Sustainability of Small-Scale Capture Fisheries to Climate Change in Pangpang Bay, Banyuwangi Regency, Indonesia

Ervina Wahyu Setyaningrum[1*], Abu Bakar Sambah[2] and Dewa Gede Raka Wiadnya[2]

ABSTRACT

Pangpang Bay, located in Banyuwangi Regency, is characterized by its mangrove forests, which are utilized for various purposes, including capture fisheries, Pacific white shrimp farming, and mangrove conservation. Among these uses, small-scale fisheries represent the most significant potential in capture fisheries; however, their sustainability may be affected by climate change. This study aims to assess the sustainability of small-scale fisheries in Pangpang Bay. To achieve this, the Rapfish methodology was employed to analyze the vulnerability of these fisheries to both small-scale and coastal factors. This research employed a descriptive method using a quantitative approach. The parameters assessed included newly introduced dimensions, specifically, coastal vulnerability and capture fisheries vulnerability, alongside other dimensions derived from the Rapfish technique. The data analysis method used was the Rapid Appraisal for Fisheries (Rapfish) sustainability analysis. The results indicated that the sustainability status of small-scale capture fisheries in Pangpang Bay, Banyuwangi, with an MDS (Multidimensional Scaling) value of 47.25, was classified as less sustainable. Conversely, dimensions with MDS values exceeding 50 are considered moderately sustainable, particularly in the domains of coastal vulnerability, resources, and technology. It is recommended that policymakers address the challenges posed by climate change, through measures such as mitigating its adverse impacts, enhancing the capacity of small-scale fishers, integrating efforts among relevant stakeholders, and strengthening regulation and law enforcement.

Keywords: Captured fisheries, Climate change, Fisherman, Sustainability

INTRODUCTION

About 2.7 million small-scale fishers in Indonesia rely on animal protein from fish, while 1.7 million of them depend on coral reef species, which are the highest number in the world, making Indonesia the eighth most fish-dependent country globally (Campbell *et al.*, 2020). Indonesia's small-scale fisheries policy aims to reduce the use of non-mechanized fishing gear and vessels of 5 GT or less, improve catch reporting, and promote environmental sustainability. This clear, measurable definition allows for more effective monitoring at sea (Halim *et al.*, 2020). Among the fishing methods currently used in Indonesian coastal waters, small-scale fisheries (SSF) are considered the most environmentally friendly. However, the impact of SSF on juvenile fish in some areas should be considered. Juvenile fish should not be commercialized, as they are an important component of the fisheries subsystem (Yonvitner *et al.*, 2020).

Globally, marine fisheries are vital for food security and livelihoods, particularly for

[1]Fisheries Science Program, Faculty of Agriculture and Fisheries, Universitas 17 Agustus 1945, Banyuwangi, Indonesia
[2]Doctoral Program in Fisheries and Marine Science, Faculty of Fisheries and Marine Science, Universitas Brawijaya, Malang, Indonesia
[*]Corresponding author. E-mail address: ervinawahyu@untag-banyuwangi.ac.id
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vulnerable communities. Yet, their methods and impacts are still not fully understood (Harper *et al*., 2020). Many in-depth studies have shown that small-scale fisheries are highly location-dependent, with fishes often facing economic vulnerability to climate change. Differences in food security and livelihood outcomes also exist across sectors most affected by climate change (Selig *et al*., 2019).

Climate change poses serious threats to coastal areas, including sea level rise, extreme weather, heavy rainfall, flooding, and storms (Furlan *et al*., 2021). These impacts lead to erosion, water quality degradation, and infrastructure damage across coastal and riverine systems (Koroglu *et al*., 2019). Climate change also alters the abundance and distribution of marine species, with ongoing trends of stock decline and dispersal likely to persist or worsen (McHenry *et al*., 2019). The fisheries sector must therefore adapt to safeguard livelihoods, food systems, and traditional fishing practices (Ojea *et al*., 2020).

To manage these risks, adaptive regulatory frameworks and targeted strategies are needed. Several tools and techniques are available to assess risk and vulnerability (Sanuy *et al*., 2020). Policymakers can support food security and local economies by distinguishing between industrial and small-scale fisheries and addressing stock depletion and habitat loss (Song *et al*., 2020). Understanding the role of fishing communities within broader socio-ecological systems is crucial for sustainability, and robust data collection is essential for comprehensive resource management and ecosystem-based approaches (Bennett, 2019).

This study aims to assess the sustainability of small-scale capture fisheries in Pangpang Bay, Banyuwangi Regency. The analysis includes Rapfish dimensions, along with two new dimensions introduced in response to local needs: coastal vulnerability and small-scale fisheries vulnerability.

MATERIALS AND METHODS

This study was conducted in Pangpang Bay, Banyuwangi Regency, Indonesia, from April to December 2023. The analysis was based on 37 attributes grouped into the following dimensions: coastal vulnerability, small-scale capture fisheries vulnerability, resource, ecological, social, economic, technological, and legal/institutional dimensions (Table 1).

