Anthropogenic Activities Alter The Seagrass Ecosystem In Southern Philippines

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Abstract
Seagrasses are economically and ecologically important marine habitats. However, anthropogenic activities resulted in their decline globally. In the Philippines, MPAs were established, but most seagrasses need to be acknowledged and directly protected, thus affecting the ecosystem productivity. To prevent this scenario, baseline information that describes the status of seagrass beds is highly needed to help implement sound management practices. The present investigation was carried out to assess the effect of anthropogenic activities on the seagrass ecosystem in 15 municipalities as sampling areas across Southern Philippines. The study used focus group discussions, key informant interviews, and household interviews guided by structured questionnaires. Some 30 to 45 fishers and gleaners were interviewed in every municipality with 476 individuals. A matrix was developed for measuring anthropogenic activities complementary to random sampling of seagrass cover assessment. The anthropogenic activities considered to degrade the seagrass ecosystem and were analyzed in the matrix included tourism, gleaning/fishing, aquaculture, industrial and domestic activities. The result of the study showed that domestic, tourism and gleaning are the prevalent anthropogenic activities affecting seagrasses. The result further showed that higher anthropogenic activities affected lower seagrass percentage cover (R^2=0.56). The result indicates that as anthropogenic activity increases, the cover condition of the seagrass ecosystem is averted. This implies that seagrasses should be acknowledged and included in the coastal management plans.

Keywords: seagrass ecosystem, anthropogenic activities, degradation, adaptive management, sustain seagrass

INTRODUCTION

The Philippine archipelago is considered the “Center of Global Marine Biodiversity” because of its abundant resources, particularly in the marine environment. Ironically, our coastal environment is mainly in the 'poor' category due to a lack of conservation and management (Carpenter and Springer, 2005). Yet, growing coastal populations and human activities on land and sea continue to pose an increasing threat to the coastal ecosystems (Lu et al., 2018).

Seagrasses are flowering plants (angiosperms) that grow in marine, fully saline environments. They are submerged in shallow oceanic, coastal, and estuarine waters worldwide, except in the Antarctic region (Green and Short, 2003; Short *et al.,* 2007). The species are divided into five families, with about half being found in tropical and the other half being in temperate regions (Short *et al.,* 2007). According to Phillips and Menez (1988), there are about 16 species that were recorded from the Philippines, while a recent study by Fortes (2013) documented 18 seagrass species from 529 sampling sites around the country.

Seagrass meadows are home to many ecologically and economically important marine resources. They harbor endangered marine creatures such as dugongs and sea turtles. Seagrasses also perform various functions, such as stabilizing the sea bottom, providing food and habitat, maintaining water quality and clarity, and supporting local economies (Duarte, 2002). Their significant role as a nursery and fishing ground also supports coastal fisheries' productivity and food security worldwide (Unsworth et al. 2018). Furthermore, they provide valuable ecological services, including stabilizing the climate through carbon sequestration and storage (Macreadie et al., 2013). Moreover, they are excellent indicators due to their sensitivity to environmental alterations, thereby being utilized as a tool in coastal resource management (Fortes and Santos 2004).

Nevertheless, seagrasses are the least conserved marine ecosystems (Hu et al., 2021), as research interests mostly focused on commodities for direct consumption or other marine ecosystems like mangroves and corals with long-term monitoring programs. Thus, they are experiencing a global decline, and their biodiversity and productivity were compromised due to multiple pressures brought primarily by anthropogenic threats (Unsworth et al. 2019) and exacerbated by climate change. In the country, an estimated 30-50% of the seagrass habitat has been lost due to poor management practices and aggravated

by human activities (Fortes, 1998; 2008) and will continue to decline unless proper conservation and management strategies are implemented. Furthermore, destructive fishing is still rampant, especially in the regional part of the country, and continues to harm coastal resources, including seagrasses (Ame and Ayson 2009). However, assessments on the degree and the relative impact of anthropogenic activities on the seagrass meadows are scarce, particularly in the Southern Philippines. Information regarding the key factors driving its degradation and identifying areas susceptible to loss is crucial to enhancing the seagrass ecosystem's conservation and support (Turschwell et al. 2021).
Therefore, this study aims to determine the effect of anthropogenic activities on the seagrass ecosystem in the Southern Philippines. The information generated is essential as a baseline for conservation and adaptive management strategies to prevent further loss of the seagrasses in the country.

