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Article

Enhancing Livelihood Resilience: A Comprehensive Analysis of Small-Scale Fishers

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ABSTRACT

Background: The aim of this research is to examine livelihood resilience and strategic policies that need to be implemented to increase the livelihood resilience of small-scale fishers.

Methods: The data collection method employed in this study was semi-structured interviews, utilizing purposeful sampling techniques. This research was conducted specifically in the context of Karimunjawa Island, Indonesia. The approach used to elucidate the fishers' livelihoods was the livelihood resilience approach, which aims to understand fishers ability to withstand and recover from various challenges and shocks. The analysis was conducted using three key variables: Buffer Capacity, Learning Capacity, and Self-Organizing Capacity, to comprehensively assess the resilience of fisher livelihoods in the Karimunjawa area.

Results: Karimunjawa fishers exhibit "medium resilience" across Buffer Capacity (0.39), Self-Organization Capacity (0.50), and Learning Capacity (0.54) dimensions. This resilience reflects their ability to navigate socio-ecological dynamics, including changes in fish resources, coastal biodiversity, land use, and exposure to coastal hazards, crucial for sustaining livelihoods. Economically, resilience is influenced by the scale of the community's livelihood activities, the volume of catches, and production management, with small-scale fishers facing constraints in accessing alternative livelihood options, compounded by rural community backgrounds.

Conclusions: This research includes contributions to the development of policies that strengthen the welfare of small-scale fishers in Karimunjawa, implementation of practical programs and initiatives to improve fisher living conditions within Karimunjawa, increased academic understanding of livelihood resilience, and a better understanding of the social and ecological impacts of small-scale fishers' activities. Thus, this research has the potential to provide a significant impact in supporting the survival of small-scale fishers and environmental conservation in the area.

KEYWORDS: coastal; Karimunjawa; livelihood; resilience; small-scale fishers

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INTRODUCTION

Marine wealth in Indonesia harbors immense potential that demands protection to ensure sustainability and augment its contribution to the national economy [1]. One strategy to preserve marine wealth within Indonesia has been creating conservation areas that safeguard environmental biodiversity [2]. Indonesia has allocated over 27 million hectares as protected areas for marine management to enhance their capacity [3]. Under the Ministry of Marine Affairs and Fisheries, National Parks have spearheaded conservation efforts in marine areas by establishing National Parks and Marine Protected Areas.

Karimunjawa Island is one of the National Parks of Indonesia, that serves as a marine conservation area. Due to its conservation status, there are restrictions on local community activities regarding the use of surrounding resources. This has significant implications for the livelihoods of nearby communities, particularly fishers, who depend on coastal resources for their livelihood [4]. Despite the designation of a special zone where only traditional fishing gear is permitted for use by fishers, the fishing communities in Karimunjawa encounter challenges [5]. Limited information regarding potential fishing areas and the utilization of basic or traditional fishing technologies contribute to the suboptimal exploitation of the traditional fishing zone, thereby resulting in social conflicts [2]. This discrepancy particularly affects traditional fishers who operate passively, as they find competing with fishers employing dynamic fishing gears challenging. Social conflicts may arise due to disputes over resource access, unequal competition, and differing perceptions of fairness and resource allocation among fishers.

These challenges can exacerbate fishers' vulnerability, impacting fish catch rates and threatening the sustainability of fisher livelihoods [6,7]. Environmental changes in coastal ecosystems, such as pollution from industrial waste and oil spills, further jeopardize coastal communities' socio-economic stability [8]. The sustainability of fisher livelihoods hinges on environmental and social factors [9–14]. Due to the environmental and social challenges being faced by fishers environmental sustainability and social sustainability are concepts that need to be integrated into the Karimunjawa society. Environmental sustainability entails the non-destructive use of fishery resources to facilitate regeneration, while social sustainability encompasses cohesive relationships within and between groups engaged in various activities [15].

Fishers, are often among the most economically vulnerable because they, heavily rely on marine resources to meet their daily needs [16–18]. Small-scale fishers, as defined by various laws, utilize traditional fishing methods and modest-sized vessels [19]. Typically, small-scale fishers engage in livelihood activities by catching fish to fulfill their daily needs using vessels of moderate size, often not exceeding around 12 gross tons (GT). Access to natural resources and the fulfillment of basic needs are

crucial for fishers, both as individuals and as groups, enabling them to utilize fisheries and marine resources that directly contribute to their livelihoods [20,21].

