited. However, some portion of the area is intended for recreational activities (i.e. diving, snorkeling, swimming). Extending approximately 500 meters from the edge of Carbin reef is considered as buffer zone, allowing migration of species with relatively limited human disturbance.

An underwater survey was conducted between the depths of 6–12 meters at eight sampling points (Table 1) using Self-Contained Breathing Apparatus (SCUBA) diving equipment. Transects were laid and the photo-quadrat method was used to gather benthic images (van Woesik et al., 2009). After the photo-quadrat, individual coral species on the same transect were photographed to attain closed-up photos for species verification. Table 1 listed the transect coordinates and depth profiles.

Benthic photographs were obtained using an underwater camera (GoPro Hero 5 with underwater casing) mounted on a 0.75-meter-high improvised PVC tetrapod (1 x 1 m base frame/ quadrat) (Figure 2a,b) with a constant vertical distance between the camera and the transect line, starting from the zero mark of the transect. Benthic still images were captured for every 1 m, across the 50 m transect line (DENR-BMB Technical Bulletin No. 05, s. 2017). As a result, each transect acquired fifty (50) photographs, for a total of 400 images for all transects. Photographs were processed and analyzed using the CPCe software by Kohler and Gill (2006). Closed-up individual coral photos were taken in the same transect for species identification. Corals were identified using published literatures (Aliño et al., 2002; Richards, 2018), and verified in the Corals of the World website (Veron et al., 2019). Coral diversity was calculated using Shannon-Weaver and Simpson's diversity indices (Arias-González et al., 2012; Ismail et al., 2022).

Table 1. Location and depth profile of the sampling points.

Transect No.	**Depth (meter)**	**Coordinate**	
		Latitude	Longitude
Transect 1	6	10°58'55.0''	123°27'13.0''
Transect 2	12	10°59'00.0''	123°27'08.4''
Transect 3	6	10°58'51.5''	123°28'05.0''
Transect 4	12	10°58'52.2''	123°28'06.2''
Transect 5	6	10°59'22.4''	123°27'54.7''
Transect 6	12	10°59'22.5''	123°27'51.7''
Transect 7	6	10°58'43.0''	123°27'52.0''
Transect 8	12	10°58'42.6''	123°27'53.8''