MATERIALS AND METHODS

Study location

This is an extensive study that covers most of the bays of Mindanao (8.4961° N, 123.3034° E). A total of 15 sites were established for the field sampling based on the presence of vast seagrass meadows, and this includes: Laguindingan (LAG), Misamis Oriental; Kauswagan (KAU), Lanao del Norte; Rizal (RIZ), Zamboanga del Norte; Lopez Jaena (LOP) Misamis Occidental; Carmen (CAR), Agusan del Norte; Cortes (COR), Surigao del Sur; Samal (SAM) Is., Davao del Norte; Mati (MAT) and Governor Generoso (GOV), Davao oriental; Glan (GLA) and Maasim (MAS), Sarangani Province; Bongao (BON), Simunul (SIM) Sibutu (SIB) and Sitangkay (SIT), Tawi Tawi.

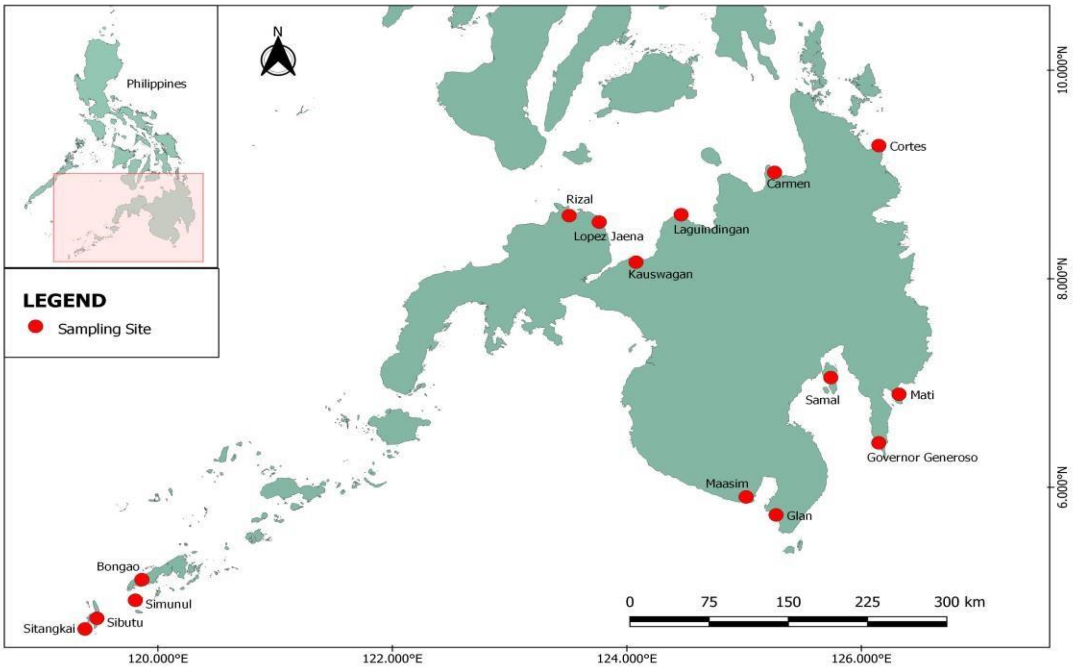

Figure 1. Map of Mindanao showing the 15 sites established for field sampling and collection of samples.

Data collection

The study adopted two approaches to assess the effect of anthropogenic activities on seagrass beds. The first approach is the socio-demographic profiling of selected coastal communities. The second is anthropogenic activity assessments using a matrix with complementary field sampling to determine seagrass cover and associated macroinvertebrates. Detailed information on the two approaches is described below.

