Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(1): 2463 – 2481 (2025)
www.ejabf.journals.ekb.eg

The Mangrove Crab (*Scylla* spp.) Sustainability Status in Sidangoli Waters, West Halmahera Regency-North Maluku Province, Indonesia

Rugaya Serosero[1]*, Riyadi Subur[1], Faizal Rumagia[2]

[1]Study Program of Aquatic Resource Management, Faculty of Fisheries and Marine, Khairun University, Jl. Jusuf Abdurrahman, Gambesi, Ternate 97719, North Maluku, Indonesia
2Study Program of Fisheries Resource Utilization, Faculty of Fisheries and Marine, Khairun University, Jl. Jusuf Abdurrahman, Gambesi, Ternate 97719 Ternate, North Maluku, Indonesia
*Corresponding Author: rugayaserosero@gmail.com

ARTICLE INFO

Article History:
Received: Dec. 31, 2023
Accepted: Jan. 28, 2025
Online: Feb. 22, 2025

Keywords:
Management,
Mud crab,
Scylla,
Sustainability,
Utilization

ABSTRACT

The current study objective was to determine the mud crabs' level of sustainability in the Sidangoli mangrove habitat in North Maluku's West Halmahera Regency. From March to June 2022, this study was carried out in the Sidangoli seas of the North Maluku province of West Halmahera. Survey and interview procedures were employed. Ecological dimensions, biological dimensions, economic dimensions, social dimensions, and institutional dimensions were all measured. Direct sampling from fishermen's and collectors' catches yields ecological and biological dimensions. Utilizing interviewing techniques and a questionnaire, information on the social, economic, and institutional elements was also collected. The mangrove crabs were divided into groups according to species, sex, and carapace measured width. Moreover, gonad development was observed. Mud crab data analysis included sex ratio, size distribution and gonad maturity stage. Mud crab sustainability management status was evaluated using the Rapid Appraisal for Fisheries RAPFISH method. The results of the analysis found that the size distribution of the carapace width of the male mud crab was 4.38-9.12mm and that of the female was 3.39-8.85mm. The percentage of mature mud crabs was 53%. The multidimensional status of the sustainability of mud crab management in Sidangoli is quite sustainable with an index value of 58.97%.

INTRODUCTION

One fishery resource that relies on mangrove forests for habitat is mud crab. Mangrove forests serve a variety of complex purposes for people, aquatic life, and the environment. As a habitat for a variety of aquatic and terrestrial creatures, mangrove forests contribute to Indonesia's high biodiversity levels. According to **Fawwaz *et al.* (2019)** and **Jacobs *et al.* (2019)**, mangrove ecosystems serve as habitat for fish, crabs, shrimp, and shellfish as well as locations for aquatic species to reproduce, care for young, and forage **(Hilmi *et al.*, 2017; Redjeki *et al.*, 2020; Ismail *et al.*, 2021)**. Strong winds, beach erosion, tsunamis, and pollutant filters are all prevented by mangrove trees, which

act as coastal defenses **(Garcia *et al.*, 2014; Khakhim *et al.*, 2021)**. Mangrove ecosystems also protect coastal areas from climatic and coastal geological disasters **(Marois & Mitsch, 2015; Hilmi *et al.*, 2017; Sánchez-Núñez *et al.*, 2019)**, and can defend against saltwater intrusion and secure fresh water supplies for coastal communities. In terms of climate change issues, mangroves are considered a blue carbon ecosystem that has the ability to absorb greenhouse gases effectively, store carbon, and control the effects of global warming **(Murdiyarso *et al.*, 2015; Barbier, 2016; Inoue, 2019; Alongi, 2020)**. The existence of mangrove forests must be preserved to counteract carbon emissions and climate change **(Hatta *et al.*, 2022)**.

Mud crab *Scylla serrata*, *Scylla paramamosain*, *Scylla olivacea* and *Scylla tranquebarica* are one of Indonesia's commercial fishery commodities **(Yusuf *et al.*, 2016)** and are well known in Southeast Asia **(Petersen *et al.*, 2013; Hungria *et al.*, 2017; Fawwaz *et al.*, 2019)** and throughout the tropical and subtropical zones of the Pacific and Indian Oceans **(Dan & Hamasaki, 2014; Mirera & Mos, 2014)**. This mangrove crab is widely exploited by coastal communities because of its high price and delicious and tasty meat **(Islam *et al.*, 2015)**. This mud crab type of *Scylla* is in great demand as a quality food ingredient because of its size, nutritional content, and tenderness **(Azra & Ikhwanuddin, 2016)**.

The Sidangoli mangrove habitat contains a large number of small yet highly productive mangrove islands. The people of Sidangoli employ mangrove crabs extensively, and they sell their catch either directly to the market or to collectors. At collectors, the cost per kilogram ranges from Rp 100,000 to Rp 150,000. Exploitation keeps happening as a result of the high selling price.

The community makes significant efforts to employ mangrove crabs because of the high value of their advantages. In order to assess the state of the mud crab population in its natural environment, management activity is required. Evaluating the sustainability of the mangrove crab resource is one of the first management steps. There hasn't been any prior study that revealed the sustainability status of this in Sidangoli and its surroundings, hence this research is very important to reveal the existing condition of mud crabs in the mangrove forest ecosystem as initial data for determining mangrove crab resource management policies. The sustainability of mangrove crab resources in their natural habitat needs to be maintained by knowing their status in the mangrove forest ecosystem based on various aspects such as ecology, biology, economy, social and institutions. The aim of this research was to reveal the status of mud crabs in the Sidangoli mangrove ecosystem, West Halmahera Regency, North Maluku.

MATERIALS AND METHODS

The research was conducted on Sidangoli waters, North Maluku Province (Fig. 1), from March to September 2022.

