Received: October 6, 2023　　*Revised: November 5, 2023*　　*Accepted: December 22, 2023*

P-ISSN: 0119-3058
E-ISSN: 2945-4093

Evaluation of Coral Reef Health Status in the Fish Sanctuary of San Esteban, Ilocos Sur

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ABSTRACT

Studies on corals are lacking in Ilocos Sur's marine protected areas (MPAs), hindering management effort development. This study evaluated the health status of coral reefs in the San Esteban Fish Sanctuary. Hard coral cover, hard coral diversity in terms of Taxonomic Amalgamation Units (TAUs), and coral reef health status in terms of live coral coverage, algae coverage, sand coverage, and coral mortality index were measured in two sampling stations inside an over-a-decade-old fish sanctuary that does not have previous data on its coral reef health status. The Underwater Photo Transect (UPT) method was employed to take image samples subjected to the Coral Point Count with Excel extensions (CPCe) software for analysis. The study revealed that the coral reef in San Esteban Fish Sanctuary is in good condition with a hard coral cover of 30.0%, falls under Hard Coral Cover Category C, and a hard coral diversity of 16.8TAUs that falls under Diversity Category D. The fish sanctuary is also in a healthy condition based on excellent live coral coverage, algae coverage, sand coverage, and low coral mortality index. The two stations are more or less the same in terms of the aforementioned parameters. Overall, it is recommended to continuously strengthen the enforcement of the fish sanctuary to protect its coral reefs, measure other parameters that might impact and indicate coral reef health status, employ evaluations inside and outside MPAs in the province, and use high-resolution cameras during image sampling for more efficient analysis.

Keywords: *Coral cover, coral reef diversity, coral health status, marine protected areas, Ilocos Sur*

INTRODUCTION

The marine environment covers the majority of the earth's surface and is home to some of the most diverse ecosystems on the planet. The high biodiversity and productivity of the ocean prompted most of the human population to depend on what the marine ecosystems provide. One of these ecosystems is the coral reef, formed from multiple generations of corals.

Coral reef ecosystems support an enormous and diverse amount of life – harboring hundreds of thousands to millions of species of marine organisms (Burkepile & Hay, 2008). It is estimated that at least 25% of marine species are supported by coral

P-ISSN: 0119-3058
E-ISSN: 2945-4093

The Vector: International Journal of Emerging Science, Technology and Management
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reefs even though they cover less than 0.1% of the ocean floor (Fisher et al., 2015). Corals are essential in conserving ecosystem biodiversity, productivity, and balance. The coral reefs' biodiversity results in direct and indirect support for humans, such as food, coastal protection, tourism, medicine, and other ecosystem services (Wolanski et al., 2003). However, coral reefs are facing significant degradation. The reasons attributed to this decrease in corals are massive bleaching events, coral diseases, and human pressures (Souter et al., 2021), which beg the need to monitor coral reefs.

Coral reef monitoring efforts that start from preliminary evaluations are essential due to the importance of data in providing appropriate recommendations to sustain coral reefs. Furthermore, collecting data from monitoring efforts is vital to commission fast and appropriate action to assist degrading reefs (Souter et al., 2021). In addition, coral monitoring helps with the successful management of marine protected areas (MPAs) in terms of resource evaluation and mapping, building resilience in MPAs, contributing to regional and global networks, performance evaluation and adaptive management, education, and awareness raising, determination of status and long-term trends of user groups, and determination of the impacts of large-scale disturbances and human activities (Wilkinson et al., 2003).

With the dawn of advanced technology, environmental monitoring and evaluation tools have developed and are now being utilized. One example of these tools is the software Coral Point Count with Excel extensions (CPCe). This program, devised by the National Coral Reef Institute (NCRI), is a simple but useful tool for efficiently evaluating coverage of benthic features in coral reefs using photographs (Kohler & Gill, 2006). This software is used worldwide as an efficient and reliable tool for monitoring and evaluating coral reefs (Tabugo et al., 2016).