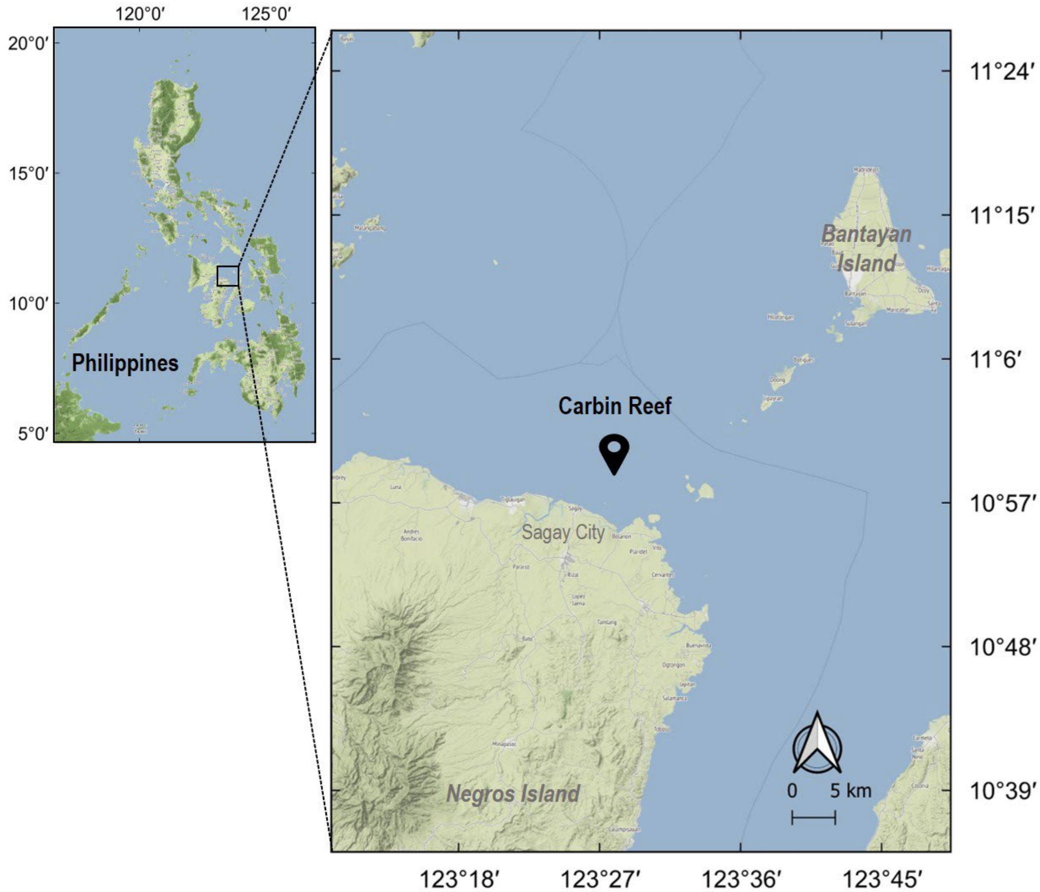

Figure 1. Study site indicating the location of Carbin Reef, Sagay Marine Reserve.

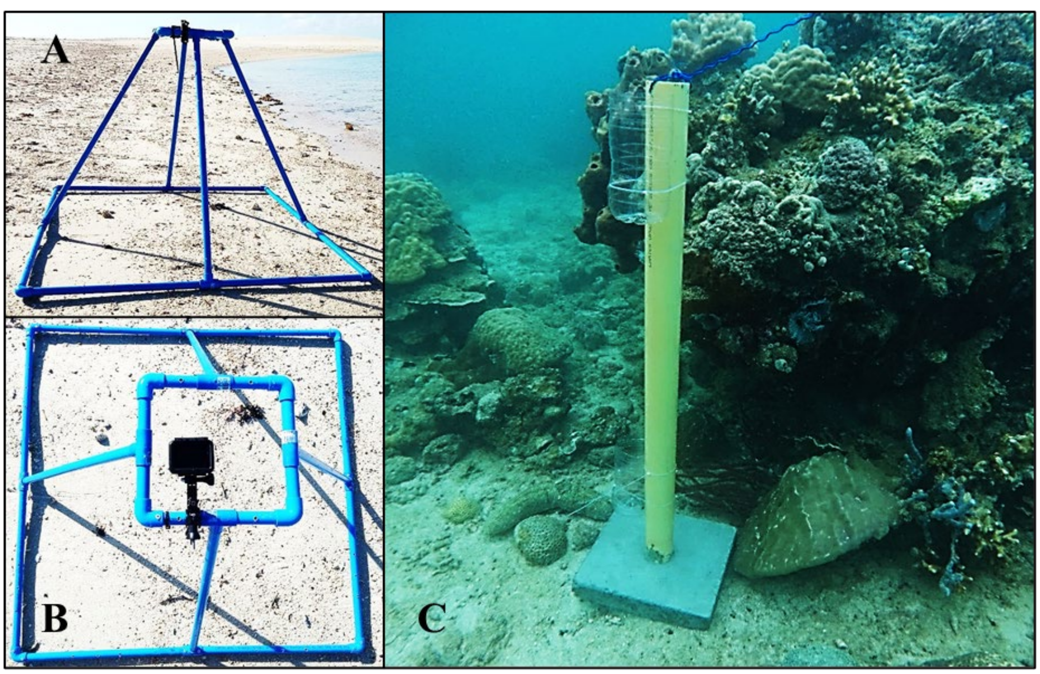

Figure 2. PVC tetrapod with 0.75-meter-height from the substrate with a 1 x 1 m base frame/quadrat (a,b); and sediment collector installed at 6-meter depth (c)

Coral diseases were also noted to provide additional background on coral health status. Prevalence of diseases and signs of compromised health were morphologically identified through the acquired photographs. Closed-up photos were taken to further verify disease prevalence. Disease identification was based from the Coral Disease Handbook of Raymundo et al. (2008).

