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Good coral cover and high diversity of corals in non-MPA reefs of the Verde Island Passage as a basis for increased protection and conservation

Miguel Enrique Ma. Azcuna[1,2,*], Jonel A. Corral[1,2], Enriquo Velasquez[1] and Jayvee Ablaña Saco[1,3]

Abstract

The Verde Island Passage (VIP) is a region in the Philippines with very high marine biodiversity. Baseline coral assessments were conducted in selected sites in the four provinces of the VIP (Batangas, Marinduque, Occidental Mindoro, and Oriental Mindoro) to compare coral abundance and biodiversity in Marine Protected Area (MPA) and non-MPA sites that were subjected to anthropogenic stressors. A total of eight sites were surveyed to measure average hard coral cover (HCC) relative to other benthic components. Generic richness and the dominant coral genera were also obtained for the eight sites. The average HCC and generic richness of Batangas MPA and Batangas non-MPA were (39.82 ± 7.59%, 22 coral TAUs) and (38.80 ± 5.56%, 27 coral TAUs), respectively. The average HCC and generic richness of Marinduque MPA and Marinduque non-MPA were (25.58 ± 2.37%, 13 coral TAUs) and (35.73 ± 4.05%, 17 coral TAUs), respectively. The average HCC and generic richness of Occidental Mindoro MPA and Occidental Mindoro non-MPA were (49.49 ± 4.50%, 26 coral TAUs) and (32.32 ± 5.60%, 19 coral TAUs), respectively. The average HCC and generic richness of Oriental Mindoro MPA and Oriental Mindoro non-MPA were (25.02 ± 4.72%, 24 coral TAUs) and (5.93 ± 2.10%, 10 coral TAUs), respectively. Batangas non-MPA and Marinduque non-MPA showed potential to become MPAs due to their higher HCC and generic richness which were attributed to natural disturbances and duration of local reef management in their MPA counterparts. Continued monitoring and assessment should be done to build on the growing database of biodiversity data that is being compiled for the VIP.

Keywords: benthic diversitty, biodiversity, coral reef, macroalgae, Marine Protected Areas (MPA)

Introduction

The Verde Island Passage (VIP) is a region in the Philippines with very high marine biodiversity (Carpenter & Springer 2005, CI-Philippines 2009). The VIP encompasses the provinces of Batangas, Marinduque, Oriental Mindoro, Occidental Mindoro, and Romblon (Figure 1). In the past decades, the VIP has been subjected to anthropogenic disturbances (*e.g.* unsustainable fishing, sedimentation, industrial pollution) and because of this, efforts need to be made to broaden the scope of protection and conservation in the VIP. One way this can be achieved is through coordinated expansion of MPA networks, wherein additional MPAs are established based on collaborative planning to address objectives across multiple governance units. Collaborative alliances in the Philippines allow communities of neighboring MPAs within a common bay to work together in managing their coastal resources (Horigue et al. 2015, Weeks et al. 2014).

Establishing large, regional MPAs that are a collection of a network of smaller MPAs can pave the way towards increased protection and conservation of marine resources. The Verde Island Passage MPA Network (VIP MPAN) is a combination of MPA and enforcement networks of Batangas Province, Oriental Mindoro Province, and Lubang and Looc in Occidental Mindoro Province (Weeks et al. 2014). Protected area and management effectiveness increased after the formalization of the VIP MPAN in 2011 (Horigue et al. 2012). This MPA Network was one of the first to incorporate connectivity objectives (Quibilan et al. 2008). To illustrate this connectivity, currents in the VIP shift seasonally, and larvae from outside sources (e.g. nearby reefs in the West Philippine Sea) can accumulate in the VIP. Interestingly, larvae spawned within the region of the VIP (e.g. Batangas and Balayan bays) may be retained (Campos et al. 2007, Villanoy et al. 2007). Establishing more MPAs in the VIP will create a wider and more connected MPA network. This will allow more source reefs to propagate larvae and more sink reefs to receive larvae. Prior to the establishment of the VIP MPAN in 2008, 30 uncoordinated locally-managed MPAs were established with a total area of 8.74 km^2 (Horigue et al. 2015). The VIP MPAN has expanded to 69 no-take MPAs covering an area of 170 km^2. While most MPAs are small (Weeks et al. 2014), efforts to increase the number and extent of MPAs in the VIP are underway to fulfill the targets for habitat representation urged by various international policies, such as the Convention on Biological Diversity (CBD) and Coral Triangle Initiative (CTI) (Horigue et al. 2015).