As a result of monitoring efforts, the Global Coral Reef Monitoring Network’s (GCRMN) Status of Coral Reefs of the World: 2020 reported that since 2009, there has been an ongoing global live hard coral loss that took 14% of the world’s coral reefs attributed to recurring mass coral bleaching events. On the other hand, the estimated global average cover of algae exhibited an approximately 20% increase in global cover since 2011. Algal dominance in reefs poses challenges for corals to maintain their biodiversity and ability to support coastal communities worldwide. Astonishingly, among the GCRMN regions, the East Asian Seas, where the Coral Triangle is located, exhibited an increase in hard coral cover and a decrease in algal cover. (Souter et al., 2021). The Philippines, one of the countries where the Coral Triangle lies, holds an estimated 26,000 km^2 biodiverse area of coral reefs (Burke et al., 2002). However, the 2014 – 2017 nationwide evaluation reports that the countrywide weighted average of hard coral cover is 22.8%, and coral generic diversity in terms of Taxonomic Amalgamation Units (TAUs) averaged 14.5. Findings from the national evaluation showed that of the 206 evaluation stations, half were in the poorest hard coral cover category, and almost 60% belonged to the poorest diversity category (Licuanan et al.,

P-ISSN: 0119-3058
E-ISSN: 2945-4093

2019). This vital sign of deterioration highlights the necessity for local monitoring of coral reefs, which will contribute to the information that man already has.

Even though the Philippines has degraded some of its coral reefs, it still sustains high marine biodiversity. Over 1,800 marine protected areas (MPAs) are established in the country to protect its remaining marine resources. Marine protected areas, in the form of fish sanctuaries, have been observed to increase living hard coral cover and fish diversity (Solandt et al., n.d.), which have significant ecological and economic impacts. Among these MPAs is the aquatic tourism site of San Esteban Fish Sanctuary, located in Barangay Bateria, San Esteban, Ilocos Sur. The sanctuary is a 34.4-hectare MPA where extractive practices are prohibited in addition to restrictions on human activities (Post, 2018).

Previously, ecosystem-focused studies in Ilocos Sur have mostly concentrated on terrestrial (Elecho et al., 2023), freshwater (Rojas, 2023), and intertidal (Domingo & Corrales, 2002) ecosystems, highlighting the need for research such as marine underwater studies that provide new information on the state of the environment in the area. The municipality of San Esteban, Ilocos Sur, has yet to hold data on the health status of coral reefs since its implementation as an MPA, making it hard to take the best steps to improve its management. Evaluating coral reef health is essential in understanding their status, which makes way to manage coral reefs effectively (Obura et al., 2019). It can also spark respect for coral reefs among the coastal community as they gain knowledge about coral reefs and their status. With the need for a more up-to-date status of coral reefs in the Philippines, this study evaluated the coral reef health status of the fish sanctuary in San Esteban, Ilocos Sur. This study provides baseline data for corals in the aforementioned fish sanctuary to provide a basis for the continuous improvement of conservation efforts for the coral reef in the said area. It also helps the men and women fisherfolk who depend on resources near the fish sanctuary.

Objectives of the Study

This study aimed to determine the percentage of hard coral cover, the hard coral diversity, and the coral reef health status in terms of live coral coverage, algae coverage, sand coverage, and coral mortality index of two sampling stations. It tested whether these parameters were significantly different between the stations.

METHODOLOGY

This portion presents the research design, study site, data collection and analysis, and ethical considerations of the study.

P-ISSN: 0119-3058
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Research Design

The study used the descriptive-comparative design to evaluate coral reefs' health status in the San Esteban, Ilocos Sur fish sanctuary. Hard coral was used to determine percentage cover and diversity. In contrast, the determination of coral reef health status was based on live coral cover, algae cover, sand cover, and mortality index of the fish sanctuary. The Underwater Photo Transect (UPT) method was adopted by van Woesik et al. (2009). Photoquadrats were subjected to analysis using the Coral Point Count with Excel extensions (CPCe) software (Kohler & Gill, 2006). The interpretation was done using the procured data from the CPCe software.

