

Status of seagrass ecosystem appreciation in social-ecological perspective using flag modelling: evidence in Bintan Island, Indonesia

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Abstract. The seagrass ecosystem plays an essential role in the ecological system in coastal areas. The seagrass ecosystem has no natural attractiveness compared to coral reef ecosystems and mangroves. The seagrass ecosystem receives less attention and appreciation due to the lack of public knowledge about seagrass in general and the benefits it provides. Lack of public awareness has led to a decline in perceptions of the seagrass ecosystem services' importance. The Teluk Bakau area on Bintan Island also faces the same problem with the seagrass ecosystem existence has not been utilized optimally because the community is not interested in empowering the seagrass ecosystem, especially for ecotourism activities. Therefore, to increase public interest in seagrass ecosystem services, it is necessary to study the understanding and improvement of communication of seagrass ecosystem services to the community from a socio-ecological perspective. This study uses flag modeling analysis divided into three criteria: ecological, socio-economic, and institutional. The ecological criteria found four species of seagrasses and 22 species of marine biota, and 12 marine biota species with economic value. Another result found two sub-criteria from critical threshold value (CTV) analysis were not appreciated categories, particularly seagrass cover and the presence of crustaceans. In the socio-economic criteria, there is one sub-criterion with not appreciated categories, specifically the income provision. Moreover, on the institutional criteria, the sub-criterion with not appreciative categories was the manager's activeness. Based on the flag modeling analysis results, the socio-ecological perspective in Teluk Bakau is quite appreciative.

Key Words: critical threshold value, ecology, ecosystem services, flag modeling, sustainable.

Introduction. Marine ecosystems are essential because they support the most extensive seafood production globally, including marine fisheries products in Indonesia, being divided into several ecosystems. One of them is the seagrass ecosystem. This ecosystem is closely related to resilience, adaptability, and transformation from an ecological and social point of view (Folke et al 2010). Seagrass beds worldwide provide ecosystem services and habitat for various marine biota species and give several services for the coastal community (Keuning et al 2011; Tuya et al 2017; Ding et al 2018; Karlina & Idris 2019). Besides that, the seagrass ecosystem provides carbon storage and climate change mitigation (Rattanachot & Prathep 2015; Rodríguez et al 2018), a function of food security (Baker et al 2015), and conservation (Bell et al 2001; Marsh et al 2012).

The seagrass provides ecosystem services, but seagrass itself is one of the most threatened ecosystems on earth (Cullen-Unsworth et al 2014; Mazarrasa et al 2018) due to the high level of existing activities, including tourism, land reclamation, oil pollution of the marine environment, dredging, boating, and sedimentation (Karlina et al 2018). The seagrass habitat is in intertidal and subtidal areas, being potentially more easily

threatened because of human activity (Cullen-Unsworth et al 2014). An amount of 7% seagrass ecosystem has been decreased globally per year, which is caused by various threats (Waycott et al 2009). In general, the most significant threat is the lack of public concern and interest in the seagrass ecosystem. Since the seagrass ecosystem may not be as attractive for humans as a coral reef or mangrove ecosystem, this has become a fundamental problem towards its sustainability. Lack of public awareness results in decreased perceptions of the importance of ecosystem services for local communities (Unsworth et al 2016; Quiros et al 2018).

In contrast, identifying seagrass ecosystem services can increase our focus on how significant seagrass's role is for humans. The seagrass area in Teluk Bakau, Bintan Island, also encounters the same problem. Due to many community activities around the seagrass beds, its existence is not well maintained. Therefore, this study aims to assess the socio-ecological aspect of seagrass status in order to improve public knowledge as well as to escalate its profile, especially in the region of Bintan Island.

Material and Method

Study sites. The research was conducted in May 2019, which included a sampling survey in the site location in Teluk Bakau, Bintan Island (Figure 1), and followed by data processing and data analysis.