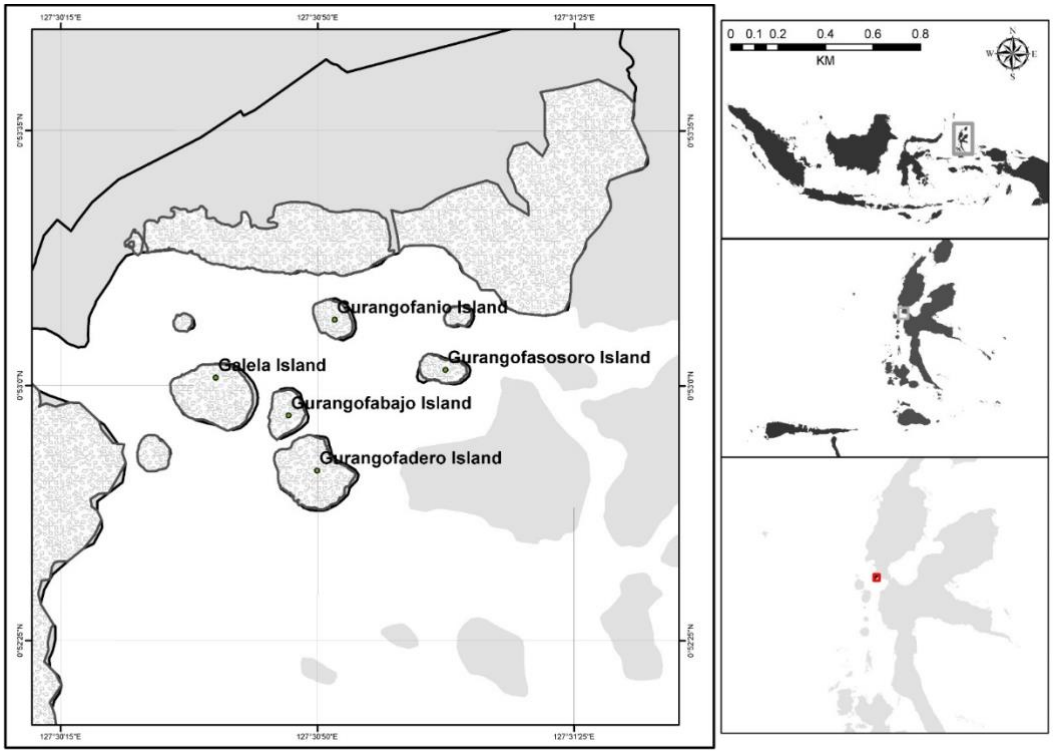

Fig. 1. Map of the study area

Samples of mud crab were gathered from gatherers. On the islands of Gumele, Mardula, Tudoku, Dowongirotu, and Balao, fishing was practiced. By looking at five factors, including the ecological, biological, economic, social, and institutional components, it was possible to assess the sustainability status of mud crabs. Every dimension under analysis had seven attributes.

Data on ecological dimensions, including mangrove density, water quality, area of mangroves, area increase, type of land use, species of mangroves, and mangrove thickness, were collected through direct surveys at research sites. Information about the rise in the area of mangroves and types of land use were also obtained by interview techniques using a questionnaire. Data on the biological dimension were obtained from the catches of fishermen who were sold to collectors. Collected mangrove crabs were separated by sex, counted, identified, measured carapace width, observed gonad development and determined the proportion of crabs that had not spawned.

Data on the social, economic and institutional dimensions were obtained through structured interviews with each of the ten respondents who are competent in their fields. The target respondents for the economic and social dimensions were mangrove crab fishermen, while the institutional dimension was the village government and related agencies (Marine and Fisheries Service and fisheries extension officers). The fishermen who were the respondents had ages that varied from 18-60 years.

The modified Rapid Appraisal for Fisheries (RAPFISH) program was used in this study's multi-dimensional scaling (MDS) methodology to manage and assess the

sustainability of the mangrove crab fisheries. According to **Pitcher *et al.* (2013)**, RAPFISH is a quick assessment method created to facilitate multidisciplinary, objective parameter analysis and evaluation. On the basis of **Schaduw (2015)**'s recommendations, improvements were made to the stages of the sustainable mangrove crab analysis utilizing the RAPFISH approach.

(1) Identifying and determining the system attributes under consideration each of the seven attributes in this study was combined with one of five dimensions, including ecological, biological, social, economic, and institutional (Table 1).

Table 1. Dimensions and attributes of mud crab management

Dimension	Attribute
Ecology	(1) mangrove density (2) water quality (3) mangrove area (4) mangrove area increase (5) land use type (6) mangrove type (7) mangrove thickness
Biology	(1) reproductive development of mud crabs (2) recruitment (3) types of mud crabs (4) size of mud crabs caught (5) number of catches each month (6) sex (7) proportion of crabs that have not spawned
Economy	(1) community income from mud crab fishing, (2) income other than mud crab fishing, (3) government budget for mangrove crab management, (4) mud crab cultivation business opportunities, (5) family profits from mud crab utilization, (6) fishing costs, (7) selling price of mangrove crabs
Social	(1) conflicts over the use of mud crabs, (2) the social impact of mud crabs on the community, (3) level of education, (4) community participation in mangrove crab management, (5) community participation in mangrove forest management, (6) community understanding about the benefits of mangrove crabs, (7) public understanding of the benefits of mangrove forests
Institutional	(1) law enforcement on the use of mud crabs, (2) local government commitment in mangrove crab management, (3) management program integration, (4) existence of marine fisheries extension officers, (5) involvement of community institutions, (6) availability of formal regulations for crab management mangroves, (7) availability of formal regulations for mangrove forest management

(2) Evaluation and grading: Each attribute's scoring was examined from multiple angles. Each dimension was scored using a Likert scale (0, 1, 2) based on the indicator

value, with a maximum score of 2 for favorable conditions, a minimum score of 0 for unfavorable situations, and a maximum score of 1 for moderate conditions.

(3) Determining the sustainability status based on categories and index values in accordance with **Kavanagh and Pitcher (2004)** guidelines. A poor scale of 0 to 100% was used to indicate the predicted score for each dimension (Table 2).

Table 2. Sustainability index categories for each dimension studied

Number	Index value	Category
1	0.00 – 25.00	Not sustainable
2	25.01– 50.00	Less sustainable
3	50.01– 75.00	Sufficiently sustainable
4	75.01– 100.00	Sustainable

(4) The stage of ordination: To locate the good and bad spots, the ordinate stages were subjected to an MDS analysis.

(5) Make use of analyses: Utilizing leverage analysis, it is possible to identify the mud crab resource management factor that is most susceptible to change. Changes in Root Mean Square indicate how each attribute has an impact (RMS).

(6) The Monte Carlo method is a technique for statistical simulation that assesses how errors affect statistical processes. The ordinate point is the point that this study evaluates.

RESULTS AND DISCUSSION

1. Ecological dimension sustainability status

The ecological dimension's analysis of the sustainability index was 49.56%, placing it in the less sustainable category. Fig. (2) shows the ordinate graph of the ecological dimension's sustainability.

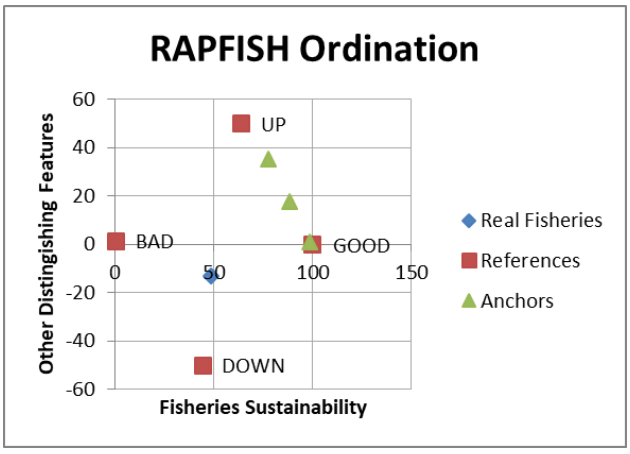

Fig. 2. Sustainability of mangrove crabs as measured by ecological dimensions

The sustainability value indicates that the mangrove crab resources will be less sustainable if the management of mud crabs in Sidangoli seas was continued under the same patterns and circumstances as they are now. Three attributes become leverage factors based on the leverage analysis, which is expressed as the root mean square (RMS) value of the seven attributes evaluated in this study. This is because their changes are sensitive to the ecological context dimension of the sustainability index value. The three attributes were mangrove area (5.25%), land use type (4.96%) and mangrove type (6.63%) (Fig. 3).

