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Research Article

Effect of siltation on coral reef health in Mabini Protected Landscape and Seascape, Davao de Oro, Philippines

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Abstract

Coral reefs are vital marine ecosystems characterized by high biodiversity and significant ecological roles; however, increasing siltation threatens their stability. In Mabini Protected Landscape and Seascape (MPLS), Mabini, Davao de Oro, Philippines, recent monitoring recorded declining coral cover, with siltation identified as a major stressor. This study assessed the seasonal effects of siltation on coral reef health by comparing indicators between low- and high-siltation sites. Coral reefs were surveyed using photo-transect method, fish visual census for indicator reef fish, and frequency of occurrence for coral disease. Siltation was measured using sediment traps and multiparameter water-quality device. Results showed higher mean live hard coral cover in low-siltation site (58.65% HCC) compared to high-siltation site (36.07% HCC). Coral genera diversity and butterflyfish abundance were also higher in low-siltation site (34 TAUs; 41.2 ind. 100m-2) than in high-siltation site (21 TAUs; 12.8 ind. 100m-2). Higher frequency of disease-affected coral colonies in high-siltation site (56 colonies) compared to low-siltation site (33 colonies). Whereas mean coral mortality did not differ significantly between low-siltation (0.25 CMI) and high-siltation (0.18 CMI) sites. Mean turbidity and sediment deposition rates were markedly higher in high-siltation site during both the dry (31.97 NTU; 150.95 g m^{-2} day^{-1}) and wet (76.66 NTU; 278.52 g m^{-2} day^{-1}) seasons, compared to low-siltation site during the dry (4.04 NTU; 16.29 g m^{-2} day^{-1}) and wet (15.17 NTU; 73.66 g m^{-2} day^{-1}) seasons. These findings indicate that siltation is a primary driver of reef degradation in MPLS and support ridge-to-reef management strategies for coral reef conservation.

Keywords

Coral reef health, Mabini Protected Landscape and Seascape (MPLS), sedimentation, siltation, turbidity

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INTRODUCTION

Coral reefs are vital marine ecosystems characterized by high biodiversity and the significant ecological roles they play (Bravo et al., 2022; Wagner et al., 2020). They are among Earth's most diverse and productive marine ecosystems, which provide critical habitat, food, and livelihood resources for millions of people worldwide (Pattiasina et al., 2018). In addition to their biodiversity, coral reefs provide humans with imperative ecosystem services such as coastal protection, food, and tourism income (Rivera et al., 2020; Souter et al., 2021). Above all, the Philippines has approximately 30,000 square kilometers of coral reefs, making it one of the most ecologically diverse coral reef areas in the world (Domingo et al., 2024).

However, these ecosystems face various environmental threats, one of which is the negative impact of siltation which can significantly impact coral health and the overall integrity of the reef system (Jones et al., 2016; Risk & Edinger, 2011; Schlaefer et al., 2021). Siltation occurs when excess fine sediment settles onto the corals, which is an undesirable state (Tuttle & Donahue, 2022; Weber et al., 2012). The shading of the corals impedes much light that is necessary for the photosynthesis of zooxanthellae, the symbiotic algae living in the coral tissues (Browne et al., 2015; Erftemeijer et al., 2012). Reduced light severely affects corals by limiting their growth, reproductive ability, and resistance to diseases or any other environmental stress (Pattiasina et al., 2018; Ramsby et al., 2024).

In the Philippines, early studies indicated that land-based pollution contributes to sedimentation impacting reefs (Gomez et al., 1994; Panga et al., 2021). This continues to be a major concern, as recent research highlights that human activities such as deforestation, mining, dam development, and unsustainable agricultural practices exacerbate soil erosion and sedimentation in rivers and coastal areas (Gacu et al., 2025). The decline of Philippine coral reefs has been linked to such siltation from river runoff (Panga et al., 2021), with anthropogenic activities and population increase driving increased sedimentation (Abreo et al., 2015). In the Mabini Protected Landscape and Seascape (MPLS), a nationally legislated marine protected area in Davao de Oro, Philippines, the increasing pressures of land development, agricultural expansion, and deforestation have led to concerns about the rising siltation in the coral reefs (DENR-PENRO Davao de Oro, 2024b).

