The Condition of Seagrass Beds in North Sulawesi following the implementation of Community-Based Coastal Management Program

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Abstract. Pusomaen district in Southeast Minahasa Regency, North Sulawesi, was designated as one of the pilot sites for the Community-Based Coastal Resource Management Program (CB-CRMP) from 1997 – 2003. This program focused on the implementation of best-practice in coastal resource management involving multiple local stakeholders. Fifteen years after its phase-out, a study was conducted on seagrass beds in Tumbak and Bentenan village in Pusomaen district to obtain the seagrass ecosystem’s current status and condition in the former pilot sites. We observed the program’s legacy in terms of community awareness concerning coastal resource management and seagrass ecosystem. A line transect method was used to assess species diversity, coverage, and dominance in 9 stations. Environmental variables (weather, human activities, depth, clarity) and communities’ behavior towards seagrass beds (domestic waste disposal, boat anchoring) were also observed. The result showed that seven stations were in moderate, one in poor, and one in healthy conditions. There were seven seagrass species found during the observation. Thalassia hemprichii and Enhalus acoroides were found in all stations, dominating the seagrass coverage. We also recorded the presence of Syringodium isoetifolium and Cymodocea rotundata in several stations. The expected CB-CRMP legacies of institutionalized community-based coastal management were nearly non-existent, while negative or indifferent behavior of the general community towards the seagrass ecosystem was observed, highlighted by domestic waste disposal and boat anchoring in the seagrass beds. Consistency of program planning and financial support from local and provincial governments were needed to maintain the legacy of CB-CRMP, while regular ecosystem monitoring was also pivotal in providing scientific data for local and provincial decision-making processes regarding coastal resource management.

1. Introduction

Seagrass beds, along with coral reefs and mangrove forests are typical ecosystems in tropical intertidal zone supporting significant ecological, socio-economic, and environmental functions. Seagrass ecosystems are the habitat, food source, spawning, and nursery ground for diverse species of fish,
mollusks, echinoderms, crustaceans, and mammals [1,2]. On a global scale, Seagrass plays a significant role in supporting climate change mitigation as one of the most effective carbon sinks, along with salt marshes and mangrove forests [3]. However, the seagrass ecosystems are continuously under pressure by environmental and anthropogenic factors and continued to decline at an alarming rate [4]. The rapid and systematic seagrass conservation and restoration effort have been conducted worldwide, although many of these efforts are concentrated towards the coastal ecosystem in general, particularly where the resources and financial supports are limited and the needs to prioritized were in favor of the more recognizable ecosystem, i.e mangroves and coral reefs [5].

Coastal conservation efforts in Indonesia has been carried out through various program since the late 1990s to early 2000s. Pusomaen district (including Bentenan and Tumbak village) in Northeast Minahasa regency, North Sulawesi was one of the pilot site for community-based coastal resources management (CB-CRM) program, initiated by USAID, University of Rhode Island, the Government of Indonesia through Bappenas (National Development Planning Board), and Bogor Agricultural Institute (IPB) [6]. It was one of the pioneering programs in coastal resource management with multi-stakeholder involvement in Indonesia. The program’s initial stage in the Pusomaen district was carried out in 1997, which include management planning and capacity building and the early stage of implementation. The initial implementation of this program includes: building community support for the longer-term planning initiative, experiment with mechanisms for community implementation, and building community capacity for execution through a learning-by-doing process. By the end of 2000, the Bentenan and Tumbak village successfully designated a local marine reserve, conducted surveys on the coral reef ecosystem, and combated destructive fishing such as bomb fishing [7]. The MPA management and plan implementation have been considered successful with the decline of coral mining and bomb fishing and local authorities’ ability (Aparat desa) in generating external financial support for sustaining their coastal management and implementation. However, it was noticed that the sustainability of these local institutions was remained to be seen after project support was ended [7].

Although implied as one of their implementation strategies, environmental monitoring was least implemented in the CB-CRM program. The only documented training for monitoring the coastal ecosystem was conducted in 2002, near the end of the program [8]. While in retrospect, it should be noted that the core of the CB-CRM program was to address the involvement of local communities in managing their coastal resources, implying that the improvement of coastal resources condition was the expected outcome of the participation of local communities in managing their environment.