Study Site

The study site is a marine protected area (MPA) located in Barangay Bateria, San Esteban, Ilocos Sur. The study site is situated in the middle of Region 1 on the northwestern coast of the Philippines. Two sampling stations were designated inside the study site, each measuring 75m by 25m, resulting in 1,875 m^2. The selection of the stations was based on the recommendation of the fisheries coordinator of the local government unit of San Esteban, Ilocos Sur. The sampling stations where the transects (white parallel lines) were laid inside the core zone of the fish sanctuary (green line) (Figure 1). The recommended number for every 500 hectares of an ecosystem being evaluated is 20 sampling sites, meaning there must be one sampling station for every 25 hectares of an ecosystem (Biodiversity Management Bureau, 2017). Since the study site has an area of 34.4 hectares, it was logical to evaluate two sampling stations with the given dimensions to suffice for the recommended amount of sampling stations per area of an ecosystem.

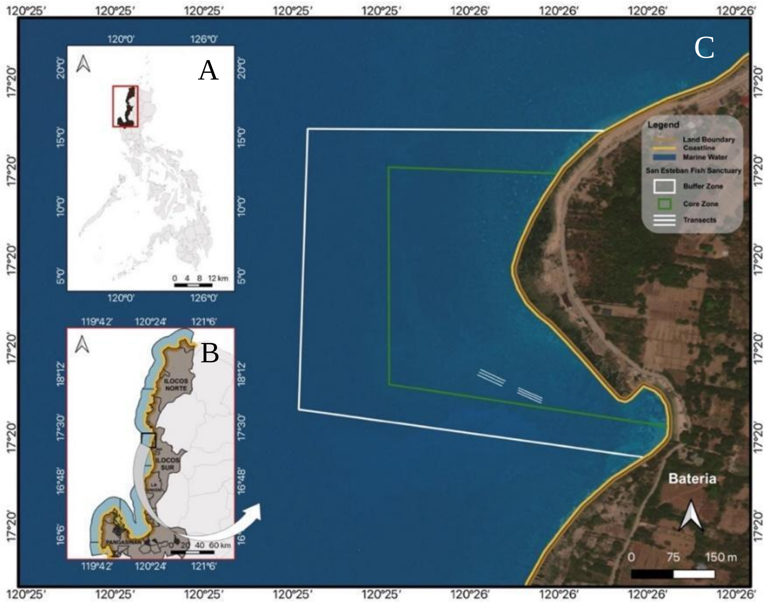
Field Evaluation

The field evaluation was done last March 22, 2023, during a dive utilizing Self-Contained Underwater Breathing Apparatus (SCUBA) gear. The Underwater Photo Transect (UPT) method was employed by laying three 50-meter transect lines parallel to the coastline for every station. The two stations are 25 meters apart, and the transect lines have 5-meter intervals. Photo quadrats were taken using an underwater camera positioned on the tetrapod at a depth of five meters. The photo quadrats were taken at every 1m mark of the transect line, producing 50 photographs per transect. A total of 150 photo quadrats with three replications were collected from each sampling station. The coordinates were monitored and recorded on the surface using a GPS device.

P-ISSN: 0119-3058
E-ISSN: 2945-4093

Figure 1

Map showing the study site. A) Map of the Philippines showing Region 1. B) Map of Region 1 showing Bateria. C) Map of Bateria showing the two sampling stations.



Data Processing

The photo quadrats were subjected to CPCe software analysis. The software generated ten random sampling points per photo quadrat. The books "Corals of the World" by Veron (2000) and "Indo-Pacific Coral Finder" by Kelley (2009) were used in identifying the hard corals to correspond to the appropriate codes in CPCe software during analysis. A marine biologist verified the identification done by the researchers.

The percentage cover of benthic features, namely live coral (hard coral and soft coral), dead coral, dead coral with algae, algae, and sand, was calculated using the following formula:

$$\%\,Cover = \frac{Total\ Sampled\ Points\ of\ Benthic\ Feature}{Total\ Number\ of\ Points\ Per\ Transect} \times 100$$

The proposed scale by Licuanan et al. (2019), as shown in Table 1, was used to categorize the hard coral cover.

P-ISSN: 0119-3058
E-ISSN: 2945-4093

The Vector: International Journal of Emerging Science, Technology and Management
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Table 1
Hard coral cover categories (Licuanan et al., 2019)

% Cover	Category
>44%	HCC Category A
33-44%	HCC Category B
22%-33%	HCC Category C
0%-22%	HCC Category D

On the other hand, the diversity of hard corals was determined by the number of hard coral Taxonomic Amalgamation Units. The categorization was based on the scale by Licuanan et al. (2019), as shown in Table 2.