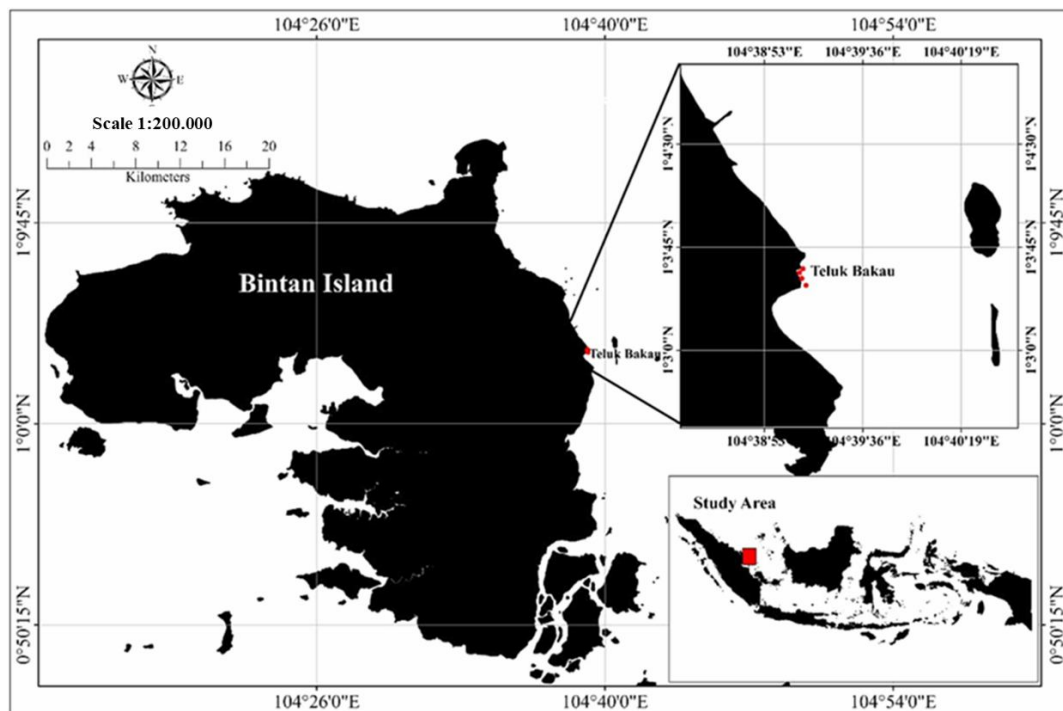


Figure 1. Study area.

Research procedure. The research consisted of several steps:

1. Preparation and sampling: based on a preliminary survey using the interview method with related stakeholders, there were three groups of factors that influence the system in seagrass beds: ecological, socio-economic, and institutional. Sampling was carried out in two parts: (a) field survey to understand the condition of the community and the environment support of the seagrass ecosystem at the research location (ecological), and (b) sampling data related to socio-economic and institutional data with sub-criteria specified in the flag modeling. Interviewees must be close to the seagrass environment, specifically those who directly or indirectly use these ecosystem services, like small-scale fishermen and people involved in the management of the seagrass ecosystem.
2. Data validation and grouping: the data was validated and grouped according to the criteria specified in the flag modeling.

3. Data processing and analysis: after inputting all the data into the predetermined criteria, data was processed and connected to the respective indicators affirmed in the flag modeling.

Management design. Seagrass category appraisal of socio-ecological aspects used a 'flag modelling' method. This method allows measuring the seagrass value in determining the ecosystem service. This analysis was carried out at the same stage as that carried out by Nijkamp & Ouwersloot (1997) modified by Karlina (2015), which was later adopted in this study as follows:

1. To identify indicators of seagrass ecosystem services in the waters of Bintan Island, they were divided into three criteria, namely:
 - A. The ecological criteria, which include the following sub-criteria:
 - a. Composition of seagrass species and coverage. The coverage percentage of seagrass species shall determine the quality of species. Common criteria for seagrass coverage are as follows: 1) rare (0-25%); 2) moderate (26-50%); 3) solid (51-75%); and 4) very dense (76-100%). Based on the obtained percentage results, the analysis was then carried out;
 - b. Fish species abundance and associated biota in the seagrass ecosystem. The method used for these criteria is a visual census in the waters.
 - B. Socio-economic criteria, which include the following sub-criteria:
 - a. Public perception, is how the community of Bintan Island can interpret seagrass ecosystem importance as a provider of ecosystem services and to the response;
 - b. Public participation, as an effort to involve the community in a healthy utilization pattern;
 - c. Economic aspect, includes income factor with direct or indirect benefit obtained by the community from existing resources. All questionnaire responses will be calculated into a particular score.
 - C. The institutional aspect that examines the factors that influence institutions' patterns and roles in seagrass conservation management is a set of rules for access and control of natural resources, forming the institutional system. Institutions provide basic rules, norms, prohibitions, contracts, and other regulated in-laws and regulations that govern individuals in society or organizations. The institutional theory aims to identify, explain and predict key influences, and later to discuss how to organize, improve, manage the institutional criteria, such as the existence of a management group, and avoid the conflict without violation for example through periodic monitoring activities
2. Establish a set of the critical threshold value (CTV) conditions as a rating as follows (Nijkamp & Ouwersloot 1997):

$$CTV = \frac{CTV_{max} - CTV_{min}}{\text{Number of classes}}$$

3. Establish a set of CTV conditions categorized as four ratings (Figure 2).

| | CTV min | CTV | CTV max |
|--|--------------|---------------|------------|
| | | | |
| | green | yellow | red |
| | > (+ -) | > (+) | > (++) |
| | < (+ -) | < (-) | < (--) |

Figure 2. Range of CTV values based on flag colors with modifications (Nijkamp & Ouwersloot 1997): green = very appreciative; yellow = moderate; red = not appreciative; black = stop.

4. The flag modeling technique is the whole process of setting alternatives to the existing sub-criteria using the Likert Scale (Table 1).

Table 1

Likert scale instruments that have been modified into three alternatives

| <i>No.</i> | <i>Answer</i> | <i>Score</i> |
|------------|-------------------|--------------|
| 1 | Very appreciative | 3 |
| 2 | Moderate | 2 |
| 3 | Not appreciative | 1 |

Source: modification from Sugiyono (2008).

Results and Discussion

A. Ecological criteria

Composition of seagrass type and cover. Four seagrass species were found in the research location, including *Enhalus acoroides*, *Thalassia hemprichii*, *Syringodium isoetifolium*, and *Thalassodendron ciliatum*, with an average cover of 49.75%. The highest seagrass cover was in case of the species *S. isoetifolium*, with 67%. This species grows in tropical and sub-tropical areas with a characteristic sand substrate habitat (Marsh et al 2012), then *E. acoroides* with an average of 61%. *E. acoroides* is often used as bio-indicator to accumulate heavy metals in seawater (Nguyen et al 2017). The seagrass cover for *T. hemprichii* and *T. ciliatum* was only 60% and 11%, respectively. *T. ciliatum* species grows on rocky substrates and has different features: rocky and sandy habitats, more leaves with narrower shapes, and no flowers (Short et al 2001). There are two important considerations related to seagrass coverage, particularly the seagrass species ability to grow in specific substrates as seen from the conditions of its rhizomes, roots, and leaves (Montefalcone et al 2014). Seagrass beds thrive in various climatic regions (from tropical latitudes to temperate) with a wide variety of habitat types (from protected bays, estuaries to open locations and from intertidal zones to depths of 40 meters (Beer 2001). Seagrass ecosystem plays an essential role in terms of coastal area productivity, especially in building an ecological system (Cullen-Unsworth et al 2014; Wawo 2017; Vanderklift et al 2020).