Despite its legislation and conservation measures, recent assessments made by the Department of Environment and Natural Resources have indicated declining coral cover of MPLS, for which siltation may be a primary stressor due to river systems discharging into the protected area, and has been identified as one of the most pressing threats to the ecological integrity of the area (DENR-PENRO Davao de Oro, 2024a). Despite of an increasing number of studies emphasizing the worldwide implications of siltation on coral reefs (Erftemeijer et al., 2012; Fisher et al., 2019), there is still a major deficiency of localized studies to investigate such implications within the Philippine context, particularly in the MPLS. This study aims to fill this knowledge gap by assessing the impact of siltation on coral reef health within MPLS and evaluates the seasonal effects of siltation by comparing coral cover, coral diversity, coral mortality, presence and abundance of indicator reef fish species, coral disease occurrence, and by quantifying turbidity, sedimentation, and physicochemical parameters during dry and wet seasons. The findings of the study are anticipated to advance our knowledge of the impact of siltation on coral reefs and to help develop effective mechanisms to counter its effects in MPLS.

METHODOLOGY

Design

This study employed a comparative quantitative field-based ecological design to examine the effects of siltation on coral reef health in the Mabini Protected Landscape and Seascape (MPLS), Davao de Oro, Philippines. Biological, ecological, and physicochemical indicators—including live hard coral cover, benthic composition, coral diversity, coral mortality, butterflyfish abundance, coral disease, turbidity, sediment deposition, and water quality—were measured using standardized coral reef monitoring protocols. Data were collected during the dry and wet seasons to evaluate seasonal variation and statistically compare low- and high-siltation reef sites.

Study Area

The study was conducted at two coral reef sites within MPLS representing contrasting sediment conditions. Site A was characterized by low sediment exposure and clearer water, whereas Site B experienced higher sediment input from nearby terrestrial sources. Site selection was validated through turbidity and sediment deposition measurements. Coral reef assessments were conducted in May 2025 (dry season), while water quality and sediment monitoring were repeated in August 2025 (wet season).

Coral Reef Assessment

Three permanent 50-m transects (5–10 m depth) were established at each site following DENR-BMB monitoring protocols. Benthic composition was assessed using photo-transects, with images analyzed in Coral Point Count with Excel Extensions (CPCe) Version 3.6. Live coral cover, coral genera diversity (Taxonomic Amalgamation Units), and Coral Mortality Index were determined using established Philippine coral reef monitoring standards.

Indicator Reef Fish Assessment

Butterflyfish (Family Chaetodontidae), recognized as indicators of coral reef condition, were surveyed using Fish Visual Census along the permanent transects. Individuals were identified and counted within a 5-m belt, and fish density was expressed as individuals per 100 m^2.

Coral Disease Assessment

Coral colonies exhibiting disease signs were recorded and photographed during reef surveys. Diseases were identified using established visual diagnostic criteria, and the frequency of each disease type was determined for every transect.

Water Quality Assessment

Water quality parameters, including turbidity, temperature, pH, salinity, dissolved oxygen, and oxidation–reduction potential, were measured using a calibrated Horiba U-53G multiparameter analyzer. Measurements were obtained during both sampling seasons and evaluated against recognized environmental standards.

Sediment Deposition

Sediment deposition was measured using cylindrical PVC sediment traps deployed for 30 days at each transect. Collected sediments were dried, weighed, and expressed as grams per square meter per day ($g\ m^{-2}\ day^{-1}$). Sedimentation levels were classified using published coral reef sedimentation thresholds.

Quality Assurance

Standardized field protocols, permanent transects, consistent observers, calibrated instruments, and uniform sediment-trap deployment ensured the reliability and comparability of data across sites and seasons.

Statistical Analysis

Descriptive statistics summarized all variables. Independent-samples t-tests compared ecological indicators between low- and high-siltation sites, while paired-samples t-tests evaluated seasonal differences in turbidity and sediment deposition. Statistical significance was set at $\alpha = .05$.

RESULTS AND DISCUSSION

Table 1 demonstrates that the low-siltation site supported significantly greater live hard coral cover than the high-siltation site, with mean coral cover values of 58.65% and 36.07%, respectively. The independent-samples t-test confirmed that this difference was statistically significant ($t = 4.71$, $p = .009$), indicating that sediment exposure is associated with reduced coral cover. According to the commonly accepted coral reef condition classification, Site A remained in excellent condition, whereas Site B was classified as having good reef condition. Although both sites retained living coral communities, the marked reduction in coral cover at Site B suggests that chronic sediment exposure may already be influencing reef structural integrity. The findings support previous studies demonstrating that elevated sedimentation decreases coral survival by reducing light availability, limiting photosynthesis of symbiotic zooxanthellae, and increasing the energetic cost required for sediment removal (Fabricius, 2005; Erftemeijer et al., 2012; Weber et al., 2012). Chronic sediment deposition may also interfere with coral recruitment and calcification, ultimately reducing overall reef complexity (Flores et al., 2012; Tuttle & Donahue, 2022). Similar declines in coral cover associated with terrestrial runoff have been reported across Philippine coral reef ecosystems (Licuanan et al., 2019; Gomez et al., 1994), suggesting that the observed differences between the two study sites reflect broader regional patterns of sediment-related reef degradation. Despite the significantly lower coral cover observed in Site B, the site remained within the "good" condition category, indicating that portions of the coral community continue to exhibit resilience to sediment stress. This resilience may result from the persistence of sediment-tolerant coral taxa and localized hydrodynamic conditions that reduce complete burial of reef substrates (Risk & Edinger, 2011; Schlaefer et al., 2021). Nevertheless, continued sediment loading may progressively reduce coral cover if appropriate watershed and coastal management interventions are not implemented.