The CB-CRM program had ended nearly sixteen years ago. Considering the successful CB-CRM program in the Pusomaen district, it was expected that the local community has internalized the value of their coastal resources through their daily behavior and activities towards their environment. Following this line of reasoning, it was also expected that there will be a better environmental condition of their coastal waters, particularly the environment closest to their village, i.e. mangroves, seagrass beds, and coral reefs [9]. Therefore, the information on the current state of the villages once designated as the pilot sites of CB-CRM was needed to assess the program’s legacy and understand the changes that occurred throughout the years. Although direct analysis of its legacy required thorough and complex study of its own. The assessment of environmental condition, --in this case, seagrass ecosystem-- may reflect the lasting impact of the program. Therefore, this study aimed to obtain information on the seagrass condition in Pusomaen district and discover the lasting impact of the community-based coastal management program that once implemented in Pusomaen district, through observation of people’s behavior towards the coastal ecosystem, e.g. waste disposal, boat anchoring, adherent to village regulation; and current environmental condition in seagrass beds along the coast of Pusomaen district, Northeast Minahasa regency, North Sulawesi.
2. Material and Methods

2.1 Sampling stations
The data collection was conducted in February 2018 with 9 sampling stations in Pusomaen district, Southeast Minahasa Regency, North Sulawesi. There are 8 stations located along the coastline of mainland Sulawesi facing the Mollucas sea, and 1 station was located in Bentenan island, a small uninhabited island adjacent to Tumbak village, Pusomaen district (Table 1, Figure. 1). Station 1 and 2 located in the vicinity of Tumbak Madani village, with different anthropogenic activities between them. Differences in anthropogenic activities also being observed in Station 7, 8, and 9 which all located in Bentenan Indah village, where Station 9 was the closest to villagers’ homes and fishing boat quays, and the other two (Station 7 and 8) were located in the edge of the village where there were no homes nearby and less human activities occurred.

| Station | Location          | Coordinates             | Substrate       |
|---------|-------------------|-------------------------|-----------------|
| 1       | Tumbak Madani 1   | 0.97040 124.88170       | Sand, Rubble    |
| 2       | Tumbak Madani 2   | 0.97202 124.88640       | Sand, Sand Rubble |
| 3       | Tumbak Induk      | 0.97287 124.88730       | Sand, Sand Rubble |
| 4       | P. Bentenan       | 0.97667 124.91078       | Sand, Sand Rubble |
| 5       | Tg. Pasir Putih   | 0.98407 124.89455       | Sand, Sand Rubble |
| 6       | Tg. Pepaya        | 0.98928 124.89381       | Sand, Sand Rubble |
| 7       | Bentenan Indah 1  | 1.00710 124.89771       | Sand, Sand Rubble |
| 8       | Bentenan Indah 2  | 1.00848 124.89931       | Sand, Sand Rubble |
| 9       | Bentenan Indah 3  | 1.00986 124.90014       | Sand, Sand Rubble |

![Figure 1](image) Maps of the Pusomaen district and the sampling stations
2.2 Methods
This study was conducted with a modified quadrat transect method from Seagrass Watch, Australia [10]. In each sampling station, a 100 m line was drawn out from the edge of seagrass beds perpendicular to the coastline, where a square frame (sized 0.5 m$^2$) was laid down from point 0 (0 m) to point 10 (100 m) with 10 m distance in between sampling points. The square frame was divided into 4 (four) equal subplots (0.25 m$^2$) to facilitate a more accurate observation of coverage (Fig 2). The transect line was replicated 3 (three) times located at 50 m parallel distance to each transect. The observations were carried out during low tide (0.2 – 1.5 m depth) in the morning till midday, by walking through the transect line or by snorkeling. In each sampling point, visual observations were recorded to determine the seagrass species composition, species dominance, and coverage percentage using guidelines from “Panduan Monitoring Padang Lamun” (Seagrass Monitoring Guidelines) [10]. The coordinates for each station were determined and marked using GPS handheld (GPSMAP 78S, Garmin Ltd.), while the weather, temperature, and other relevant characteristics of each station during the sampling were also recorded.

2.3 Data Analysis
Seagrass species were identified with reference to “Panduan Monitoring Padang Lamun” (Seagrass Monitoring Guidelines) [10] and “Taxonomy and Biogeography of Seagrasses” [11]. The conditions of Seagrass beds were generated from the means of cover percentage of seagrass on each sampling point. The collected data were analyzed in Microsoft Office Excel (Microsoft Corp) to determine the value of mean seagrass coverage ($\bar{C}_x$) and mean seagrass species coverage ($SC\bar{x}$), with the following formula:

$$\bar{C}_x = \frac{\sum_{i=1}^{n} S_{p}(x)}{n} \times 100\%$$

$C_x$: mean seagrass coverage, $S_{p}(x)$: subplot seagrass coverage

While the dominance of each seagrass species in a transect was analyzed by dividing the total of particular species’ coverage with the following formula:

$$SC\bar{x} = \frac{\sum_{i=1}^{n} C_{x}}{n} \times 100\%$$

$SC\bar{x}$: mean species coverage, $C_{x}$: plot seagrass species coverage, $n$: number of sampling plots

Mean species coverage ($SC\bar{x}$) was used to determine the ranking of different seagrass species coverage in a particular transect. Thus, the seagrass species with the highest coverage were the most dominant in that particular transect.