Table 2
Hard coral diversity categories (Licuanan et al., 2019)

# of Taxonomic Amalgamation Units (TAUs)	Category
>26 TAUs	Diversity Category A
22 – 26 TAUs	Diversity Category B
18 – 22 TAUs	Diversity Category C
0 – 18 TAUs	Diversity Category D

To determine the coral reef health status of the stations, the percentage cover of live coral, algae, and sand and the coral mortality index were used (Zamani & Madduppa, 2011). Finally, the mortality index was calculated by the following formula (English et al., 1997):

$$Mortality\ Index = \frac{\%\ Cover\ of\ Dead\ Coral + Dead\ Coral\ with\ Algae}{\%\ Cover\ of\ Dead\ Coral + Dead\ Coral\ with\ Algae + Live\ Coral}$$

The stations were categorized as excellent, good, fair, or poor depending on live coral coverage, algae coverage, sand coverage, and coral mortality index. The coral reef health status of the whole fish sanctuary was also measured by getting the average of the parameters used in the coral reef health status of the sampling stations.

Table 3
Categories of coral reef health status based on different parameters (Zamani & Madduppa, 2011)

Parameters	Criteria for Coral Reef Health			
	Excellent	**Good**	**Fair**	**Poor**
Live coral coverage	75-100%	50-74.9%	25-49.9%	0-24.9%
Algae coverage	0-24.9%	25-49.9%	50-74.9%	75-100%
Sand coverage	0-24.9%	25-49.9%	50-74.9%	75-100%
Coral Mortality Index	0.75-1.00	0.50-0.0749	0.25-0.499	0.00-0.249

Data Analysis

Mean described the hard coral cover, hard coral diversity, and the coral reef health status in terms of live coral cover, algae cover, sand cover, and mortality index. Independent sample t-test determined if there is a significant difference between the percentage cover and diversity of hard corals and the coral reef health status in terms of live coral coverage, algae coverage, sand coverage, and coral mortality index on the two sampling stations at 0.05 level of significance.

RESULTS AND DISCUSSIONS

Percentage of Hard Coral Cover

The hard coral percentage cover in Station 1 is 24.3%, which falls under Hard Coral Cover Category C. The coral reefs under the HCC Category C have slightly higher than the 22.8% national average of hard coral cover (Licuanan, 2020). Moreover, there is a noticeable high coral cover of encrusting *Porites* at 10.4% as compared to other genera. The percentage cover of hard corals in Station 2 is 35.8%, which falls under Hard Coral Cover Category B. The reefs under this hard coral cover category were higher than the 22.8% national average hard coral cover and the Tubbataha Reefs Marine Natural Park percentage hard coral cover average (Licuanan, 2020). A noticeable high cover of encrusting *Porites* corals was also observed, with 11.2% cover. On the other hand, there is a higher percentage of hard coral cover in Station 2 at 35.8% than in Station 1 at 24.3%.

Table 4

Percentage of hard coral cover in station 1, station 2, and San Esteban fish sanctuary

Hard Coral	Station 1	Station 2	San Esteban Fish Sanctuary
Total Mean Hard Coral Cover	24.3	35.8	30.0
Other benthic components	75.7	64.2	70.0
Total % Cover	**100**	**100**	**100**

Note: HCC Category A (>44%), HCC Category B (33%-44%), HCC Category C (22%-33%), HCC Category D (0%-22%)

Meanwhile, the mean percentage cover of hard corals in San Esteban Fish Sanctuary with 30.0% cover. It falls under Hard Coral Cover Category C and is higher than the 22.8% national average for hard coral cover (Licuanan, 2020). The observation of the high percentage cover of encrusting *Porites*, with 10.8%, coincides with the observation in the two stations.