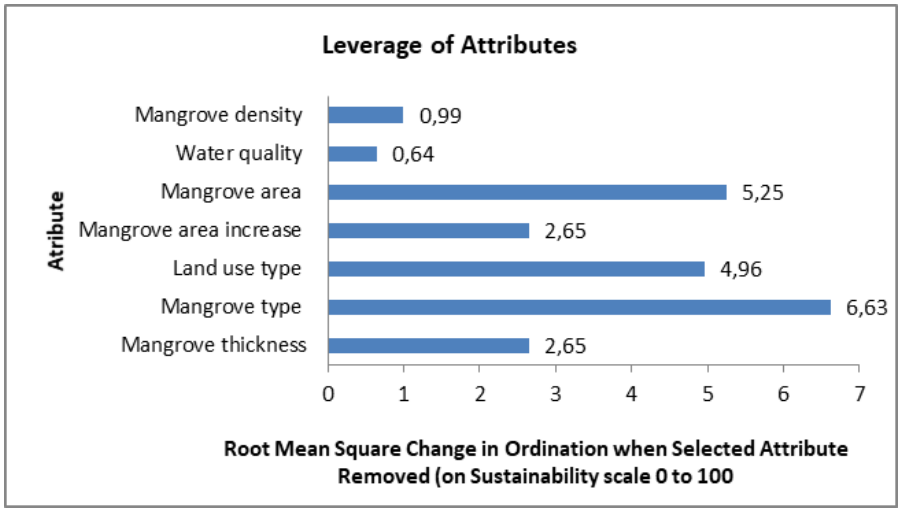

Fig. 2. The results of the analysis of the ecological dimensions of leverage

According to observations made in the field, the mangrove area in Sidangoli Village serves as a habitat for mud crabs and is home to a variety of animals, including fish (*Caranx melampygus*, *Lutjanus variegatus*), crustaceans from the shrimp (*Penaeus monodon*), crabs (*Scylla serrata* and *Scylla paramamosain*), and molluscs from the gastropod class (*Littorina scabra*, *Telescopium telescopium*, *Tectus fenestratus*, *Terebralia sulcata*). According to **Garcia *et al.* (2014)**, mangroves serve as a habitat for a variety of animals, including fish, crabs, primates, reptiles, and birds. **Asri *et al.* (2020)** stated that mangrove habitats have a mix of aquatic, terrestrial, and transitional species. Mangrove trees are home to the majority of land animals, while aquatic and transitional species are found in stems, roots, and the water column. **Sari *et al.* (2022)** found six species of birds, namely sea eagles (*Sula lencogastes*), little egrets (*Egretta garzetta*), striated storks (*Butorides striata*), white-winged pigeons (*Chlidonias leucopterus*), terns (*Sterna hirundo*) and *Gigis alba*) in Youtefa Bay, Papua. **Azlad *et al.* (2015)** found insects, birds, bats, monkeys, langurs, mangrove cats, snakes and at low tide occupying the top of mangrove trees.

The composition of the mangrove species in the fishing location consisted of 3 families (Rhizophoraceae, avicenniaceae, sonneratiaceae) with 5 mangrove species (*Rhizophora apiculata*, *Rhizophora stilosa*, *Bruguera gymnorhiza*, *Sonneratia alba*,

Avecennia alba). The diversity of mangrove species can be a natural habitat for mangrove crabs. **Malik *et al.* (2019)** found seven types of mangroves namely *Avicennia marina*, *Bruguiera gymnorrhiza*, *Rhizophora mucronata*, *Rhizophora stylosa*, *Sonneratia alba*, *Sonneratia caseolaris*, and *Xylocarpus granatum* in West Sulawesi.

At the fishing area, the mangrove environment spans 2 to 7 acres. It goes without saying that this size cannot be extended further, but it can be preserved so that it does not contract as a result of the conversion of mangrove forests into firewood, residential land, house support poles, and bridge piers. There hasn't been any agriculture activity on the mangrove land at any of the fishing spots or the nearby waters. In the Sidangoli mangrove area, the lever factor of different land use types needs to be preserved. Currently, only fishing, harvesting of crabs, shrimp, and shellfish are done on the mangrove land. Mud crabs will continue to exist if this situation is maintained because their natural habitat supports reproduction. Settlements around mangrove forests tend to increase in line with the increase in population in that location. This will certainly have an impact on increasing ecological pressure in the mangrove area because it is located close to residential areas and various other economic activities. This will certainly have an impact on increasing ecological pressure in the mangrove area because it is located close to residential areas and various other economic activities.

Even though land use in the area tends to be low, if it is not controlled through the implementation of appropriate policies by the relevant agencies, it will have an impact on excessive pressure on the existence of the mangrove forest. **Ngongolo *et al.* (2015)** stated that mangrove restoration through protection is an effort to maintain the condition of the existing ecosystem so that more is not lost. Transfer of functions of mangrove forests for various purposes (cultivation, timber harvesting, agriculture, settlement) is an activity that causes damage to mangrove forests **(Giri *et al.*, 2015; Richards & Friess, 2016; Thomas *et al.*, 2017; Romanach *et al.*, 2018; Bryan-Brown, 2020)**. Decreasing the quality of mangrove areas has an impact on reducing ecological capabilities and affecting changes in socio-economic behavior **(Malik *et al.*, 2017)**.

2. Status of biological dimension sustainability

The biological dimension's sustainability index analysis score is 48.78%. This index falls under the less sustainable group according to the sustainability standards. Mud crab management that follows the same procedures and guidelines as it does currently will make Sidangoli's mud crab resources less viable to preserve.

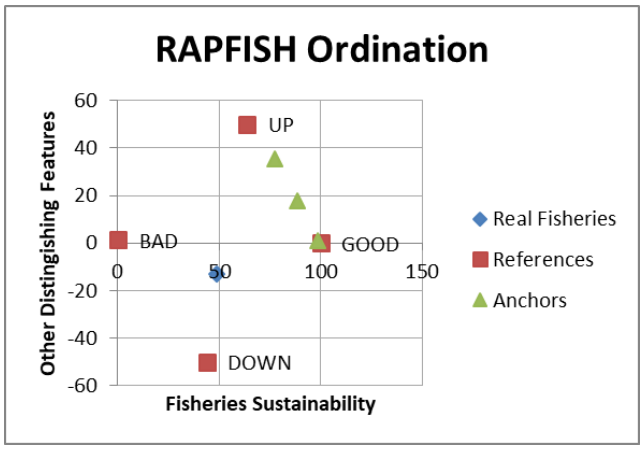

Fig. 4. The sustainability ordination chart for the biological dimension

Three variables mud crab size (4.20%), mangrove crab reproductive development (4.90%), and sex (4.90%) are a lever factor in this biological dimension based on the root mean square value of the seven attributes evaluated in this study (Fig. 5)