Socio-demographic profiling

The study used focus group discussions (FGD), key informant interviews (KII), and household interviews to determine the socio-demographic profile of selected coastal communities and their utilization and activities in the seagrass beds. For the FGDs, a set of open-ended questionnaires written on *manila* paper was used to prompt 10–15 fishers and gleaners into free discussions. For KIIs and household interviews, a well-structured questionnaire was utilized to assess the status of the seagrass, the coastal community, and how they affect the seagrass beds. A total of 30–45 fishers and gleaners were interviewed per area. All the data obtained were encoded in Microsoft Excel 2016 for data analysis.

Anthropogenic activity assessment

FGDs were employed to identify the various anthropogenic activities affecting the seagrass beds in each sampling area.

A matrix was developed for measuring anthropogenic activities modified from Angulo et al. (2016) and was complementary to random sampling of seagrass cover assessment. Anthropogenic activities analyzed in the matrix that were considered to degrade the seagrass ecosystem included tourism, gleaning/fishing, aquaculture, and industrial and domestic activities. A score of 1 – low disturbance up to 3 – high disturbance was given per anthropogenic activity based on the distance of such activity to the seagrass beds within a 500-meter distance.

Seagrass cover assessment

The study employed the random quadrat method to determine the seagrass species composition and cover. A steel quadrat measuring 0.25 m^2 with 25 grid cells was randomly thrown ten times within the seagrass beds and served as points for the assessment. If possible, species composition was identified up to species level using a laminated field guide (McKenzie, 2003). The percent cover of areal biomass was estimated by direct observation, looking down at the seagrass canopy through the water, and estimated. The exact location of the quadrats was recorded using a handheld Geographic Positioning System (GPS). All data in the field were written on a slate board and later transcribed for data analysis.

Macroinvertebrates assessment

The macrobenthic invertebrates were assessed in seagrass beds using a combined transect line, quadrat, and core method following the protocols of Short et al. (2001) and McKenzie et al. (2001). Two to three 50-m transect tapes were laid in seagrass beds parallel to the shoreline to determine the macrobenthic invertebrates associated with seagrass beds. A wooden stick was driven to the substrates to anchor and securely hold both ends of the transect tape. The survey was done within 2 meters to the right and 2 meters to the left of the 50-m transect line. All macrobenthic invertebrate species found within the 200 m^2 were recorded. The exact location of the transect was identified using a handheld Geographic Positioning System (GPS) and recorded. All data were written on a slate board, transcribed, and encoded using an Excel program for further analysis of valuation and population structure.

Data analysis

The seagrass cover was estimated using the equation by English et al. (1994). The relationship between anthropogenic activities and seagrass percent cover was modeled using linear regressions.

RESULTS

Seagrass species composition and cover

Eight species of seagrasses were identified across the 15 sampling sites in Mindanao belonging to two families: Cymodoceaceae and Hydrocharitaceae. The Cymodoceaceae includes *Cymodocea rotundata, C. serrulata, Syringodium isoetifolium, Halodule pinifolia,* and *H. uninervis.* On the other hand, the Hydrocharitaceae family includes *Enhalus acoroides*, *Halophila ovalis*, and *Thalassia hemprichii* (Table 1). Except for *C. serrulata*, which occur only in two sites, namely, Laguindingan and Bongao, the other three target seagrass species are found in all 15 sampling sites. However, in Bongao, *C. serrulata* was observed to occur minimally.

Seagrass cover ranged from 26.50% to 91.30% (Table 2), with the highest cover in Panglima Alari, Sitangkai, and the lowest cover in Tubig Indangan, Simunul, with both sites located in the province of Tawi-Tawi. Seagrasses were found in very good conditions in five sampling sites, good in five sites, and fair in five sites. The sites with very good seagrass cover condition included Sitangkai (91.30%), Mati (84.4%), Lopez Jaena (82.80%), Laguindingan (80.45%), and Sibutu (80.40%). The five sites with good seagrass cover condition included Governor Generoso (74.6%), Gumasa, Glan, Sarangani (60.5%), Cortes (60%), Rizal (58%), and Samal Island (57.6%). The five sites with fair seagrass cover condition included Carmen (48.00%), Bongao (44.20 %), Kauswagan (40.95%), Maasim (32.8%) and Tubig Indangan, Simunul (26.5%).