Efforts to scale up marine biodiversity conservation corridors and seascapes are currently underway (C-I Philippines 2009). Over the years, methods to expand MPAs were optimized to prioritize biodiversity conservation. For instance, considerations were made as to where to place additional MPAs to minimize biodiversity loss (*e.g.* sites with high biodiversity) (Visconti et al. 2010).

[1]Verde Island Passage Center for Oceanographic Research and Aquatic Life Sciences (VIP CORALS), Batangas State University, Batangas City, Philippines
[2]Batangas State University ARASOF-Nasugbu, Bucana, Nasugbu, Batangas, Philippines
[3]Batangas State University Lobo, Tabangao, Lobo, Batangas, Philippines

*Corresponding author: miguel.azcuna@g.batstate-u.edu.ph

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This study was part of the MBioassessment-VIP project that investigated if coral abundance and diversity differed between MPA (less-impacted) and non-MPA (highly-impacted) sites of the VIP, with the latter exposed to at least one anthropogenic stressor (e.g. sedimentation, human settlements). The hypothesis was that MPA protection would result in higher coral cover and generic richness (Purwanto et al. 2021, Magdaong et al. 2014). In this study, baseline assessments of benthic cover and hard coral biodiversity were obtained for one MPA and one non-MPA site in four out of five provinces bordering the VIP (Batangas, Marinduque, Oriental Mindoro, Occidental Mindoro). The province of Romblon was not included in this study due to logistical constraints. Although the study sites do not encompass the entirety of the VIP, the data obtained in this study will be supplemented with more datasets from additional sites in the future.

Materials and Methods

Study Sites

Reconnaissance surveys were conducted in the four provinces to select sites that met the criteria of Luzon et al. (2019). The identified coral reefs were required to match a set of criteria: 1) Reef should be continuous and at least 25 x 75 m size; 2) Reef should be at least 100 m from the shore; 3) The minimum depth should be 5 m; 4) Reefs should face the dominant monsoon; 5) There should be no rivers within close proximity. Benthic surveys were conducted in eight sites in the VIP. A map of the four provinces with the locations of the sites is shown in Figure 1. Table 1 summarizes the locations and characteristics of the sites. The surveys in sites 5-6 were conducted on March to May 2022, while the surveys in sites 1-4 and 7-8 were conducted on November 2020 to February 2021. Prior informed consent was obtained from the municipal governments of the four provinces before implementation of the study.

Data Collection

In each site, five 50-m transects were laid on the reef crest or fringing reef at a minimum depth of 5 m and maximum depth of 15 m, following the contour of the reef. The positions of the transects were determined using random numbers. Benthic cover was determined using the photo line-intercept transect method (Nakajima et al. 2010, English et al. 1997) on 50-m transects at each site. Fifty (50) 1 x 1 m benthic photos were obtained for each transect, for a total of 250 photos per site. Photos were processed using CPCe 4.1 (Kohler & Gill 2006) to obtain values for benthic cover, generic diversity, and dominant coral genera. Ten (10) random points were assigned for scoring in each photo for a total of 500 points per transect and 2500 points per site. For benthic cover, points were scored as hard coral, macroalgae, rock, sand/rubble, sponge, or 'other living organism'. If a point was scored as hard coral, it was further identified to the genus level, whenever possible. Average percent cover values were computed for each benthic type by dividing the number of points for each benthic type