Table 1
Comparison of Hard Coral Cover Between Low- and High-Siltation Sites

Variable	Transect	Site A (Low-Siltation Site)	Site B (High-Siltation Site)
Hard Coral Cover (%)	T1	52.24	29.39
	T2	60.49	41.06
	T3	63.21	37.78
Mean ± SD		58.65 ± 5.71	36.07 ± 6.02
Hard Coral Cover Category		Category A	Category B
Reef Condition		Excellent	Good
Independent Samples t-test	t	4.71	
	df	4	
	p-value	.009*	

Note. HCC = Hard Coral Cover. Category A = Excellent (50–75% cover); Category B = Good (25–49% cover). $p < .05$ indicates a statistically significant difference between sites.

The benthic composition showed substantial differences between the two study sites. Site A was dominated by living hard corals, whereas Site B contained considerably greater abiotic substrate, indicating reduced biological dominance and increased sediment accumulation. Coral diversity followed a similar pattern, with Site A supporting 34 taxonomic amalgamation units (TAUs), compared with only 21 TAUs in Site B. These findings suggest that sediment exposure not only reduces coral abundance but also alters the overall composition and diversity of benthic communities. The dominance of abiotic substrates in Site B is consistent with ecological succession occurring after chronic physical disturbance. Elevated sediment deposition inhibits larval settlement, limits substrate availability, and promotes unstable bottom conditions that prevent successful coral recruitment (Cooper et al., 2009; Thanopoulou et al., 2022). Over time, these processes reduce species richness and shift reef communities toward simplified benthic assemblages dominated by non-living substrates. Similar relationships between declining coral diversity and deteriorating water quality have been documented in coral reefs throughout Southeast Asia and the Caribbean (Roberts et al., 2017; Panga et al., 2021). Higher coral diversity in Site A also implies greater ecological resilience. Diverse coral assemblages generally exhibit enhanced resistance to environmental disturbances because functional redundancy allows ecosystem processes to continue even when individual species decline (Obura & Grimsditch, 2009). Conversely, reduced diversity in Site B may lower the adaptive capacity of the reef, making it increasingly vulnerable to future stressors such as climate warming, disease outbreaks, and extreme weather events (Souter et al., 2021). Consequently, conserving water quality remains essential for maintaining both coral cover and community diversity.

Table 2
Comparison of Benthic Lifeform Composition and Coral Diversity Between Low- and High-Siltation Sites
Panel A. Benthic Lifeform Composition

Benthic Lifeform	Site A (%)	Site B (%)
Hard coral	58.65	36.07
Algae	10.39	5.88

Benthic Lifeform	Site A (%)	Site B (%)
Dead coral	8.29	—
Abiotic components	20.10	48.38
Soft coral	≤ 3.79	≤ 3.79
Other biotic components	< 3.00	< 3.00

Panel B. Coral Diversity

Indicator	Site A	Site B
Total Taxonomic Amalgamation Units (TAUs)	34	21
Diversity Category	Category A (Very High)	Category C (Moderate)

Note. TAUs = Taxonomic Amalgamation Units. Site A exhibited greater live coral cover and coral diversity, whereas Site B was dominated by abiotic substrates, indicating greater habitat degradation associated with sedimentation.