A long-term decline in fish catch often leads to conflicts among fishers, underscoring the critical need for integrated fisheries management [22,23]. This management approach is essential in effectively addressing dwindling fish stocks. However, the competition for fishing resources can intensify due to social and economic factors, including population growth, which can escalate conflicts over access to these resources. To manage these challenges, direct policy interventions and robust governance measures are necessary, complemented by inclusive stakeholder engagement.

Resilience, in this context, refers to a system's capacity to adapt to shocks, acknowledging disruption and change as inherent features of complex systems [8]. It focuses on mechanisms that enable systems to absorb disturbances, cope with uncertainty, and effectively manage risks. Societal resilience involves preparing for and enduring shocks and stresses—whether environmental, social, or economic—while ensuring that essential functions can be maintained. Livelihood resilience specifically emerges from vulnerabilities inherent in work environments, shaped by dynamic forces and factors. A people-centered analysis typically begins by evaluating individuals' assets, livelihood aspirations, and the strategies they employ to achieve these aspirations. Transformations in structures, processes, and vulnerability contexts can significantly influence livelihood outcomes [24].

Vulnerability directly affects livelihood sustainability and can be identified through several factors. Shocks, such as floods, storms, and civil conflicts, can directly destroy assets and force individuals to leave their homes and sell assets prematurely [20,21]. Additionally, global economic changes, including fluctuations in exchange rates and terms of trade, can complicate the economy for marginalized fishers [25]. Trends significantly impact the economic returns of chosen livelihood strategies, while seasonal price shifts affect the community's ability to access employment opportunities and food, posing significant challenges for marginalized fishers [26].

The concept of livelihood resilience stems from the vulnerabilities present in the work environment. Resilient livelihoods are shaped by many different forces and factors that are constantly changing. A people-centered analysis will likely start with a simultaneous investigation of people's assets, their goals (the livelihoods they seek), and the livelihood strategies they adopt to achieve these goals [27]. In some cases, fishers migrate as a strategy to reduce their vulnerability, moving either within the country or abroad in response to economic opportunities offered elsewhere, acting as a 'pull factor' [28]. Asset vulnerability varies according to the research focus. The proposed framework identifies five assets, including tangible assets such as

labour, human capital, and productive assets (focusing on housing); and intangible assets such as household relationships (household composition and structure, as well as cohesion within the household) and social capital (cooperation and cohesion in society) [29]. However, in the context of small-scale fisheries, assets and resources have been critically associated with social identity and have a direct impact on fisher livelihoods.

In current research developments, livelihood approaches can be classified into three main components: Buffer Capacity, Learning Capacity, and Self-Organization Capacity [30]. In general, Buffer capacity involves the ability to absorb and mitigate the negative impacts of disruptions by having sufficient reserves or support, such as financial savings or social support [24]. Learning capacity pertains to the ability to learn from past experiences and new information to enhance responses to future challenges, through training, education, and adopting best practices [11,31]. Self-organization capacity is the ability to independently organize, manage, and adapt to changes without significant external assistance, by establishing effective networks, institutions, and internal cooperation mechanisms [30]. Together, these dimensions ensure that a system or community can function effectively and resiliently in the face of various challenges and pressures.

This study adopts a livelihood approach to understand the intricate relationship between fishers and their environment. The livelihoods framework illuminates key factors influencing fisher livelihoods and their interconnections [24]. Addressing economic, social, and ecological challenges requires effective resilience-building strategies to navigate natural and anthropogenic changes.

MATERIALS AND METHODS

Traditional fishers in Karimunjawa tend to catch fish in smaller quantities, both for domestic and commercial purposes in places crowded with foreign tourists [32]. Their local wisdom regarding environmental awareness, fishing techniques, and fishing gear tends to preserve the biodiversity of underwater ecosystems around the Karimunjawa Islands [33]. Even though Karimunjawa Island has become a conservation area, conflicts also occur due to differences in interests in implementing zone restrictions in Karimunjawa Island [33].