This research adopts a descriptive and quantitative approach grounded in the philosophy of positivism. Both primary and secondary data were utilized. Primary data were collected through surveys, direct observations, and structured interviews with fishers using questionnaires. Secondary data were obtained from Sentinel 2 satellite imagery.

Purposive and proportional sampling methods were employed to select respondents. Sampling was based on specific criteria aligned with the research objectives, targeting respondents with knowledge of local conditions, including professionals working directly in the field. Respondents were taken from fisher groups in the study location, specifically in Kedungringin, Wringinputih, Kedunggebang, and Kedungasri villages, totaling approximately 298 participants.

The sustainability analysis was conducted using the Rapid Assessment for Fisheries (Rapfish) method, a multidisciplinary assessment tool developed by the University of British Columbia, Canada. Rapfish employs a ranking technique based on multidimensional scaling (MDS) to evaluate various quantifiable attributes. Attribute selection followed the frameworks proposed by (Nababan *et al*., 2007; Allison *et al*., 2009). The sustainability index of small-scale fisheries in the Rapfish method, as adopted from Pitcher and Preikshot (2001) and Nababan *et al*. (2007), ranges from 0 to 100, where values indicate sustainability status from bad to good (Table 2).

Table 1. Attributes on each dimension.

Dimension	Attribute	Parameter
Coastal vulnerability	Geomorphology	Rocky/rocky/ low cliff beach/ estuary/lagoon/ sand beach, swamp, delta/ mangrove/ coral reefs
	Erosion/ accretion	Shoreline change (m·year^{-1})
	Coastal slope	% Coastal slope
	Distance of vegetation from shore	Distance of plants on the beach to the highest tide (m)
	Average wave height	Average wave height (m)
	Average tidal range	Average high tide (m)
Vulnerability of capture fisheries	Exposure	Standardization of SPL data for the last 10 years (2013–2022)
	Sensitivity	Standardize the number of fishermen and catches
	Adaptive capacity	Standardization of mangrove area and number of fish landing sites
Ecology	Mangroves	Tree density
	Estuary	Ph
		Brightness
		Biological oxygen demand (bod)
		Total ammonia
Resources	Diversity of catch species	Number and type of catches
	Gonad maturity level of captured fish	Gonad maturity level of captured fish
Technology	Fishing base	Distribution of fishing base
	Destructive/illegal fishing methods	Fishing with tools and methods that are destructive and or not in accordance with applicable regulations
	Fishing trip duration	Number of hours (time) on a fishing trip
	Type/nature of fishing gear	Whether or not the fishing gear is operational
	Fishing boat size	Boat length
Economy	Asset ownership	Change in value/amount of fishery business assets
	Fishery household income	Income of households whose main income is from fishing activities
	Level of subsidies to the fishery	Number of types of subsidies to fisheries
	Alternative livelihoods	Number of types of alternative livelihood
Social	Number of fishermen compared to the total population of the region	Number of fishermen and total population
	Education level	Fishery household education level
	Stakeholder participation	Stakeholder engagement
	Fisheries conflicts	Resource conflicts, policy conflicts, fishing conflicts, and intersectoral conflicts
	Frequency of community meetings on fisheries resource management	Community meetings on fisheries resource management
	Frequency of fisheries extension	Fisheries extension activities
Legal/ institutional	Availability of formal and informal fisheries management regulations	Formal and informal regulations of fisheries management
	Justice in law	Application of justice in law
	Availability of law enforcement personnel at the location	Law enforcement personnel at the research site
	Democracy in policy making	Democracy in policy making
	Roles of formal institutions responsible for fisheries resource management	There are formal institutions responsible for supporting fisheries resource management
	Availability and role of local community leaders	Availability and role of local community leaders

Table 2. Index interval and sustainability status of small-scale fisheries.

Sustainability status	Sustainability index interval
Bad	0–25
Poor	>25–50
Ade quate	>50–75
Good	>75–100

The MDS analysis in the RAPFISH program package simultaneously performs leverage analysis, Monte Carlo analysis, stress value calculation, and the coefficient of determination (r^2). Leverage analysis is used to determine sensitive attributes. These attributes are prioritised based on the magnitude of change in the root mean square (RMS) of ordination ranks along the X-axis. A greater RMS change indicates a stronger influence of the attribute on the sustainability of small-scale capture fisheries management in Pangpang Bay, Banyuwangi Regency.

Monte Carlo analysis was used to estimate the potential impact of errors in the analytical process, with a 95% confidence interval. The results are expressed as a Monte Carlo index and compared with the MDS index value. A small difference between the two indicates minimal evaluation error, low variation in scoring, high stability in repeated analyses, and minimal data entry or missing data errors.

RESULTS AND DISCUSSION

The Rapfish analysis results for the combined eight dimensions indicate a less sustainable status, with a sustainability index of 47.25% (Table 3). Validation of the Rapfish simulation results for each dimension showed a relatively high coefficient of determination (r^2), with an average value of 0.93. Additionally, the average stress (S) value was 0.16, which is below the threshold of 0.25, indicating a good fit of the Rapfish model and suggesting that the simulation results reliably represent the underlying data (Alder *et al*., 2003).

