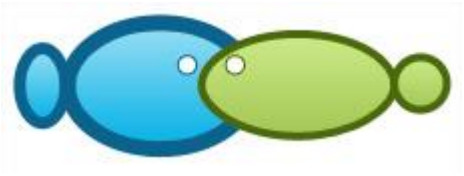

Co-management strategies for mangrove ecosystem in South Tabulo village, Boalemo Regency, Indonesia

[1]Lukman Mile, [2]Nuralim Pasisingi, [3]Yuniarti Koniyo, [4]Sri N. Hamzah, [1]Rieny Sulistijowati, [1]Asri S. Naiu, [3]Juliana, [4]Rita M. Harmain

[1] Fisheries Technology Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, 96128 Gorontalo City, Indonesia; [2] Aquatic Resources Management Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, 96128 Gorontalo City, Indonesia; [3] Aquaculture Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, 96128 Gorontalo City, Indonesia; [4] Marine Science Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, 96128 Gorontalo City, Indonesia.
Corresponding author: N. Pasisingi, nuralim@ung.ac.id

Abstract. The mangrove ecosystem is crucial for preserving the stability and sustainability of both terrestrial and marine environments. This study explored the ecological condition and co-management practice of the mangrove ecosystem in South Tabulo village, Boalemo Regency, Gorontalo Province. Vegetation data collection and stakeholder interviews were conducted during August 2024. The mangrove area was divided into three stations: rehabilitation (site 1), conversion (site 2), and undisturbed by human activity (site 3). Twelve true mangrove species from the *Avicennia*, *Bruguiera*, *Ceriops*, *Rhizophora*, *Sonneratia*, and *Xylocarpus* genera were found during the study with presence frequency values ranging from 13 to 86%. The average pH, temperature, and salinity values of the mangrove ecosystem waters were 7.72-7.82, 27.32-28.36°C, and 7.36-30.71 ppm, respectively. Referring to the Decree of the Minister of Environment of the Republic of Indonesia Number 201 of 2004, mangroves at all sites were in a good category with an average density (1075-2688 ind ha^{-1}) with moderate to very dense criteria. The diversity and dominance index values of the mangrove ecosystem in South Tabulo village are in the low to moderate category. A stakeholder analysis of the mangrove ecosystem management in South Tabulo village showed that the village government and the Seaweed Cultivation Research Center have very high interests and influence. The mangrove group has low interests and high influence, while the community and fishermen have low interests and influence. The implementation of mangrove co-management in South Tabulo village has not yet been optimal and requires improvement by enhancing the roles and responsibilities of each stakeholder.
Key Words: conservation, Gorontalo, rehabilitation, stakeholder, Tomini Bay.

Introduction. Mangroves are part of the termed "Blue Forests" which are among the most valuable and productive coastal ecosystems on the planet (Himes-Cornell et al 2018). The ecosystem is a coastal area threatened by human activities and plays a crucial role in maintaining the balance of coastal environments. Recent research has shown that human activities are the primary factors driving the decline of mangrove vegetation in Indonesia (Analuddin et al 2023; Rizal et al 2023). Mangroves function as natural protectors of land from erosion and coastal abrasion, habitats for various types of fauna, and effective carbon absorbers, making them one of the main components in climate change mitigation efforts. In addition, the mangrove ecosystem supports coastal communities' social and economic life and helps them meet their daily needs. Rising coastal disasters, such as tidal flooding, tidal waves, and erosion, are closely linked to increased land conversion and mangrove degradation (Suardana et al 2023).

Human population expansion, economic needs, and minimal public understanding of the importance of the sustainability of the mangrove ecosystem have caused the rampant conversion of mangrove forests to occur recently. Many studies have discussed

mangrove and coastal management policies (van Oudenhoven et al 2015; Yamindago 2015; Dalimunthe 2018; Katili et al 2018; Susilo et al 2018; Damastuti & de Groot 2019; Abidin et al 2021; Firdaus et al 2021; Damastuti et al 2022; Sahputra et al 2022; Rizal et al 2023) and mangrove ecological aspects in Indonesia (Rumahorbo et al 2019, 2020; Abidin et al 2021; Sumarmi et al 2021; Ke et al 2022; Wardhani et al 2022; Analuddin et al 2023; Lintong et al 2023; Rahim et al 2023; Abubakar et al 2024; Oktorini et al 2024). However, the co-management strategy, particularly in South Tabulo village, has not been thoroughly explored. Community involvement is key to successful mangrove conservation, but achieving lasting results requires overcoming challenges in governance, inclusivity, and knowledge integration, while effectively utilizing socio-economic and ecological factors (Valenzuela et at 2020; Gómez-Ruiz et al 2022; Karpowicz et al 2024; Fuady et al 2025). Therefore, community participation is needed in sustainable mangrove management. Active community involvement is an effort to increase the effectiveness of mangrove management and conservation. In South Tabulo village, Mananggu District, Boalemo Regency, Gorontalo Province, mangrove land rehabilitation efforts have been carried out as a disaster mitigation measure to create a disaster-responsive village. However, the conversion of part of the mangrove land into ponds is also carried out to meet regional economic needs. Thus, this study can provide an overview of the level of involvement of the managers and users of the mangrove ecosystem in South Tabulo village. This research aimed to explore the ecological condition and co-management practices of the mangrove ecosystem in South Tabulo village, Boalemo Regency, Gorontalo Province. The results of this study are expected to serve as a data source for optimizing the management of sustainable mangrove ecosystems.

Material and Method

Time and study sites. This research was conducted in August 2024 in South Tabulo village, Mananggu District, Boalemo Regency, Gorontalo Province, Indonesia. The mangrove ecology observation location includes three stations, namely the mangrove rehabilitation area (site 1), the land conversion area (site 2), and the area without human activity (site 3).