The noticeable high percentage cover of encrusting *Porites* corals can be attributed to their ability to withstand physical damage from wave action (Morgan & Kench, 2017). It can also be a manifestation of one of the characteristics of *Porites* corals, which is strong recruitment (Green et al., 2008). One of the notable observations in the two sampling stations in the study site is that a large number of encrusting *Porites* coral colonies are juveniles, indicated by the modest cover of many individual colonies. Finally, the observed high percentage cover of encrusting *Porites* corals, which are composed mostly of juvenile colonies in the study, might indicate population recovery from anthropogenic stress as suggested by the population model by Zhao et al. (2016).

Hard Coral Diversity in terms of Taxonomic Amalgamation Units (TAUs)

The hard coral diversity of Station 1 falls under Diversity Category D at 14.0TAUs, slightly lower than the national average of 14.5TAUs (Licuanan, 2020).

Table 5

Hard coral diversity in terms of taxonomic amalgamation units (TAUs) of the two stations

Taxonomic Amalgamation Units (TAUs)	Station 1			Station 2		
	T1	**T2**	**T3**	**T1**	**T2**	**T3**
Total	11	13	18	20	20	19
Average TAUs Per Station		14.0			19.7	
Average TAUs in the Fish Sanctuary				16.8		

On the other hand, the hard coral diversity in Station 2 falls under Diversity Category C at 19.7TAUs, slightly higher than Station 1 and the aforementioned national average. Overall, the hard coral diversity in San Esteban Fish Sanctuary, which is the average Taxonomic Amalgamation Units (TAUs) in the two stations, belongs to Diversity Category D with 16.8TAUs, slightly higher than the 14.5TAUs national average. The higher hard coral diversity in Station 2 can be attributed to its higher percentage of hard coral cover compared to Station 1. Hard coral cover is observed to have a positive link with hard coral diversity, which means that a higher hard coral cover can result in higher hard coral diversity (Fabricius, n.d.).

Coral Reef Health Status

The health status of the coral reef was determined from indicators namely; Live Coral Coverage, Algal Coverage, Sand Coverage, and Coral Mortality Index.

In terms of live coral coverage, station 2 has a good status while station 1, and the San Esteban Fish Sanctuary fall under a fair health status. Meanwhile, all the stations have an excellent status in terms of algal coverage and sand coverage. Moreover, station 2 registered a fair status in terms of coral mortality index while Station 1 and San Esteban Fish Sanctuary have poor conditions.

Table 6
Coral reef health status

Parameter	Station 1	Status	Station 2	Status	San Esteban Fish Sanctuary	Status
Live Coral Coverage	39.3%	Fair	54.1%	Good	46.7%	Fair
Algal Coverage	22.7%	Excellent	19.9%	Excellent	21.3%	Excellent
Sand Coverage	5.33%	Excellent	3.5%	Excellent	4.4%	Excellent
Coral Mortality Index	0.2	Poor	0.3	Fair	0.2	Poor

The slightly low live coral coverage of Station 1 does not disqualify it from being a healthy reef because it has a low coral mortality index, presumably it is still growing. Some studies observed the presence of massive algae and algal extracts by Rasher and Hay (2010) cause rapid bleaching and death when in direct contact with coral tissues, so it is unlikely in both sampling stations since low algae and sand coverage was observed. Moreover, excessive sedimentation also affects coral mortality when high-nutrient sediments are trapped in the coral's tissue, decreasing oxygen and pH and leading to tissue degradation (Weber et al., 2012) which is not observed in the sampling

P-ISSN: 0119-3058
E-ISSN: 2945-4093

The Vector: International Journal of Emerging Science, Technology and Management
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stations. Other reasons for the low mortality in both stations might be from the good governance in the sanctuary for strict protection of the coral reef area from anthropogenic stress, such as fishing pressure and potentially destructive recreational activities inside the sanctuary. There has been documentation about maintaining coral cover inside MPAs (Selig & Bruno, 2010). In addition, the presence of obligate corallivorous butterflyfishes (*Chaetodon* spp.), which serve as indicators of good coral reef health (Samways, 2005), was abundant in sampling stations.

Overall, the San Esteban Fish Sanctuary, with its excellent algae and sand cover, and low coral mortality index despite having a slightly low live coral cover, is in a healthy condition.