Sediment Collection

The sedimentation rate per day was determined to gain insights on potential impacts of weather events and anthropogenic run-offs on the reef (Rogers, 1990). Four sediment collectors (Figure 2c) were deployed in each of the 6 m deep transect sites, vertically mounted to the reef. These sediment collectors were made of PVC pipe (which serves as a post) and a cement platform to stabilize the post. At 70 and 20 cm, respectively above the substrate, plastic bottles (about 15 cm high and 8 cm diameter) were affixed to a reference pvc pipe/post. The plastic bottles containing sediment were removed from the post after 7 days and taken to the laboratory for processing. Small organisms were removed from the plastic jar with tweezers. The sediments were filtered through a filter paper (Whatman Filter No. 1) and gently washed multiple times with distilled water to remove salts. The filtered sediment were oven-dried at 70°C until a constant weight was attained. Sedimentation rate was determined in milligrams of sediment per square centimeter (cm^2) per day. Sedimentation rate was calculated as: Sedimentation rate = (sediment weight) ÷ (number of days at the site × r^2). The sediment weight is the total weight minus the filter weight, and the area of the jar opening is πr^2 (r= radius in cm) (Rogers et al., 1994).

Results and Discussion

Benthic Cover

Coral ecosystem of Carbin reef was characterized as a fringing reef. Carbin reef had 26.09% live hard coral cover (HCC), while abiotics such as sand, rock, and rubble had a greater average proportion of 43.25% (Figure 3). The coral cover of Carbin reef was in fair condition, according to the criteria (23–33%) outlined in DENR-BMB (2017). Dead corals, on the other hand, had a greater percentage cover of 22.36, which was closer to the overall mean live HCC. This has caused a decline in the hard coral cover within Sagay Marine Reserve from the 33% HCC estimated by Licuanan et al. (2014). This suggests that ecological processes may be present that are causing the coral reef community to deteriorate (Tabugo, 2016). Anthropogenic influences such as fishing, underwater leisure activities (i.e., diving, snorkeling) (Gomez, 2004) and natural disturbances such as intense ocean currents associated with monsoons and typhoons (Hughes and Connell, 1999) were identified as possible reasons of significant rubble cover and coral death in the area. Conversely, the active patrol by the local fisheries enforcers and the absence of apprehensions does not connect the deterioration of the reef to illegal fishing activities. The most significant damaged could have happened during Typhoon Haiyan which traversed across the Sagay Marine Reserve's four bordering reefs, including Carbin Reef, in November 2013, resulting to the loss in coral reef cover (Bantigue, 2016). Dead corals with algae showed 22.36% prevalence (Fig. 3) which is comparable to less impacted areas of Eastern Samar. Being one of the directly hit areas, dead coral cover in Eastern Samar after the onslaught of Typhoon Haiyan ranged from 20-60% (Anticamara and Go, 2017).