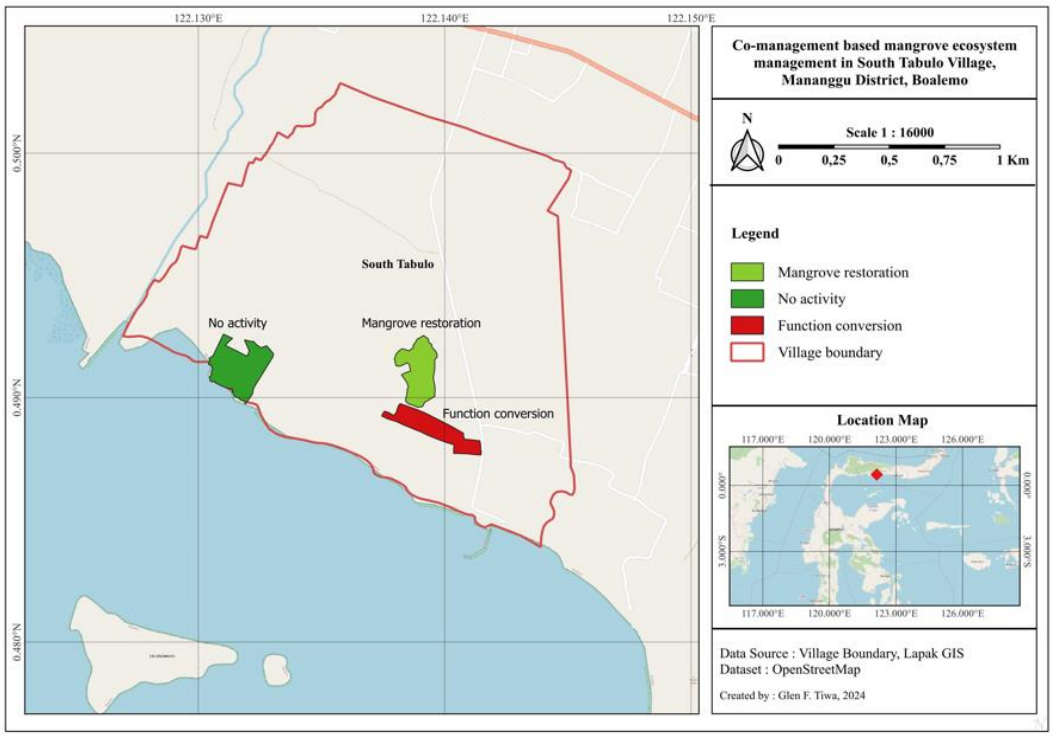

Figure 1. Location of ecological data collection for mangrove ecosystem in South Tabulo village.

Research design. This research study focuses on the ecological conditions of the mangrove ecosystem and the analysis of stakeholder interests and influences on its management in South Tabulo village. A combined quantitative and qualitative descriptive approach was applied to the research data to ensure comprehensive and objective results. The sampling process was conducted purposively (Sugiyono 2017). The tools and materials used for data collection are listed in Table 1.

Table 1

Equipment and materials utilized during the study

No.	*Tools and materials*	*Description*
1	Stationery	Documentation of research results
2	GPS Garmin - etrex 10	Tagging of research site coordinate points
3	Roll meter	Measurement of quadrat transects
4	Rope	Making line transects
5	Thermometer	Water temperature measuring instrument
6	Portable refractometer ATC	Water salinity measuring instrument
7	Pen type pH meter – 009(I)A	Water pH measuring instrument
8	Identification guide book	Mangrove species identification reference
9	Questionnaire	Respondent interview instrument

Data collection

Mangrove ecology and water quality. Observations of the mangrove ecosystem's condition were conducted at each site using two line transects positioned perpendicularly from the sea toward the land. Along each transect, 5 x 5 meter quadrats were arranged in a zigzag pattern to facilitate the observation and identification of mangrove species. The number of quadrats used varied between 6 and 16, depending on the mangrove area in the field. The layout of the transect placement follows Figure 2. Mangrove species identification was based on Noor et al (1999). pH, temperature, and salinity measurements were conducted in situ at each observation transect.

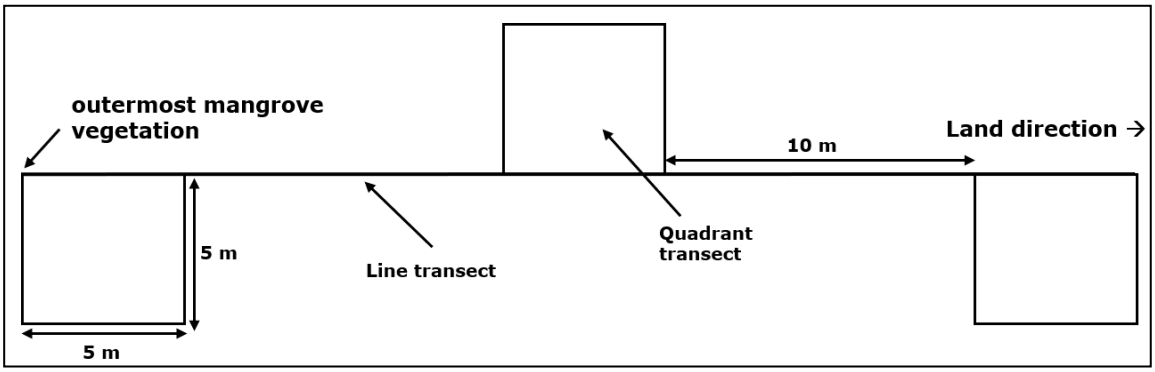

Figure 2. The transect placement for observing mangrove vegetation.

Stakeholders. Primary data, including respondents' perceptions of area management, the level of importance, and the degree of influence in implementing collaborative management programs for mangrove management, were obtained directly through interviews. A total of 50 respondents were interviewed, including mangrove managers of South Tabulo village, such as the village government and the Seaweed Cultivation Research Center (LRBRT) (4 people), fishermen (8 people), mangrove groups (17 people), and local communities (21 people) as mangrove users in South Tabulo village. Secondary data supporting the interview results was sourced from literature reviews, including journals and other relevant scientific references.

Data analysis

The existing condition of the mangrove ecosystem. Analysis of mangrove ecological conditions included identification, presence, species density, diversity index, and dominance as reviewed below.

A. Presence. The presence of mangrove species i (Fi) is the probability of the occurrence of mangrove species i in all observations. The calculation was done through the ratio of the number of quadrants where a certain species is present to the total number of quadrants using English et al (1994) as follows:

$$Fi = \frac{pi}{\Sigma p}$$

where: Fi = presence of mangrove species i;
pi = number of quadrants where species i was found;
Σp = total number of observation quadrants.

B. Density. The density of mangrove species refers to the number of individuals of a particular species in an area, while the relative density is the comparison between the number of individuals of that species and the total number of individuals of all mangrove species (Bengen 2001). The calculation of the density of the i^{th} mangrove species (Ki) is obtained based on the total number of individuals of the i^{th} mangrove species in the total sampling area (English et al 1994) as in the following equation:

$$Ki = \frac{ni}{A}$$

where: Ki = density of mangrove species i (ind ha^{-1});
ni = total number of individuals of mangrove species i (ind);
A = total transect sampling area (ha).

Determination of the category of mangrove ecosystem damage based on density data refers to the Decree of the Minister of Environment of the Republic of Indonesia Number 201 of 2024 concerning standard criteria and guidelines for determining mangrove damage (Table 2).

Table 2

Standard criteria for mangrove damage

Criteria		*Density (ind ha^{-1})*
Good	Very dense	≥ 1500
	Dense	≥ 1000 - < 1500
Damaged	Rare	< 1000

C. Diversity. According to the nature of the community, diversity is determined by the number of types and the evenness of the abundance of individuals of each type obtained. The greater the value of a diversity, the more types are obtained, and this value is very dependent on the total value of the individuals of each type or genera. The number of individuals of each species was used to calculate the diversity index (Odum 1993):

$$H' = \sum \frac{ni}{N} In \frac{ni}{N}$$

where: H' = Shannon-Wiener diversity index;
ni = number of individuals of mangrove species i (ind);
N = total number of mangrove individuals of all species (ind).