Associated biota. A number of 22 species associated with the seagrass were found, namely mollusks, crustaceans, and fish. During sampling, 12 species of biota were found targeted by fishermen, consisting of six species of fish, four species of mollusks, and two species of crustaceans (Figure 3). The dominant types of mollusk found were *Loligo duvaucelii* and *Strombus sp.*, while the dominant crustacean found was *Portunus pelagicus*. Mollusks are one of the most diverse species associated with seagrass habitats. Among the mollusca phylum, gastropods are an association group of seagrass biota which is considered as an economically valuable commodity for the fishery in many countries (Matsumoto 2018). Fish found in seagrass were generally herbivores. The feeding activities of herbivore fishes increase seagrass productivity by removing older seagrass blades and cleaning epiphytes, sometimes increasing light availability (Douglas et al 2018). In general, the gastropods:crustacean ratio in the mesograzer community varies from region to region (Duffy et al 2015). Seagrass beds provide a complex physical structure with various associated biota as primary products, including phytoplankton, periphyton, and macroalgae. They provide many essential ecosystem services.

Seagrass ecosystem is also the most productive ecosystem on earth (Leopardas et al 2014). Seagrass beds are closely related to fauna diversity due to seagrass ecosystem's role as a habitat, food source, a sheltered area, etc. There have been studies related to epibenthic fish and invertebrates in the seagrass area. Mazarrasa et al (2018) explained In general, infauna and epifauna community structures in seagrass beds have a vital role in this ecosystem's ecological processes.

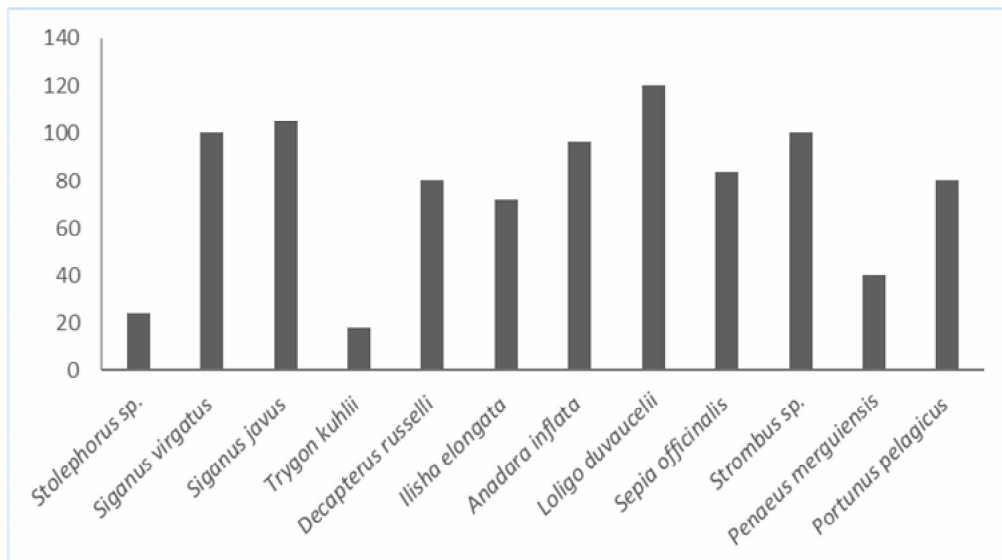


Figure 3. Graph of type and amount of fishermen's catch (kg month⁻¹).

B. Social-economic criteria. Seagrass beds are closely related to the diversity of marine fauna, especially for people living in Teluk Bakau who are fishermen, due to marine fauna's economic value. In some fishing activities, fishermen in Teluk Bakau use traps to catch crustaceans. Some fishermen also catch marine fauna by using nets and fishing rods. Data from community livelihoods indicate that local fishermen in Teluk Bakau commonly earn from marine products ranging from various types of fish to crustaceans, bivalves, and gastropods. This status was one of the indicators for coastal communities' socio-economic criteria (Table 2).