Table 1. Anthropogenic activity matrix.

Anthropogenic Activities	LAG	KAU	RIZ	LOP	CAR	COR	MAT	SAM	GOV	MAA	GLA	BON	SIM	SIB	SIT
Gleaning	3	3	1	2	2	1			1	3	1	1	3		
Cage		2		2		1									
Fish pond						1	3				2				
Tourism	3	2	1	1	3	2	2	3	2	3	3	3	2	1	2
Mining			3												
Coal plant		3													
Domestic		1	2		1	1	1	1	1	3	1	3	3	3	2
Commercial shipping				1				3				1	1		1

Seaweed farming												3		3	
Total:	6	**11**	**7**	**6**	**6**	**6**	**6**	**7**	**4**	**9**	**7**	**11**	**9**	**7**	**5**

*1 – low disturbance; 2 – medium disturbance; 3 – high disturbance (Angulo *et al.,* 2016).

Anthropogenic impact and seagrass cover relationship

Figure 2 shows that anthropogenic impact increases with decreasing seagrass cover. Kauswagan and Bongao showed the highest impact of anthropogenic activities; the most common anthropogenic activity is tourism, followed by domestic and gleaning (Table 1). A total of eight (8) species of seagrass were found in the selected coastal areas in Southern Philippines, namely *C. rotundata, C. serrulata, T. hemprichii, E. accoroides, H. ovalis, H pinifolia, H. uninervis,* and *S. isoetifolium.* Each area has at least six (6) species present during field sampling. Populations of *T. hemprichii* and *C. rotundata* provide consistent coverage, with generally more species co-occurring in all the areas of Mindanao.

Table 2. Estimated percentage seagrass cover and the condition equivalent based by Amran (2010) in the 15 sampling sites in Mindanao

Sites	Seagrass cover (%)	Condition
Tubajon, Laguindingan, Misamis Oriental	80.45	Very good
Kauswagan, Lanao del Norte	40.95	Fair
Lopez Jaena, Misamis Occidental	82.80	Very good
Sebaca, Rizal, Zamboanga del Norte	58.00	Good
Gosoon, Carmen, Agusan del Norte	48.00	Fair
Burgos, Cortes, Surigao del Sur	60.00	Good
Sanipaan, Samal Island City, Davao del Norte	57.60	Good
Dahican, Mati, Davao del Sur	84.40	Very good
Lavigan, Governor Generoso, Davao Oriental	74.60	Good
Tubig Indangan, Simunul, Tawi-Tawi	26.50	Fair
Pasiagan, Bongao, Tawi-Tawi	44.20	Fair
Ambutong, Sapal, Sibutu, Tawi-Tawi	80.40	Very good
Panglima Alari, Sitangkai, Tawi-Tawi	91.30	Very good
Gumasa, Glan, Sarangani	60.50	Good
Tinoto, Maasim, Sarangani	32.80	Fair

Seagrass Cover Condition: >75.4% Very good, 50.5 - 75.4% Good, 25.5 - 50.4% Fair, 5.5 - 25.4% Poor, < 5.5% very poor (Amran, 2010)

Macroinvertebrates and seagrass cover relationship

Seagrass meadows support highly diverse macroinvertebrate communities around the world (Ogden, 1980; Heck and Orth, 1980; Orth, 1992). Macroinvertebrates include echinoderms, mollusks, and crustaceans. Figure 2 shows a slightly direct relationship between macroinvertebrate count and the seagrass cover (%). If the seagrass is abundant, macroinvertebrates could be enhanced in terms of their population.

