Livelihood vulnerability of small-scale fishermen's households to climate variability in Bengkulu City, Indonesia

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Abstract. The relevance of this study to climate change lies in its examination of climate variability—encompassing fluctuations in temperature, rainfall, and seasonal patterns—which directly reflects global climate change dynamics. Such variability has profound implications for small-scale capture fisheries, influencing marine productivity, increasing the frequency of extreme weather events, and generating uncertainty in fishing seasons. By employing the Livelihood Vulnerability Index (LVI) based on the IPCC framework, this study systematically evaluates the exposure, sensitivity, and adaptive capacity of small-scale fishing households to climate-induced stressors. The sampling method employed was accidental sampling, involving 100 small-scale fishermen engaged in one-day fishing activities. The results showed that the LVI index value of 0.234 indicates a low level of livelihood vulnerability of fishermen's households. However, strengthening adaptive capacity remains needed to address future climate uncertainty. Regression analysis showed that age, ship ownership, and fishing distance significantly influence vulnerability, whereas fishing experience and household size did not. The coefficient of determination (R^2) of 0.590 indicates that the model explains 59% of the variation in livelihood vulnerability. These findings underscore the importance of adaptation strategies and risk-based policies in enhancing the resilience of small-scale fishers to climate-related stress.

1 Introduction

Fishermen rely heavily on fisheries resources for their livelihoods, yet the distribution, accessibility, and productivity of these resources are increasingly disrupted by climate change. Fluctuations in temperature, rainfall, wind patterns, and ocean currents alter fish mobility and availability, making fishing activities more uncertain and hazardous. Climate

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variability also deteriorates environmental conditions and intensifies livelihood pressures by damaging fishing gear, increasing operating costs, and reducing access to markets during extreme events such as tornadoes or tidal flooding [1]. These disturbances function as continuous stressors, heightening household vulnerability and threatening long-term livelihood security.

In the western coastal region of Bengkulu, which directly faces the Indian Ocean, climate-related risks are amplified by strong winds, high waves, and shifting seasonal patterns. Fishermen frequently misinterpret seasonal cues, resulting in unsafe fishing decisions and reduced catch productivity [2]. These climate-induced disruptions interact with fishermen's socio-economic conditions, influencing their livelihood assets, adaptive strategies, and overall resilience. Income has become a key indicator for assessing livelihood vulnerability because it reflects the household's ability to maintain and optimize livelihood assets under environmental stress [1]. To comprehensively measure such vulnerability, the Livelihood Vulnerability Index (LVI) is widely used, as it captures exposure, sensitivity, and adaptive capacity—three core dimensions of vulnerability as defined by the Intergovernmental Panel on Climate Change (IPCC) [3].

Despite the growing body of literature on climate impacts in coastal communities, three essential research gaps remain. First, previous studies in Indonesia have examined fishermen's perceptions and adaptation responses. Yet, empirical assessments of livelihood vulnerability using the LVI–IPCC framework remain limited, especially for small-scale fishers operating in high-risk coastal zones such as Bengkulu. Second, the integration of LVI with econometric modelling to identify socio-economic determinants of vulnerability is rarely conducted, even though such integration is crucial for understanding how climate exposure interacts with household characteristics to shape vulnerability outcomes. Third, studies specifically focusing on Bengkulu's western coastline—a region uniquely exposed to the dynamics of the Indian Ocean—are scarce, leaving a contextual gap in understanding how climate variability affects livelihood structures in this particular ecological and socio-economic setting.

Given these gaps, the novelty of this study lies in its combined application of the LVI–IPCC approach and a Multiple Regression Model to simultaneously measure livelihood vulnerability and identify key determinants of vulnerability among small-scale fishing households in Bengkulu City. This dual analytical framework provides a more comprehensive, evidence-based assessment than previous studies, which typically rely on either descriptive vulnerability indices or qualitative adaptation analyses. Moreover, this research provides new empirical insights into how climate variability affects coastal households explicitly in Bengkulu, a region with high exposure but limited adaptive capacity. By identifying statistically significant socio-economic drivers—such as age, vessel ownership, and fishing distance—this study offers targeted policy recommendations to strengthen resilience within coastal communities facing climate change. Therefore, this study aims to analyze (1) the livelihood vulnerability of small-scale fishing households under the pressure of climate variability and (2) the socio-economic factors influencing livelihood vulnerability in Bengkulu City.