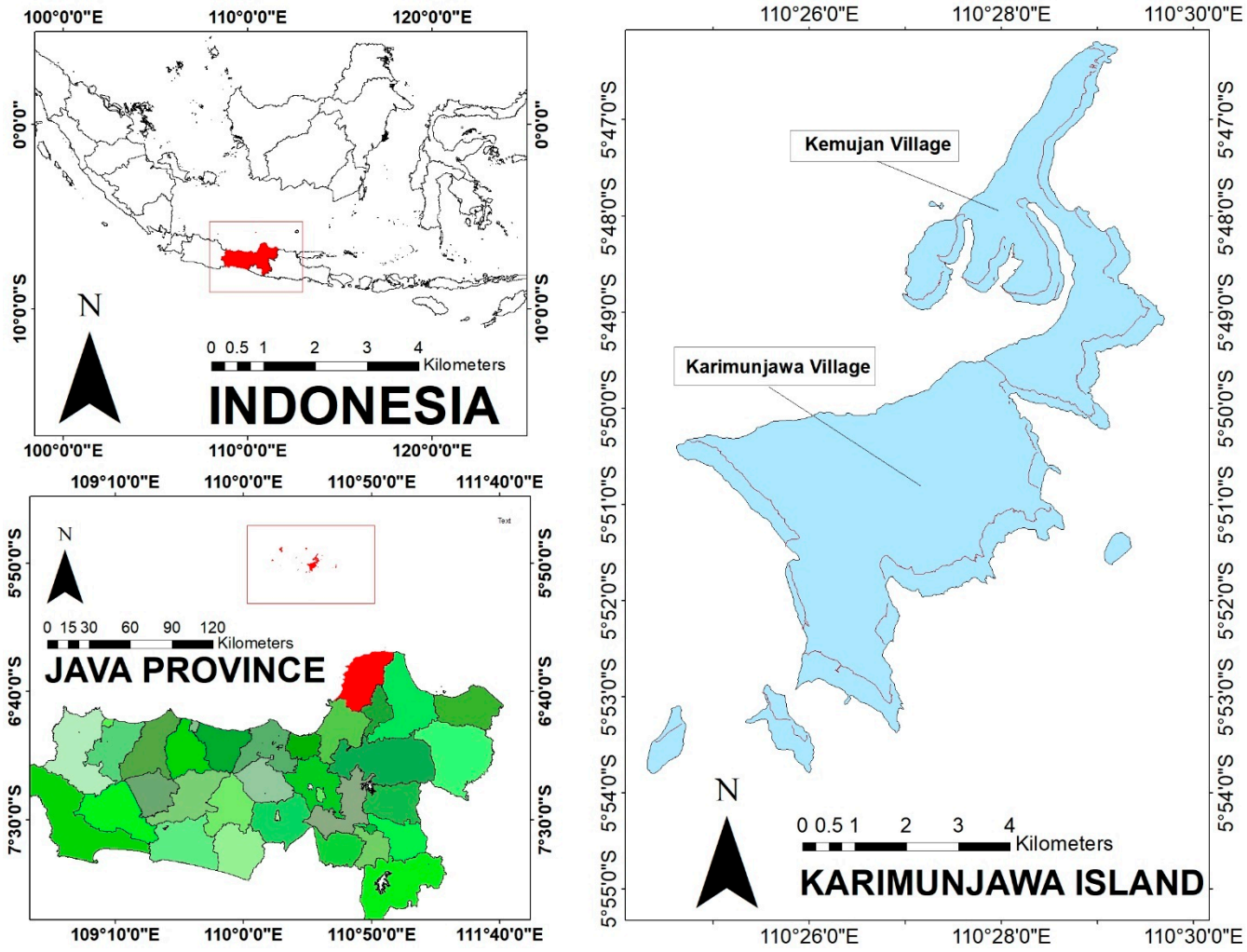

Figure 1. Research Location.

Karimunjawa Island is one of Indonesia's national conservation areas (Karimunjawa National Park), located in Central Java, representing the integrity and uniqueness of the northern coast of Central Java (see Figure 1). The park is situated at coordinates 5°40'39''–5°55'00'' LS and 110°05'57''–110°31'15'' E, covering a total area of 111,625 hectares in the Java Sea [34]. Karimunjawa National Park consists of 27 islands and is renowned for its natural beauty, biodiversity, and significant non-biological potential. Its well-preserved ecosystems include coral reefs, seaweed, seagrass beds, diverse marine life, mangrove forests, mountains, and remnants of lowland tropical forests [2,35].

