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Coral reef condition in Illana Bay, Zamboanga del Sur, Philippines: Basis for conservation management

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ABSTRACT

Coral reef monitoring is essential for guiding local conservation strategies, particularly in areas exposed to increasing human pressures. This study assessed reef condition in six Marine Protected Areas (MPAs) along Illana Bay, Zamboanga del Sur, southern Philippines, to establish baseline ecological indicators for management. SCUBA-based photo-quadrat surveys were conducted, and benthic composition was quantified using Coral Point Count with Excel extensions (CPCe). Hard coral cover (HCC) differed substantially among MPAs, ranging from 27.60% (San Pablo; Category C) to 45.48% (Dumalinao; Category A). Coral diversity based on Taxonomic Amalgamation Units (TAUs) ranged from 15 to 27 species, with Dumalinao showing the highest richness (27 species; Category A) and Dimataling the lowest (15 species; Category C). Across all MPAs, Acropora branching was the most dominant hard coral sub-category (mean cover = 8.855%), followed by Porites massive (5.093%) and Porites encrusting (4.438%). Shannon diversity index values were low (0.69–1.10), indicating relatively low diversity and uneven community structure. The results suggest that reef assemblages in Illana Bay MPAs remain moderately degraded and are likely influenced by both natural disturbances and persistent anthropogenic stressors. Enhanced enforcement of protective ordinances, targeted community-based interventions, and long-term monitoring are recommended to support reef recovery and resilience.

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INTRODUCTION

Coral reefs are exceptionally biodiverse and productive ecosystems that support fisheries, coastal protection, and local livelihoods (Snelgrove *et al.*, 2017, Villanoy et. al., 2011). Globally, reefs are under increasing stress, and a large proportion of coral habitats are at risk. In the Philippines, coral reefs fringe many of the country's more than 7,100 islands and occur within a globally significant center of coral and reef-fish diversity (Gomez *et al.*, 1994; De Vantier and Turak, 2017). Reef condition varies widely because exposure to environmental drivers (e.g., monsoons and coastal processes) and human pressures differs across space and time (Licuanan *et al.*, 2019).

Assessment of coral reef status is therefore essential for evidence-based ecosystem protection and conservation in Illana Bay, Zamboanga del Sur. Illana Bay is a major marine resource in Southern Philippines, with coastal waters covering approximately 501,000 hectares. Long-term pressures, including destructive and illegal fishing and land-based sediment inputs, have contributed to reef degradation and declining fishery productivity, requiring stronger and more coordinated coastal management at the local level. Standardized reef assessment and monitoring can help LGUs and MPA managers understand current reef condition, identify priority threats, and track whether management actions are improving reef health over time. Monitoring results also support community engagement by communicating ecological trends and the potential economic and food-security consequences of reef decline.

The main objective of this study was to determine the present status of coral reefs within selected Marine Protected Areas (MPAs) in Illana Bay using quantitative indicators of benthic cover (including live hard coral cover) and hard coral diversity. The outputs are intended to support local conservation decisions, including enforcement priorities, education and outreach, and the design of repeat monitoring. This report serves as baseline information on coral reef condition in the six coastal LGUs of Illana Bay (Tabina, Dimataling, San Pablo, Dumalinao, Pagadian City, and Tukuran) as of June 2023. Future assessments can use these results for comparative analysis to detect change and evaluate management effectiveness.

MATERIALS AND METHODS

Research setting

The study was conducted in the coastal waters of six municipalities along Illana Bay, Zamboanga del Sur: Tukuran, Pagadian City, Dumalinao, San Pablo, Tabina, and Dimataling (Fig. 1).