The interrelationships between the sustainability dimensions of in small-scale capture fisheries in Pangpang Bay, Banyuwangi Regency are schematically presented in Figure 1. This figure shows the linkage among the eight dimensions using a kite diagram, which depicts suatainability scores on a scale of 0–100%, divided into four categories at 25% intervals: poor, less sustainability,

Table 3. Sustainability index, stress values, and coefficient of determination (r^2) for small-scale capture fisheries in Pangpang Bay, Banyuwangi Regency.

Dimensions	Index value	Category	Stress	r²
Coastal vulnerability	59.79	Sufficiently sustainable	0.14	0.93
Vulnerability of small-scale capture fisheries	35.20	Less sustainable	0.17	0.92
Ecology	40.25	Less sustainable	0.14	0.94
Resources	56.21	Sufficiently sustainable	0.22	0.90
Technology	53.57	Sufficiently sustainable	0.14	0.93
Economy	46.09	Less sustainable	0.17	0.93
Social	41.20	Less sustainable	0.15	0.94
Legal/institutional	45.70	Less sustainable	0.16	0.94
Sustainability of Pangpang Bay small-scale capture fisheries	47.25	Less sustainable	0.16	0.93

moderately sustainable, and good. In the diagram, the further the index extends outward, the better the sustainability status; conversely, scores closer to the center indicate lower sustainability.

Small-scale fisheries in Pangpang Bay generally fall within the 25% to 75% sustainability range, indicating low to very low sustainability levels, as shown in Figure 2. Overall, the sustainability status of small-scale capture fisheries in Pangpang Bay, considering coastal vulnerability, resource reliability, technology, and ecological, economic, and social dimensions, is categorized as "unsustainable". Therefore, alternative efforts or programs are needed to improve the situation toward a 'moderately sustainable' or 'good' status.

This conclusion is further supported by the difference in MDS and Monte Carlo analysis results. The Monte Carlo simulation addresses uncertainties caused by factors such as scoring discrepancies, data entry errors, and variation in scores, which may result in high stress values. The simulation, conducted with 25 replications

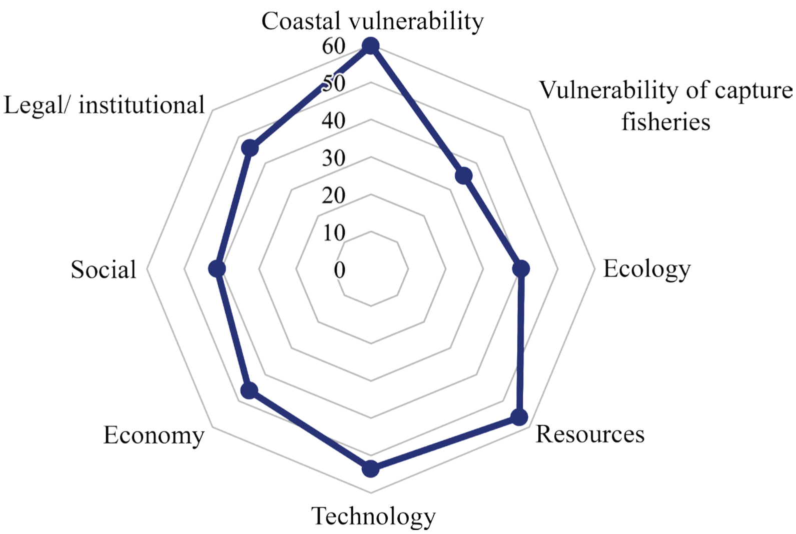

Figure 1. Kite diagram showing the sustainability indices of eight dimensions in small-scale capture fisheries in Pangpang Bay, Banyuwangi Regency. Higher scores indicate better sustainability status.

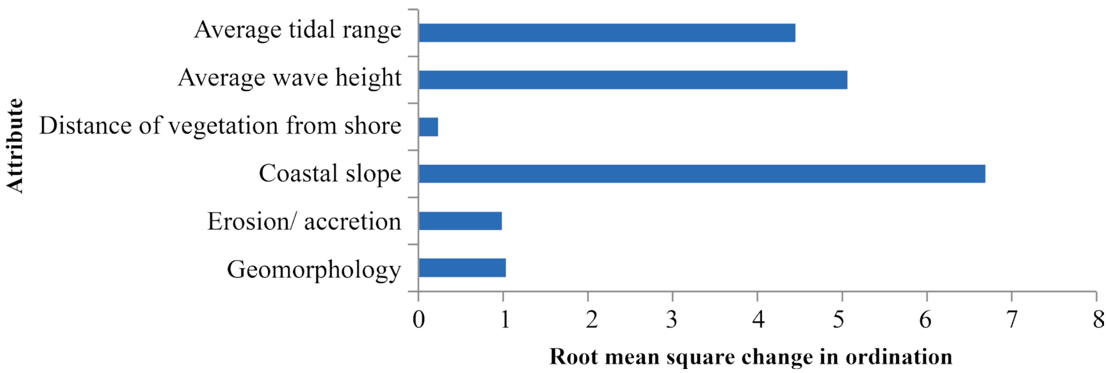

Figure 2. Leverage analysis for the coastal vulnerability dimension in Pangpang Bay, showing the root mean square (RMS) change in ordination for each attribute.

across the eight dimensions at a 95% confidence level, showed differences between MDS and Monte Carlo values ranging from 0.06 to 0.99. These results indicate that the MDS analysis using the Rapfish has a high level of precision (Table 4) (Kavanagh and Pitcher, 2004).