The composition of coral genera differed markedly between the two sites, reflecting contrasting environmental conditions. Site A was characterized by relatively high abundances of branching *Acropora*, *Echinopora*, *Leptoseris*, and massive *Porites*, whereas Site B was dominated primarily by branching *Porites*, *Millepora*, and *Mycedium*. These differences indicate that chronic sediment exposure influences not only overall coral diversity but also species composition by favoring taxa capable of tolerating elevated sediment loads.Branching *Acropora* species are widely recognized as fast-growing but environmentally sensitive corals that require clear water and high light availability for optimal growth (Fabricius, 2005; Flores et al., 2012). Their substantially greater abundance in Site A suggests that low sediment exposure provided favorable conditions for growth and recruitment. In contrast, the dominance of branching *Porites* and *Millepora* in Site B indicates a community increasingly composed of stress-tolerant taxa capable of surviving under more turbid conditions. Similar shifts toward sediment-tolerant coral assemblages have been reported in reefs affected by chronic terrestrial runoff and dredging activities (Jones et al., 2016; Cooper et al., 2009). The observed changes in coral community composition have important ecological implications. Structural complexity generated by branching corals provides essential habitat for numerous reef-associated fishes and invertebrates (Bravo et al., 2022). As sedimentation favors more tolerant but morphologically simpler coral assemblages, habitat heterogeneity declines, potentially reducing biodiversity across multiple trophic levels. These findings further support the hypothesis that sedimentation acts as a major ecological filter shaping coral reef community structure in the study area.

Table 3
Relative Abundance of Coral Genera (Taxonomic Amalgamation Units) Between Study Sites

Coral Genus (TAU)	Site A (%)	Site B (%)
Acropora branching	20.85	5.25
Acropora corymbose	—	0.07
Acropora hispidose	5.64	—
Acropora plate	0.20	—
Astreopora	0.34	—
Coeloseris	0.07	0.14
Echinophyllia	2.24	0.13
Echinopora	5.90	3.25
Euphyllia	0.68	2.71
Favia	0.07	—
Favites	0.14	—
Fungia	4.55	0.34
Goniastrea	0.20	—
Goniopora	0.34	0.14
Hydnophora	0.47	0.61
Leptoseris	3.93	—
Lobophyllia	0.07	—
Millepora	—	4.26
Montipora foliose	0.88	—
Mycedium	0.88	3.79
Other branching corals	—	0.61
Other encrusting corals	1.02	0.20
Other foliose corals	0.27	—
Other massive corals	0.14	0.67
Oxypora	0.41	—
Pachyseris foliose	0.61	0.34
Pavona	1.77	1.56
Pectinia	0.47	0.20
Pocillopora	0.41	0.54
Porites branching	2.04	9.92
Porites encrusting	0.68	—
Porites massive	3.05	1.22
Seriatopora	0.27	0.14
Stylophora	0.07	—

Coral Genus (TAU)	Site A (%)	Site B (%)
Total TAUs	34	21
Diversity Category	Category A (Very High)	Category C (Moderate)

Note. Dash (—) indicates that the coral genus was not observed at the corresponding site. Site A supported a broader and more evenly distributed coral assemblage, whereas Site B was characterized by lower diversity and a greater dominance of stress-tolerant genera, particularly Porites branching and Millepora.

Table 4 shows that the mean coral mortality index was slightly higher in the low-siltation site (0.25 ± 0.10) than in the high-siltation site (0.18 ± 0.15). However, the independent-samples *t*-test indicated that the difference was not statistically significant (t = 0.67, p = .540). These findings suggest that despite the substantial differences observed in coral cover and diversity between the two sites, recent coral mortality alone does not adequately explain the variation in overall reef condition. Instead, the results indicate that chronic environmental stress may affect coral communities through mechanisms other than immediate mortality. Coral reefs exposed to persistent sedimentation frequently exhibit sublethal physiological responses before widespread mortality becomes evident. Suspended sediments reduce photosynthetic efficiency by limiting light penetration, increase the energetic cost of sediment rejection, and impair calcification and reproductive success without necessarily causing immediate colony death (Weber et al., 2012; Flores et al., 2012; Bessell-Browne et al., 2017). Consequently, coral populations may remain alive while experiencing reduced growth, diminished reproductive output, and lower competitive ability. These chronic effects may gradually alter reef community structure long before mortality indices detect significant changes. The absence of significant differences in mortality also highlights the importance of considering multiple biological indicators when evaluating reef health. Coral cover, community composition, disease prevalence, and reef-associated fish assemblages often respond more rapidly to environmental degradation than mortality indices alone (Cooper et al., 2009; Díaz-Pérez et al., 2016). Therefore, the present findings suggest that sedimentation primarily influences coral vitality through long-term ecological stress rather than acute mortality events. This emphasizes the need for integrated reef monitoring programs that incorporate both structural and functional indicators of ecosystem condition.

Table 4
Comparison of Coral Mortality Index Between Low- and High-Siltation Sites

Variable	Transect	Site A (Low-Siltation Site)	Site B (High-Siltation Site)
Coral Mortality Index	T1	0.36	0.16
	T2	0.21	0.04
	T3	0.17	0.35
Mean ± SD		0.25 ± 0.10	0.18 ± 0.15
Mortality Category		Moderate Mortality	Low Mortality
Independent Samples t-test	t	0.67	
	df	3	
	p-value	.540	

Note. Coral Mortality Index (CMI) values indicate the proportion of recently dead corals relative to live coral cover. No statistically significant difference was observed between the two study sites (p > .05).