The H' is categorized into three levels: low, medium, and high. If H' < 1.0 indicates low diversity where the ecosystem is under stress and dominated by only one or a few species. If 1.0 ≤ H' ≤ 3.0 then the diversity is classified as medium and reflects a fairly stable ecosystem with a more even distribution of species. H' > 3.0 reflects high diversity, indicating a healthy and stable ecosystem where many species are evenly distributed. This index is important for assessing the condition of the mangrove ecosystem as one of the initial steps in the management and preservation of biological resources in coastal areas (Odum 1983).

D. Dominance. The dominance index (D) is used to determine the extent to which a group of biota dominates other groups. A large enough dominance will lead to an unstable or stressed community. The dominance index is calculated using the Simpson dominance index formula (Odum 1983 in Latuconsina et al 2012) with the following formula:

$$\mathbf{D} = \sum_{i=1}^{s} \left[\frac{Ni}{N}\right]^2$$

where: D = Simpson's dominance index;
Ni = number of individuals of mangrove species i;
N = total number of mangrove individuals of all species;
s = number of mangrove species.

The dominance index ranges from 0 to 1, where the smaller the dominance index value, the more it indicates that there is no dominant species, conversely the greater the dominance, the more it indicates that there is a certain dominant species (Odum 1983).

Stakeholder analysis. The results of interviews with stakeholders focused on their level of interest and influence in sustainable mangrove ecosystem management in South Tabulo village. All interview data were analyzed quantitatively based on several indicator score references in Table 3 and Table 4 (Lasoma 2023). The level of interest and influence of stakeholders were then grouped based on the type of indicator (Table 5) and mapped based on the matrix as presented in Figure 3.

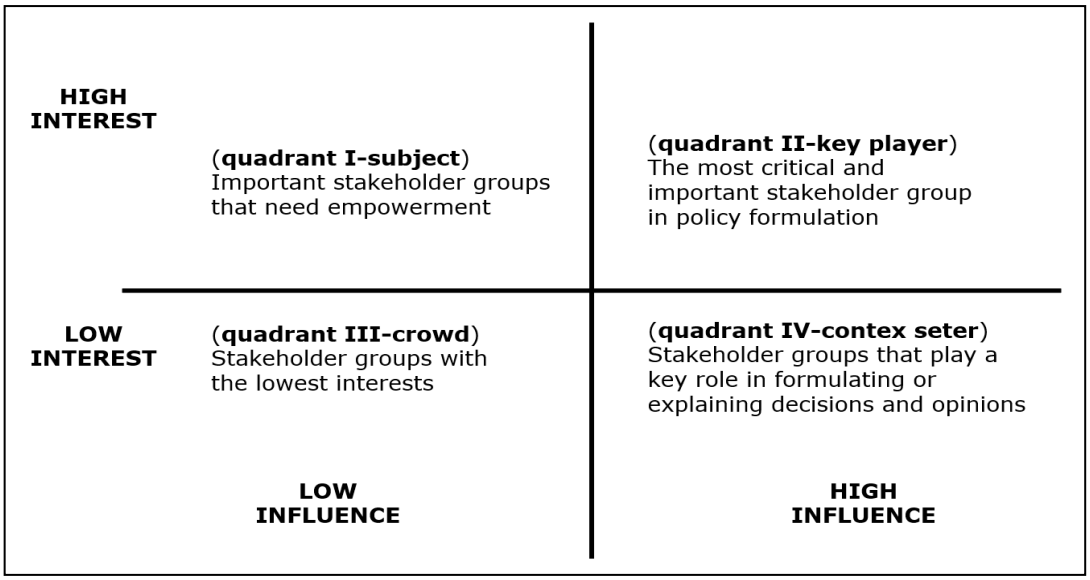

Figure 3. Stakeholder interest and influence analysis matrix (Muqorrobin et al 2013; Abudi et al 2022).

Table 3

Quantitative assessment score of stakeholder interest level

No.	*Score*	*Indicators*	*Variables*
1.	5	Involved in all processes (agriculture, plantations, tourism, forestry, spatial planning)	Involvement
	4	Involved in 3 processes	
	3	Involved in 2 processes	
	2	Involved in 1 process	
	1	Not involved	
2.	5	Receives 4 benefits (economic, social, environmental, and public trust)	Benefits of management
	4	Receives 3 benefits	
	3	Receives 2 benefits	
	2	Receives 1 benefit	
	1	Receives no benefits	
3.	5	High priority	Management priorities
	4	Priority	
	3	Medium priority	
	2	Less priority	
	1	Not a priority	
4.	5	81-100% Dependence	Dependence on resources
	4	61-80% Dependence	
	3	41-60% Dependence	
	2	21-40% Dependence	
	1	≤ 20% Dependence	

Table 4

Quantitative assessment score of stakeholder influence level

No.	*Score*	*Indicators*	*Variables*
1.	5	Involved in the entire process (policy determination, implementation according to goals and targets, monitoring, evaluation, sanctions)	Management rules or policies
	4	Involved in 3 processes	
	3	Involved in 2 processes	
	2	Involved in 1 process	
	1	Not involved	
2.	5	Contributes to all points (planning, implementation, coaching, supervision, evaluation)	Role and participation
	4	Contributes to 3 points	
	3	Contributes to 2 points	
	2	Contributes to 1 point	
	1	Does not contribute	
3.	5	Authority in all processes (presence, direction, supervision, and agency/organization rules)	Authority in management
	4	Authority in 3 processes	
	3	Authority in 2 processes	
	2	Authority in 1 process	
	1	Does not have authority	
4.	5	All interactions (management plans, collaboration, mutual influence between stakeholders working together, changing management direction)	Interaction with agencies
	4	3 interactions	
	3	2 interactions	
	2	1 interaction	
	1	Does not provide anything	

Table 5

Criteria and indicators of the level of stakeholder interest and influence

Value	*Description*	*Criteria*	*Score*
17-20	Highly dependent/influenced by mangroves	Very high	5
13-16	Dependent/influenced by mangroves	High	4
9-12	Quite dependent/influenced by mangroves	Medium	3
5-8	Less dependent/influenced by mangroves	Quite low	2
1-4	Not dependent/influenced by mangroves management	Low	1

Each quadrant provides different options for increasing stakeholder participation in mangrove management. The options referred to according to Farahisah et al (2020) are as follows:

- quadrant I consists of stakeholders who have high interests in mangrove resources, but low influence in management. This group is considered important, but needs to be empowered;
- quadrant II is the most critical group because it has equally high influence and interests. Stakeholders in this quadrant need to build good and harmonious working relationships to ensure the effectiveness and support of the coalition in resource management. They can also play a role in formulating management policies;
- quadrant III includes stakeholders with low interests and influence over resources. Although not directly involved in management, they are very important in monitoring and evaluation;
- quadrant IV is a group with high influence and low interests. This stakeholder group can make a major contribution or significant disruption to management, so it needs to be empowered so that its influence can support management, both as a facilitator and involvement in decision-making.