Fig. 1. Map of the Sampling Sites. a. Map of Zamboanga Peninsula showing the location of Yllana Bay; b. Specific locations of the sampling sites in Yllana Bay

Procedure for coral reef assessment

Coral reef monitoring was conducted in the Marine Protected Area (MPA) in Six locations namely: Municipality of Tabina, Dimataling, San Pablo, Dumalinao, Pagadian City and Tukuran, Zamboanga del Sur all are in the Illana Bay. Self-Contained Underwater Breathing Apparatus (SCUBA) diving and Photo Quadrat Method (PQ) were used in obtaining photographs for study procedure (Fig. 2). Digital images were acquired using Sea Life DC2000 Underwater Camera, mounted on a 1.5m high aluminium bar that acts as a monopod. The aluminium bar must be pre calibrated to a certain height depending on the camera to be used before the sampling proper to ensure that the resulting image must cover an area of 1 square meter (1x1m). A total of six sampling stations were identified at the area for coral reef assessment. Still images were captured at every 1m marked along the established transect line thus creating fifty (50) picture frames for each transect. GPS coordinates were noted for every start of transects lay. Photographs were analyzed using the CPCe software by Kohler and Gill, 2006.

Fig. 2. Photoquadrat coral reef assessment. a. Layouting of the quadrat; b. Photo capturing for photo quadrat

Data analysis

Coral Point Count with Excel-extension (CPCe) program/software was designed specifically to quickly manage and effectively calculate statistical coral coverage over a specified area.

The frequency of corals/substrates, identification and data analysis were run by specifying a digital image, defining a frame border, overlaying random points, and saving the data to a file (Kohler and Gill, 2006).

The obtained underwater photographs were overlaid to a random of distributed points. This assessment employed 10 points randomly distributed for analysis (Fig. 3). The overlaid point was then characterized such as; coral, algal assemblage, abiotic materials, macro-algae, Halemeda, other biotic organisms and undeterminable objects like shadows and transect line. The coded photographs were then saved as a file with CPC extension. The data from individual frames in the whole extent of the transect line were analyzed to produce quantitative population estimates including species diversity estimates. Multiple frames were combined for a single transect datasheet containing header information, statistical parameters of each species/substrate type (relative abundance, mean and standard deviation) and diversity indices (Shannon-Weaver and Simpson's) were calculated for each transect (Kohler and Gill, 2006).

Fig. 3. CPCe operation and analysis

Percent cover was computed using the following equation:

$$\%\ \text{cover} = \frac{\text{Total Sample Points of Category x 100}}{\text{Total no. of Points per transect}}$$

Coral reef status was then categorized based on live Hard Coral Cover as established by *Licuanan et al. (2019):* HCC Category A= >44% live coral cover, HCC Category B= 34-44% live coral cover, HCC Category C= 22-33% live coral cover and HCC Category D= 0-22% live coral cover. Hard Coral Diversity status was then categorized based on Taxonomic Amalgamation Units (TAUs) as established by Licuanan *et al.* (2019): HCC Category A= >26 TAUs, HCC Category B= >22-26 TAUs, HCC Category C= >18-22 TAUs, and HCC Category D= 0-18 TAUs

RESULTS

Benthic ecosystem in coral reefs of six coastal municipalities

Benthic communities within Illana Bay MPAs exhibited a gradient in live hard coral (HC) cover and algal assemblage (AA) dominance (Table 1). Live hard coral cover ranged from 27.60% in San Pablo to 45.48% in Dumalinao, with intermediate values in Dimataling (29.04%), Pagadian City (29.24%), Tabina (37.56%), and Tukuran (42.08%). Based on national condition thresholds for hard coral cover (Licuanan *et al.*, 2019), Dumalinao falls under Category A (>44%), Tabina and Tukuran under Category B (34–44%), and Dimataling, Pagadian City, and San Pablo under Category C (22–33%).