Butterflyfish assemblages differed markedly between the two study sites. The low-siltation site supported 12 butterflyfish species with a total density of 41.20 individuals per 100 m², whereas the high-siltation site contained only four species and a substantially lower density of 12.80 individuals per 100 m². These findings closely correspond with the observed differences in hard coral cover and coral diversity, indicating that reef fishes responded strongly to changes in habitat quality associated with sediment exposure. Butterflyfishes (Family *Chaetodontidae*) are widely recognized as sensitive biological indicators because many species depend directly on live corals for food, shelter, or reproduction (Iskandar et al., 2021; Cooper et al., 2009). Consequently, reductions in coral cover often result in rapid declines in butterflyfish abundance and species richness. The greater diversity observed in Site A reflects the availability of structurally complex coral habitats that provide numerous ecological niches, whereas the simplified benthic environment in Site B likely reduced habitat suitability for coral-dependent fishes. The dominance of *Chaetodon octofasciatus* and *Chaetodon baronessa* in both sites further suggests that only a limited number of relatively adaptable species persisted under elevated sediment conditions. Similar reductions in butterflyfish diversity following coral degradation have been documented throughout Indo-Pacific coral reefs, where habitat loss significantly reduced coral-feeding fishes (Pratchett et al., 2006). Declining butterflyfish populations may also have broader ecological implications because reef fishes contribute to trophic regulation, nutrient cycling, and reef resilience (Bravo et al., 2022). Therefore, the observed reductions in butterflyfish assemblages reinforce the conclusion that chronic sedimentation negatively affects both benthic and associated reef communities.

Table 5
Butterflyfish Species Richness and Density Between Low- and High-Siltation Sites

Butterflyfish Species	Site A (Individuals 100 m^{-2})	Site B (Individuals 100 m^{-2})
Chaetodon adiergastos	2.80	—
Chaetodon baronessa	6.80	3.20
Chaetodon kleinii	3.20	—
Chaetodon lunulatus	1.60	—
Chaetodon octofasciatus	15.20	5.60
Chaetodon punctatofasciatus	0.80	—
Chaetodon vagabundus	1.60	1.60
Chaetodon xanthurus	2.00	—
Coradion melanopus	1.60	—

Butterflyfish Species	Site A (Individuals 100 m^{-2})	Site B (Individuals 100 m^{-2})
Forcipiger flavissimus	1.60	—
Parachaetodon ocellatus	1.60	—
Heniochus varius	2.40	2.40
Species Richness	12	4
Total Density (Individuals 100 m^{-2})	41.20	12.80

Note. Butterflyfish (Family Chaetodontidae) are widely recognized as biological indicators of coral reef condition because of their close dependence on live coral habitats.

The occurrence of coral diseases was substantially greater in the high-siltation site, where 56 diseased coral colonies were recorded compared with only 33 colonies in the low-siltation site. White Plague Disease was the most prevalent disease in Site B, whereas Dark Spot Syndrome occurred most frequently in Site A. The greater frequency and diversity of diseases observed in Site B indicate that chronic sediment exposure may compromise coral health and increase susceptibility to pathogenic infections. Sedimentation has been identified as a major environmental stressor that weakens coral immune responses by reducing energy available for defense mechanisms and increasing physiological stress (Pollock et al., 2014; Morais et al., 2022). Fine sediments can also transport pathogenic microorganisms and organic matter that promote microbial proliferation on coral surfaces, increasing opportunities for disease transmission (Fabricius, 2005; Weber et al., 2012). Experimental studies have demonstrated that reefs exposed to elevated suspended sediments consistently exhibit higher disease prevalence than reefs with lower sediment loads (Pollock et al., 2014; Page et al., 2023), supporting the patterns observed in the present study. Several ecologically important reef-building genera, particularly *Acropora*, *Porites*, and foliose corals, were affected by multiple diseases across both sites. Because these genera contribute substantially to reef framework development, disease-induced declines may reduce habitat complexity and impair ecosystem functioning over time (Bravo et al., 2022). The predominance of White Plague Disease in the high-siltation site further suggests that sedimentation and declining water quality may act synergistically to increase disease susceptibility. Consequently, effective sediment management should be considered an essential component of coral disease prevention and long-term reef conservation.