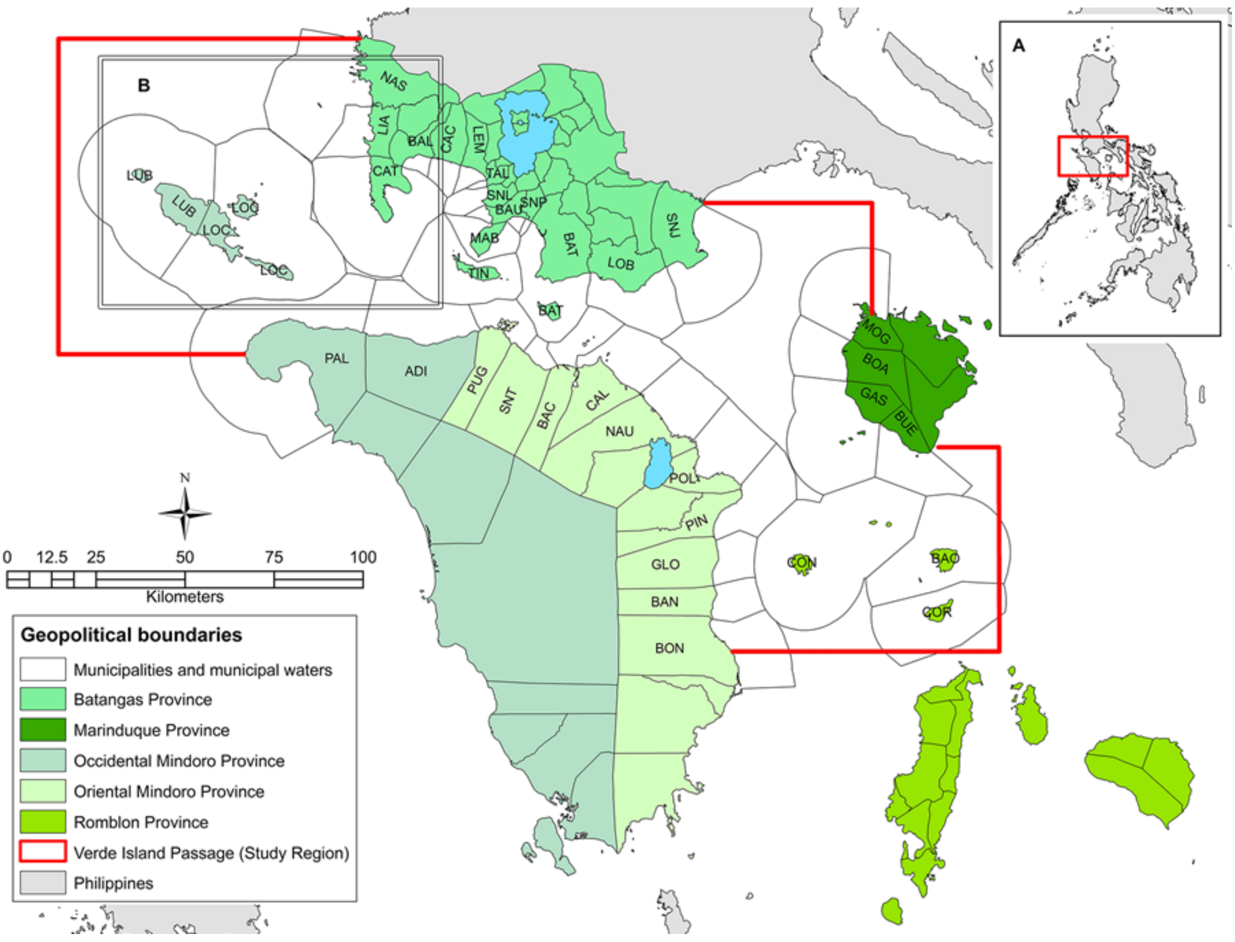

Figure 1. Map showing the provinces and municipalities that encompass the VIP. Taken from Horigue et al. (2015

by 500 points and averaging the component values across the five transects per site. For each site, generic richness was used as a proxy for biodiversity, and the three coral genera with the highest percent abundance were identified as the dominant genera in that site. Percent abundance of dominant coral genera was computed by dividing the number of points for each coral genera by 500 points and averaging the values across the five transects per site.