Internationally recognized in 2020, the park encompasses 22 islands, with five inhabited by local communities. As part of Indonesia's commitment to environmental conservation, Karimunjawa is designated as a Marine Protected Area, safeguarding its diverse marine ecosystems [2,36]. The park includes nine distinct zones tailored for specific conservation purposes, such as coral reefs, mangroves, seagrass beds, research, education, tourism, traditional use, and historic, cultural, and special purposes.

Samples were taken in two villages, Kemujan Village and Karimunjawa Village, both exhibiting characteristics typical of fishing communities within the waters of Karimunjawa National Park. According to information from *Balai Taman Nasional Karimunjawa* (Karimunjawa National Park Office—BTNK), Karimunjawa Village benefits from excellent access to tourism activities, allowing fishers to diversify their livelihoods by working as tour guides or engaging in other tourism-related ventures [34]. In contrast, fishers in Kemujan Village, despite being in the same area as Karimunjawa Village, have limited access to tourism, leading to a disparity in livelihood diversification. Notably, small-scale fishers in Kemujan predominantly use traditional fishing gear.

This study employed a semi-structured interview design, with data collection conducted between July and September 2023. A total of 73 fisher respondents participated in the study, selected purposively based on their use of specific traditional fishing gear, including "tonda" fishing rods, fishing nets, and fish spears. The sampling method ensured representation from various segments of the fishing community. Fishers were approached at meeting points on the landing beaches around the coast of Kemujan Village (49 respondent) and Karimunjawa Village (24 respondent), where they routinely engage in transactions. The identification of livelihood resilience in this study was categorized into low resilience, medium resilience, and high resilience, as indicated in Table 1.

Table 1. Resilience indicator classification.

Resilience Score	Category
>0.30	Low resilience
0.30–0.50	Medium resilience
<0.50	High resilience

Source: Adopted from Jakariya [9].

Resilience is about the capacity of a system to adapt to shocks, recognizing that disruption and change are integral components of complex systems that focus on mechanisms and processes that help systems absorb disturbances and shocks, and cope with uncertainty and risk [8]. Resilience is the capacity of a society to prepare for, withstand, and maintain functionality during environmental, social, or economic shocks and stresses. Livelihood resilience arises from vulnerabilities in livelihood activities.

Livelihoods are shaped by many different forces and factors that are constantly changing. People-centered analysis begins with a simultaneous investigation of people's assets, their goals (the Livelihoods they seek), and

the livelihood strategies they adopt to achieve these goals. Important feedback may occur between: (a) Structure and process transformation and vulnerability contexts; and (b) Livelihood outcomes and livelihood assets [24]. The equation to see how the livelihood resilience index is used can be seen in equation (1) [37].

$$R_L = \frac{\sum_{i-1}^{n} w_{M_i} M_{hi}}{w_{M_i}} \quad (1)$$

Within the livelihood resilience equation R_L represents a dimension of livelihood resilience, integrating indicators such as buffer capacity, learning capacity, and self-organization capacity. M_{hi} is an indicator measuring household livelihood resilience. w_{M_i} denotes the weight assigned to each indicator M_i. Determining the priority of the main factors that cause vulnerability will be the basis for developing a strategy that will be carried out to analyze vulnerability from the perspective of small-scale fishers. To determine the results of the livelihood resilience index estimation, it can be estimated by equation (2) [38]. In calculating the index, it is denoted as a scale of 0–1.

$$Score\ Indicator = \frac{\sum_{n-1}^{N} W_n V_n}{\sum_{n-1}^{N} W_n} \quad (2)$$

This formula calculates the indicator score for livelihood resilience, where W_n is the weight of each indicator question and V_n is the corresponding variable value. The value of each dimension is measured based on equation (3).

$$Score\ Dimension = \frac{\sum_{i-1}^{N} W_i i_i}{\sum_{i-1}^{N} W_i} \quad (3)$$