Significant Difference in the Percentage of Hard Coral Cover, Hard Coral Diversity in terms of Taxonomic Amalgamation Units (TAUs), and Coral Reef Health Status of the Two Stations

The results of the independent sample *t*-test renewal there is no significant difference in the percentage of hard coral cover, hard coral diversity in terms of Taxonomic Amalgamation Units (TAUs), and coral reef health status in terms of live coral coverage, algal coverage, sand coverage, and coral mortality index of the two stations with 0.241, 0.055, 0.108, 0.567, 0.196, and 0.441 probability level, respectively.

Implies that the percentage of hard coral cover, hard coral diversity in terms of Taxonomic Amalgamation Units (TAUs), and coral reef health status in terms of live coral coverage, algae coverage, sand coverage, and coral mortality index of the two stations are more or less the same.

Table 7

Significant difference in the percentage of hard coral cover, hard coral diversity in terms of Taxonomic Amalgamation Units (TAUs), and Coral Reef Health Status of the Two Stations

Parameter	Station 1		Station 2		*p*-value
	$\underline{x}$	SD	$\underline{x}$	SD	
Hard Coral Cover	24.3	13.3	35.8	16.0	0.241
Taxonomic Amalgamation Units (TAUs)	14.0	3.6	19.7	0.6	0.055
Live Coral Coverage	39.3	11.7	54.1	4.2	0.108
Algal Coverage	22.7	5.3	19.9	5.9	0.567
Sand Coverage	5.3	1.4	3.5	1.5	0.196
Coral Mortality Index	0.3	0.03	0.3	0.04	0.441

CONCLUSIONS

The study found that the percentage of hard coral cover in the fish sanctuary is higher than the national average at 30.0%, which falls under Hard Coral Cover Category C, while the hard coral diversity in terms of TAUs is slightly lower than the national average at 16.8TAUs which falls under Diversity Category D. The coral reef health status in terms of live coral coverage, algae coverage, sand coverage characteristics of the coral reefs, and coral mortality index in the fish sanctuary indicated a healthy reef. The parameters between the two stations are more or less the same. While the field evaluation was limited only to inside the study site, which is a marine protected area, the results of this study can be used as baseline data for policy-making and comparisons in future research.

RECOMMENDATIONS

The implementation of the fish sanctuary in San Esteban, Ilocos Sur, as a marine protected area (MPA) should be continuously strengthened. The results of this study will be discussed with the community and policy-makers in the municipality where the study was conducted. Continuous monitoring of coral reef health status is also important to understand the ecological changes happening in the reef, to determine different factors that affect coral reef health status, and to determine the mechanisms of how these factors affect coral reef health status. The comparison of the health status between and among coral reefs inside and outside MPAs in the province, including their level of implementation, is required to see whether the implementation of MPAs and their level of implementation impacts coral reef health status is highly advised.

ETHICAL STATEMENT

The study site is a locally-managed marine protected area (MPA), so permission to SCUBA dive and take *in situ* photographs of the benthic environment in San Esteban Fish Sanctuary in Bateria, San Esteban, Ilocos Sur was secured from the local government unit before the actual field evaluation. Because of the image-based nature of the assessment, no extractive activity was administered in any shape or form.

ACKNOWLEDGMENT

This endeavor would not have been possible without the assistance of the Provincial Government of Ilocos Sur, headed by Hon. Gov. Jeremias Singson, and the PGIS– Dive Center, headed by Mr. Christopher Ian Verzosa, together with his staff in the office. We could not have taken this journey without the Local Government Unit of San

Esteban, Ilocos Sur, headed by Hon. Mayor Ray M. Elaydo and the Office of the Municipal Agriculturist of San Esteban Ilocos Sur, headed by Mrs. Rosemarie Etrata, together with the Municipal Fisheries Coordinator, Mr. Mark Anthony Vergara. We are also grateful to our research panelists, Prof. Adora G. Ilac, Mrs. Joanna Mae S. Foronda, and Prof. Jessy C. Domingo, to our statistician, Mr. Mhark Jay O. Benitez, and to the Department of Agriculture – Bureau of Fisheries and Aquatic Resources (DA-DFAR) Provincial Fisheries Officer of Ilocos Sur; Mr. Martin Allayban, who guided us throughout the study with wise and ethical decision-making. Lastly, we would like to acknowledge our families and friends who gave unwavering support during the entire research process.