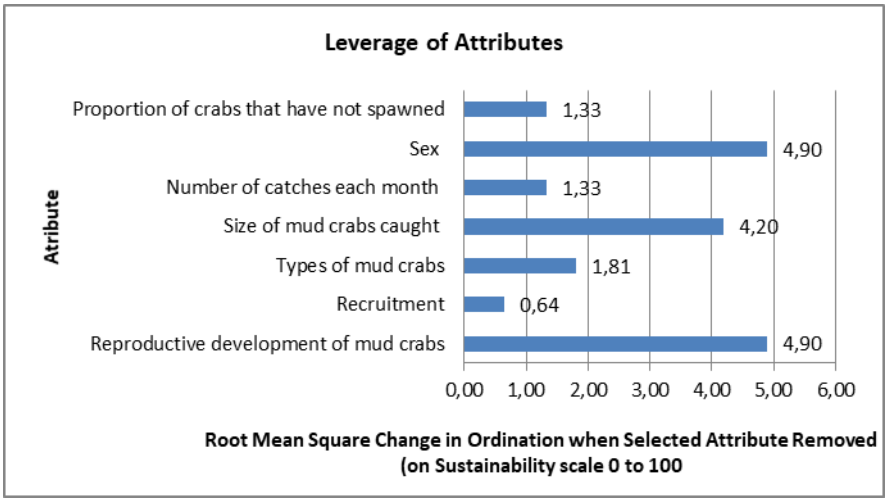

Fig. 5. The outcomes of the biological dimension's leverage analysis

The amount of the crabs caught were on average categorized as crabs that were worth catching although some crabs were still small, namely 3.39-8.85mm (females) and 4.38-9.12mm (males). **Tetelepta *et al.* (2018)** found mangrove crabs with larger sizes, namely males with a carapace width of 8.8-17.8cm and 9.8-17.2cm in female crabs in Katonia Bay, West Seram. Mud crabs caught at the study site were dominated by male mud crabs with a ratio of 1 : 0.52. Some research results also found this unbalanced ratio and was dominated by male crabs, such as **Viswanathan *et al.* (2019)** found a ratio of 1 : 0.87 and **Paul *et al.* (2021)** with a ratio of 1 : 0.96. Male mangrove crabs were more

dominantly caught because they have more active movement activity than female crabs. **Sunarti *et al.* (2016)** found that the activity of male crabs and the physiological mechanisms of organ performance are more active than that of the females. Although in management it is recommended not to catch female crabs that are mature or have spawned at least once in their life cycle, balance in catch also needs to be a concern. Catching a large number of male crabs in a fishing period can also affect the balance of the population. There will be a shortage of adult male crabs to fertilize female mangrove crabs.

Mud crabs from the surveyed catches were in various reproductive developments. The average catch of female crabs is at gonad maturity stage I (12%), gonad maturity stage II (35%), gonad maturity stage III (30%), gonad maturity stage IV (23%). The proportion of gonadal immature crabs was 47% and gonadal mature (53%). Mud crabs obtained from collectors on average have a large size (male and female) because they have a high selling price. Thus, to maintain the sustainability of mangrove crab resources, it is necessary to monitor the size, sex of the crabs caught and the development of their sex ratio. Thus, comprehensive management of the biological aspects is needed so that the availability of resources is maintained.

3. Sustainability of economic dimension

It is under the less sustainable category because the analysis of the sustainability index on the economic dimension is 41.85%. Fig. (6) shows the coordination chart for the sustainability's economic component.

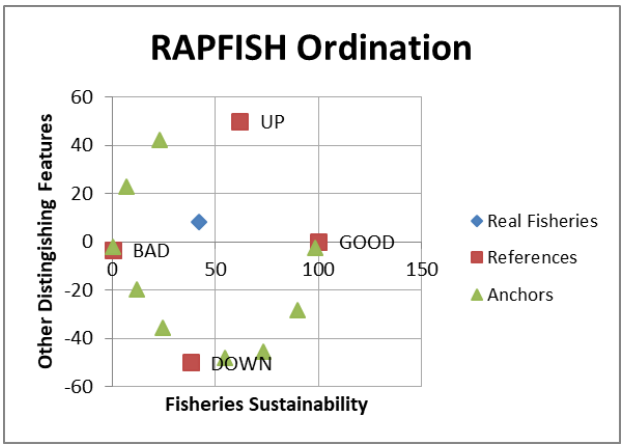

Fig. 6. Ordination of the economic components of mud crab sustainability

According to the leverage analysis (Fig. 7), there are three attributes that are unfavorable or in poor condition, making them leverage factors. These three attributes are the budget for managing mangrove crabs (4.86%), the use of other resources in the mangrove forest ecosystem (4.23%), and the benefits to families of using mangrove crabs (3.08%). The three attributes with the highest RMS values suggest that improvement

efforts should be focused on these three, as improving their circumstances will have an impact on the sustainability index. The atributtes with the lowest RMS value show that the conditions of attributes are good enough and do not need to be prioritized for improvement. The results of the leverage analysis from the economic dimension are presented in Fig. (7).

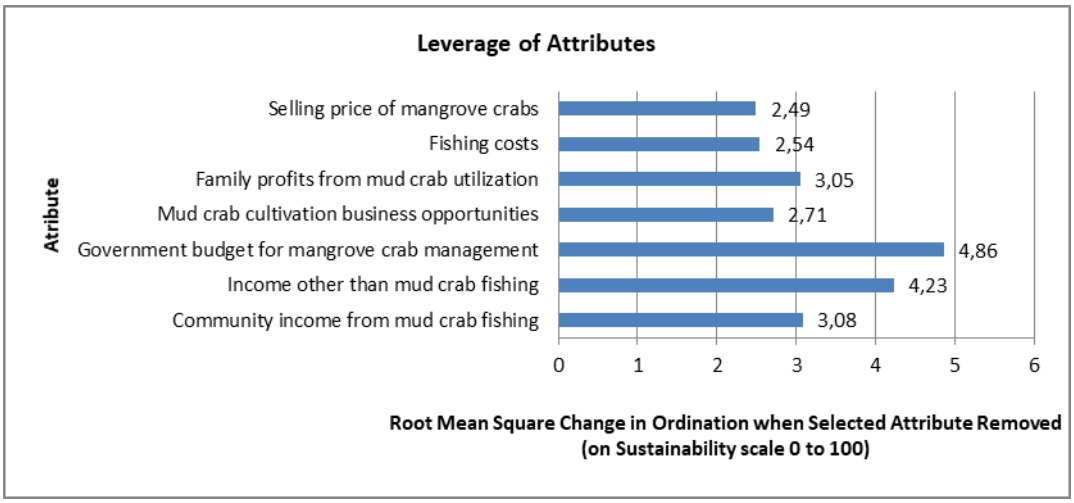

Fig. 7. Economic dimension leverage analysis (Econometric dimension leverage analysis)

Efforts to manage mangrove crabs have not been optimal. The government budget for mud crab management activities is not yet available; new management efforts are limited to submitting verbal prohibitions in the form of a ban on catching mud crabs that carry eggs and mature gonads. This prohibition is in line with Minister of Maritime Affairs and Fisheries Regulations No.1 of 2015 namely catching crabs (*Scylla* spp.) can be done with a carapace width of > 150mm and for females that have mature gonads or mature eggs.