This equation determines the score for each dimension of livelihood resilience (buffer capacity, learning capacity, self-organization capacity), with W_i representing the weight and i_i being the score derived from equation (2). Through established mathematical equations, a livelihood resilience index is derived, offering a holistic portrayal of the economic resilience of small-scale fishing households. It emphasizes access to resources, adaptation to environmental changes, and engagement in socio-economic activities, which form the cornerstone of assessing and formulating strategies to enhance the resilience of small-scale fishers amidst the intricate dynamics of the fishing context [25]. This comprehensive framework facilitates a nuanced understanding of the challenges and opportunities faced by fishing communities, guiding targeted interventions for sustainable livelihoods. Detailed explanations of the measurement dimensions can be found in Table 2.

Table 2. The dimensions of resilience.

Dimension	Indicator	Information	Measurement
Buffer Capacity	Production	Production results in one fishing trip	Number
	Cost	Costs incurred in one fishing trip	Number
	Labour	Proportion of family members engaged in fishery industries	Percentage
	Income	Net income from one fishing trip	Number
	Resource Access	Fishers' access to resources to meet needs.	Very Difficult = 5, Difficult = 4, Modest = 3, Little = 2, No Access = 1
	Proportion of Fishery Income	Percentage of income for fishers with income outside of fishery	Percentage
	House Conditions	The condition of the fisher's house	Very Good = 5, Good = 4, Ordinary = 3, Ugly = 2, Very Ugly = 1
	Health Access	Fishers' travel time to access healthcare	Distance (minutes)
	Water Sources	Fishers' access to clean water sources	Very Easy = 5, Easy = 4, Ordinary = 3, Hard = 2, Very Hard = 1
Learning Capacity	Education	The highest education level attained by fishers	Level of Education
	Experience	Fishers' experience in fishing activities	Years
	Alternative Livelihood	Alternative livelihoods to earn extra income	Yes = 2, No = 1
	Work Duration	Working hours in one fishing trip	Working hours
	Asset Ownership	Ownership of assets used for fishing	Yes = 2, No = 1
Self-organization Capacity	Family Members	Number of family members in the household	Number
	Organization	Membership in fishery cooperatives or other associations	Yes = 2, No = 1
	Communication	Access to communication	Very Easy = 5, Easy = 4, Ordinary = 3, Hard = 2, Very Hard = 1
	Social Activity	Social activities carried out to gain new experiences	Very Much = 5, A Lot = 4, Medium = 3, A Little = 2, Very Little = 1
	Loan	Access to bank loans	Very Easy = 5, Easy = 4, Ordinary = 3, Difficult = 2, Very Difficult = 1
	Saving	Savings ownership	Yes = 2, No = 1
	Subsidy	Opportunities to receive fishery subsidies from the government	Very Helpful = 5, Helpful Enough = 4, Ordinary = 3, Less Helpful = 2, Not Helpful = 1

Source: Adopted from previous research [30,37,39–46].

In the dynamic landscape of fishers' livelihoods, three pivotal dimensions stand out: "buffer capacity", "learning capacity", and "self-organization capacity" [30]. The dimension of buffer capacity illuminates the resilience of fishers, depicting their ability to navigate and manage resources amidst the uncertainties inherent in fishing activities [24]. Concurrently, the dimension of learning capacity underscores the crucial role of continuous learning and skill acquisition, enabling fishers to adapt to evolving fishing environments and socioeconomic dynamics [47]. Complementing these, the dimension of self-organization capacity highlights the significance of community cohesion and collective action, empowering fishers to navigate challenges and access resources within their fishing communities [21]. By integrating these dimensions into our research framework, we gain comprehensive insights into the multifaceted aspects of fishers' livelihoods.

RESULTS

Fisher Livelihood Identification

The main livelihood in Kemujan Village and Karimunjawa Village within the Karimunjawa National Park Area revolves around fishing. Fishers predominantly utilize traditional and environmentally friendly fishing gear, reflecting the community's commitment to preserving local wisdom. Karimunjawa fishers exhibit a unique characteristic of upholding traditional fishing practices passed down through generations, which not only sustain local customs but also contribute to biodiversity conservation in the region [2].