Further analysis was made to categorize the conditions of seagrass meadow based on the Ministerial Ordinance of the Ministry of Environment, Republic of Indonesia (Keputusan Menteri Lingkungan Hidup RI) number 200/2004, regarding the Criteria for Seagrass Destruction and the Guidelines for The State of Seagrass Beds [12], i.e.:

a. Rich/Healthy state, for seagrass bed with $\geq 60\%$ coverage;
b. Moderate/Less Healthy state, for seagrass bed with $30 – 59.9\%$ coverage, and;
c. Poor state, for $\leq 29.9\%$ for seagrass bed with coverage
Other observations on the characteristic (the type of seagrass beds species, location remoteness, substrate, depth) of each station were visually observed on-site, while anthropogenic activities, people behavior towards seagrass beds observed through visual and direct interviews were analyzed descriptively in order to understand the dynamics of seagrass beds condition and bio-ecological functions in the study area.

3. Results and Discussions

3.1 Seagrass biodiversity
Seagrass beds in the Pusomaen district are multispecies beds with distinct characteristics of sand/rubble patches and mounds where the seagrasses were absent or sparsely grown. There were 7 species of seagrass discovered in all sampling stations, comprised of two families, i.e. Hydrocharitaceae (3 species, i.e. *Enhalus acoroides*, *Thalassia hemprichii*, and *Halophila ovalis*); and Cymodoceaceae (4 species, i.e. *Cymodocea rotundata*, *Syringodium isoetifolium*, *Halodule uninervis*, and *H. pinifolia*) (Table 2).

Table 2. Seagrass species composition in each sampling station

| Family           | Station |
|------------------|---------|
| **Species**      | 1 2 3 4 5 6 7 8 9 |
| Hydrocharitaceae |         |
| *Enhalus acoroides* | + + + + + + + + |
| *Thalassia hemprichii* | + + + + + + + + |
| *Halophila ovalis* | +       |
| Cymodoceaceae    |         |
| *Cymodocea rotundata* | + + + + + + + |
| *Halodule uninervis* | +       |
| *H. Pinifolia*    |         |
| *Syringodium isoetifolium* | + + + + + + + |

Table 2 showed that Station 9 (Bentenan Indah 3) has the highest species composition (6 species), while the lowest species composition (2 species) was found in Station 3 (Tumbak Induk). Two Hydrocharitaceae species, *E. acoroides*, and *T. hemprichii* were the most common species found in all stations, while *H. uninervis* and *H. pinifolia* was the least common and found only in Station 6 (Tanjung Pepaya) and Station 9 (Bentenan Indah 3), respectively (Table 2).

*Enhalus acoroides* and *Thalassia hemprichii* were two of the most common tropical seagrass species found in Indonesia [13]. Both species are climax seagrass species, where their long life span and a relatively larger size will remain unchanged if there were no drastic changes in the environment. *Syringodium isoetifolium* was known for its rapid colonization of disturbed beds and with considerably faster growth and elongation of the rhizome, its also in spatial competition with other species, i.e. *Halodule uninervis* [15]. *Syringodium* and *Halodule* species are pioneering species that may grow rapidly in a newly formed patch in a seagrass bed, although they might be replaced later on with other climax species [16]. This may explain its ubiquity in seagrass beds with newly formed barren patches and mounds found throughout the sampling areas.

The number of seagrass species found in Pusomaen is similar to other seagrass beds in North Sulawesi, i.e. Talisei island [17], North Likupang [18], and Kema [19]. However, it is considerably lower than Kampung Ambon, Likupang, which has the highest species diversity found in North Sulawesi with 10 species, including the least common *Halophila decipiens*, *H. minor*, and *H.
The species found in this study were representing 58.3% of all tropical seagrass species found in Indonesia, and 12.7% of the world seagrass species (55 species) [21].