The Monte Carlo analysis yielded an average ordination score of 47.41 for Pangpang Bay. When compared to the MDS sustainability score of 47.25, the difference of 0.44. This small difference confirms the consistency and reliability of the sustainability assessment for small-scale capture fisheries in Pangpang Bay. Although the overall sustainability category remains "less sustainable", the results of the Monte Carlo analysis suggest potential for index refinement. With appropriate interventions targeting leverage variables of each dimension, there is an opportunity to improve the sustainability status toward the 'moderately sustainable' or "good" categories.

Achieving environmental sustainability in small-scale fisheries also requires ensuring social sustainability. Balancing fisheries management and marine conservation goals is essential, particularly when considering alternative livelihoods (Charles *et al*., 2016). Human behaviour is closely linked to policy, institutional arrangements, law enforcement, and compliance. While conservation has traditionally been the regulatory focus, it often fails to fully capture the potential benefits to local communities (Kamat, 2014). There has been a shift from purely environmental or political concerns to legal and governance frameworks. For example, countries like Brazil employs specialised environmental police officers to enforce environmental laws (Serafim *et al*., 2019).

Small-scale fisheries are not just technical concerns but have broad policy implications for communities and ecosystems. They play a vital role in ensuring livelihoods and food security (Johnson, 2018). Fishing is a collective activity involving people, vessels, labor, local knowledge, environmental resources, and technology. Understanding fishing techniques alone is insufficient for ensuring fish distribution across communities and markets. Strengthening small-scale fisheries value chains offers a pathway to more inclusive and sustainable governance that extends beyond vessels and gear (Smith, 2019).

Coastal vulnerability dimension

The analysis results for the coastal vulnerability dimension (Table 4) show an MDS value of 59.79, placing it in the 'moderately sustainable' category for small-scale capture fisheries. To elevate this dimension into the 'good' or 'sustainable' category, Pangpang Bay should focus on improving the key leverage variables

Table 4. Comparison of sustainability index values obtained from MDS and Monte Carlo analyses for eight dimensions in small-scale capture fisheries in Pangpang Bay, Banyuwangi Regency.

Dimensions	Sustainability index		
	MDS	**Monte Carlo**	**Difference**
Coastal vulnerability	59.79	58.79	0.99
Vulnerability of small scale fisheries	35.20	35.94	0.74
Ecology	40.25	40.70	0.45
Resource	56.21	56.11	0.10
Technology	53.57	53.73	0.16
Economy	46.09	46.47	0.38
Social	41.20	41.86	0.66
Legal/institutional	45.70	45.64	0.06
Pangpang Bay average	47.25	47.41	0.44

identified in Figure 2. Enhancing these sensitive attributes would contribute significantly to increasing the overall sustainability index.

Figure 2 shows that the coastal slope is the most influential attribute in increasing the coastal vulnerability dimension index, followed by 'average wave height', 'average tidal range', and 'erosion/accretion'. These four variables are considered key leverage factors for improving the sustainability of small-scale capture fisheries in Pangpang Bay, Banyuwangi Regency.

Areas with high coastal vulnerability typically exhibit low adaptive capacity. Such areas are characterized by narrow beach widths, high wave heights, shoreline erosion patterns, and lower coastal slopes and elevations (Serafim *et al*., 2019). In contrast, Pangpang Bay exhibits a relatively high coastal slope, which reduces flood risk. Moreover, as a semiclosed bay, it is less affected by direct oceanic influence, resulting in moderate tidal ranges and relative lower vulnerability level with respect to tidal fluctuations.

In addition, mangrove vegetation along the Pangpang Bay coastline continues to thrive, playing a crucial role in stabilizing sediments. Extensive mangrove planting efforts have led to increasing dense mangrove growth, which acts as a natural barrier, reducing wind impact on the shoreline. This helps minimize erosion and, in some areas, promotes accretion. As explained by (Kantamaneni *et al.*, 2019), coastal areas without vegetation are significantly more vulnerable to environmental pressures than those with vegetation cover.

Vulnerability dimension of small-scale capture fisheries

The sustainability analysis results for the vulnerability dimension of small-scale capture fisheries (Table 4) show an MDS value of 35.20, placing it in the 'less sustainable' category. To improve this status to 'moderately sustainable' or 'good', efforts should focus on enhancing the key leverage attributes identified in Figure 3, which can significantly contribute to increasing the sustainability index for small-scale fisheries in Pangpang Bay.

The exposure attribute significantly influences vulnerability index in small-scale capture fisheries. Effective input management, such as enforcing catch limits, is essential, especially in co-managed small-scale fisheries. However, insufficient monitoring can jeopardize both fishery resources and fisher livelihoods. In the absence of adequate support, small-scale fishers who do not qualify for government assistance may resort to aggressive or unsustainable fishing practices. Additionally, traceability requirements for marine commodities entering the global market now demand detailed information on fishing grounds and gear used.