Karimunjawa fishers demonstrate a strong awareness of the need to sustainably manage natural resources. Furthermore, regulations governing the use of fishing gear within the Karimunjawa National Park restrict the utilization of certain gear types to safeguard marine ecosystems. The Karimunjawa National Park Agency, vested with the authority to enforce these regulations, ensures adherence to prescribed guidelines. Consequently, fishers primarily employ simple fishing gear, aligning with conservation objectives. The production outcomes of fishers categorized by the fishing gear utilized are presented in Table 3.

Table 3. Income and production costs of fishers based on fishing gear.

Fishing Gear	Respondent (*n*)	Average Gross Income (USD)	Operating Costs (USD)	Average Net Income (One Trip) (USD)
Fishing rod "tonda"	37	$17.67	$6.71	$9.21
Fishing nets	25	$17.00	$5.92	$8.46
Fish spear	11	$24.35	$6.18	$12.95

Fish Spear is a fishing gear used as an alternative to fishing rods to catch various types of reef fish, such as Lodi, Grouper, Yellowtail, and Green fish. Eleven respondents utilized fishing spears as their primary fishing gear. Spearfishing yields a higher net income compared to other fishing gear due to the higher selling price of reef fish. For instance, the Red Lodi fish sells for $5.51/kg, while some fishers also obtain Balung grouper, which fetches $3.98/kg. However, despite its lucrative returns, the use of this fishing gear comes with inherent risks.

Fishing nets were employed by 25 respondents. The average net income for fishers using fishing nets is $11.93 per day of fishing. These nets are employed to capture anchovies and other fish that tend to congregate. Lastly, the “tonda” line, a fishing line with artificial bait, was utilized by the majority of respondents. This gear is commonly used to catch several fish species, including Mackerel, Tuna, and Squid. The “tonda” line entails higher costs compared to other fishing gear due to additional expenses for purchasing bait. Nevertheless, it remains popular among fishers due to its simple operational procedures, versatility in catching various species, and minimal operational risks. Additionally, certain fish species, such as mackerel selling at $3.06/kg and squid at $3.92/kg, make this fishing gear a preferred choice among fishers in search of profitable catches.

Vulnerability Identification

Vulnerability is a condition experienced by society due to changes in natural, social, and governmental structures [16,17]. Changes or shocks that occur in coastal communities can have both negative and positive effects on community survival. The natural aspect relates to the resources provided by nature and managed by humans. Meanwhile, the social aspect encompasses the entirety of human relations within the environmental context. Finally, the governmental aspect is crucial as communities require support from policymakers to provide positive momentum for advancing general welfare. The context of vulnerability in this study is presented in Table 4.

Table 4. The vulnerability context of Karimunjawa small-scale fishers.

Dimension	Vulnerability
Natural	• Barges are mobilized around the conservation area, and there is an oil spill that causes pollution to the marine ecological conditions • Tourism activities contribute to increased plastic waste, carbon waste, and pressure on coral reefs • Damage to coral reefs as fish habitats • Extreme climate change

Table 4. *Cont.*

Dimension	Vulnerability
Social	• The use of fishing gear is harmful to the ecosystem • Lack of understanding from fishers about the importance of conservation areas • Exploitation of fish resources • Fishers have limited knowledge of how to use technology • Lack of stakeholder support for fisher livelihood resilience
Government	• Lack of coordination between stakeholders to campaign for the importance of MPAs • Lack of participation of fishers in conservation efforts • Lack of regulatory compliance among government and resource users • Management of MPAs in the past was hampered by uncertainty in authority decision-making and local government conflicts • The government's role is still lacking in resource management • Lack of enforcement and compliance with resource management regulations is further exacerbated by the unfenced and invisible (to the public) demarcation of the boundaries of conservation areas such as MPAs

Livelihood Resilience

This research identifies the resilience of fisher livelihoods in Karimunjawa National Park using three dimensions: the fishers' ability to face challenges (Buffer Capacity), their learning ability to adapt to changing conditions (Learning Capacity), and their management ability (Self-Organization Capacity). In coastal areas, the most prominent problems are environmental, economic, and social conditions, as well as perceptions of environmental damage, which directly affect fishers' livelihood activities [9].