Efforts to maintain the sustainability of mud crab populations in their natural habitat can be carried out by utilizing other resources available in mangrove forests such as fish, shrimp and shellfish **(Hilmi *et al.*, 2017; Redjeki *et al.*, 2020; Ismail *et al.*, 2021)**. By increasing other activities, it is hoped that there will be a balance in the pattern of utilization of mangrove crab resources.

An economically significant species of crustacean for aquaculture and fisheries are mud crabs **(Shi *et al.*, 2019)**. According to **Bera and Maiti (2022)**, the mangrove ecosystem is especially helpful for those living in rural areas since they may use fish, crabs, shrimp, and mangroves as firewood. For nearby people, the economic resources present in mangrove ecosystems provide a source of food, income, and wealth **(Das *et al.*, 2022)**. Because the utilization of mangrove crabs provides the community with such substantial advantages, integrated monitoring must be supported in order to ensure sustainability. At the study site, mud crabs are sold between Rp. 100,000 and Rp. 150,000 per kg. Catching efforts are maintained as a result of this value. The cost to purchase mud

crabs is furthermore high in several countries, including Malaysia, up to RM 68 per kg (for one crab that reaches or exceeds 250g) **(Shakawi *et al.*, 2022)**. Catching mud crabs naturally provides enormous economic benefits. The country of Bangladesh has utilized the potential of mangrove crabs in their country and made them the third highest export commodity **(Islam, 2018)**.

The monitoring process is a necessary management action in the utilization of mud crabs because of the large economic benefits received from this business. In addition, direct community involvement in protecting mangrove crab resources and their habitat is also important so that the resources can survive. Non-governmental organizations can also be formed specifically to supervise mangrove crabs and their habitat. The success of management activities requires the participation of various parties, especially the participation of the community around the location to be managed.

4. Status of social dimension in sustainability

The social dimension's analysis of the sustainability index was 65.97%, placing it in the fairly sustainable category. Fig. (8) shows the graph for social dimension sustainability coordination.

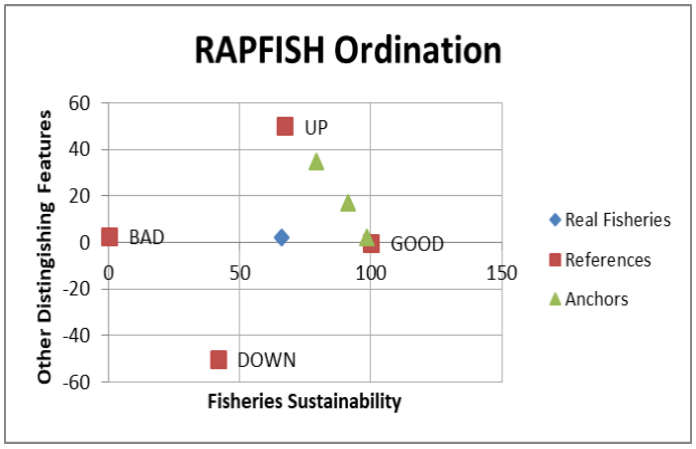

Fig. 8. How social factors affect the sustainability of mangrove crabs

According to the leverage analysis, to attribute community understanding about the benefits of mangrove crabs (4.17%) and public understanding of the benefits of mangrove forests (3.47%) is a lever attribute. The results of the social dimension's leverage analysis are shown in Fig. (8).

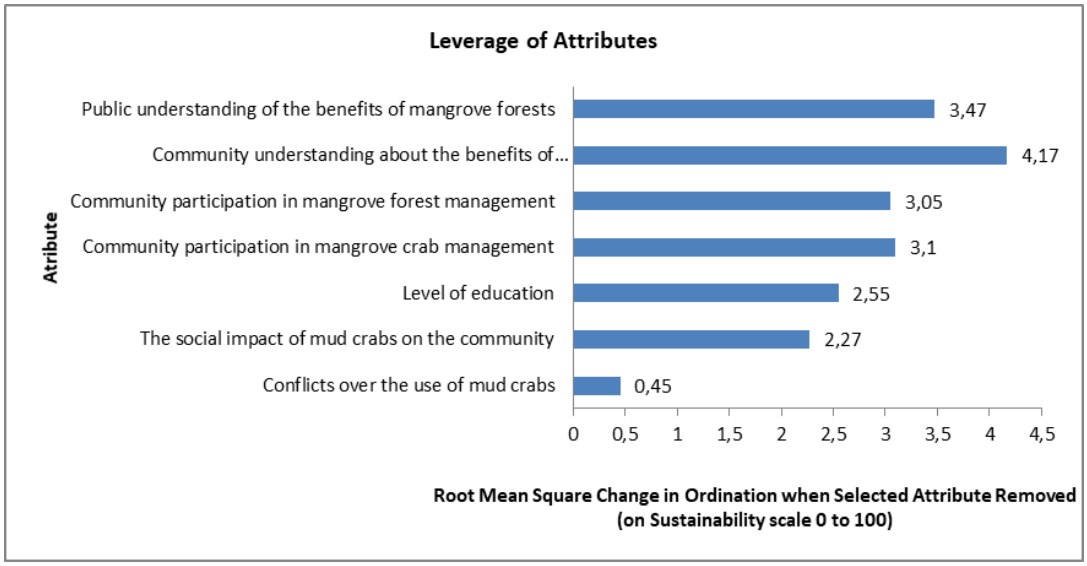

Fig. 9. Social dimension leverage analysis

An important lever attribute that needs to be improved is community knowledge of mangrove crabs and mangrove forests. In order to help, fisheries extension officers' proactive engagement is crucial outreach and training to the community so that it can increase community understanding and participation in the management of mangrove crabs and mangrove forests. Community involvement in the monitoring process is the key to the success of these management activities.

The presence of mangrove crabs gives an important meaning for the fishing community of mangrove crab catchers. Mud crabs are often also a by-catch from fishing efforts using gill nets at sea. Based on the interview results that there was no conflict in utilizing mud crabs. The mangrove crabs produced are very useful in improving the welfare of fishermen because of their high selling value. Not all communities have expertise in catching mud crabs, but they do participate in maintaining the sustainability of mud crabs.

5. Sustainability status of institutional dimension

It is classified as quite sustainable because the institutional dimension's analysis of the sustainability index is 58.69%. Fig. (10) shows the organizational dimension sustainability ordination chart.