Therefore, it is crucial that all fisheries stakeholders, including the Indonesian government, collaborate to raise awareness of these evolving market requirements, particularly among small-scale fishers. Ensuring the sustainability of fish stocks requires proper management across all fisheries, including small-scale operations (Halim *et al*., 2019). Strategies to strengthen adaptive capacity must consider local contexts and appropriate

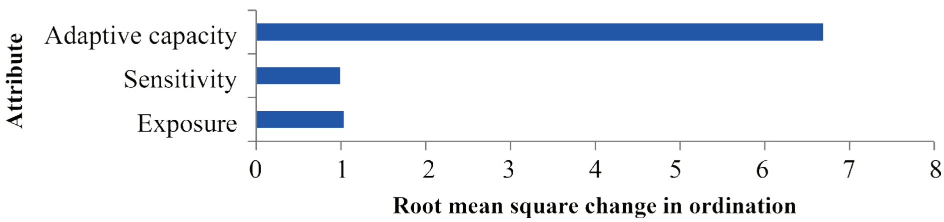

Figure 3. Leverage analysis for the vulnerability dimension of small-scale capture fisheries in Pangpang Bay, showing root mean square (RMS) changes in ordination.

timing to avoid ineffective or maladaptive outcomes (Ruiz-Díaz *et al*., 2020). Regular surveillance are necessary. Moreover, broader participation (both within and outside the fishing community) will help build resilience, close governance gaps, and raise awareness of the risks associated with destructive fishing practices.

Ecological dimension

Based on the results of the ecological dimension analysis (Table 4), the MDS value of 40.25 places small-scale capture fisheries in the 'less sustainable' category. To raise the ecological sustainability status to 'moderately sustainable' or 'good', efforts should focus on improving the key leverage attributes identified in Figure 4.

As shown in Figure 4, the 'brightness' attribute is the most influential factor in increasing the ecological dimension index, followed by 'total ammonia (TAN)'. The brightness value in Pangpang Bay is between 15 cm and 45 cm, which does not meet water quality standards, indicating turbid water with low transparency. This turbidity reduces light penetration, which is further limited by the bay's shallow water depth. The primary causes include sediment runoff from upstream rivers, agricultural waste, and effluents from shrimp ponds, which accumulate in the estuary over time. Climate change further exacerbates water turbidity, especially during rainfall, which increases bottom pressure and may cause upwelling and sediment resuspension.

In this context, ecological knowledge is essential to address resource degradation due to climate change and extreme events that may disrupt ecosystem stability and alter population dynamics. It is important for ecologists to support policy-making in small-scale fisheries (SSF) to align with the SDGs and FAO guidelines. Smith *et al*. (2021) emphasize the importance of scaling up research on SSF by building on existing progress. Similarly, Zhang *et al*. (2018) highlight the need to investigate ecological dynamics and environmental impacts of small-scale fisheries as part of a comprehensive strategy to ensure food security and ecosystem sustainability.

Resource dimension

Based on the assessment results for the resource dimension in Pangpang Bay (Table 4), the MDS value of 56.21 places small-scale capture fisheries in the 'moderately sustainable' category. To improve this dimension to the 'good' category, efforts should focus on enhancing the leverage attributes that have the most significant impact on the sustainability index, as shown in the following analysis.

Figure 5 shows that the 'diversity of catch species' is the most influential attribute in increasing the sustainability index for the resource dimension, followed by the the 'level of gonad maturity of captured fish'. Over the past decade, changes in the size of fish caught have significantly affected the sustainability of small-scale fisheries in Pangpang Bay. This situation suggests needs for environmentally friendly policies and management responses to address the declining size of harvested fish which is a key indicator of dwindling fish stocks.

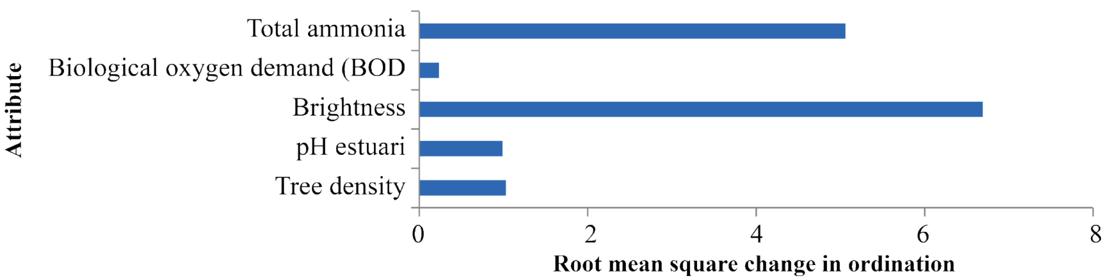

Figure 4. Leverage analysis for the ecological dimension in Pangpang Bay, showing root mean square (RMS) changes in ordination.