Table 6
Occurrence of Coral Diseases and Affected Coral Genera Between Low- and High-Siltation Sites

Coral Disease	Affected Coral Genera (Site A)	Occurrence (Site A)	Affected Coral Genera (Site B)	Occurrence (Site B)
Black Band Disease (BBD)	—	—	Porites branching, Porites massive	8
Dark Spot Syndrome (DSS)	Coral foliose, Acropora branching, Pavona, Pocillopora, Porites massive	11	Coral foliose, Porites massive	7
Purple Band Disease (PBD)	Coral mushroom, Porites massive	2	Coral foliose, Porites massive	2
Skeletal Eroding Band (SEB)	Coral mushroom	2	—	—
White Plague Disease (WPD)	Acropora branching, Coral foliose, Porites massive	9	Coral foliose, Porites branching, Porites massive	24
White Syndrome (WS)	Acropora branching, Coral foliose, Coral mushroom	5	Coral mushroom	7
Yellow Blotch Disease (YBD)	Acropora branching, Favia, Porites massive	4	Coral foliose	8
Total Diseased Colonies	—	33	—	56

Table 7 demonstrates that turbidity differed significantly between the two study sites during both sampling seasons. During the dry season, the high-siltation site recorded a mean turbidity of 31.97 ± 14.03 NTU compared with only 4.04 ± 5.04 NTU in the low-siltation site. This difference remained significant during the wet season, when turbidity further increased to 76.66 ± 11.99 NTU in Site B and 15.17 ± 6.44 NTU in Site A. Seasonal analysis further revealed that turbidity increased significantly only in Site B, indicating that rainfall intensified suspended sediment inputs in the already degraded reef environment. These findings demonstrate that sediment dynamics within the study area are influenced by both chronic and seasonal processes. Elevated turbidity during the wet season is consistent with increased terrestrial runoff transporting fine sediments into coastal waters, thereby reducing water clarity and limiting the penetration of photosynthetically active radiation required by symbiotic zooxanthellae (Fabricius, 2005; Storlazzi et al., 2015). Reduced light availability decreases photosynthetic efficiency, lowers calcification rates, and increases physiological stress, ultimately impairing coral growth and survival (Bessell-Browne et al., 2017; Jones et al., 2016). The persistent turbidity observed in Site B during both seasons further suggests that sediment inputs originate not only from seasonal rainfall but also from continuous watershed-derived sources and local hydrodynamic processes. The ecological consequences of elevated turbidity extend beyond coral physiology. Reduced water transparency limits visual foraging by reef fishes, alters benthic primary productivity, and suppresses coral recruitment by decreasing larval settlement success (Cooper et al., 2009; Thanopoulou et al., 2022). The significant seasonal increase observed exclusively in Site B therefore reinforces the hypothesis that chronic sediment exposure, compounded by wet-season runoff, constitutes one of the primary environmental stressors affecting reef condition within the Mabini Protected Landscape and Seascape. These findings emphasize the importance of integrated watershed management strategies that reduce terrestrial sediment discharge before it reaches sensitive coral reef ecosystems.

Table 7
Comparison of Turbidity Levels Between Low- and High-Siltation Sites During the Dry and Wet Seasons
Panel A. Dry Season Turbidity

Statistic	Transect	Site A (Low-Siltation)	Site B (High-Siltation)
Turbidity (NTU)	T1	9.83	35.86
	T2	1.63	43.64
	T3	0.66	16.40
Mean ± SD		4.04 ± 5.04	31.97 ± 14.03
Water Quality Classification		Excellent	Poor
Independent Samples t-test	t	−3.24	
	df	3	
	p-value	.047*	

Panel B. Wet Season Turbidity

Statistic	Transect	Site A (Low-Siltation)	Site B (High-Siltation)
Turbidity (NTU)	T1	12.28	86.21
	T2	10.68	80.56
	T3	22.54	63.20
Mean ± SD		15.17 ± 6.44	76.66 ± 11.99
Water Quality Classification		Fair	Poor
Independent Samples t-test	t	−7.82	
	df	3	
	p-value	.004*	

Panel C. Seasonal Comparison

Site	Dry Season Mean ± SD	Wet Season Mean ± SD	t	df	p-value
Site A	4.04 ± 5.04	15.17 ± 6.44	−1.95	2	.190
Site B	31.97 ± 14.03	76.66 ± 11.99	−11.11	2	.008*

Note. NTU = Nephelometric Turbidity Unit. p < .05 indicates statistical significance.