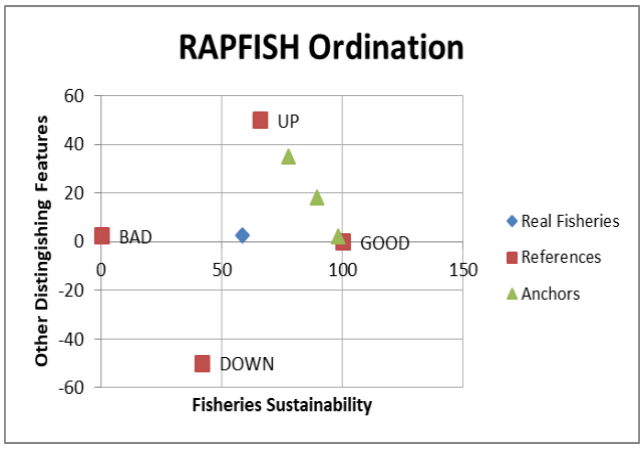

Fig. 10. Mangrove crab sustainability ordinance organizational dimensions

Two leveraging variables were identified in the institutional dimension (Fig. 11): involvement of community institutions (3.33%) and availability of formal regulations for crab management mangroves (3.05%). Increasing the performance of the extension personnel to make them more active is the approach that may be built from this dimension. Dissemination of regulations and help from connected entities and non-governmental organizations entrusted with managing these resources are necessary for law enforcement for the use of mud crabs. This has to do with the penalties that those who break these guidelines will face. This rule-making policy must be scrutinized, regulated and agreed upon by all parties, so that it does not become a conflict between communities or with law enforcement agencies or agencies. The non-governmental organization for management has not yet been formed, so it is necessary to form such an institution to oversee the management process. To be able to carry out supervision properly, formal regulations are needed that are prepared by the local government based on the law above.

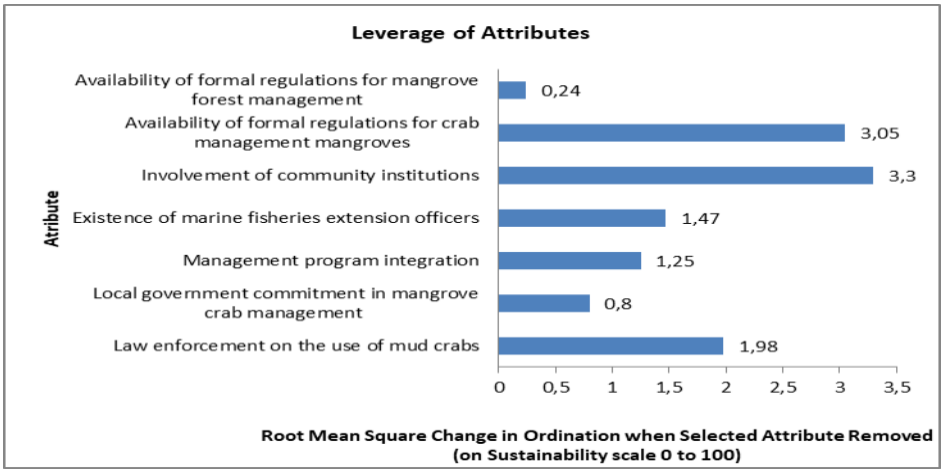

Fig. 11. Analysis of institutional dimension leverage

Law enforcement on the use of mangrove crabs has not been carried out optimally. This condition is related to the unavailability of formal regulations in the study location related to the management of mangrove crabs and their habitat (mangrove forest). Even so, the rules for catching gonad crabs have been understood by some fishermen. The presence of fishery extension workers and other social organizations that function as surveillance is urgently needed. Therefore, it is necessary to have an integrated water resources management program. The government's commitment to managing mangrove crab resources is very much needed both in preparing regulations, monitoring and evaluating the sustainability of these fishery resources.

6. Status of multidimensional sustainability

The sustainability of a region's resources needs thorough integration of all auxiliary factors, such as ecological, biological, economic, social, and institutional factors. Three categories of mud crab sustainability status were identified in the Sidangoli mangrove waters, namely less sustainable (ecological, economic, and biological dimensions) and quite sustainable (social and institutional dimensions), based on the findings of the sustainability analysis of the five dimensions (Fig. 12).

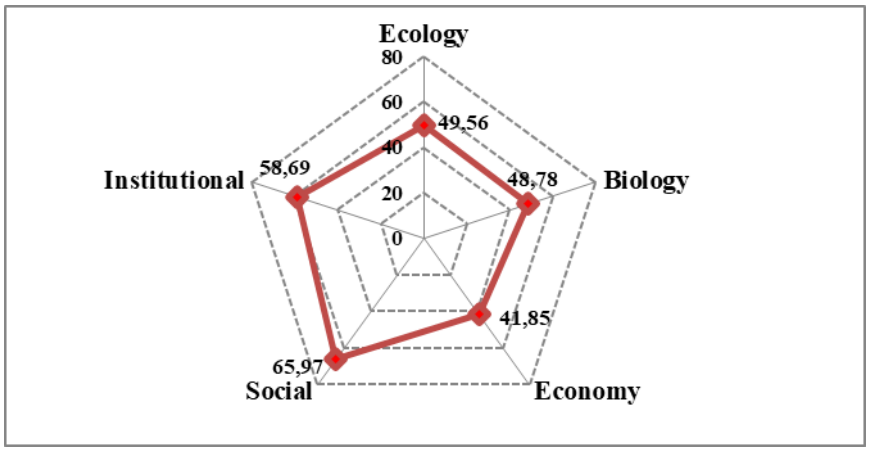

Fig. 12. Mangrove crab management dimensions kite diagram

A multifaceted investigation of the Sidangoli mud crab fishery's sustainability produced a combined value of 58.97%, which is reasonably sustainable. In order to raise the sustainability index values on the dimensions (ecological, economic, and social dimensions), efforts must be made to improve sensitive traits on those dimensions these dimensions. Policies on improvement should not override other aspects/dimensions, so that these conditions are maintained.

The coefficient of determination for the five dimensions shows that the accuracy of the results of the sustainability index values can be scientifically accounted for with an R^2 value ranging from 0.93 to 0.95. This value indicates that the attributes used in the studied system are good enough to explain each dimension of sustainability analyzed, and shows that the relationship between the independent variables and the dependent variable

is strong. The stress value obtained ranges from 0.15 - 0.19 and is included in the very good category because the value is close to zero. The stress value is a measure to see the accuracy of the results obtained whether they are close to the original data (goodness of fit), if the stress value is closer to zero it indicates that the resulting data can be trusted. **Kavanagh (2004)** stated that the value of S-stress is allowed if it is below 0.25 or <25%, while the value of the coefficient of determination (R^2) ranges from 0 – 1.

A Monte Carlo analysis was conducted to determine the impact of mistakes or disturbances on the sustainability of the mangrove crab fishery. Since the ordinate points used to determine the state of the mud crab fishery in Sidangoli waters are fairly stable, errors or disruptions may be overcome, according to the findings of the Monte Carlo analysis, which shows that the points in the scatter plot are in the amassing place.