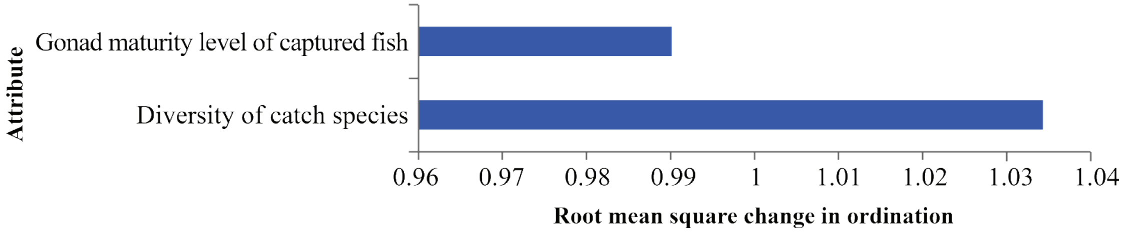

Figure 5. Leverage analysis for the resource dimension in Pangpang Bay, showing root mean square (RMS) changes in ordination.

If left unaddressed, continued harvesting of immature fish that have not yet spawned will disrupt the natural recruitment process, further degrading fishery resource. Therefore, ensuring that fish are allowed to reach reproductive maturity before being caught is critical for maintaining population stability and supporting long-term sustainability in the bay's small-scale fisheries.

Policymakers in Banyuwangi Regency should focus on increasing the selectivity of fishing gear used in small-scale capture fisheries in Pangpang Bay. The use of non-selective gear often results in the captures of fish across various size classes. Enhancing gear selectivity will help ensure that only mature fish are harvested, thereby supporting sustainable stock regeneration. As noted by Arthur (2020), government regulation and resource privatization are crucial in improving small-scale fisheries management worldwide. Furthermore, strengthening informal institutions and promoting collective action among fishing communities can lead to more efficient resource use and improved fishery yields.

Technology dimension

The assessment result for the technology dimension in Pangpang Bay, Banyuwangi Regency, shows an MDS value of 53.57 (Table 4), placing small-scale capture fisheries in the 'moderately sustainable' category. To elevate this dimension to the 'good' sustainability category, efforts should focus on enhancing the leverage variables that have a strong impact on the index value, as shows in the following analysis.

Figure 6 shows that the variable 'length of time at sea' has the greatest influence on increasing the technological dimension index, followed by 'fishing vessel size'. This is because small-scale fishers in Pangpang Bay typically operate on a one-day fishing system. Consequently, fish activities occur daily, leading to continuous exploitation of fish resource in the bay. This may result in a gradual decline in fish abundance. If the duration of fishing trips increases, it is likely to be accompanied by an increase in vessel size, allowing fishers to access more distant fishing grounds with potentially larger catches.

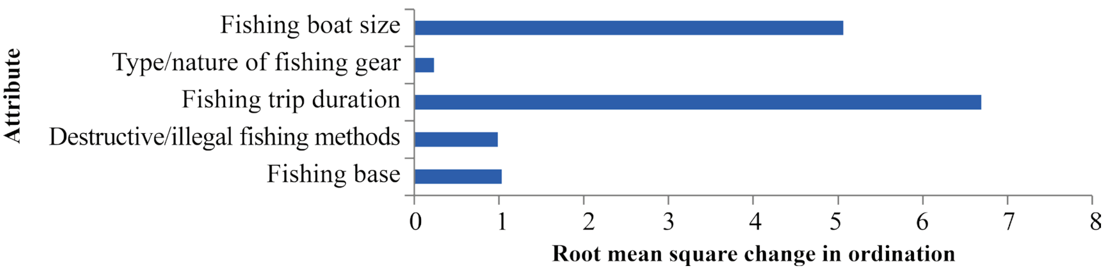

Figure 6. Leverage analysis for the technology dimension in Pangpang Bay, showing root mean square (RMS) changes in ordination.

Nevertheless, although the one-day fishing system is used by small-scale fishers of Pangpang Bay, the fishing gear used is generally selective. Selective fishing gear enables fishers to target fish sizes that meet market demand, thereby reducing the likelihood of unsold catch. As a result, even though the total catch may be lower, the fish harvested tend to have higher economic value. In contrast, fishers who do not adapt their fishing practices, such as vessel size and type, gear selectivity, fishing time, target species, or fishing grounds, may continue to fish in large volumes without regard to sustainability. Variations in sustainability outcomes can emerge when fishing practices differ across a fishery. In contrast, excessive homogeneous fishing, defined as the intensive targeting a single species without consideration for ecosystem balance, can threaten the survival of that species and destabilize the marine ecosystem. Effective management policies can be implemented by utilizing effective tools to identify potential problems (Damasio *et al*., 2023).

Economic dimension

The assessment of the economic dimension for small-scale capture fisheriesin Pangpang Bay yielded an MDS value of 46.09 (Table 4). This indicates that the fisheries fall into the 'less sustainable' category. To elevate the index to a 'moderate' or 'good' category, targeted efforts should focus on improving the variables that exert the greatest influence on the index value, as identified through leverage analysis.