Table 1. Percent cover of major benthic ecosystem in coral reefs of six coastal municipalities in Illana Bay, Zamboanga del Sur

Major category	Mean percentage (%)					
	Tabina	Dimataling	San Pablo	Dumalinao	Pagadian city	Tukuran
Coral (HC)	37.56	29.04	27.60	45.48	29.24	42.08
Algae Assemblage (AA)	41.85	66.93	62.92	30.04	64.34	48.57
Abiotic (AB)	17.89	2.74	8.11	20.19	6.00	8.35
Macroalgae (MA)	-	-	-	-	-	-
Halimeda (HA)	-	-	-	-	-	-
Other Biota (OB)	2.71	1.28	1.37	4.29	0.42	1.00
Tape, shadow, Blocks IND (TWB)	4.13	5.27	2.13	2.27	4.07	6.80

Table 2. Sub-categories (% of transect) of corals and other biotic and abiotic factors by municipality

Sub-categories	Tabina	Dimataling	San Pablo	Dumalinao	Pagadian City	Tukuran	Mean
Coral (HC)							
Acropora branching (ACB)	0.07	18.44	3.74	10.84	10.61	9.43	8.855
Acanthastrea (ACAN)	15.34	-	-	0.41	0.07	-	2.63
Acropora digitate (ACD)	-	-	-	0.07	-	-	0.011
Astreopora (AST)	0.14	-	-	1.30	-	0.36	0.29
Caulastrea (CAU)	0.07	-	0.21	-	0.14	-	0.07
Coscinarea (COS)	0.14	-	-	0.07	-	-	0.035
Diploastrea heliopora (DIP)	0.28	-	0.62	-	0.44	0.36	0.283
Cyphastrea (CYP)	-	-	-	-	0.94	2.30	0.54
Echinophyllia (ECHY)	-	0.29	1.03	-	-	0.22	0.256
Echinopora (ECHI)	-	-	0.27	2.18	0.41	0.21	0.511
Euphyllia (EUP)	0.21	0.27	0.07	0.41	0.20	0.21	0.228
Favia (FAV)	0.07	0.20	0.49	0.89	0.07	-	0.286
Favites (FVI)	0.48		0.20	0.89	0.56	0.57	0.45
Fungia (CMR)	0.21	1.98	1.57	0.75	1.39	2.21	1.35
Galaxea (GAL)	0.07	-	1.09	-	-	-	0.193
Goniastrea (GONIA)	0.97	-	0.07	0.41	0.15	0.43	0.338
Leptoseris (LEPS)	0.35	0.86	0.55	0.07	0.42	1.44	0.615
Lobophyllia (LOB)	-	-	-	-	-	0.36	0.06
Merulina (MER)	-	-	0.07	0.07	0.34	0	0.08
Montipora branching (MONTB)	-	-	-	0.14	0.07	0.39	0.01
Montipora encrusting (MONTE)	0.14	0.20	-	0.27	-	-	0.101
Montipora foliose (MONTF)	-	-	1.09	0.55	0.14	-	0.296
Mycedium (MYC)	-	-	0.47	0.27	0.20	-	0.156
Oulophyllia (OULO)	-	-	-	-	-	0.14	0.023
Oxypora (OXY)	0.07	1.03	1.08	-	0.07	-	0.375
Pachyseris encrusting (PACE)	0.07	0.07	0.95	0.20	-	0.29	0.263
Pachyseris foliose (PACF)	-	0.07	1.61	0.14	-	0.22	0.34
Pavona (PAV)	-	3.82	0.14	0.14	0.34	0.22	0.776
Pectinia (PEC)	-	-	0.07	-	0.07	0.29	0.071
Platygyra (PLAT)	-	-	-	0.48	-	-	0.08
Pocillopora (POC)	0.62	-	-	7.08	0.07	0.29	1.343
Porites branching (PORB)	7.04	0.50	2.07	0.75	3.16	8.45	3.661
Porites encrusting (PORE)	3.02	0.48	8.56	4.30	4.69	5.58	4.438
Porites massive (PORM)	7.71	0.55	1.59	10.51	3.84	6.36	5.093
Stylophora (STY)	0.28	0.29	-	-	-	-	0.095
Symphyllia (SYM)	0.21	-	-	0.14	0.36	0.71	0.236