Results

Mangrove condition and water quality. The mangrove ecosystem vegetation found in the mangrove area of South Tabulo village consists of 12 species with the frequency of presence and density values of each presented in Tables 6 and 7.

Table 6

Frequency of presence of species and water quality of the mangrove ecosystem of South Tabulo village

No	*Species*	*Presence*		
		Site 1	*Site 2*	*Site 3*
1	*Avicennia alba*	0.57	0.63	0
2	*Avicennia lanata*	0	0.19	0.14
3	*Avicennia officinalis*	0.14	0.13	0
4	*Bruguiera gymnorrhiza*	0.57	0	0.43
5	*Bruguiera parviflora*	0	0	0.86
6	*Ceriops decandra*	0.57	0.31	0.14
7	*Ceriops tagal*	0.43	0.69	0.14
8	*Rhizophora apiculata*	0.43	0.38	0.86
9	*Rhizophora mucronata*	0.14	0.69	0.86
10	*Sonneratia alba*	0.86	0.56	0.43
11	*Sonneratia caseolaris*	0.71	0.25	0.14
12	*Xylocarpus* sp.	0	0	0.43
	Average	0.37	0.32	0.37
	Water quality (mean±st. dev)			
1	pH	7.82±1.06	7.72±0.87	7.87±0.97
2	Temperature (°C)	27.32±0.96	28.31±0.59	28.36±0.55
3	Salinity (ppm)	7.36±2.38	21.78±11.55	30.71±0.95

Table 7

The density of mangrove species in South Tabulo village

No.	Species	Density (ind ha^{-1})		
		Site 1	Site 2	Site 3
1	*Avicennia alba*	1850	650	0
2	*Avicennia lanata*	0	400	100
3	*Avicennia officinalis*	400	100	0
4	*Bruguiera gymnorrhiza*	550	0	1800
5	*Bruguiera parviflora*	0	0	6400
6	*Ceriops decandra*	1450	1700	50
7	*Ceriops tagal*	21000	2400	4250
8	*Rhizophora apiculata*	1200	200	700
9	*Rhizophora mucronata*	1400	100	4600
10	*Sonneratia alba*	2000	2250	250
11	*Sonneratia caseolaris*	2400	5100	100
12	*Xylocarpus* sp.	0	0	700
	Average (ind ha^{-1})	2688	1075	1579

In this study, six of the twelve mangrove species were found at all stations, namely *C. decandra*, *C. tagal*, *R. apiculata*, *R. mucronata*, *S. alba*, and *S. caseolaris*. The presence of the *S. alba* species reached 86% and was found most dominantly at site 1, while *C. tagal* and *R. mucronata*, with a presence of 69%, were most dominant at site 2. The species *B. parviflora*, *R. apiculata*, and *R. mucronata* each had the highest presence of 86% at site 3. The pH and temperature parameters of the three observation stations did not differ much. The highest salinity value at site 3 and the lowest at site 1 were influenced by the distance from seawater, as presented in Figure 1.

Referring to the Decree of the Minister of Environment of the Republic of Indonesia Number 201 of 2024, the average density value of the mangrove condition status of South Tabulo village at all stations is in a good category with moderate to very dense criteria. The best mangrove condition is at the rehabilitation station (site 1) followed by the no human activity station (site 3) and land conversion (site 2).

Diversity and dominance index of mangrove. The diversity index (H') and dominance (D) values of mangrove species are presented in Figure 4.

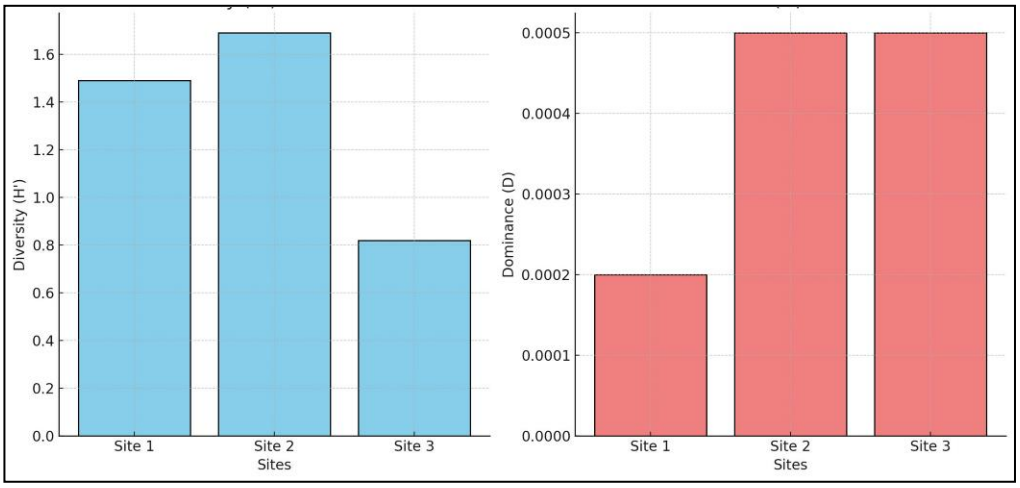

Figure 4. Diversity and dominance indices of mangrove communities among three sites in South Tabulo village.

The highest mangrove diversity index value was recorded at site 2 (H' = 1.69) followed by site 1 (H' = 1.49) and site 3 (H' = 0.82) with low to moderate categories. Based on

the dominance index value, the three sites were in the low category with values of site 1 (D = 0.0002), site 2 (D = 0.0005) and site 3 (D = 0.0005).

Level of interest and influence of stakeholders. The matrix of four stakeholders with a combination of interests and influence on managing the mangrove ecosystem in South Tabulo village is plotted in Figure 5.

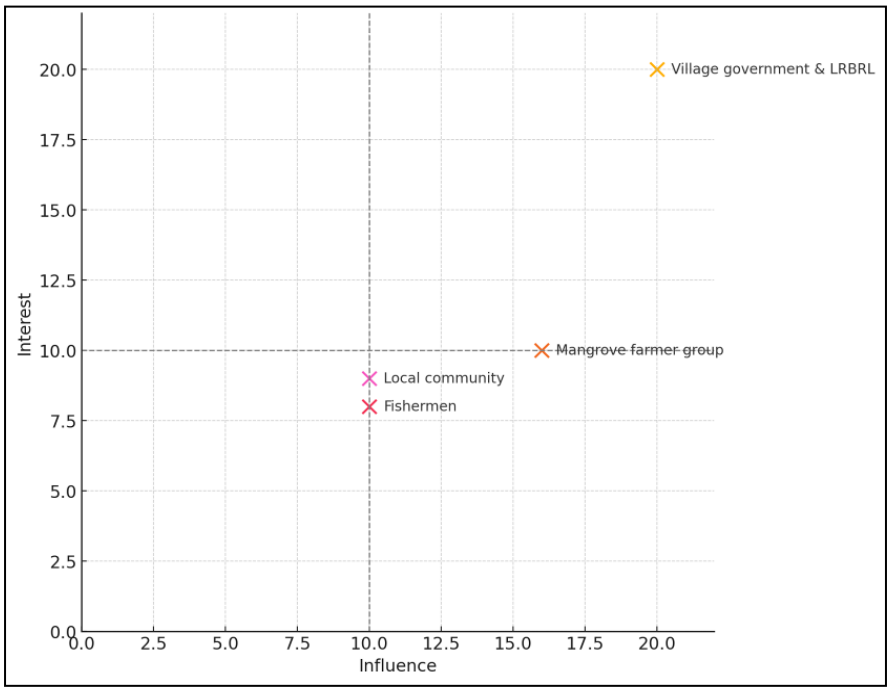

Figure 5. Matrix of analysis of stakeholders' interests and influence for co-management based mangrove ecosystem management in South Tabulo village.