The parameters used will determine resilience measures based on buffer capacity, learning capacity, and self-organization capacity. Overall, it appears that the collective resilience of the community in Karimunjawa is closely related to coastal exposure. The buffer capacity dimension represents the individual's support in maintaining fishers' livelihoods, as detailed in Table 5.

Table 5. Buffer capacity.

Dimension	Indicator	Standard Deviation	Score Indicator	Score Dimension	Deviation
Buffer Capacity	• Production	0.15	0.19	0.39	0.09
	• Cost	0.20	0.40		
	• Labour	0.33	0.18		
	• Income	0.16	0.26		
	• Resource Access	0.17	0.50		
	• Proportion of fishery income to total family income	0.22	0.50		
	• House conditions	0.31	0.77		
	• Health Access	0.33	0.50		
	• Water Sources	0.43	0.23		

The Buffer Capacity dimension of fishers has a value of 0.39, indicating their resilience capacity in adapting to challenges. This reflects the socio-ecological dynamics of the coastal environment, including changes in fish resources, coastal biodiversity, land use, and exposure to coastal hazards, which are crucial for livelihood resilience. In the socio-economic aspect, factors such as the scale of community businesses, catch volumes, and production management play significant roles. Small-scale fishers face economic constraints in accessing business development opportunities, compounded by their relatively disadvantaged backgrounds in rural communities. Small-scale fishers need to have learning capabilities to support the development of their livelihoods. The assessment results for learning capacity are shown in Table 6.

Table 6. Learning capacity.

Dimension	Indicator	Standard Deviation	Score Indicator	Score Dimension	Deviation
Learning Capacity	• Education	0.34	0.63	0.54	0.35
	• Experiences	0.22	0.36		
	• Alternative Livelihoods	0.50	0.58		
	• Work Duration	0.24	0.54		
	• Asset Ownership	1.85	1.75		

Fisher have a dimensional value of 0.56 (Table 6) which can be interpreted that the average respondent already has moderate resistance to their learning capacity. This dimension discusses experience, level of employment, side jobs other than fishing, duration of going to sea, and assets owned to support income. This is shown in Table 5, which is a table of dimensions of learning capacity owned by fisher (learning capacity). Social activities greatly support resilience in this dimension. Information obtained in social activities can support additional income owned by fisher [48]. If viewed from each dimension indicator produced, on average

fisher have high resilience to the ownership of the assets needed to catch fish because it has a value of 1.75. The assets owned by fisher start from boat ownership, fishing gear ownership, boat engines that are owned by themselves without renting from others.

Educational ability also has high robustness in this measure, with a value of 0.68 (Table 6). Education greatly affects fisher's income in order to maintain their livelihood. Higher education has a positive influence on the income patterns of fisher [38]. This happens because, with higher education, fishers are able to earn additional income besides fishing; moreover, different fishing patterns can emerge at this level. The circumstances also support an indicator value of 0.58 for other forms of livelihood ownership, indicating that fishers have resilience in generating additional income. Fishers may engage in non-formal work such as construction, farming, pond management, assisting the tourism sector, etc., to supplement their income and meet daily expenses. Achieving these conditions also requires the ability to self-organize effectively to sustain their livelihoods. An analysis of self-organization capabilities can be found in Table 7.

Table 7. Self-organization capacity.

Dimension	Indicator	Standard Deviation	Score Indicator	Score Dimension	Deviation
Self-organization Capacity	• Family member	0.23	0.55	0.50	0.13
	• Organization activity	0.50	0.47		
	• Communication	0.18	0.58		
	• Social activity	0.31	0.42		
	• Loan	0.43	0.82		
	• Saving	0.50	0.44		
	• Subsidy	0.24	0.19		

Table 7 shows the ability of fisher to organize their living needs, which is measured through the participation of fisher in their social relationships. The average fisher has a medium self-organization capacity dimension value with a dimension value of 0.50. This can be interpreted that fisher have not been able to manage their lives to gain additional capabilities in maintaining their livelihoods. Measured from the resulting indicators, the lowest scores in the dimensions sequentially are communication, number of family members, and government assistance which each have a value of 0.18; 0.23; and 0.24. So that support from the government is also needed to encourage capacity building and the role of fisher organizations, which can support their livelihoods.