C. Institutional criteria. Along the Trikora coast, the seagrass beds are a conservation area based on Regent's Decree No. 36 / VIII / 2007 dated 23 August 2007, Bintan Regency 2007 (SK Bupati Bintan No. 261/VIII/2007) and known as TRISMADES (Trikora Pilot Seagrass Management Site) program. The conservation area of the seagrass in Bintan Island is precisely on the east coast of Bintan Island, Riau Islands. This TRISMADES conservation area focused on three villages, particularly Teluk Bakau, Malang Meeting, and Berakit, and managed by the Oceanographic Research Center-LIPI (P2O-LIPI). The TRISMADES program started in November 2007 and ended in October 2010. This program was the first coastal community-based seagrass management program in Indonesia. This program was a pilot project expected to demonstrate integrated management of seagrass beds with associated habitats to prevent future ecosystem degradation and enable sustainable use of Bintan's coastal resources. The community currently manages the institution, but that is no longer a priority; the manager is still working but no longer focuses on empowering seagrass activities. In addition, funding is also not supported by the COREMAP program (Coral Reef Rehabilitation and Management Program) (Table 2).

The status of seagrass ecosystem appreciation in social-ecological perspective using flag modeling. The preparation of indicators and critical threshold values uses analysis to describe the seagrass ecosystem's sustainable management using ecological, socio-economic, and institutional criteria (Table 2). The importance of the seagrass ecosystem's existence is the key to seagrass appreciation and to support the community's economy. Ecological, socio-economic, and institutional indicators are the primary keys in determining scale.

Based on the sustainability criteria analysis (Table 2), there is one sub-ecological criterion with a red mark: the catch of crustaceans. The socio-economic criterion attribute that describes unsustainability is community participation in maintaining seagrass beds. There is one institutional criterion that describes unsustainability, namely activities in the management of the seagrass ecosystem.

Figure 4 shows that there are two green marks on the institutional aspect, this shows the management group's high appreciation on the importance of seagrass ecosystems. A management group in Teluk Bakau is one of the TRISMADES program in collaboration with Bintan Regency and P2O-LIPI. This program is a pilot program for seagrass management on the East Coast of Bintan Island because there are rare and protected species, namely turtles and dugongs. This area is stipulated in the Decree of the Regent of Bintan Number 36 / VIII / 2007. So, the management group's existence is still involved in educational activities that advise on the importance of conserving seagrass resources. Since the program ended, private resorts have been built along the seagrass area, blocking access to community areas and impacting less monitoring and protection of the conservation area from the coastal community. Until now, the lack of access to the management group has become an obstacle in the management process.

Table 2
Critical threshold value (CTV) for each attribute of seagrass management sustainability

| Criteria | Indicator | Sustainable | Simply sustainable | Not sustainable | Result |
|----------------|---------------------------------------|-------------|--------------------|-----------------|--------|
| | | 3 | 2 | 1 | |
| Ecology | Seagrass cover | 67-100 | 34-66 | 0-33 | 49.5 |
| | Fish | 67-100 | 34-66 | 0-33 | 33 |
| | Mollusca | 67-100 | 34-66 | 0-33 | 45 |
| | Crustacea | 67-100 | 34-66 | 0-33 | 22 |
| Social economy | Perception | 67-100 | 33-66 | 0-33 | 42 |
| | Participation | 67-100 | 33-66 | 0-33 | 33 |
| | Income | 67-100 | 33-66 | 0-33 | 25 |
| Institutional | The existence of the management group | 67-100 | 33-66 | 0-33 | 100 |
| | Understanding | 67-100 | 33-66 | 0-33 | 100 |
| | No offense | 0-33 | 33-66 | 67-100 | 60 |
| | Conflict | 0-33 | 33-66 | 67-100 | 60 |
| | Liveliness | 67-100 | 33-66 | 0-33 | 20 |