Based on the results of the analysis, the mangrove group (interest value = 10, influence = 16) occupies quadrant I, which means that this party is quite dependent on the ecosystem's existence and influences the management of the mangrove ecosystem. Mangrove managers (Village Government and LRBRL of South Tabulo village) occupy plots in quadrant II (interest = 20, influence = 20), where this party is very dependent and greatly influences the ecosystem and mangrove management, respectively. Fishermen and community groups occupying plots in quadrant III (interest value for fishermen group = 8; interest value for community = 9; influence value for fishermen and community groups = 10) show an interest value of less to quite dependent on the existence of mangroves and quite influential in mangrove management. Quadrant IV, which shows parties with very high influence and low interest, is not filled by any stakeholders.

Discussion. The existence of mangrove ecosystems in South Tabulo village can support people's lives in terms of economics and society. The majority of the population of South Tabulo village are fishermen with moderate to fairly good welfare levels (Fachrussyah et al 2024). Mangroves are a spawning ground, nursery, and protection for various aquatic fauna with high economic value. Training programs for the community on the benefits, planting techniques, and maintenance of mangroves are often held by government agencies, universities, and NGOs (Mile et al 2025).

Mangrove ecosystem. Land conversion at site 2 was balanced by mangrove rehabilitation activities at site 1. Therefore, although there are areas of mangrove land conversion into ponds (Figure 1), mangrove density in South Tabulo village is still in the good category with moderate to very dense individual densities. Variations in the

frequency of presence and density values of mangrove species in this study were influenced by the life characteristics of the species and external factors in the form of human activities. The high density of certain species is caused by the suitability of the substrate and adaptation to the environment. Generally, species that are able to survive on less stable substrates and have high adaptability to less suitable environmental conditions have higher presence values (Sanadi et al 2023). Conversely, large tree roots influence low density, which can inhibit optimal growth (Agustini et al 2016). In addition, human activities such as development and logging in mangrove areas also affect mangrove density (Nanulaitta et al 2019).

The moderate diversity index and low mangrove dominance value in South Tabulo village indicate that community stability is relatively low. According to Bahri et al (2020), ecosystems with stable species distribution will have a higher diversity index, while ecosystems that do not support species development will have a low diversity index. However, species diversity will remain high if the area is managed with a zoning system that allows the use of the area based on needs and purposes. Zones are designed to reduce conflicts between human activities and ecosystem protection to maintain species diversity (Setiarno et al 2020). Competition between species for nutrients and sunlight also affects species differences in a mangrove community (Parmadi et al 2016).

Stakeholder roles. The mangrove ecosystem is a place for breeding, spawning, and raising young for various types of fish, shellfish, crabs, and shrimp (Kariada & Irsadi 2014). Due to the high function of this ecosystem, the protection of the mangrove area is stated in the Regional Regulation of Gorontalo Province Number 7 of 2016 concerning Mangrove Ecosystem Management. Meanwhile, the authority for implementation is carried out by the regional government as stated in Law Number 23 of 2014 concerning Regional Government.

Based on the results of this study, the high level of interest and influence by the management (village government and LRBRL South Tabulo is due to full involvement or participation in the management process. However, the involvement and participation of all stakeholders in the ecosystem management program, including mangrove rehabilitation carried out by the mangrove manager, has not been optimal. The role and responsibility of the South Tabulo village local government as the mangrove manager can be maximized as follows:

- holding a mangrove group discussion forum and coordinating with the government to support the success of mangrove ecosystem management;
- monitoring and mediating various social problems between communities related to the use of mangrove ecosystems;
- as an information channel between the government and the community.

LRBRL, which is also the mangrove manager of South Tabulo village, is expected to optimize its role and responsibilities as follows:

- drafting regulations and policies together with related agencies (Department of Marine Affairs and Fisheries DKP and Ministry of Marine Affairs and Fisheries of the Republic of Indonesia), and coordinating them with the village local government and communities;
- formulating solutions or resolutions to overcome social problems that occur in the community of South Tabulo village;
- drafting and designing guidelines or technical instructions for managing the mangrove ecosystem in South Tabulo village according to regional conditions.

The mangrove group is expected to maximize its roles and responsibilities as follows:

- policy facilitator in monitoring the sustainability of mangrove ecosystems;
- participate and play an active role in the preparation and design of management activities and their implementation;
- act as a critical group that provides suggestions, criticism of mangrove ecosystem data, and information related to management in South Tabulo village.

Fishermen and village communities do not participate in the rehabilitation of the mangrove ecosystem in South Tabulo village and are not directly involved in the

programmed management process. Fishermen and communities as partners are expected to play a role and be responsible:

- actively monitor and maintain the mangrove ecosystem;
- participate in maintaining the environment around the mangrove ecosystem to support the success of sustainable management.

Mapping of co-management concept. One of the serious threats to the existence of the mangrove ecosystem of South Tabulo village is land clearing or illegal logging carried out by local residents for the purposes of private plantation land. Based on the results of the interview, the illegal logging activity has been going on for a long time. The government's lack of supervision in enforcing strict sanctions against perpetrators of illegal logging also has the potential to worsen the situation. Good cooperation between stakeholders in the aspects of planning, rehabilitation implementation, and management is needed as a conservation effort (Martuti et al 2018).

The existence of mangrove forests indirectly provides benefits for physical and bioecological sustainability (Saru 2014). According to Choirunnisa & Gravitiani (2022), the mangrove ecosystem is one of the marine economic sectors that needs to be managed and developed in coastal areas. From a legal perspective, mangrove forest management must be carried out continuously and consistently by involving the government and the community. However, the legal stigma of management in Indonesia still provides very little contribution in terms of supervision or control of mangrove forest management. The participation of coastal communities carried out individually or in groups plays a very important role in sustainable mangrove forest management. An evaluation involving all parties is needed to determine the success of replanting mangrove forests (Lestariningsih et al 2021). This is in accordance with the mandate of Law of the Republic of Indonesia Number 23 of 1997 Article 6 paragraph (1) concerning Environmental Management which reads, "Everyone has the right and obligation to participate in the context of environmental management".