The 'level of fishery subsidies' is the most influential attribute in improving the economic dimension index, followed by 'fishery household income' and 'asset ownership' (Figure 7). This reflects the complex role of subsidies in small-scale fisheries. While subsidies can contribute to increased exploitation of fishery resources, their absence may render small-scale fishing economically unsustainable. This presents a challenging dilemma.

To address this issue, subsidies should be directed toward offshore fisheries, where fish stocks remain relatively abundant, rather than to coastal areas already experiencing overfishing. Additionally, subsidies can be justified when they support value-added production processes that enhance the market value of fishery products, thereby increasing fishers' income. Conversely, if the level of subsidies is reduced, adjustments to the pricing structure of fish should be made to ensure fair compensation for fishers, especially under conditions of sustainable catch levels.

From an economic perspective, management plans should promote strategies that encourage environmentally responsible fishing practices, including improved fishing techniques and seafood marketing, initiatives such as eco-certification. Emphasizing responsible environmental management and promoting a fishing culture that increases the value of both the activity and its products is essential (Gómez and Maynou, 2020). Furthermore, adaptive management strategies, such as modified fishing quotas, can enhance resilience to climate change and reinforce stewardship of marine resources. In this context, place attachment and social capital are essential to foster leadership and participatory governance in small-scale fisheries, particularly in ecological diverse areas. These elements can also support limited alternative livelihoods outside of fishing (Eurich *et al*., 2024).

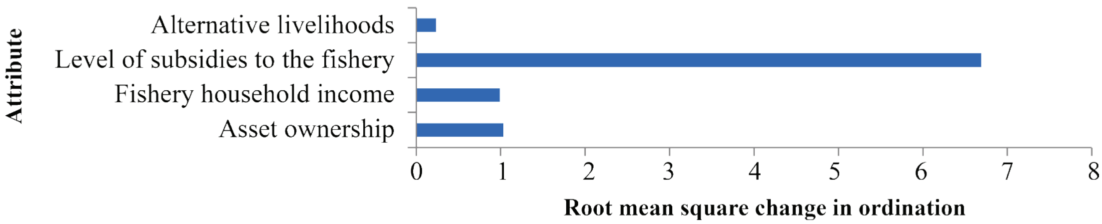

Figure 7. Leverage analysis of the economic dimension in Pangpang Bay. The attribute 'level of subsidies to the fishery' has the greatest influence on the economic sustainability index.

Social dimension

The results of the social dimension assessment (Table 4), with an MDS value of 41.20, indicate that small-scale capture fisheries in Pangpang Bay, fall into the 'less sustainable' category. However, the index values for the social dimension can be improved to a 'moderate' or 'good' category by prioritizing interventions based on the key leverage variables identified below.

As illustrated in Figure 8, the attribute that exerts the most significant influence on enhancing the social dimension index is 'stakeholder participation', followed by the 'frequency of community meetings pertaining to fisheries resource management' and 'frequency of fisheries extension activities'. Stakeholder participation is critically important for the sustainability of fisheries. The active involvement of multiple actors, including fishers, government agencies, and local communities, is imperative to ensure the effective and sustainable management of fisheries resources, ultimately benefiting all parties involved.

Well-managed stakeholder engagement has been demonstrated to improve quality of life, reduce environmental degradation, and promote economic sustainability. Therefore, stakeholder participation should be considered a fundamental element of any sustainable development strategy (Habumuremyi and Tarus, 2021). Allocating resources to enhance stakeholder capacities can also mitigate implementation challenges, thereby fostering more favorable conditions for sustainability. Moreover, the socio-cultural dynamics of stakeholders have been identified as a significant predictors of long-term development outcomes (Njue *et al*., 2021).

Legal/institutional dimension

The assessment of the legal and institutional dimension (Table 4), yielded an MDS value of 45.70, placing small-scale fisheries in Pangpang Bay in 'less sustainable' category. To improve this index to a 'sufficient' or 'good' sustainability category, priority should be given to enhancing the leverage variables that most strongly influence this dimension.

As Illustrated in Figure 9, the 'availability of law enforcement personnel at the site' emerges as the most significant factor in enhancing the legal and institutional dimension index. This is followed by the 'role of formal institutions supporting fisheries