Table 1. Summary of Site Locations in the Verde Island Passage

Site Number	Site	Location	GPS Coordinates	Reef Characteristics
1	Batangas MPA	Brgy. Soloc, Lobo (LOB), Batangas	N 13.61512, E 121.24663	Facing Habagat/Southwest monsoon
2	Batangas non-MPA	Brgy, Pagkilatan, Batangas City (BAT), Batangas	N 13.62679, E 121.23472	Facing Habagat/Southwest monsoon, presence of human settlements
3	Marinduque MPA	Brgy. Libas, Buenavista (BUE), Marinduque	N 13.23436, E 121.95725	Facing Habagat/Southwest monsoon
4	Marinduque non-MPA	Brgy. Caganhao, Boac (BOA), Marinduque	N 13.4117, E 121.8203	Facing Habagat/Southwest monsoon, presence of human settlements
5	Occidental Mindoro MPA	Sitio Diumanod, Brgy. Udalo, Abra de Ilog (ADI), Occidental Mindoro	N 13.47763, E 120.80870	Facing Amihan/Northeast monsoon
6	Occidental Mindoro non-MPA	Sitio Sigman, Brgy. Udalo, Abra de Ilog (ADI), Occidental Mindoro	N 13.47412, E 120.79938	Facing Amihan/Northeast monsoon, sedimentation from nearby road construction, presence of human settlements
7	Oriental Mindoro MPA	Brgy. Agsalin, Gloria (GLO), Oriental Mindoro	N 12.88171, E 121.48949	Facing Amihan/Northeast monsoon, presence of human settlements and resorts
8	Oriental Mindoro non-MPA	Brgy. Sabang, Puerto Galera (PUG), Oriental Mindoro	N 13.52291, E 120.97548	Facing Amihan/Northeast monsoon

Table 2. Summary of Benthic Composition of MPA and non-MPA sites of the VIP

Site	Coral (% ± SD)	Rock (% ± SD)	Macroalgae (% ± SD)	Sand/Rubble (% ± SD)	Other Live (% ± SD)
1 - Batangas MPA	39.82 ± 7.59	15.39 ± 4.84	0.25 ± 0.25	42.80 ± 7.33	0.60 ± 0.30
2 - Batangas non-MPA	38.80 ± 5.56	16.87 ± 1.11	23.68 ± 2.66	16.28 ± 3.30	1.77 ± 1.08
3 - Marinduque MPA	25.58 ± 2.37	54.24 ± 1.72	6.14 ± 2.29	11.80 ± 2.54	0.42 ± 0.18
4 - Marinduque non-MPA	35.73 ± 4.05	46.23 ± 1.60	2.07 ± 2.35	13.49 ± 3.55	0.43 ± 0.20
5 - Occidental Mindoro MPA	49.49 ± 4.50	12.95 ± 1.35	21.89 ± 3.00	4.09 ± 2.64	16.52 ± 4.82
6 - Occidental Mindoro Non-MPA	32.32 ± 5.60	40.57 ± 4.73	8.14 ± 5.70	7.76 ± 2.19	9.89 ± 2.13
7- Oriental Mindoro MPA	25.02 ± 4.72	23.33 ± 15.54	3.16 ± 3.66	40.75 ± 25.59	2.45 ± 2.33
8 - Oriental Mindoro Non-MPA	5.93 ± 2.10	1.59 ± 1.60	10.83 ± 9.39	77.12 ± 6.22	4.12 ± 2.39

Table 3. Generic Richness (Coral TAUs) and Dominant Coral Genera (Percent Abundance) in MPA and non-MPA sites of the VIP

Province	MPA site (% ± SD)	Non-MPA site (% ± SD)
Batangas	22 coral TAUs	27 coral TAUs
	Porites 10.60 ± 4.29	*Galaxea* 21.86 ± 3.94
	Acropora 10.13 ± 2.58	*Porites* 3.56 ± 1.15
	Goniastrea 4.41 ± 3.04	*Lobophyllia 1.84* ± 0.56
Marinduque	13 coral TAUs	17 coral TAUs
	Porites 15.70 ± 1.55	*Porites* 15.91 ± 5.75
	Montipora 1.96 ± 1.19	*Merulina* 3.81 ± 0.88
	Goniastrea 1.19 ± 0.37	*Montipora* 1.60 ± 1.60
Occidental Mindoro	26 coral TAUs	19 coral TAUs
	Heliopora 9.93 ± 1.86	*Platygyra* 10.31 ± 7.29
	Porites 9.59 ± 1.78	*Porites* 7.04 ± 4.98
	Lobophyllia 4.18 ± 0.35	*Heliopora* 2.02 ± 1.43
Oriental Mindoro	24 coral TAUs	10 coral TAUs
	Porites 5.37 ± 3.19	*Galaxea* 3.07 ± 1.43
	Montipora 1.84 ± 2.79	*Acropora* 0.60 ± 0.39
	Merulina 1.78 ± 0.56	*Goniopora* 0.81 ± 1.05

Table 4. Categories of Hard Coral Cover based on Percent Abundance (Taken from Licuanan 2020).