The implementation of the mangrove ecosystem management program in South Tabulo village has involved all stakeholders but has not been optimal and balanced. The village government and LRBRL, as managers and main policymakers, must not ignore the involvement of other stakeholders that have been formed in the planning and preparation of the management concept, including mangrove farmer groups and the community as parties who directly utilize resources. Some respondents admitted that the mangrove ecosystem utilization program in South Tabulo village was not fully understood by them. The program is also not supported by adequate organization to foster local stakeholders in improving their progress, skills, and knowledge. Therefore, partnerships through good and effective coordination between stakeholders are very important to the management program's success.

Co-management or partnership-based management is one solution to prevent sustainable resource management problems. It aims to maintain and improve mangrove ecosystem resources by prioritizing each stakeholder's role, responsibility, and utilization. This partnership involves the government and the community in a balanced manner because the optimal use of the ecosystem is determined by the right form of management (Muqorrobin et al 2013). The implementation of mangrove ecosystem management in South Tabulo village based on co-management based on the results of this study is presented in Table 8.

According to Fadhila et al (2015), sustainable mangrove forest management will be achieved if natural resources' economic value and the environment are considered. Therefore, it is also necessary to consider the calculation of the benefits of the mangrove ecosystem at all observation sites in South Tabulo village. Suhardi et al (2024) stated that ongoing research and conservation initiatives for Indonesia's mangrove ecosystems play a crucial role in ensuring their long-term sustainability while supporting the communities and environments that depend on them. Effective mangrove restoration depends on greater community involvement, capacity building, budgeting, and stakeholder engagement. Government policies on sustainable land use, law enforcement, and institutional frameworks are essential for managing mangroves (Utami et al 2024).

Table 8

Co-management mapping of mangrove ecosystem in South Tabulo village

Criteria	*Existing condition*	*Ideal conditions expected*	*Management strategy*
Preparation of mangrove management plan	The preparation of the management concept is only carried out by the government, while other stakeholders are involved only in decision-making regarding the implementation of the concept and field techniques.	Involve all stakeholders without limiting their areas of responsibility and responsibility.	Conduct initial identification of all stakeholders who are the targets of partnership cooperation in accordance with the co-management concept.
Program implementation	The implementation of the management program is carried out by involving the cooperation of all stakeholders, but is not yet optimal because there are still many limited spaces.	Cooperation between stakeholders must be implemented in a balanced and optimal manner.	Holding comprehensive and open discussions between all stakeholders, and building management agreements taking into account the capabilities and capacities of each party.
Organizing	The organization of mangrove ecosystem management is supportive, because coordination and communication between the government and mangrove groups is running well.	Communication with stakeholders must run well, both bottom-up and top-down. Coordination between stakeholders also needs to take place continuously.	Establish an institution that oversees local stakeholders in South Tabulo village.
Program monitoring and evaluation	Monitoring and evaluation are carried out three times a month, but only involve the heads of stakeholder groups	Supervision and evaluation must involve all stakeholders without exception so that the information obtained is comprehensive and not ordinary.	Establish a meeting forum for all stakeholders to supervise, evaluate and monitor the programs that have been implemented.

Conclusions. The mangrove ecosystem in South Tabulo village, Gorontalo Province, is in good condition, with moderate to very high-density levels. Stakeholders with the highest levels of interest and influence in mangrove ecosystem management include the village government and the South Tabulo Village Seaweed Cultivation Research Center, which serve as the primary management authorities. However, the land conversion program for pond development and the rehabilitation efforts under the sustainable mangrove management initiative have not fully involved mangrove groups, fishermen, and the local community. As a result, the implementation of ecosystem co-management remains suboptimal. The active participation of all stakeholders is crucial in applying the co-management approach, as their involvement in decision-making integrates diverse perspectives, experiences, and interests. This inclusive approach ensures that policies and management practices align with the needs and aspirations of all parties involved, ultimately enhancing the effectiveness and sustainability of the co-management initiative.

Acknowledgements. This research was funded by the Institute for Research and Community Service (LP2M) of Universitas Negeri Gorontalo based on Decree Number

657/UN47/HK.02/2024 and Contract Number B/860/UN47.D1/PT.01.03/2024 through the Faculty's Leading Collaborative Research Scheme. We sincerely thank "Tim Sulit" and Musdalifah Mahua, S.Pi., for technical assistance during the research.

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

References

Abidin Z., Setiawan B., Muhaimin A. W., Shinta A., 2021 The role of coastal biodiversity conservation on sustainability and environmental awareness in mangrove ecosystem of southern Malang, Indonesia. Biodiversitas 22(2):648-658.

Abubakar S., Kepel R. C., Djamaluddin R., Wahidin N., Harahap Z. A., 2024 Mangrove land cover classification using unmanned aerial vehicles in Jailolo Bay, West Halmahera, Indonesia. AACL Bioflux 17(1):133-141.

Abudi M. K., Hamzah S. N., Kasim F., 2022 [Co-management mangrove ecosystem in the Langge Village, Anggrek District, North Gorontalo Regency]. Acta Aquatica: Aquatic Sciences Journal 9(2):76-87. [in Indonesian]

Agustini N., Ta'alidin Z., Purnama D., 2016 [Mangrove community structure in Kahyapu village, Enggano Island]. Jurnal Enggano 1(1):19-31. [in Indonesian]

Analuddin K., Armid A., Ruslin R., Sharma S., Kadidae L. O., Haya L. O. M. Y., Septiana A., Rahim S., McKenzie R. A., La Fua J., 2023 The carrying capacity of estuarine mangroves in maintaining the coastal urban environmental health of Southeast Sulawesi, Indonesia. Egyptian Journal of Aquatic Research 49(3):327-338.

Bahri S., Kurnia T. I. D., Ardiyansyah F., 2020 [Diversity of bivalve classes in the mangrove forest of Bama Beach, Baluran National Park]. Jurnal Biosense 3(1):56-70. [in Indonesian]

Bengen D. G., 2001 [Coastal ecosystems and natural resources. Center for Coastal and Marine Resources Studies]. Pusat Kajian Sumberdaya Pesisir dan Lautan Institut Pertanian Bogor, Bogor, 62 pp. [in Indonesian]

Choirunnisa L. A. D., Gravitiani E., 2022 [Application of benefit transfer in coastal mangrove ecosystem management of Pacitan Regency based on circular economy]. Jurnal Kebijakan Sosial Ekonomi Kelautan dan Perikanan 12(1):65-77. [in Indonesian]

Decree of the Minister of Environment of the Republic of Indonesia Number 201 of 2024.

Dalimunthe S. A., 2018 Who manages space? Eco-DRR and the local community. Sustainability 10(6):1705.

Damastuti E., de Groot R., 2019 Participatory ecosystem service mapping to enhance community-based mangrove rehabilitation and management in Demak, Indonesia. Regional Environmental Change 19(1):65-78.

Damastuti E., de Groot R., Debrot A. O., Silvius M. J., 2022 Effectiveness of community-based mangrove management for biodiversity conservation: a case study from Central Java, Indonesia. Trees, Forests and People 7:100202.