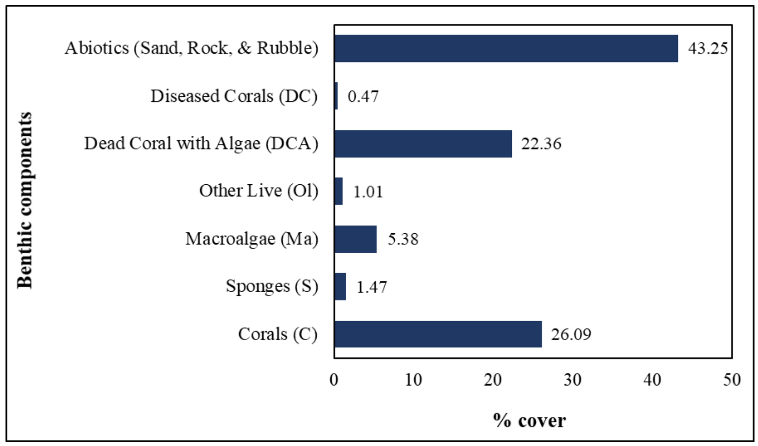

Figure 3. Percentage of benthic cover in Carbin Reef, Sagay Marine Reserve

Hard Coral Species

Using the CPCe software, this study identified a total of 55 hard coral species belonging to 33 genera and 12 families (Figure 4). Carbin reef is dominated by the three genera *Porites*, *Fungia*, and *Goniastrea*. The genus *Porites* included *P. asteroides, P. cylindrica,* and *P. lobata.* The genus *Fungia* included *F. concinna*, while genus *Goniastrea* was composed of *G. deformis*, and *G. edwardsi*. *Porites lobata* was the most dominant species having a mean of 3.32%, followed by *F. concinna* (1.99%), and *G. edwardsi* (1.81%) (Figure 4). The dominant species, *P. lobata*, is a member of the genus *Porites* and is one of the most prolific reef-building coral genera in the tropical Pacific Ocean, with a massive growth form (Lough and Cooper, 2011). Both massive and sub-massive corals are resistant to strong water currents and can be found in shallow and mid-depth environments (Roberts, 2018) indicating a good reef characteristic for Carbin Reef.