7. Mangrove crab management recommendations for Sidangoli waters

An overview of the management of the mangrove crab fishery in Sidangoli seas was acquired through the RAPFISH analysis of the five aspects. The attributes with the highest values are thought to be highly sensitive to changes in the sustainability index's value, whether they are high or low. In order to improve the sustainability status of mud crabs in Sidangoli, West Halmahera Regency, the following policy recommendations are made with respect to sensitive qualities and proposed policy priorities:

1. Keep the environment in good condition and ensure that the medium-density mangrove vegetation is present efforts to increase it, as well as controlling community pressure through a ban on logging mangroves for various uses and carrying out mangrove rehabilitation on damaged mangroves. If the natural habitat of mud crabs is maintained, it can also increase the production of mud crabs
2. Improve monitoring of caught crabs in terms of size, proportion of mature gonads, and proportion of sexes so that the sustainability of mangrove crab resources can be maintained.
3. Developing minimum cultivation activities for enlargement activities so as to maintain the sustainability of mangrove crabs in their natural habitat. So far, the utilization of mangrove crabs is still sourced from nature while Sidangoli waters have a cluster of mangrove islands that can be utilized.
4. Establish local community-based organizations or non-governmental organizations to be involved in the management of mangrove areas and mangrove crabs. In this case, local government support is very influential. Routine training, counseling and outreach activities to local communities, mangrove crab fishermen and other fishermen to maintain the preservation of mangrove ecosystems and mud crabs so that they can be utilized in a sustainable manner.
5. Conduct training, counseling and outreach about existing rules and making local regulations for the use and management of mangrove crabs. It is necessary to involve the government (related agencies) in supervising the use of mangroves and crabs so that they can be utilized in a sustainable manner.

CONCLUSION

Multidimensional analysis shows that the Sidangoli mangrove area's mud crab population is moderately sustainable, with a sustainability index value of 58.97%. According to the examination of each dimension, the sustainability index values for the environment (49.56%), biology (58.69%), and economy (41.85%) fall into the less sustainable category. While the institutional dimension (58.69%) and the social dimension (65.97%) are in a very sustainable position, the other two dimensions are not. Mangrove area (5.25%), type of land use (4.96%), and type of mangrove (6.63%) (ecological dimension), as well as mangrove crab size (4.20%), development of mangrove crab reproduction (4.90%), and sex (4.90%) (biological dimension), are characteristics that are sensitive to the sustainability index of the Sidangoli mangrove area dimension), budget in mangrove crab management (4.86), utilization of other resources in mangrove forest ecosystems (4.23), as well as family benefits in utilizing mangrove crabs (3.08) (economic dimension), community understanding of the benefits of mangrove crabs (4.17) and community understanding of the benefits of mangrove forests (3.47) (social dimension) and the attributes of community institution involvement (3.33), availability of formal regulations for mangrove crab management (3.05) (institutional dimension).

REFERENCES

Alongi, DM. (2020). Carbon balance in salt marsh and mangrove ecosystems: A global synthesis. *J Mar Sci Eng*, 8 (10): 767.

Asri, N. S. M.; Hambali, K.; Amir, A. and Norazlimi, N. A. (2020). Birddiversity in mangrove areas in Tumpat, Kelantan. *Malay NatJ*, 72(1):63-75.

Azlad, M. J.; Richard, A. N. and Lawes, M. J. (2015). The role of habitat heterogeneity in structuring mangrove bird assemblages. *Diversity*, 7(2):118-136.

Azra, M. N. and Ikhwanuddin, M. (2016). A review of maturation diets for mud crab genus Scyllabroodstock: Present research, problems and future perspective. *Saudi J Biol Sci*, 23(2):257-267.

Barbier, E. B. (2016). The protective service of mangrove ecosystems: A review of valuation methods. *Marine Pollution Bulletin*, 109(2): 676-681.

Bera, R. and Maiti, R. (2022). Mangrove dependency and livelihood challenges -A study on Sundarbans, India. *Reg Stud Mar Sci*, 50: 102135.

Bryan-Brown, D. N.; Connolly, R. M.; Richards, D. R.; Adame, F.; Friess, D. A. and Brown, C. J. (2020). Global trends in mangrove forest fragmentation. *Sci Rep*, 10 (1): 1-8

Dan, S. and Hamasaki, K. (2014). Evaluation of the effects of probiotics in controlling bacterial necrosis symptoms in larvae of the mud crab (*Scylla serrata*) during mass seed production. *Aquac Int.*, 23 (1): 277- 296.

Das, S. C.; Das, S. and Tah, J. (2022). Mangrove Forests and People's Livelihoods. In: Das, S.C.; Pullaiah, and Ashton, E. C. (Eds.). *Mangroves: Biodiversity, Livelihoods and Conservation*. Springer, Singapore.

Fawwaz M, Vemilia P, Mutmainnah P, Baits M. (2019). *Scylla serrata* Forskal as natural source of glucosamine HCl. *J Res Pharm*., 23 (2): 259-266.

Fitri, A. D. P.; Boesono, H.; Sabdono, A. and Adlina, N. (2017). Resources management strategy for mud crabs (*Scylla* spp.) in Pemalang Regency. *IOP Conf Ser Earth Environ Sci*, 55 (1): 12008.

Garcia, K. B.; Malabrigo, P. L. and Gevana, D. T. (2014). Philippines' mangrove ecosystem: status, threats and conservation. In: *Mangrove ecosystems of Asia*. Springer, New York.

Giri, C.; Long, L.; Abbas, S.; Murali, R. M.; Qamer, F. M.; Pengra, B. and Thau, D. (2015). Distribution and dynamics of mangrove forests of South Asia. *Journal of Environmental Management*, 148: 101-111.

Hatta, S. M.; Salleh, E.; Suhaili, N. S. and Besar, N. A. (2022). Estimation of carbon pool at mangrove forest of Kudat, Sabah, Malaysia. *Biodiversitas*, 23(9): 4601-4608.

Hilmi, E.; Kusmana, C.; Suhendang, E. and Iskandar, I. (2017). Correlation analysis between seawater intrusion and mangrove greenbelt. *Indonesian J For Res*., 4(2): 151-168.

Hungria, D. B.; dos Santos, T. C. P.; Pereira, L. Â.; da Silva, U. and Ostrensky. A. (2017). Global status of production and commercialization of soft-shell crabs. *Aquac Int.*, 25(6): 2213-2226.

Inoue, T. (2019). Carbon Sequestration in Mangroves. In: Kuwae, T. and Hori, M. (Eds.). *Blue Carbon in Shallow Coastal Ecosystems*. Springer. Singapore. 73-99.

Islam, M.; Aleem, N. and Rahman, M. (2015). Mud crab aquaculture, present status, prospect and sustainability in Bangladesh. *World Aquaculture*, 46: 58-60.

Islam, M. S. (2018). Mass Engagement of the Local Communities in Mud Crab Culture in the Sundarban Area, Bangladesh: A Potential Livelihood under Threats of Climate Change. *Progress in Aqua Farming and Marine Biology*, 1(1): 180007. https://academicstrive.com/PAFMB/PAFMB180007.pdf

Ismail; Sulistiono; Hariyadi, S. and Madduppa, H. (2021). Diversity, density, and Importance Value Index of mangroves in the Segara Anakan lagoon and its surrounding area, Cilacap Regency, Indonesia. *IOP Conf. Series: Earth and Environmental Science*, 744(012034): 1–14.