Category	Percent Abundance
A	Greater than 44%
B	33 – 44 %
C	22 – 33%
D	0 – 22%

Table 5. Categories of Hard Coral Diversity based on Generic Richness (TAU) (Taken from Licuanan 2020).

Category	Coral TAUs
A	Greater than 26 coral TAUs
B	22 – 26 coral TAUs
C	18 – 22 coral TAUs
D	0 – 18 coral TAUs

Results

Substrate Composition

Table 2 shows a summary of benthic composition in the surveyed sites. In Batangas province, the MPA and Non-MPA sites had Category B hard coral cover (HCC) (refer to Table 4). Taking into account the average macroalgae cover of 8.4% in Philippine reefs (Licuanan et al. 2019), macroalgae cover was low in the MPA site but high in the non-MPA site at 23.68%. Sand/rubble was higher at 42.80% for Batangas MPA, and this was attributed to a typhoon that hit Batangas province a few weeks prior to the survey that resulted in fragmentation of dominant *Acropora* colonies at the site. In Batangas Non-MPA, sand/rubble was 16.28%. Dead coral or rock for colonization was 15.39% and 16.87% for the MPA and non-MPA sites, respectively.

In Marinduque province, the non-MPA site had higher coral cover with Category C HCC while the MPA site had Category D HCC. For the MPA and non-MPA sites, macroalgae cover was low at 6.14% and 2.07%. The cover for sand/rubble was 11.80% and 13.49% for the MPA and non-MPA sites. The amount of rock for colonization was 54.24% and 46.23% for the MPA and non-MPA sites.

In Occidental Mindoro, the MPA site had higher coral cover with Category A HCC while the non-MPA site had Category C HCC. Macroalgae cover was high in the MPA site at 21.89%, while for the non-MPA site, macroalgae cover was close to the average reported by Licuanan et al. (2019). The cover for sand/rubble was 4.09% and 7.76% for the MPA and non-MPA sites. The amount of rock for colonization was 12.95% and 40.57% for the MPA and non-MPA sites. For other live organisms, soft corals were abundant in the MPA and non-MPA sites.

In Oriental Mindoro, the MPA site had higher coral cover with Category C HCC while the non-MPA site had Category D HCC. Macroalgae cover was low in the MPA site at 3.16% and above-average in the non-MPA site at 10.83%. The cover for sand/rubble was 40.75% and 77.12% for the MPA and non-MPA sites. The amount of rock for colonization was 23.33% and 1.59% for the MPA and non-MPA sites. For other live organisms, soft corals were abundant in the MPA and non-MPA sites.

Generic Diversity and Dominant Coral Genera in MPA and Non-MPA Sites

Table 3 lists the generic richness and dominant coral genera in both MPA and non-MPA sites of the VIP. In Batangas, generic richness (GR) for the non-MPA site was higher at Category A GR (refer to Table 5), while the MPA site had Category B GR. The dominant genera in the MPA site were *Porites*, *Acropora*, and *Goniastrea*. In the non-MPA site, the dominant genera were *Galaxea*, *Porites*, and *Lobophyllia*.

In Marinduque, generic richness (GR) for the MPA and non-MPA sites were both Category D GR, albeit the non-MPA site had more TAUs. The dominant genera for the MPA site were *Porites*, *Montipora*, and *Goniastrea*. For the non-MPA site, the dominant genera were *Porites*, *Merulina*, and *Montipora*.

In Occidental Mindoro, generic richness (GR) for the MPA site was higher at Category B GR, while the non-MPA site had Category D GR. The dominant genera for the MPA site were *Heliopora*, *Porites*, and *Lobophyllia*. For the non-MPA site, the dominant genera were *Platygyra*, *Porites*, and *Heliopora*.