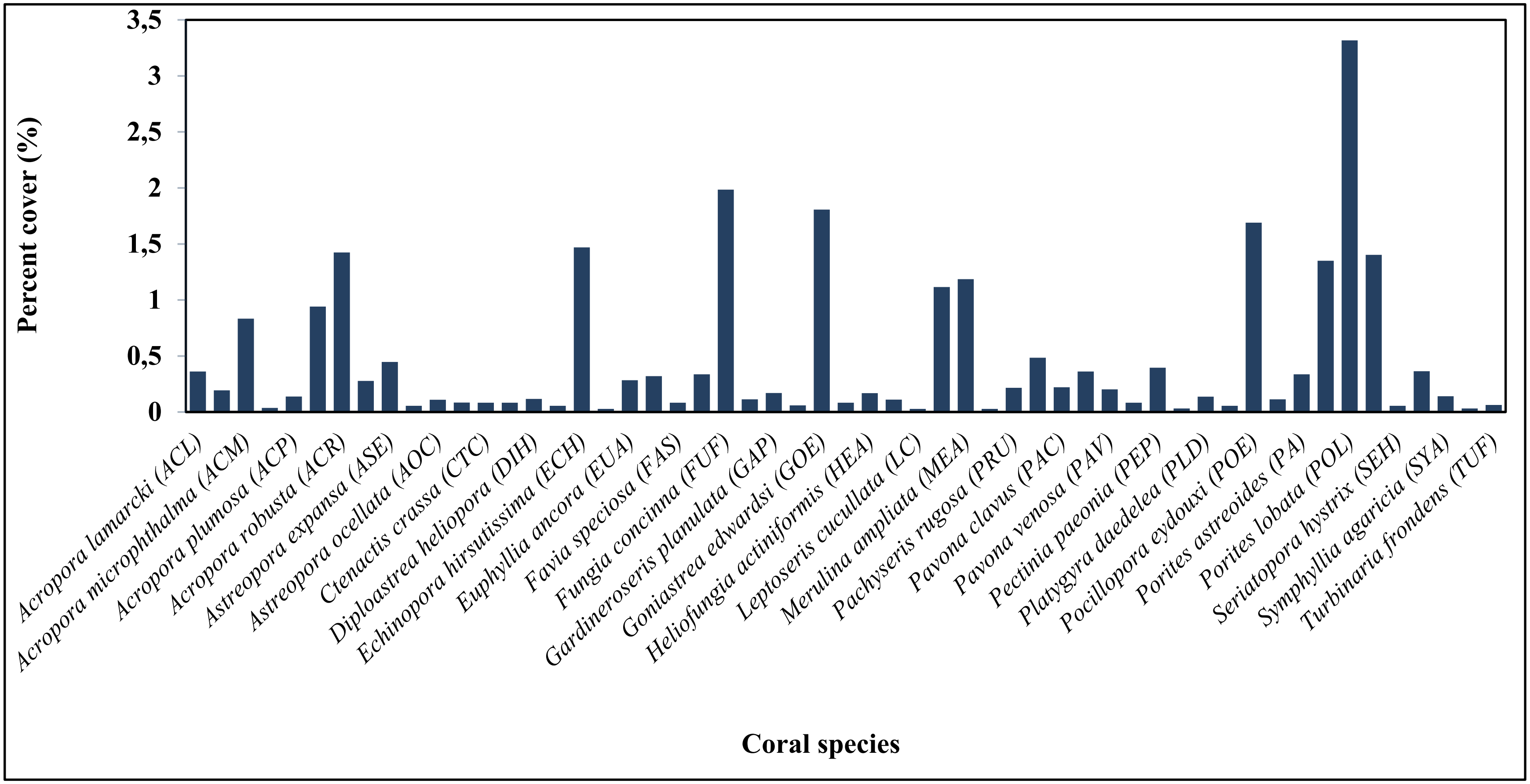

Figure 4. Species composition and percent cover of live hard corals in Carbin Reef, Sagay Marine Reserve

Considering the dearth of diversity data in Carbin reef, the total number of species identified in this study expand the previous report of Maliao et al. (2004) having 28 coral genera. Unfortunately, previous studies only give an overall number and do not detail which corals were found, therefore it is not possible to compare our results with previous reports in Sagay Marine Reserve (Maliao et al., 2004; Licuanan et al., 2017). While Maliao et al., 2004 noted *Porites* spp. dominance comparably observed in this study (*Porites lobata*), *Favia stelligera* mentioned by the latter authors were not found in this study. This could either be due to their population decline or with the differences on surveyed area. Thus, we could assume that this is the first comprehensive assessment of coral diversity in Carbin Reef which could be extended in other major reefs of Sagay Marine Reserve.

Coral Diversity

Table 2 shows the coral diversity in Carbin reef using Shannon-Weaver and Simpson's Indices for each transect. These indices were used to characterize the numerical structure of a coral community and quantify its diversity. In terms of species diversity, Transect 6 had the highest value of H = 2.87, while Transect 3 had the lowest diversity of H = 2.45. Transects 1, 2, 4, 5, and 6 fell into the moderate category, whereas Transect 3 fell into the low species diversity category, according to definition of diversity value and its qualitative equivalence (Fernando, 1998). Transects 1, 2, 4, 5, and 6 may be significantly stressed based on these findings. Gonçalves and Menezes (2011) noted that values greater than 3.0 suggest a stable ecosystem, while values less than 1.0 indicate pollution and habitat destruction.

Table 2. Diversity indices of hard coral cover found in different transect locations

Transect No.	Depth (m)	Shannon-Weaver Index (H)	Simpson's Index (1-D)
1	6	2.66	0.90
2	12	2.75	0.92
3	6	2.45	0.87
4	12	2.63	0.91
5	6	2.69	0.90
6	12	2.87	0.90
Overall Mean		**2.68**	**0.90**

Coral Diseases

The overall prevalence of coral diseases, including symptoms of reduced health was 0.47% in the Carbin Reef. White band illness, bleached coral point, and white syndrome were examples of coral diseases observed. These symptoms of deterioration could be due to various natural stressors and competitive overgrowth—notably of sponges, and red and brown algae, observed in four transects (2, 4, 5, and 6). Another sign of compromised health is sediment damage where corals covered with silt/organic particulates exhibited discoloration and minimal coral die-offs along the sediment-covered area. However, even the sedimentation observed in these transects were relatively high, this could not be attested due to the loss of sedimentation traps, which requires further studies. Transect 2 particularly exhibited a greater percentage of white syndrome (1.2) (Figure 5). White syndrome can be caused by a variety of infections, including *Vibrio harveyi* (Luna et al., 2010), as well as stresses in the environment (Hughes and Conell, 1999). *Porites*, *Montipora*, *Echinopora*, and *Heliopora* were the four genera most usually affected by white syndrome. Some authors have concluded that *Vibrio* infections in corals are opportunistic in nature (Bourne and Munn, 2005; Bourne et al., 2007) as *Vibrio* spp. were both observed in healthy and ill corals. Multiple factors, such as host density (Bruno et al., 2007) and temperature (Colwell, 1996) have been shown to influence the chance of successful infections in models of illness happening in environmental context.