Kavanagh, P, and Pitcher, T. J. (2004). *Implementing microsoft excel software for rapfish: A technique for the rapid appraisal of fisheries status*. University of British Columbia Fisheries Centre Research Report 12 (22004). https://epub.sub.uni-hamburg.de/epub/volltexte/2011/12204/pdf/12-2.pdf.

Khakhim, N.; Musthofa, A.; Wicaksono, A.; Lazuardi, W.; Pratama, D. N. D. and Marfai, M. A. (2021). Adaptation of mangrove ecotourism management to coastal environment changes in the Special Region of Yogyakarta. *J Environ Manag Tourism*, 3(51): 754-765.

Malik, A.; Mertz, O. and Fensholt, R. (2017). Mangrove forest decline: consequences for livelihoods and environment in South Sulawesi. *Reg Environ Change*, 17(1): 157-169.

Malik, A.; Rahim, A.; Sideng, U.; Rasyid, A. and Jumaddin, J. (2019). Biodiversity assessment of mangrove vegetation for the sustainability of ecotourism in West Sulawesi, Indonesia. *AACL Bioflux*, 12(4): 1458-1466.

Marois, D. E. and Mitsch, W. J. (2015). Coastal protection from tsunamis and cyclones provided by mangrove wetlands–a review. *Int J Biodiv Sci Ecosyst Serv Manag*., 11(1): 71-83.

Mirera, D. O. and Moksnes, P. O. (2014). Comparative performance of wild juvenile mud crab (Scylla serrata) in different culture systems in East Africa: Effect of shelter, crab size and stocking density. *Aquac Int*., 23 (1): 155-173.

Murdiyarso, D.; Purbopuspito, J.; Kauffman, J. B.; Warren, M.; Sasmito, S.; Donato, D. C. and Kurnianto, S. (2015). The potential of Indonesian mangrove forests for global climate change mitigation. *Nature Climate Change*, 5: 1089-1092. https://www.nature.com/articles/nclimate2734.

Ngongolo, K.; Mtoka, S. and Mahulu, A. (2015). Challlenges dan opportunities for restoring the threadned mangroves. *J of Scientific Research & Report*, 5(5): 352-360.

Paul, P.; Islam, M. D. S.; Khatun, S.; Bir, J. and Ghosh, A. (2021). Reproductive biology of mud crabs (*Scylla olivacea*) collected from Paikgachha, Khulna, Bangladesh**.** *Journal of Advanced Veterinary and Animal Research,* 8(1): 44-50.

Petersen, E. H.; Phuong, T. H.; Van Dung, N.; Giang, P. T.; Dat, N. K.; Tuan, V. A.; Nghi, T. V. and Glencross, B. D. (2013). Bioeconomics of mud crab, Scylla paramamosain, culture in Vietnam. *Rev Aquac*., 5 (1): 1-9.

Pitcher, T. J.; Lam, M. E.; Ainsworth, C.; Martindale, A.; Nakamura, K.; Perry, R. I. and Ward, T. (2013). Improvements to Rapfish: a rapid evaluation technique for fisheries integrating ecological and human dimensions. *Journal of Fish Biology*, 83: 865–889.

Redjeki, S.; Hartati, R.; Nuraeni, R. A. T.; Riniatsih, I.; Endrawati, H. and Widianingsih, W. (2020). Co-existence between *Scylla serrata* and *Scylla transquebarica* in the lagoon of Segara Anakan, Cilacap, Indonesia. The 5th International Conference on Tropical and Coastal Region Eco Development. *IOP Conf. Series: Earth and Environmental Science*, 530(012043): 1-10.

Richards, D. R. and Friess, D. A. (2016). Rates and drivers of mangrove deforestation in Southeast Asia, 2000-2012. *Proceedings of the National Academy of Sciences of the United States of America*, 113: 344-349.

Romañach, S. S.; De Angelis, D. L.; Koh, H. L.; Li, Y.; Teh, S. Y.; Barizan, R. S. R. and Zhai, L. (2018). Conservation and restoration of mangroves: global status, perspectives, and prognosis. *Ocecoaman*, 154: 72-82.

Sánchez-Núñez, D. A.; Bernal, G. and Pineda, J. E. M. (2019). The relative role of mangroves on wave erosion mitigation and sediment properties. *Estuar Coast*., 42(8): 2124-2138.

Sari, A.; Tuwo, A.; Saru, A. and Rani, C. (2022). Diversity of fauna species in the mangrove ecosystem of Youtefa Bay Tourism Park, Papua, Indonesia. *Biodiversitas*, 23(9): 4490-4500.

Schaduw, J. N. W. (2015). Sustainability of Mangrove Ecosystem Management on Mantehage Island, Wori District, North Minahasa Regency, North Sulawesi Province. LPPM *Journal for Science and Technology*, 2(2): 60-70.

Shakawi, A. M. H. A.; Hassan, R. and Mustapah, D. S. (2022). Effects of water parameters on population structure of mud crab from Buntal Mangroves, Kuching, Sarawak, Malaysia: A GLM analysis. *Biodiversity*, 23(5): 2580-2585.

Shi, X.; Lu, J.; Wu, Q.; Waiho, K.; Aweya, J. J.; Fazhan, H.; Zhang, Y.; Li, S.; Zheng, H.; Lin, F.; You, C.; Ikhwanuddin, M. and Ma, H. (2019). Comparative analysis of growth performance between female and male mud crab (*Scylla paramamosain*) crablets: Evidences from a four-month successive growth experiment. *Aquac*. 505: 351-362.

Sunarti, Y.; Soejoedono, R. D.; Mayasari, N. L. P. I. and Tahya, A. M. 2016. RNA expression of farnesoic acid O-methyltransferase in mandibular organ of intermolt and premolt mud crabs *Scylla olivacea*. *AACL Bioflux,* 9(2): 270-275.

Tetelepta, J. M. S.; Natan, Y.; Ongkers, O. T. S. and Pattikawa, J. A. (2018). Some population biology aspects of edible orange mud crab Scylla olivacea (Herbst, 1796) of Kotania Bay, western Seram District, Indonesia. *AACL Bioflux,* 11(4): 1203-1212.

Thomas, N.; Lucas, R.; Bunting, P.; Hardy, A.; Rosenqvist, A. and Simard, M. (2017). Distribution and drivers of global mangrove forest change, 1996–2010. *PLoS ONE*, 12(6): e0179302.

Viswanathan, C.; Pravinkumar, M.; Suresh, T. V.; Elumalai, V. and Raffi, S. M. (2019). Reproductive biology of the orange mud crab *Scylla olivacea* (Herbst, 1796) from the Pichavaram mangroves of south-east India. *Indian J Fish*, 66(1): 26-33.

Yusuf, S.; Soejoedono, R. D.; Mayasari, N. L. P. I. and Tahya, A. M. (2016). RNA expression of farnesoic acid o-methyl transferase in mandibular organ of intermolt and premolt mud crabs Scylla olivacea. *AACL Bioflux,* 9(2): 270-275.