REFERENCES

Biodiversity Management Bureau (2017). *Guidelines of the evaluation of coastal and marine ecosystems* no. 2017-05. https://www.bmb.gov.ph/index.php/resources/ downloadables/laws-and-policies/technical-bulletins/technical-bulletin-2017?download=278:technical-bulletin-2017-05

Burke, L., Selig, E., & Spalding, M. (2002). *Reefs at risk in Southeast Asia*. World Resources Inst. https://www.wri.org/research/reefs-risk-southeast-asia

Burkepile, D., & Hay, M. (2008). *Coral reefs*. Encyclopedia of Ecology, 2008(2), 426–438. https://doi.org/10.1016/b978-0-444-63768-0.00323-1

Domingo, A.C. & Corrales, J.A. (2002). Growth performance and survivorship of sea urchin (*Tripneustes gratilla*) in grow-out culture. *The Vector: International Journal of Emerging Science, Technology and Management* (IJESTM), 11(1). Retrieved from https://vector.unp.edu.ph/index.php/1/article/view/152

Elecho, K. A., Batara, J. A., Gascon, V. B., Segismundo, A. B., Raboy, M. R., & Domingo, J. C. (2023). Taxonomy of insects in San Juan, Ilocos Sur, Philippines. *Asian Journal of Biodiversity*, 2023, 14(1). http://dx.doi.org/10.7828/ajob.v14i1.1546

English, S. C., Wilkinson, C. R., & Baker, V. (1997). Survey Manual for Tropical Marine Resources (2nd Edition). *Australian Institute of Marine Science eBooks*. http://epubs.aims.gov.au/handle/11068/13062?show=full

Fabricius, K. (n.d.). *Patterns in hard coral diversity and cover on inshore reefs of the GBR* eAtlas. https://eatlas.org.au/content/patterns-hard-coral-diversity-and- cover-inshore-reefs-gbr

Fisher, R., O'Leary, R., Low-Choy, S., Mengersen, K., Knowlton, N., Brainard, R., & Caley, M. (2015). Species richness on coral reefs and the pursuit of convergent global estimates. *Current Biology*, 2015 (25), 500–505. https://doi.org/10.1016/j.cub.2014.12.022

Kelley, R. (2009). *Coral Finder Indo Paci*. BYO Guides. http://www.russellkelley.info/print/indo-pacific-coral-finder/

Kohler, K. E., & Gill, S. M. (2006). Coral Point Count with Excel extensions (CPCe): A visual basic program for the determination of coral and substrate coverage using random point count methodology. *Computers & Amp; Geosciences*, 2006(32), 1259– 1269. https://doi.org/10.1016/j.cageo.2005.11.009

Licuanan, W., Robles, R., & Reyes, M. (2019). Status and recent trends in coral reefs of the Philippines. *Marine Pollution Bulletin*, 2019(142), 544–550. https://doi.org/10.1016 /j.marpolbul.2019.04.013

Licuanan, W. Y. (2020). New scales to guide the evaluation of hard coral cover and diversity in the Philippines. *Philippine Journal of Fisheries*, 2020, 121–126. https://doi.org/10.31398/tpjf/27.2.2020-0008

Obura, D. O., Aeby, G., Amornthammarong, N., Appeltans, W., Bax, N., Bishop, J., Brainard, R. E., et al. (2019). Coral Reef Monitoring, Reef Assessment Technologies, and Ecosystem-Based Management. *Frontiers in Marine Science*, 2019 (6). https://doi.org/10.3389/fmars.2019.00580

Post, K. (2018). *Increasing the resilience of marine ecosystems: Creating and managing marine protected areas in the Philippines*. Marine Conservation Philippines. https://www.marineconservationphilippines.org/wp-content/uploads/2018/02/marine-protected-areas-in-the-philippines

Rasher, D. B., & Hay, M. E. (2010). Chemically rich seaweeds poison corals when not controlled by herbivores. *Proceedings of the National Academy of Sciences of the United States of America*, 107(21), 9683–9688. https://doi.org/10.1073/-pnas.0912095107