Turbinaria (TURB)	-	-	-	2.18	0.51	1.15	0.64
Total no. of hard coral species	22	15	23	27	25	24	
Algae assemblage (AA)							
Algal assemblage (AA)	1.61	-	-	0.34	-	-	0.325
Crustose Coralline algae (CA)	-	0.36	-	-	-	-	0.06
Dead Coral (DC)	37.91	34.69	34.69	11.46	48.96	31.91	33.27
Dead coral with algae (DCA)	2.32	31.88	28.23	18.24	15.38	16.66	18.78
Abiotic (AB)							
Rubble (R)	2.54	-	1.15	9.14	-	0.28	2.185
Sand (S)	15.35	0.41	6.82	8.53	6.00	7.93	7.506
Sedimentary rock (RCK)	-	-	-	0.21	-	-	0.035
Silt (SI)	-	2.13	0.14	2.32	-	0.14	0.788
Macroalgae (MA)							
Halimeda (HA)							
Other Biota (OB)							
Other invertebrates (OT)	0.07	0.07	-	0.34	0.15	0.50	0.188
Seagrass (SG)	0.56	-	0.07	-	-	-	0.105
Soft coral (SC)	0.70	0.58	0.14	1.29	-	-	0.451
Sponge (SP)	1.38	0.63	1.16	2.66	0.28	0.50	1.101
Tape, Shadow, Blocks, IND. (TWB)							
Tape, shadow blocks IND (TWB)	4.13	5.27	2.13	2.27	4.07	6.80	4.111

Algal assemblage cover was highest in Dimataling (66.93%), Pagadian City (64.34%), and San Pablo (62.92%) and lowest in Dumalinao (30.04%). Abiotic components (AB) ranged from 2.74% (Dimataling) to 20.19% (Dumalinao), while other biota (OB) remained low across sites (0.42–4.29%; Table 1).

Hard coral richness (Taxonomic Amalgamation Units; TAUs) varied among MPAs (Table 3). Dumalinao recorded the highest richness (27 TAUs; Category A, >26 TAUs), followed by Pagadian City (25 TAUs) and Tukuran (24 TAUs) (both Category B, >22–26 TAUs). San Pablo had 23 TAUs (Category B), Tabina had 22 TAUs (Category C, >18–22 TAUs), while Dimataling had the lowest richness (15 TAUs; Category D, 0–18 TAUs) based on the thresholds in Licuanan *et al.* (2019).

Sub-categories of benthic ecosystems in coral reefs

Results indicate substantial contributions of dead coral (DC) and dead coral with algae (DCA) within the algal assemblage complex (Table 2). Mean DC was 33.27% across sites, peaking in Pagadian City (48.96%) and remaining lowest in Dumalinao (11.46%). Mean DCA was 18.78%, with the highest values observed in Dimataling (31.88%) and San Pablo (28.23%). These sub-category patterns provide baseline indicators for detecting future shifts between coral- and algae-dominated states under continued disturbance or improved management.

The five most common hard coral species across MPAs are summarized in Table 3, based on transect point counts. Across all sites, Acropora branching (ACB) exhibited the highest mean occurrence (8.855), followed by Porites massive (5.093) and Porites encrusting (4.438; Table 3).

Acropora branching (ACB) was particularly abundant in Dimataling (18.44%), and remained relatively high in Dumalinao (10.84%), Pagadian City (10.61%), and Tukuran (9.43%). In contrast, several sites showed higher contributions from stress-tolerant massive and encrusting forms, including Porites massive and Porites encrusting (Table 2 and 3).

Table 3. Top five hard coral sub-categories occurring along transects

Species/Sub-categories	Mean
Acopora branching (ACB)	8.855
Porites massive (PORM)	5.093
Porites encrusting (PORE)	4.438
Porites branching (PORB)	3.661
Acanthastrea (ACAN)	2.63

DISCUSSION

Live hard coral cover in Illana Bay MPAs (27.60–45.48%) indicates mostly moderate condition (Categories B–C) with one higher performing site (Dumalinao; Category A). National assessments have documented that many Philippine reefs remain under chronic pressure and frequently fall within low-to-moderate cover categories, emphasizing that local management improvements can still yield measurable gains (Licuanan *et al.*, 2019, Feliciano et.al., 2018). At broader Indo-Pacific scales, long-term datasets show substantial regional declines in coral cover over past decades, highlighting the importance of protecting remaining coral habitat and preventing avoidable local losses (Bruno and Selig, 2007, Cabral and Geronimo, 2018).