The sediment deposition data provide direct evidence supporting the turbidity results. During the dry season, sediment deposition in Site B was approximately nine times greater than that recorded in Site A, while during the wet season deposition increased substantially in both sites but remained significantly higher in Site B. Seasonal paired comparisons further demonstrated significant increases in sediment deposition during the wet season in both reef sites, confirming that rainfall-driven runoff substantially influences sediment transport dynamics throughout the study area. Sediment deposition represents one of the most critical physical stressors affecting coral reefs because accumulated sediments directly bury coral tissues, reduce gas exchange, and require considerable metabolic energy for sediment removal (Erftemeijer et al., 2012; Weber et al., 2012). Chronic exposure to high sediment loads also inhibits larval settlement and recruitment, thereby reducing reef recovery following natural disturbances (Brunner et al., 2021; Tuttle & Donahue, 2022). The extremely high deposition rates observed in Site B therefore provide a mechanistic explanation for the lower coral cover, reduced diversity, and higher disease occurrence documented in earlier tables. These findings indicate that sedimentation operates as a long-term ecological filter that gradually alters reef community structure rather than producing only short-term mortality events. The pronounced seasonal increase in sediment deposition further highlights the influence of watershed processes on coastal reef ecosystems. During periods of increased precipitation, rivers and surface runoff transport larger quantities of suspended sediments into nearshore waters, where local circulation patterns facilitate sediment accumulation on reef substrates (Morgan et al., 2025; Sherman et al., 2016). Similar relationships between seasonal runoff and reef degradation have been documented throughout tropical coastal ecosystems (Storlazzi et al., 2009; Good et al., 2025). Consequently, effective coral reef conservation within the study area should incorporate land-based sediment management, erosion control, and watershed rehabilitation to minimize sediment delivery into marine protected areas.

Table 8
Comparison of Sediment Deposition Rates Between Low- and High-Siltation Sites During the Dry and Wet Seasons
Panel A. Dry Season Sediment Deposition

Statistic	Transect	Site A ($g\ m^{-2}\ day^{-1}$)	Site B ($g\ m^{-2}\ day^{-1}$)
Sediment Deposition	T1	15.00	158.67
	T2	9.17	142.13
	T3	24.71	152.04
Mean ± SD		16.29 ± 7.85	150.95 ± 8.32
Sedimentation Category		Moderate	High
Independent Samples t-test	t	−20.38	
	df	≈2.8	
	p-value	.000035*	

Panel B. Wet Season Sediment Deposition

Statistic	Transect	Site A ($g\ m^{-2}\ day^{-1}$)	Site B ($g\ m^{-2}\ day^{-1}$)
Sediment Deposition	T1	67.06	268.02
	T2	91.46	236.19
	T3	62.47	331.34
Mean ± SD		73.66 ± 15.58	278.52 ± 48.44

Statistic	Transect	Site A (g m^{-2} day^{-1})	Site B (g m^{-2} day^{-1})
Sedimentation Category		High	Very High
Independent Samples t-test	t	−6.97	
	df	≈2.4	
	p-value	.0119*	

Panel C. Seasonal Comparison

Site	Dry Season Mean ± SD	Wet Season Mean ± SD	t	df	p-value
Site A	16.29 ± 7.85	73.66 ± 15.58	4.37	2	.0486*
Site B	150.95 ± 8.32	278.52 ± 48.44	4.86	2	.0398*

Note. Sediment deposition is expressed in g m^{-2} day^{-1}. $p < .05$ indicates statistical significance.

Unlike turbidity and sedimentation, the measured physicochemical parameters remained relatively stable between study sites and generally fell within acceptable environmental ranges for tropical coral reef ecosystems. Water temperature, pH, dissolved oxygen, and oxidation–reduction potential all remained within conditions capable of supporting normal coral metabolism during both seasons. Although salinity declined slightly during the wet season, reflecting freshwater inputs associated with increased rainfall, the observed variation was relatively small and unlikely to represent the primary factor influencing reef condition. The similarity of physicochemical conditions between sites suggests that the contrasting biological responses observed throughout this study cannot be attributed solely to differences in basic water chemistry. Instead, these findings indicate that suspended sediments and associated reductions in water clarity constitute the dominant environmental variables driving coral degradation in the study area. Previous investigations have likewise demonstrated that reefs may experience severe ecological decline despite maintaining acceptable physicochemical conditions when chronic sedimentation persists (Fabricius, 2005; Erftemeijer et al., 2012). Fine suspended sediments exert primarily physical rather than chemical stress by reducing light availability, smothering coral colonies, and impairing feeding and respiration processes (Weber et al., 2012; Jones et al., 2016). The relatively consistent physicochemical measurements also strengthen the interpretation that sedimentation was the principal factor associated with the observed reductions in coral cover, diversity, reef fish abundance, and increases in coral disease. This distinction is important because it identifies sediment management, rather than general water chemistry remediation, as the priority conservation intervention for the Mabini Protected Landscape and Seascape. Future monitoring programs should therefore continue measuring conventional physicochemical parameters while placing greater emphasis on sediment transport, turbidity dynamics, and watershed-derived runoff as indicators of long-term reef health.