Sedimentation Rate

In this study, force majeure did not permit the researchers to acquire enough data for sedimentation rate. Four sediment collectors were installed within the 6-meter transect depth. However, only one sediment collector was recovered and retrieved after 7 days. The sediment collector either tipped over due to strong wave currents and loss due to human disturbances. Nonetheless, one sediment collector installed in Transect 3 revealed a daily sedimentation rate of 1.62 mg/cm^2. This number is much lower than Pastorok and Bilyard's (1985) predicted sedimentation rates of >50 mg/cm^2/day, which are considered catastrophic for some coral communities. Varied corals can endure different sedimentation rates, ranging from 10 mg/cm^2/d to >400 mg/cm^2/d (Patorok and Bilyard, 1985). While this provide a positive outlook on potential sedimentation impacts in Carbin reef, effective monitoring techniques is further required. This study was done in summer, when total rainfall was at its lowest. The results could have been different during the rainy season. In the same way, spatial variability may occur when water current changes and the effects of adjacent Himoga-an River run-offs potentially reach the reef area.

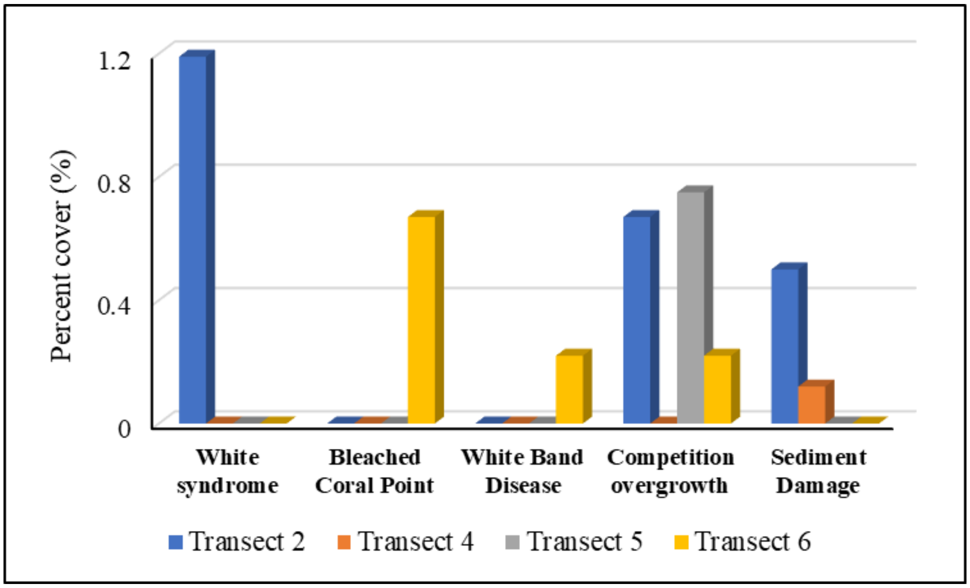

Figure 5. Diseases and signs of compromised health prevalent in corals found in four transects

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Conclusion

This study identified a total of 55 coral species throughout Carbin Reef, providing the first comprehensive species list for Sagay Marine Reserve. Overall, benthic cover suggests that the reef is considered in fair condition but might potentially be in decline, based on the established criteria by the Department of Environment and Natural Resources of the Philippines. Thus, this study showed that Carbin Reef has a moderately diverse reef ecosystem, but experience moderate stress considering the presence of various coral diseases. The two signs of compromised health include sediment damage and competition overgrowth. Likewise, natural disturbances like intense wave current and occurrence of Typhoon Haiyan in year 2013 could have attributed to the deterioration of the reef, causing the presence of massive coral rubble and dead corals with algae. Although, sedimentation rate per day was below the maximum sedimentation that can be tolerated by most corals, this only represented the dry season. Future year-round studies with considerations of water current and pollution sources are needed.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential, or perceived conflict of interests.

Ethics committee approval: Ethics committee approval is not required.

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Disclosure: -

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