In Oriental Mindoro, generic richness (GR) for the MPA site was higher at Category B GR, while the non-MPA site had Category D GR. The dominant genera for the MPA site were *Porites*, *Montipora*, and *Merulina*. For the non-MPA site, the dominant genera were *Galaxea*, *Acropora*, and *Goniopora*.

Soft corals were present in some sites and they were categorized as 'Other live organisms' in Table 2. Examples of soft corals were *Anthelia* in Batangas non-MPA site, *Xenia* in Oriental Mindoro non-MPA site and Occidental Mindoro MPA site, and *Sarcophyton* in Occidental Mindoro MPA site.

Discussion

A comparison of the average HCC of the surveyed sites with reported HCC averages for the West Philippine Sea and the Visayan Sea revealed that the MPA sites of the four provinces had average HCC higher than the average reported for their regions (West Philippine Sea: 26 ± 1.6%, Visayan Sea: 22.9 ± 2.2%) (Licuanan et al. 2019). This could attest to the effectiveness of MPA protection in increasing HCC. For the non-MPA sites, Batangas, Marinduque, and Occidental Mindoro had average HCC higher than the average for their regions, while Oriental Mindoro had below average HCC. Human settlements and the proliferation of resorts were attributed to the lower HCC and diversity in Oriental Mindoro non-MPA.

When comparing average HCC of MPA and non-MPA sites per province, the Batangas and Marinduque MPA sites had average HCC close to or below their counterpart non-MPA sites. The reasons could be that the sites were declared as MPAs only recently (Batangas MPA ~10 years ago, Marinduque MPA ~5 years ago). In addition, a typhoon in 2020 affected the Batangas MPA site and fragmented several *Acropora* colonies. For Occidental Mindoro and Oriental Mindoro, the MPAs were established for a longer time and had average HCC higher than their counterpart non-MPA sites.

An additional proxy for assessing MPA potential is generic richness because high biodiversity contributes to the resilience of a coral reef (Bellwood & Hughes 2001). Based on generic richness, Batangas non-MPA site has potential in becoming a future MPA with its Category A GR. The 27 TAUs recorded was higher than the average reported for the West Philippine Sea (19.2 TAUs) by Licuanan et al. (2019). The non-MPA site of Marinduque had low generic richness with Category D GR, but its 17 TAUs were higher than the average reported for the Visayas Sea (13.8 TAUs) by Licuanan et al. (2019). The case is similar for the non-MPA site of Occidental Mindoro which had 19 TAUs. It was also observed that *Heliopora* was dominant in Occidental Mindoro. This has implications because *Heliopora* is known to exhibit aggressive behavior toward other corals in the competition and dominance for space in coral reefs (Atrigenio et al. 2020). Future surveys in this site should monitor the dominance of *Heliopora*. Lastly, the non-MPA site of Oriental Mindoro had low generic richness with Category D GR and 10 TAUs which was lower than the average for the region.

Conclusions and Recommendations

The baseline assessments in the four provinces of the VIP indicate that for Occidental Mindoro and Oriental Mindoro, HCC and generic richness were higher in MPA sites compared to non-MPA sites. However, the opposite was observed for Batangas (generic diversity) and Marinduque (HCC and generic diversity), and the observed higher HCC and generic diversity in the non-MPA sites of these provinces may be attributed to natural disturbances and duration of local reef management. Contrary to expectations, three out of four non-MPA sites showed good coral cover and diversity. It is uncertain why local stressors (e.g. human settlements, road construction) did not have adverse effects on coral cover and diversity, but these observations highlight their resilience to disturbances. Endorsing these sites to their respective municipal governments as MPAs will be beneficial for the VIP MPAN. Other types of assessments (*e.g.* ecological and social factors) should be conducted as secondary steps towards endorsing these sites as MPAs. Furthermore, annual or semi-annual monitoring should be conducted in all of the sites to reveal upward or downward trends for coral cover and generic richness. Future explorations in the VIP will facilitate coral reef assessments in more sites to give a more comprehensive assessment of HCC and generic richness in this biodiverse region.

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