English S., Wilkinson C. Baker V., 1994 Survey manual for tropical marine resource. Autralian Institute of Marin Science, Townsville, 368 pp.

Fachrussyah Z. C., Mahmud F., Pasisingi N., 2024 Welfare of the fishermen community of South Tabulo village, Mananggu District, Boalemo Regency, Gorontalo. Jurnal Perikanan Unram 14(3):1380-1392.

Fadhila H., Saputra S. W., Wijayanto D., 2015 [Economic valuation of mangrove ecosystem in Kartika Jaya village, Patebon Subdistrict, Kendal Regency, Central Java]. Diponegoro Journal of Maquares. Management of Aquatic Resources 4(3): 180-187. [in Indonesian]

Farahisah H., Yulianda F., Effendi H., 2020 [Management of mangrove ecosystems in the Musi River estuary as an effort to mitigate carbon emissions]. Jurnal Pengelolaan Lingkungan Berkelanjutan (Journal of Environmental Sustainability Management) 4(3):565-575. [in Indonesian]

Firdaus M., Hatanaka K., Saville R., 2021 Mangrove forest restoration by fisheries communities in Lampung Bay: a study based on perceptions, willingness to pay, and management strategy. Forest and Society 5(2):224-244.
Fuady M., Buraida Kevin M. A., Farrel M. R., Triaputri A., 2025 Mangrove forest conservation for disaster mitigation and community welfare in Banda Aceh: a sustainable development goals (SDG's) approach. Journal of Lifestyle and SDGs Review 5(3):e04787.
Gómez-Ruiz P. A., Betancourth-Buitrago R. A., Arteaga-Cote M., Carbajal-Borges J. P., Teutli-Hernández C., Laffon-Leal S., 2022 Fostering a participatory process for ecological restoration of mangroves in Pantanos de Centla Biosphere Reserve (Tabasco, Mexico). Ecosystems and People 18(1):112-118.
Himes-Cornell A., Grose S. O., Pendleton L., 2018 Mangrove ecosystem service values and methodological approaches to valuation: where do we stand? Frontiers in Marine Science 5:376.
Kariada N. T. M., Irsadi A., 2014 [Role of mangrove as water pollution biofilter in milkfish pond, Tapak, Semarang]. Jurnal Manusia dan Lingkungan 21(2):188-194. [in Indonesian]
Karpowicz D. A., Mohan M., Watt M. S., Montenegro J. F., King S. A. L., Selvam P. P., Nithyanandan M., Robyn B., Ali T., Abdullah M. M., Doaemo W., Ewane E. B., 2024 Mangrove-based carbon market projects: 15 considerations for engaging and supporting local communities. Diversity 16(9):574.
Katili A. S., Utina R., Tamu Y., Nusantari E., 2018 Management of coastal biodiversity based on social-cultural values in constructing conservation character education. Biodiversitas 19(5):1763-1768.
Ke G. N., Utama I. K. A. P., Wagner T., Sweetman A. K., Arshad A., Nath T. K., Neoh J. Y., Muchamad L. S., Suroso D. S. A., 2022 Influence of mangrove forests on subjective and psychological wellbeing of coastal communities: case studies in Malaysia and Indonesia. Frontiers in Public Health 10:898276.
Lasoma R. M., 2023 [Co-management based mangrove ecosystem management in Dulangeya Village, Botumoito District, Boalemo Regency, Gorontalo Province]. MSc thesis, Magister Manajemen Sumberdaya Perairan Fakultas Perikanan dan Ilmu Kelautan, Universitas Diponegoro Semarang, 68 pp. [in Indonesian]
Latuconsina H., Nessa M. N., Rappe R. A., 2012 [The composition of species and structure of seagrass fish community in Tanjung Tiram – Inner Ambon Bay]. Jurnal Ilmu dan Teknologi Kelautan Tropis 4(1):35-46. [in Indonesian]
Law of The Republic of Indonesia Number 23 of 1997 concerning Environmental Management, 25 pp. Available at: https://peraturan.bpk.go.id/Details/46018. Accessed: November, 2024. [in Indonesian]
Law of The Republic of Indonesia Number 23 of 2014 concerning Regional Government, 147 pp. Available at: https://peraturan.bpk.go.id/Details/38685/uu-no-23-tahun-2014. Accessed: November, 2024. [in Indonesian]
Lestariningsih S. P., Widiyastuti T., Dewantara J. A., 2021 [The level of community participation in mangrove forest rehabilitation in Mempawah Hilir sub-district, Mempawah district]. NATURALIS - Jurnal Penelitian Pengelolaan Sumber Daya Alam dan Lingkungan 10(1):1-12. [in Indonesian]
Lintong O., Kepel R. C., Djamaluddin R., Lagarense B. L., Ngangi E. L. A., Pangemanan N. P. L., Montolalu R. I., Mantiri D. M. H., Lumingas L. J. L., 2023 Community structure of mangroves in Minahasa Peninsula, North Sulawesi, Indonesia. AACL Bioflux 16(3):1390-1400.
Martuti N. K. T., Susilowati S. M. E., Sidiq W. A. B. N., Mutiatari D. P., 2018 [The role of community groups in the rehabilitation of mangrove ecosystems on the coast of Semarang City]. Jurnal Wilayah dan Lingkungan 6(2):100-114. [in Indonesian]
Mile L., Pasisingi N., Koniyo Y., Hamzah S. N., Sulistijowati R., Naiu A. S., Harmain R. M., 2025 [Mangrove planting as an effort to conserve the mangrove ecosystem in South Tabulo village, Boalemo Regency]. Jurnal Dinamika Pengabdian 10(2):242-252. [in Indonesian]