### 3.2 Seagrass beds conditions

Seagrass coverage of all stations ranged from 22.66±3.71% (Station 3, Tumbak Induk) to 63.13±7.3% (Station 2, Tumbak Madani 2). There were 7 stations in a moderate state (less healthy seagrass bed), while one station was in a healthy state (Station 2, Tumbak Madani 2), and the other one station was in a poor state (Station 3, Tumbak Induk) (Table 3).

| Station | Location       | % cover±SE | Status [7] | CDR Potential (Ton/Ha/Year) [22] |
|---------|----------------|------------|------------|----------------------------------|
| 1       | Tumbak Madani 1| 33.13±11.71| Moderate   | 4.6102202                        |
| 2       | Tumbak Madani 2| 63.13±7.3  | Healthy    | 7.2064202                        |
| 3       | Tumbak Induk   | 22.66±3.71 | Poor       | 3.7041464                        |
| 4       | Pulau Bentenan | 46.31±3.92 | Moderate   | 5.7508174                        |
| 5       | Tg. Pasir Putih| 39.84±5.71 | Moderate   | 5.1909036                        |
| 6       | Tanjung Pepaya | 53.9±6.7   | Moderate   | 6.407656                         |
| 7       | Bentenan Indah 1| 43.75±5.67| Moderate   | 5.529275                         |
| 8       | Bentenan Indah 2| 31.25±5.63| Moderate   | 4.447525                         |
| 9       | Bentenan Indah 3| 31.77±5.9 | Moderate   | 4.492528                         |

*)CDR/Carbon Dioxide Removal was a process in which carbon dioxide gas (CO₂) is removed from the atmosphere and sequestered for long periods of time. CDR Potential was calculated using the Seagrass Carbon Converter [22]

Table 3 showed that the mean seagrass coverage for all stations was 40.64±6.25%, categorized in a moderate or less healthy state. The highest coverage was found in Tumbak Madani village (Station 2; 63.13±7.3%), while the lowest was found in the nearby Tumbak Induk village (Station 3; 22.66±3.71%). The contrasting condition of these adjacent stations was presumably resulted from the various anthropogenic activities in the coastal line bordering the seagrass beds in both station. Seagrass beds in Station 2 were located near the villagers’ houses, where small non-motorized fishing boats were parked in the back of the houses, causing no disturbance to the seagrass bed. Station 3 was located right in the back of the village’s fish market, where large fishing boats (pajeko) were unloading their catch. In any given days, at least two of these pajeko were present in the fish market, causing moderate oil spillage and sometimes fish and other domestic waste present in the waters. Even though oil spillage, sedimentation and waste from anthropogenic activities might not directly affect the survival rate of the seagrass, they might affect water clarity and light availability, which in turn, may hamper growth and survival of several species of seagrass [23,24]. Thus, in Station 3, only climax species, i.e. Enhalus acoroides and Thalassia hemprichii were found growing in a sparse colony with relatively low coverage.
Along with seagrass density and biomass, seagrass coverage is also a significant factor to their ability in carbon stocking and sequestration [22]. For example, seagrass beds with the highest coverage (63.13±7.3%) in Station 3, may potentially sequester carbons as many as 7.2064202 ton/Ha/Year [22]. Seagrass bed is one of the “blue carbon” ecosystems where their ability to naturally remove carbon dioxide were significant, implying that their conservation is also an important tool in mitigating the current and future climate change and environmental disaster [22,25].

3.3 Species dominance

The result of species coverage showed that *Thalassia hemprichii* was dominant for the whole study area with 13.65±3.31% mean coverage, followed by *Syringodium isoetifolium* (11.30±2.87%), *Enhalus acoroides* (8.05±1.91%), and *Cymodocea rotundata* (7.18±2.24%). The other three species accumulated less than 0.5% in coverage, i.e. *Halodule pinifolia* (0.35%); *H. uninervis* (0.12%) and *Halophila ovalis* (0.08%). (Fig. 2)

![Figure 2](image2.png)

**Figure 2.** Mean seagrass species coverage (dominance) in the study area

![Figure 3](image3.png)

**Figure 3.** Species composition and dominance for each station in the study area

Species dominance was associated with the role and opportunity of each species towards different environmental characteristics of each seagrass bed. *Halophila* species were identified with its pioneer role in the succession or colonization of disturbed or damaged seagrass beds which have been
inhabited by other organisms, i.e algae and bryophytes [26]. Figure 3 showed that in seagrass beds with lower species diversity (2-3 species), either E. acoroides, T. hemprichii, or S. Isoetifolium were dominant. However, in higher species, diversity beds (4-6 species), E. acoroides and T. hemprichii coverage decreased, or substituted by stenohaline species, i.e. Syringodium and Cymodocea. The last group including Halodule and Halophila species were found in really low dominance, either as separate colonies in niche habitats (patches, mounds, and barren substrate), or opportunistic colonies within the dominant Enhalus, Thalassia, and Syringodium communities.