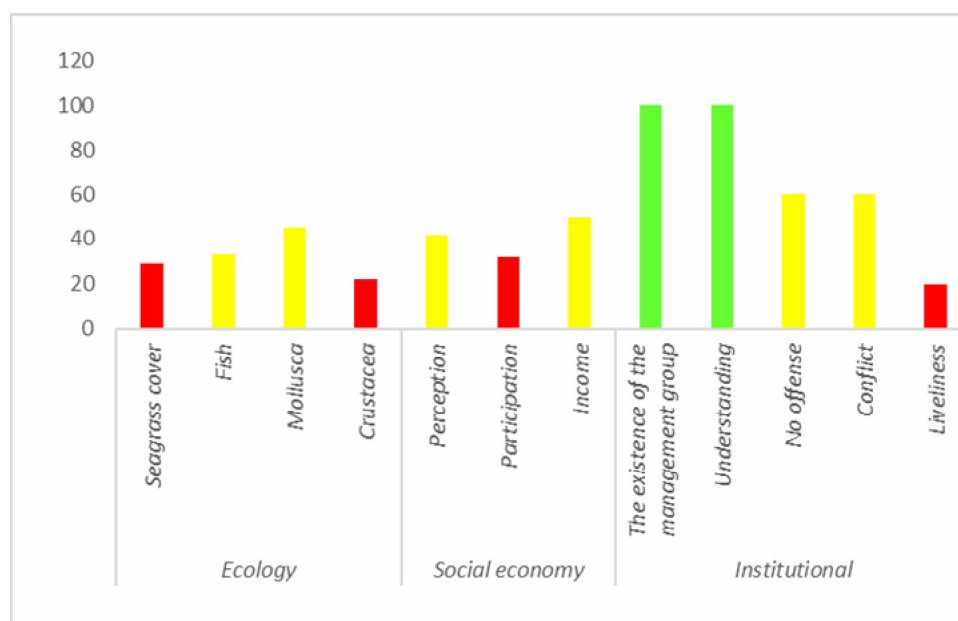


Figure 4. The status of seagrass ecosystem appreciation in social-ecological perspective using flag modeling.

The results of the interview indicate that there is a management group, but only about 20% are active in management activities. The community's perception of seagrass is

considerably clear, but participation has decreased over time because there was no further follow-up on the seagrass's importance. Generally, people see seagrass as a place to play and fish in certain seasons. However, in practice, community participation is felt to have decreased compared to 2007. The lack of knowledge about seagrass ecosystem services will reduce the level of public awareness of its existence. Then there must be a follow-up by reminding the public of the importance of seagrass ecosystem services, either directly or indirectly. Most of the people in Teluk Bakau are fishermen who use the seagrass ecosystem services as a place to find fish, mollusks, and crustaceans. When viewed as a whole, the appreciation status of seagrass ecosystems in a socio-ecological perspective can be said that in all criteria there are 6 indicators that are quite appreciative, namely the presence of mollusks and fish, community perceptions of the importance of the existence of seagrass ecosystems that minimize violations and does not cause management conflicts, the income, no offense and conflict (Figure 4). Then there are 4 indicators that are not appreciated, namely a decrease in the percentage of seagrass cover and the presence of crustaceans, then a decrease in activity in terms of management due to lack of participation which affects the level of activity in the management of seagrass ecosystems, that in the long term the level of community participation will decrease in the management phase, if there is no follow-up by the motivators when the project activity ends (Pita et al 2010).

Conclusions. There are three criteria of seagrass appreciation status, including ecological, social-economic, and institutional appreciation. There are three indicators of appreciation in ecology criteria: seagrass cover, fishes and mollusk, and the indicator which is not appreciated, i.e., the crustacean. In the social-economic criteria, there are two indicators of appreciation: perceptiveness and participation, and the indicator that is not appreciated, i.e., income. Institutionally, two indicators which are very appreciated are: management group existence and comprehension. The indicators that are not appreciated are obedience, conflict, and liveness.

Conflict of interest. The authors declare that there is no conflict of interest.

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