High algal assemblage cover and elevated DC/DCA in several MPAs (especially Dimataling, Pagadian City, and San Pablo) suggest that a large portion of benthic space is either occupied by algae or represents recent coral mortality surfaces available for algal colonization.

Competition between corals and benthic algae can suppress coral recruitment and growth through shading, abrasion, and allelopathic effects, and is widely recognized as a key process influencing reef community trajectories (McCook *et al.*, 2001). Experimental evidence also demonstrates that reduced herbivory can erode reef resilience and facilitate macroalgal proliferation following bleaching or other disturbances (Hughes *et al.*, 2007).

The field reported stressors in Illana Bay (e.g., fishing pressure, anchoring, sewage inputs, and siltation) are consistent with mechanisms known to favor algal dominance and reduce coral recovery potential. Terrestrial runoff and sedimentation can reduce coral calcification, growth, and recruitment while increasing susceptibility to disease and partial mortality (Fabricius, 2005, Licuanan et. al., 2017). Where nutrient enrichment occurs, reefs may be more prone to macroalgal blooms, reinforcing coral–algal competition dynamics (Lapointe, 1997). These pathways suggest that effective MPA outcomes in Illana Bay will depend not only on fisheries enforcement, but also on coordinated ridge-to-reef actions that reduce sediment and wastewater inputs into nearshore habitats.

The dominance of Acropora branching (mean 8.855%) indicates the presence of fast-growing framework builders that can contribute to rapid increases in coral cover under favorable conditions. Trait-based syntheses classify branching competitive taxa as capable of rapid space occupation but also relatively vulnerable to disturbance (Darling *et al.*, 2012, Barnes et al., 2015). Consistent with this, bleaching studies have reported marked taxon-specific susceptibility during thermal stress events, often with branching taxa among those most affected (Marshall and Baird, 2000, Morgan et. al., 2016, Shen et. al., 2010). For Illana Bay, this implies that short-term increases in coral cover may be driven by Acropora recovery, but that gains could be fragile if thermal stress and physical impacts remain unmanaged.

Differences among MPAs in both coral cover and richness suggest variable effectiveness of local protection or exposure to external stressors. Global analyses indicate that MPAs deliver stronger ecological outcomes when key enabling conditions are present including effective enforcement and sufficient age/size (Edgar *et al.*, 2014), while capacity shortfalls like staffing, budget, and local compliance mechanisms, commonly limit MPA performance worldwide (Gill *et al.*, 2017, Licuanan et. al., 2017). In the Philippine context, evaluations of locally managed MPAs highlight that many sites are small and unevenly enforced, leading to variable ecological benefits (Muallil *et al.*, 2019, Licuanan and Aliño, 2014, Licuanan, 2020).

Accordingly, Illana Bay MPAs may benefit from prioritizing compliance and enforcement in lower-performing sites, while using Dumalinao as a reference benchmark for achievable reef condition under current regional pressures.

Taken together, the results support a management approach that combines strengthened enforcement to reduce direct physical damage and illegal fishing, anchoring controls in reef areas, and land–sea coordination to address sedimentation and wastewater inputs. These interventions are most likely to shift benthic composition toward higher coral cover and lower DCA/AA dominance, and can be tracked through repeat photoquadrat monitoring.

CONCLUSION

This baseline assessment shows that coral reefs in the Illana Bay MPAs are generally in fair condition but vary widely among sites, with some MPAs performing well while others show signs of stress, low coral diversity, and reduced recovery potential. The results of the study suggest that conservation efforts should be exerted to increase species diversity of coral reef species.

RECOMMENDATIONS

Based on the result of this study, it is recommended a strict implementation of local ordinances pertaining to protection and conservation measures of the coral reef ecosystems in Illana Bay due to increasing anthropogenic activities and environmental problems observed in the area. An Information Education Campaign (IEC) should be considered to raise awareness in the communities residing near the coastal areas.

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