DISCUSSION

The results of the study are discussed descriptively by linking them to the previously discussed dimensions of livelihood resilience. These findings align with previous research, indicating that small-scale fishers exhibit moderate resilience in maintaining their livelihoods [8]. There are many factors that influence fisher to gain the resilience they have. A high level of education has a positive effect on fishing patterns and income [30], productive age determines household welfare [35], and the use of modern fishing gear can provide large catches [30]. Therefore, it is necessary to support the government and the social environment to help fisher in order to improve the quality of income they have, so that welfare can occur for fisher.

In terms of the buffer capacity dimension, fishers fall into the “low resilience” category, indicating a lack of access to resources [49]. Factors such as decreased income, environmental damage, difficulty accessing basic needs, and natural disasters contribute to this situation [50]. Recommendations are made to strengthen the life support capacity of fishers by enhancing their production capacity.

Policy alternatives, such as strengthening community organizations, providing training in other fields, and organizing fishers into cooperatives or associations, are suggested [33]. Other policy alternatives that can be used are strengthening community organizations, providing training in other fields, and grouping fisher to organize them as cooperatives or associations. This is done so that fisher can be involved as a team when there are government initiatives, grants, loans and training are always given to groups and not to individuals; even market relations are reserved for groups and not for individuals [26]. This can be done because fisher in Karimunjawa have good learning capacity.

The learning capacity and self-organization capacity of Karimunjawa fishers fall under the category of “medium resilience”, where fishers are able to access education, acquire skills in other fields, and participate in organizational membership. Research conducted in China, the experiences fisher gain in fishing and the knowledge they gain from members in their social network can positively contribute to the resilience of their livelihoods [30]. For example [51], Non-Govermental Organization (NGO) training is beneficial for coastal communities to raise awareness, build capacity, and forge relationships with sources of support, enabling them to build resilient communities. This policy can be implemented, because the measurement results in this study indicate that fisher have a relatively good organizational capacity.

CONCLUSIONS

Fishers in Karimunjawa are vulnerable to natural, social and governmental aspects. Natural disturbances occur due to ecosystem damage and climate change in Karimunjawa, resulting in decreased

income for small-scale fishers. The social disturbance occurred due to limited access to resources for fisher: starting from technology, organization, and conflicts of interest that occurred in Karimunajwa. Meanwhile, government disturbance occurs due to inconsistent policies, inadequate area management, and complicated government structures. Karimunjawa fisher have a value of "medium resilience" occurring in the dimensions of Buffer capacity (0.39), Self-organization capacity (0.50), and Learning capacity (0.54). This refers to the socio-ecological dynamics of the coastal environment, changes in the area's environment in the form of the amount of fish resources, coastal biodiversity, land occupation, exposure to coastal hazards, are considered important for livelihood sustainability. In the socio-economic aspect it is influenced by the scale of the community's business, the number of catches, and the management of their production. Small-scale fishers face economic limitations in accessing business development opportunities, in addition to their relatively poor backgrounds in rural communities.

Appropriate policy strategies can be carried out through strengthening individual fisher through other training, to help obtain alternative livelihoods. Strengthening community organizations can also be done, to strengthen social access that exists in small-scale fishing communities: starting from business development, strengthening microfinance, and developing assistance from the government. It can be seen that NGO training is beneficial for coastal communities to raise awareness, build capacity, and establish relationships that connect with sources of support, which will enable them to build resilient communities. This policy is not only to overcome fisher's income, but also can help reduce pressure on the environment (e.g., over-fishing, destructive fishing gear, etc.). Suggestions to the government are better to provide assistance in adding renewable assets and technologies that are environmentally friendly in supporting the achievement of fisher's welfare and environmental sustainability. In addition, they are expected to be able to follow the social and ecological changes that occur by providing counseling on the importance of livelihood diversification to increase their income. Stakeholders can also help provide other training in carrying out environmentally friendly cultivation, as well as provide knowledge to fisher that there is added value that can be carried out in the post-production process.

DATA AVAILABILITY

All data generated from the study are available in the manuscript.

AUTHOR CONTRIBUTIONS

ZA and IS designed the study. WW, NSBM, and DDI assisted in data analysis. Lastly, ZA also wrote articles based on input from all the authors.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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