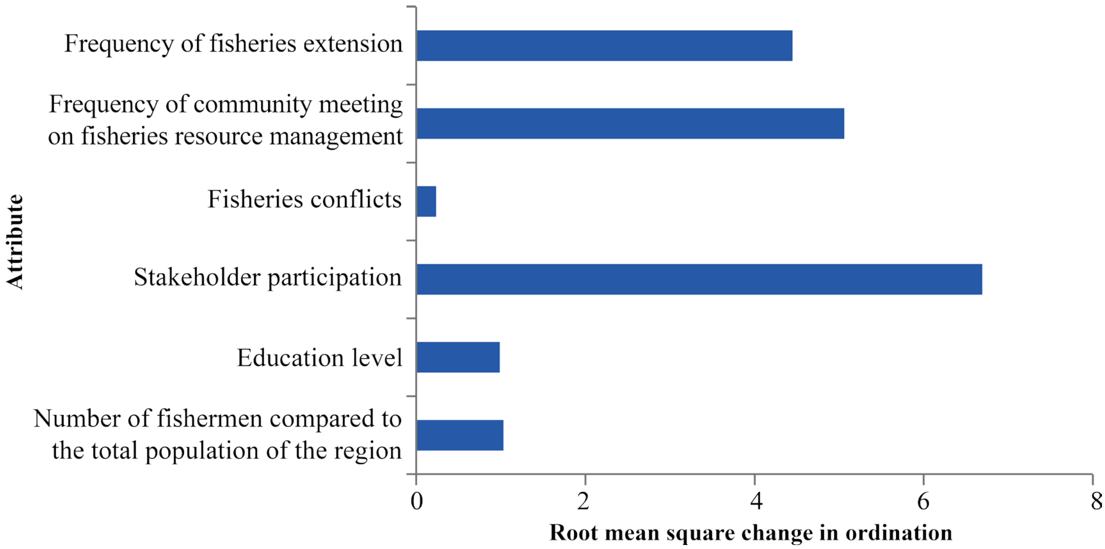

Figure 8. Leverage analysis of the social dimension in Pangpang Bay. 'Stakeholder participation' is the most influential attribute in improving the social sustainability index.

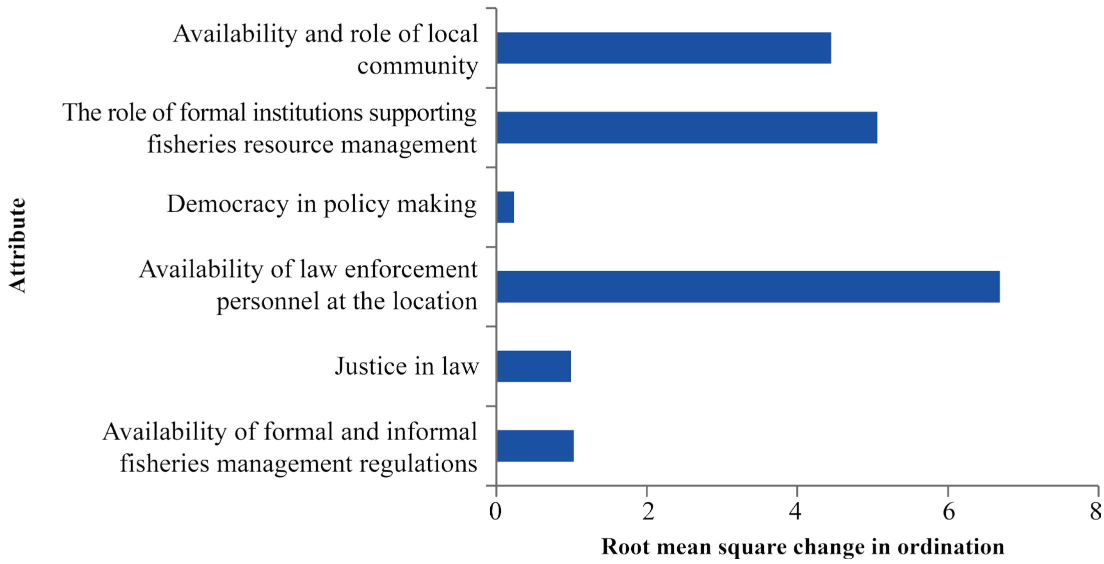

Figure 9. Leverage analysis of the legal and institutional dimension in Pangpang Bay. The 'availability of law enforcement personnel at the location' is the most influential attribute in improving the legal and institutional sustainability index, followed by the 'role of formal institutions supporting fisheries resource management' and the 'availability and role of local community leaders', as indicated by the root mean square change in ordination.

resource management' and the 'availability and role of local community leaders'. Strengthening integrity and ethical conduct of law enforcement personnel requires the collective support of all relevant authorities and institutions. It is the resposibility of both the government and law enforcement agencies to foster a moral and ethical environment.

Enhancing the ethical awareness of law enforcement personnel through targeted training and educational is essential to this goal. Personnel are more likely to uphold principles of fairness and honesty when embedded in an institutional culture that values transparency and ethical conduct.

The effectiveness of government policies also depends heavily on public support, particularly from the fishing community. Although Indonesia's National Development Planning System emphasizes sustainable resource management, the country continues to face challenges in enforcing fisheries and ecosystem legislation, often due to a lack of proactive enforcement machanisms (Bailey *et al.*, 2016). Any effort to strengthen future law enforcement in Indonesia must include a moral and ethical dimension. A comprehensive approach should focus on reinforcing integrity and ethical standards within law enforcement agencies, promoting transparency and accountability, reforming legal systems and institutions, and increasing legal awareness among the general population (Suwito *et al.*, 2023).

CONCLUSIONS

The overall sustainability status of small-scale capture fisheries in Pangpang Bay, Banyuwangi Regency is classified as 'less sustainable'. However, assessment of specific dimensions, namely coastal vulnerability, resources, and technology, indicate a 'moderately sustainable' status. In contrast, the ecological, social, economic, and legal/institutional dimensions remain in the 'less sustainable' category. Nevertheless, the sustainability status of each dimension can be improved by prioritizing and strengthening the key leverage variables identified within each dimension.

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