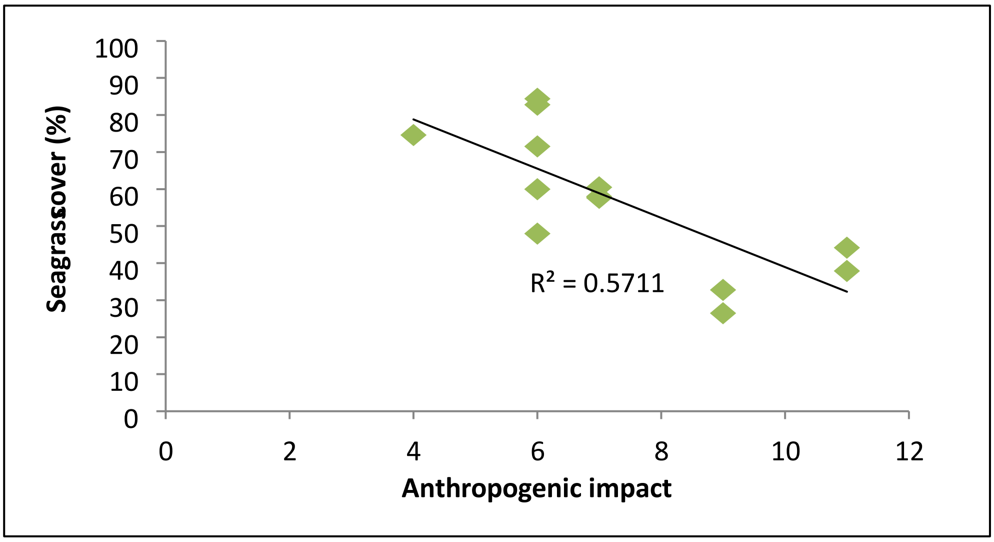

Figure 2. Relationship of the anthropogenic impacts to the seagrass cover.

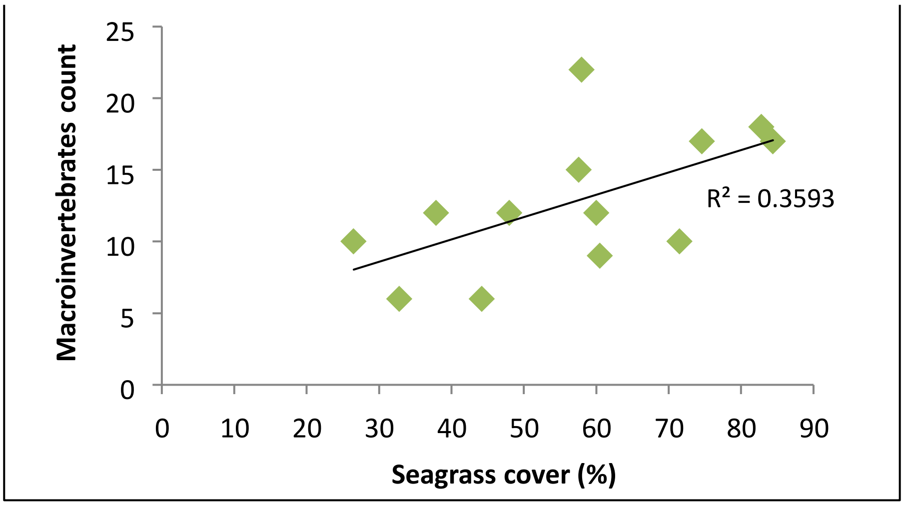

Figure 3. Relationship between macroinvertebrates and seagrass cover.

DISCUSSION

Seagrasses can be an excellent indicator of environmental change and impact and an incredibly valuable coastal habitat performing a range of critical ecosystem functions (Seagrass-Watch HQ, 2006-2015). They are excellent markers in coastal resource management as they are one of the absorbers of the anthropogenic impacts on the coastal ecosystem (Ame and Ayson 2009). High anthropogenic activity could lead to an unhealthy coastal environment.

The results showed that Mindanao has a rich seagrass diversity, corresponding to eight species. These species are the most common seagrasses observed in the country. Seagrass cover is a good indicator of a healthy environment (Madden et al., 2009)**.** Seagrass covers across 15 sites showed fair to high percentage covers. The results indicate that despite the anthropogenic disturbances, seagrass meadows in all sites still have high coverage and are in good condition.