Table 9
Comparison of Physicochemical Parameters Between Low- and High-Siltation Sites During the Dry and Wet Seasons

Parameter	Dry Season Site A	Dry Season Site B	Wet Season Site A	Wet Season Site B
Temperature (°C)	29.55	29.61	29.66	29.61
pH	7.96	7.42	7.31	7.74
Salinity (ppt)	32.10	32.24	29.69	29.80
Dissolved Oxygen (mg L^{-1})	7.24	7.08	6.96	6.27
Oxidation–Reduction Potential (mV)	231.00	238.33	248.33	244.00
Temperature Status	Passed	Passed	Passed	Passed
pH Status	Passed	Passed	Passed	Passed
Salinity Status	Within Optimal Range	Within Optimal Range	Below Optimal Range	Below Optimal Range
Dissolved Oxygen Status	Passed	Passed	Passed	Passed
ORP Classification	Strongly Oxidized	Strongly Oxidized	Strongly Oxidized	Strongly Oxidized

Note. ORP = Oxidation–Reduction Potential. Physicochemical parameters generally remained within acceptable ranges for coral reef ecosystems, except for the slight reduction in salinity during the wet season.

Conclusion and Recommendations

This study demonstrated that siltation is a major environmental factor influencing coral reef health within the Mabini Protected Landscape and Seascape (MPLS). Coral reefs located in the low-siltation site consistently exhibited significantly higher live hard coral cover, greater coral genera diversity, richer butterflyfish assemblages, and lower coral disease occurrence than reefs exposed to higher sediment loads. Conversely, the high-siltation site was characterized by elevated turbidity and sediment deposition rates across both dry and wet seasons, reduced live coral cover, lower taxonomic diversity, greater dominance of abiotic substrates, and a higher prevalence of coral diseases. Although coral mortality indices did not differ significantly between sites, the combined biological and environmental indicators demonstrate that chronic sediment exposure adversely affects reef condition through long-term ecological stress rather than immediate mortality. These findings indicate that sustained sedimentation alters reef community structure, reduces habitat quality, and weakens ecosystem resilience. The study further revealed that seasonal rainfall intensified sediment-related impacts, particularly in the high-siltation site, where both turbidity and sediment deposition increased significantly during the wet season. In contrast, basic physicochemical parameters, including temperature, pH, dissolved oxygen, salinity, and oxidation–reduction potential, generally remained within acceptable environmental ranges, suggesting that sedimentation rather than water chemistry was the principal driver of the observed ecological differences. The consistency among multiple biological indicators—including coral cover, benthic composition, coral diversity, reef fish assemblages, coral disease occurrence, turbidity, and sediment deposition—provides robust evidence that sediment-related stress is a key determinant of coral reef condition within MPLS. Consequently, this study contributes important baseline information for understanding sedimentdriven reef degradation in Philippine marine protected areas and provides empirical evidence to support ecosystem-based conservation and management strategies.

Based on the findings, integrated sediment management should be incorporated as a priority conservation strategy within the Mabini Protected Landscape and Seascape. Management interventions should adopt a ridge-to-reef framework that strengthens watershed protection, controls soil erosion, rehabilitates riparian vegetation, regulates land-use activities that contribute to sediment runoff, and promotes nature-based solutions capable of reducing sediment delivery into coastal waters. Collaboration among protected area managers, local government units, watershed stakeholders, and surrounding communities is essential to minimize terrestrial sediment inputs and maintain favorable environmental conditions for coral reef recovery and resilience. Continuous long-term monitoring should likewise be institutionalized using standardized coral reef assessment protocols that simultaneously evaluate coral cover, coral diversity, reef fish assemblages, coral diseases, turbidity, sediment deposition, and physicochemical parameters across both dry and wet seasons. Such integrated monitoring will enable managers to detect ecological changes, evaluate the effectiveness of conservation interventions, and implement adaptive management strategies based on scientific evidence. Future studies should further quantify sediment sources and transport pathways using watershed modeling, remote sensing, and hydrodynamic analyses while also investigating the long-term physiological responses of corals to chronic sediment exposure, including calcification, recruitment, bleaching susceptibility, reproductive success, and recovery potential under changing climatic conditions. Expanding similar investigations to other Philippine marine protected areas would also facilitate broader regional comparisons and strengthen national coral reef conservation policies.

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