Rojas, C. B. (2023). Assessment of the diversity of macrofauna of Govantes River in Vigan City, Ilocos Sur, Philippines. *Asian Journal of Biodiversity*, 2023, 14(1). http://dx.doi.org/10.7828/ajob.v14i1.1547

Samways, M. J. (2005). Breakdown of butterflyfish (Chaetodontidae) territories associated with the onset of a mass coral bleaching event. *Aquatic Conservation- Marine and Freshwater Ecosystems*, 15(S1), S101–S107. https://doi.org/10.- 1002/aqc.694

Selig, E. R., & Bruno, J. F. (2010). A global analysis of the effectiveness of marine protected areas in preventing coral loss. *PLoS ONE*, 5(2), e9278. https://doi.org/10.1371/journal.pone.0009278

Solandt, J., Comley, J., Harding, S. P., Trono, R., & Raines, P. S. (n.d.). Effectiveness of fish sanctuaries in the Mabini marine reserve, Philippines, after a decade of protection. *Silliman Journal*, 44(2), 35-60. https://www.researchgate.net/profile/ Jean-Luc Solandt/publication/237531809_Reef_fish_populations_around_ Danjugan_Island_Negros_Occidental_Philippines/links/55b20f1808ae9289a08 4f bd8/Reef-fish-populations-around-Danjugan-Island-Negros-Occidental-Philippines

Souter, D., Planes, S., Wicquart, J., Logan, M., Obura, D., & Staub, F. (2021). *Status of coral reefs of the world: 2020 report*. Global Coral Reef Monitoring Network (GCRMN)/International Coral Reef Initiative (ICRI). https://gcrmn.net/2020report/

Tabugo, S. R. M., Manzanares, D., & Malawani, A. (2016). Coral reef evaluation and monitoring made easy using Coral Point Count with Excel extensions (CPCe) software in Calangahan, Lugait, Misamis Oriental, Philippines. *Computational Ecology and Software*, 6(1), 21–30. http://www.iaees.org/publications/journals/ ces/articles/2016-6(1)/coral-reef-evaluation-and-monitoring

Weber, M., De Beer, D., Lott, C., Polerecky, L., Kohls, K., Abed, R. M. M., Ferdelman, T. G., & Fabricius, K. E. (2012). Mechanisms of damage to corals exposed to sedimentation. Proceedings of the *National Academy of Sciences of the United States of America*, 109(24). https://doi.org/10.1073/pnas.1100715109

Veron, J. E. N. (2000). Corals of the world, vol. 1, 2, 3 (1st ed.). *Australian Institute of Marine Science and CRR Ald Pty Ltd*. https://www.biblio.com/book/corals-world-vol-1-2-3/d/1535407210

Wolanski, E., Richmond, R., McCook, L., & Sweatman, H. (2003). Mud, marine snow and coral reefs. *American Scientist*, 2003 91(1), 44. https://doi.org/10.1511/2003.1.44

Wilkinson, C., Green, A., Almany, J., & Dionne, S. (2003). Monitoring coral reef marine protected areas: Version 1. A practical guide on how monitoring can support effective management of MPAs (1st ed.). *Australian Institute of Marine Science and the IUCN Marine Program.* https://repository.library.noaa.gov/view/noaa/ 10859

Zamani, N. P., & Madduppa, H. (2011). A standard criteria for assessing the health of coral reefs: Implication for management and conservation. *Journal of Indonesia Coral Reefs*, 1(2), 137-146. https://www.researchgate.net/profile/Hawis_Madduppa/ publication/262260292_A_Standard_Criteria_for_Assesing_the_Health_of_Coral_Reefs_Implication_for_Management_and_Conservation/links/53f4c8750cf2fcea cc6e9f2f

P-ISSN: 0119-3058
E-ISSN: 2945-4093

Zhao, M., Riegl, B., Yu, K., Shi, Q., Zhang, Q., Liu, G., Yang, H., & Yan, H. (2016). Model suggests potential for *Porites* coral population recovery after removal of anthropogenic disturbance (Luhuitou, Hainan, South China Sea). *Scientific Reports*, 6(1). https://doi.org/10.1038/srep33324