Despite the substantial increase in awareness of seagrass conservation, its environmental conditions continued to decline as its associated problems remained insufficiently addressed (Fortes and Santos 2004). Waycott et al. (2009) revealed that the global seagrass aerial cover is declining, and the loss is accelerating at an alarming rate. This loss was caused by direct impacts from coastal development and dredging activities and indirectly through declining water quality. Furthermore, Fortes and Santos (2004) revealed that rapid economic and human growth are the primary causes of seagrass losses. In the present study, nine major anthropogenic impacts were listed across fifteen sites, with tourism as the most common activity occurring in all sites. Although tourism could increase economic revenue for the municipalities, disturbances through recreational activities and the establishment of facilities negatively impacted the seagrass beds. It was observed in the Mexican Caribbean, where ecological tourism makes the turtlegrass, *T. testudinum*, sparser, shorter, grow more slowly, and have more epiphytes (Herrera-Silveira et al. 2009). In addition, seagrass habitat destruction due to the unregulated expansion of coastal development for tourism is among the major pressures identified by coastal communities in Maribojoc Bay, Bohol, Philippines (Mascariňas and Otadoy, 2023). Moreover, the results revealed a decrease in seagrass cover with increasing anthropogenic activities, consistent with previous reports on the negative impact of human activities on seagrass beds.

Across fifteen sites, Kauswagan and Bongao had the highest total impact of anthropogenic activities. High disturbances in Kauswagan were brought by the coal plant and the high gleaning activities due to its wide intertidal area. For Bongao, domestic, tourism, and seaweed farming are the various activities that attributed the total impact of anthropogenic disturbances to the seagrass beds. Tawi-Tawi is known as the major exporter of seaweeds in the country. Thus, a high dependency on seaweed farming is observed. Eklof et al. (2006) revealed that seaweed farming affects the above-ground biomass and production of seagrasses. It was supported by Kelly et al. (2020), showing that placing seaweed farms above seagrass beds reduced productivity and shoot density. Furthermore, the growing population in coastal areas increases resource overuse and coastal development, thereby accelerating seagrass loss. If this loss continues without effort to mitigate its impact, ecological losses will increase, causing even more significant ill-afforded economic losses (Waycott et al., 2009).

Seagrasses are well-known for enhancing faunal diversity, with increasing complexity augmenting the abundance and diversity of the associated macrofauna (Rodil et al., 2021). This complexity aggregates organic matter and detritus and thus forms various microhabitats that could provide food sources for macrofauna. Furthermore, it provides an excellent refuge, especially for vulnerable life stages such as juveniles seeking to avoid predation (McCloskey and Unsworth 2015). The results are consistent with previous reports that the abundance of associated macrofauna increases with increasing seagrass cover. However, anthropogenic activities reduced associated macroinvertebrates, same as observations by Leopardas et al. (2016), where a decrease in macrofauna heterogeneity was observed in the area of Bolinao, Pangasinan, with local anthropogenic disturbances. It was supported by the study of McCloskey and Unsworth (2015), which revealed that small-scale disturbances on seagrass beds reduced its shoot density and cover and, thus, negatively impacted the associated fauna. The baseline information showed an inverse relationship between anthropogenic activities and seagrass cover. Higher anthropogenic activity could lead to low seagrass cover.

Furthermore, seagrass cover (%) and macroinvertebrates count have a direct relationship. Higher seagrass cover could enhance the presence of macroinvertebrates. The increasing population also indicates a decrease in seagrass conditions over time (Orth *et al.,* 2006). Increasing population with existing anthropogenic activities calls to develop/create adaptive management strategies to sustain seagrass ecosystem (*i.e.* MPA establishment, IEC, policies). Further study should be conducted to assess the stress resistance of the seagrass to the different stressors or anthropogenic activities. This could be done through genetic analysis.

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