Muqorrobin A., Yulianda F., Kodiran T., 2013 [Co-management mangrove ecosystem in the Pasarbanggi village, Rembang District, Central Java]. Bonorowo Wetlands 3(2): 114-131. [in Indonesian]
Nanulaitta E. M., Tulalessy A. H., Wakano D., 2019 [Analysis of mangrove's rapidity as one of the ecotourism indicators in the Alariano beach waters of Amahai Sub-District, Maluku Central District]. Jurnal Hutan Pulau-Pulau Kecil 3(2):217-226. [in Indonesian]
Noor Y. R., Khazali M., Suryadiputra I. N. N., 1999 [Mangrove introduction guide in Indonesia]. PHKA/WI-IP, Bogor, 220 pp. [in Indonesian]
Odum E. P., 1983 Basic ecology. Saunders College Publishing, Philadelphia, 320 pp.
Odum E. P., 1993 [Fundamentals of ecology]. 3rd edition. Translator: Tjahyono Samingan, Gadjah Mada University Press, Yogyakarta, 697 pp. [in Indonesian]
Oktorini Y., Darlis V. V., Fatmawati R., Miswadi, Khaidir, Rahmatdillah, Prianto E., Jhonnerie R., 2024 Mapping and sustainable management of mangrove ecosystem in Buruk Bakul village, Indonesia: integrating high-resolution imagery, spatial analysis, and policy recommendations. AACL Bioflux 17(6):2828-2836.
Parmadi E. H., Dewiyanti I., Karina S., 2016 [The importance value index of mangrove vegetation in the Kuala Idi area, East Aceh Regency]. Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah 1(1):82-95. [in Indonesian]
Rahim A., Soeprobowati T. R., Putranto T. T., 2023 Assessment of mangrove biodiversity and community structure as a basis for sustainable conservation and management plan in Tambakbulusan, Demak, Central Java. AACL Bioflux 16(2):753-767.
Regional Regulation of Gorontalo Province Number 7 of 2016 concerning Mangrove Ecosystem Management, 36 pp. Available at: https://peraturan.bpk.go.id/Details/14239. Accessed: December, 2024. [in Indonesian]
Rizal A., Sachoemar S. I., Aliah R. S., Haryanti, Susanto J. P., Muhami, Sukmadi I., 2023 Sustainable management of coastal resources in Mentawai Islands District, West Sumatra Province, Indonesia. GeoJournal of Tourism and Geosites 46(1):285-292.
Rumahorbo B. T., Keiluhu H. J., Hamuna B., 2019 The economic valuation of mangrove ecosystem in Youtefa Bay, Jayapura, Indonesia. Ecological Questions 30(1):47-54.
Rumahorbo B. T., Hamuna B., Keiluhu H. J., 2020 An assessment of the coastal ecosystem services of Jayapura City, Papua Province, Indonesia. Environmental and Socio-Economic Studies 8(2):45-53.
Sahputra E., Harahap R. H., Wahyuningsih H., Utomo B., 2022 Assessing the sustainability status of mangrove forest ecosystem management by coastal community in Jaring Halus village, North Sumatra, Indonesia. Biodiversitas 23(1):1-9.
Sanadi S., Tampubolon N., Widiastuti N., Simatauw F. F. C., Bato M., Duwit B., 2023 [Analysis of mangrove vegetation in Bonkawir village, Waisai city, Raja Ampat Regency]. Jurnal Sumberdaya Akuatik Indopasifik 7(2):201-214. [in Indonesian]
Saru A., 2014 [Ecological potential and management of mangrove ecosystems in coastal areas]. Institut Pertanian Bogor Press, Bogor, 185 pp. [in Indonesian]
Setiarno, Hidayat N., Bambang T. A., Luthfi M. S., 2020 [Composition, structure and plants diversity in nature reserves of Bukit Tangkiling]. Jurnal Hutan Tropika 15(2): 150-162. [in Indonesian]
Suardana A. A. M. A. P., Anggraini N., Nandika M. R., Aziz K., As-Syakur A. R., Ulfa A., Wijaya A. D., Prasetio W., Winarso G., Dimyati R. D., 2023 Estimation and mapping above-ground mangrove carbon stock using Sentinel-2 data derived vegetation indices in Benoa Bay of Bali Province, Indonesia. Forest and Society 7(1):116-134.
Sugiyono, 2017 [Quantitative, qualitative and R&D research methods]. Alfabeta, Bandung, 334 pp. [in Indonesian]
Suhardi R. M., Rahardi W., Shih H. C., Mantiquilla J. A., Wu Y. H., Shiao M. S., Chiang Y. C., 2024 A review of the mangrove ecosystem in Indonesia: biodiversity, conservation, and challenges in sustainable management. Ecological Genetics and Genomics 32:100282.

Sumarmi S., Purwanto P., Bachri S., 2021 Spatial analysis of mangrove forest management to reduce air temperature and CO_2 emissions. Sustainability 13(14): 8090
Susilo H., Takahashi Y., Sato G., Nomura H., Yabe M., 2018 The adoption of silvofishery system to restore mangrove ecosystems and its impact on farmers' income in Mahakam Delta, Indonesia. Journal of the Faculty of Agriculture, Kyushu University 63(2):433-442.
Utami W., Sugiyanto C., Rahardjo N., 2024 Mangrove area degradation and management strategies in Indonesia: a review. Journal of Degraded and Mining Lands Management 11(3):6037-6047.
van Oudenhoven A. P. E., Siahainenia A. J., Sualia I., Tonneijck F. H., van der Ploeg S., de Groot R. S., Alkemade J. R. M., Leemans R., 2015 Effects of different management regimes on mangrove ecosystem services in Java, Indonesia. Ocean and Coastal Management 116:353-367.
Valenzuela R. B., Yeo-Chang Y., Park M. S., Chun J. N., 2020 Local people's participation in mangrove restoration projects and impacts on social capital and livelihood: a case study in the Philippines. Forests 11(5):580.
Wardhani M. K., Rosyid D. M., Armono H. D., 2022 Land use change of mangrove forest for eco-tourism in the south coastal, Bangkalan, East Java-Indonesia. International Journal of GEOMATE 23(98):136-146.
Yamindago R. I. A., 2015 Restoring coastal ecosystems - a case study Malang and Gresik Regency, Indonesia. Journal of Coastal Conservation 19(2):119-130.

Received: 10 February 2025. Accepted: 07 March 2025. Published online: 10 May 2025.
Authors:
Lukman Mile, Fisheries Technology Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, Jendral SudirmanStreet, No. 6, 96128, Gorontalo City, Indonesia, e-mail: lukmanmile@ung.ac.id
Nuralim Pasisingi, Aquatic Resources Management Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, Jendral Sudirman Street, No. 6, 96128, Gorontalo City, Indonesia, e-mail: nuralim@ung.ac.id
Yuniarti Koniyo, Aquaculture Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, Jendral Sudirman Street, No. 6, 96128, Gorontalo City, Indonesia, e-mail: yuniarti.koniyo@ung.ac.id
Sri Nuryatin Hamzah, Marine Science Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, Jendral Sudirman Street, No. 6, 96128, Gorontalo City, Indonesia, e-mail: sri.nuryatin@ung.ac.id
Rieny Sulistijowati, Fisheries Technology Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, Jendral SudirmanStreet, No. 6, 96128, Gorontalo City, Indonesia, e-mail: rienysulistijowati@ung.ac.id
Asri Silvana Naiu, Fisheries Technology Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, Jendral SudirmanStreet, No. 6, 96128, Gorontalo City, Indonesia, e-mail: asri.silvana@ung.ac.id
Juliana, Aquaculture Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, Jendral Sudirman Street, No. 6, 96128, Gorontalo City, Indonesia, e-mail: juliana@ung.ac.id
Rita Marsuci Harmain, Marine Science Study Programme, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, Jendral Sudirman Street, No. 6, 96128, Gorontalo City, Indonesia, e-mail: ritamarsuci@ung.ac.id

How to cite this article:
Mile L., Pasisingi N., Koniyo Y., Hamzah S. N., Sulistijowati R., Naiu A. S., Juliana, Harmain R. M., 2025 Co-management strategies for mangrove ecosystem in South Tabulo village, Boalemo Regency, Indonesia. AACL Bioflux 18(3):1119-1134.