The variety of substrate ranged from muds, soft sands, coarse sands, and rubble presumably caused fluctuation in coverage due to different species growing in these substrates. Several seagrass species, i.e. Halophila ovalis and Syringodium isoeiifolium were found in coarser substrates bordering the reef flats. However, their smaller and patchy form of colonies caused relatively lower coverage compared to Enhalus or Thalassia dominated beds. The latter beds generally had denser and larger colonies with longer leaf blades contributing to higher coverage.

The succession and fluctuation pattern of seagrass species assemblage and dominance in the Pusomaen district are not observed throughout this study and need to be observed in further specific studies. Determining the limiting and supporting factors for each seagrass species to grow in certain areas in different periods of time, including various environmental, seasonal, and anthropogenic factors perpetually at play are important tools to understand the dynamics of seagrass beds and eventually develop suitable management to utilize the coastal resources sustainably.

3.4 The community-based coastal management program and seagrass conservation

This study was conducted in seagrass beds located in Tumbak and Bentenan village in Pusomaen district, which had been designated as the pilot site of “Proyek Pesisir” (Community-based coastal resource management program/CB-CRMP), from 1997 – 2003. This project was one of the pioneering coastal management in Indonesia, focusing on implementing decentralized best-practices in coastal management involving multiple local stakeholders and establishing marine sanctuary in the areas supported by local legislation (Perda) [6].

The legacy of CB-CRMP program in Tumbak and Bentenan Village, in terms of on-going or institutionalized community-based coastal management, was nearly non-existent. However, in a separate interview, the head of Tumbak Village (Hukum Tua) still acknowledged several legislation related to coastal resource use, despite the village authorities’ absence of formal enforcement. The observation conducted alongside seagrass conditions survey implied much negative behavior of the villagers in both Tumbak and Bentenan, i.e. domestic waste disposal directly in the coastal waters, oil spillage from pajeko boats in Tumbak fish market (directly on the seagrass beds), reckless anchoring of boats in the seagrass beds, and general indifference towards seagrass beds importance in their daily activities. The initial evidence of degrading environmental conditions affecting the seagrass beds was observed in Tumbak Induk and Bentenan Indah where the seagrass coverage and species diversity were poor and moderate, respectively.

Apart from the general indifference of the villagers towards seagrass beds, the CB-CRMP program initiated in 1997 was focused more on the socio-economic and institutional discourse on coastal management. Apropos to coastal ecosystem management in general, the focus of CB-CRMP to seagrass beds was minimal compared to other ecosystems, i.e. mangroves and coral reefs. Two of the CB-CRMP documentation found related to seagrass were the monitoring guidelines of the coastal ecosystem, including methods in assessing seagrass coverage and species dominance; and a map showing the location of seagrass beds with general remarks of the area, which are 51 hectares in total [7,8,27]. However, despite the well-documented results of CB-CRMP, there were no documented
baseline data on seagrass ecosystem status in the Pusomaen district, which retrospectively would provide valuable information on the impact of the program’s implementation through analyzing the difference between baseline and monitoring data.

Ultimately, The CB-CRMP program provides a valuable lesson for the stakeholders in coastal management to maintain the legacy of such program implementation in coastal communities. The program’s final report already highlighted the need for continuing support to these communities by local institutions to enhance the probability of sustained coastal resources management efforts [7]. The reports acknowledged that despite the enactment of provincial and district coastal law that legitimizes and encourages community-based management, local institutions must also develop program strategies and budgets to provide continuing support to these villages as well as other coastal communities [7].

4. Conclusion
The first step towards a sustainable seagrass ecosystem is understanding the valuable services it provides to the coastal community. The relatively favorable seagrass condition in the Pusomaen district implied that there’s still room for improvement, particularly in conserving multispecies seagrass beds in North Sulawesi. The availability of spatio-temporal data of seagrass conditions along with continuous community engagement in an adaptive framework is two important factors in initiating a successful seagrass conservation program. The collaboration and cooperation between stakeholders, including coastal community, local and regional government, academia, and private sectors are of utmost priority in order to achieve a mutual understanding of the importance of a sustainable coastal environment, particularly in the seagrass ecosystem.

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