2 Methodology

This research was conducted in Bengkulu City (Figure 1), which was intentionally selected because it is the most significant capture fisheries production area in Bengkulu Province, with a production of 41,919 tons. This makes Bengkulu City the most critical contributor to capture fisheries production in Bengkulu Province, accounting for 50.81% of the total [4]. In this research, the analysis unit consists of small-scale fishermen who serve as key informants

https://doi.org/10.1051/e3sconf/202568205002

to gather information about their livelihood vulnerability in relation to the impact of climate variability. The method used in determining the respondents is accidental sampling, with a total of 100 fishermen selected. The questionnaire was carefully designed to gather information on socio-economic characteristics and livelihood vulnerability related to the impacts of climate variability, as chosen by small-scale fishermen based on their knowledge, understanding, and experience.

Data were analyzed using the livelihood vulnerability index (LVI) calculated using the balanced average method [5]. After calculation, the LVI results can be interpreted as follows: > 0.75 = High vulnerability, 0.50 - 0.75 = Moderate vulnerability, and < 0.50 = Low vulnerability. A multiple linear regression model was used to analyze the factors influencing the livelihood vulnerability of small-scale fishers by involving various variables selected from previous studies, namely the age of the fisherman [6, 7], boat ownership status [2], fishing experience [7], number of family dependents [8], and fishing distance [7].

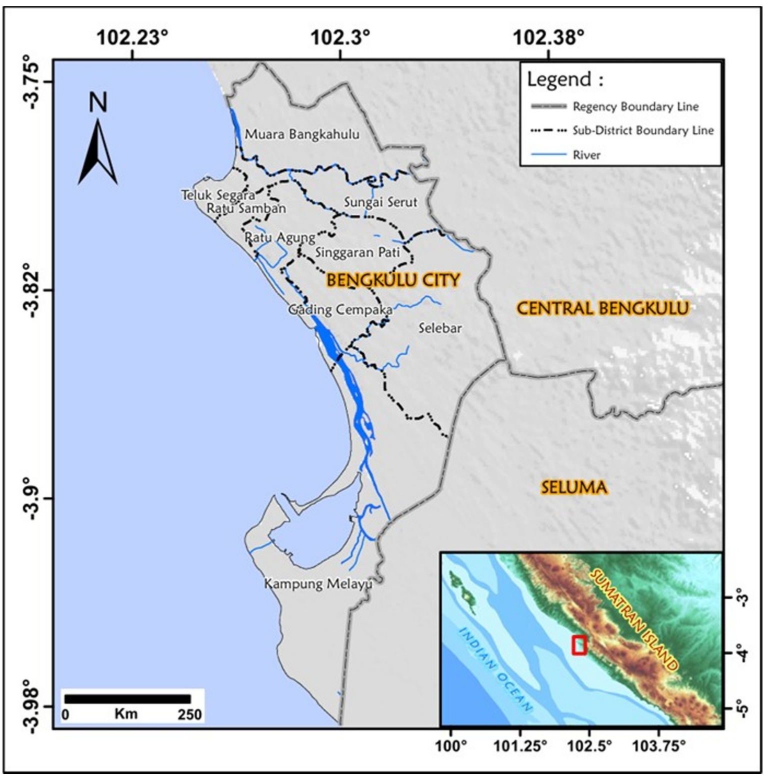

Figure 1. Research Area

3 Results and discussion

3.1 Characteristics of small-scale fishermen

The characteristics of respondents observed in this survey are described descriptively, including age, level of formal education, number of dependents, fishing experience, and participation in fishing groups (Table 1). The age distribution of fishermen in Bengkulu City shows an average age of 47 years. This indicates that the majority of fishermen are still in the productive age group (15–65 years). Age is a physical ability to perform a job and influences a person's maturity in adopting new technology [9]. The education level of small-scale fishermen in Bengkulu City shows that they have completed junior high school. A person's level of education influences their mindset and ability to accept innovation. The higher the level of education attained, the better the way of thinking and insight. This is reflected in attitudes and actions, especially in managing an area, compared with those with lower levels of education [9].

The number of family members plays a role in determining the extent of household needs; the more family members, the greater the needs. However, a high number of family members can also motivate the head of the family to work harder to meet the existing burden of responsibilities. Family dependents include individuals who live in the same household as the head of the family, as well as those who do not live with the head of the family but are still dependent on him for daily needs [10]. Based on the data, the highest percentage of family dependents is 3-4 people, accounting for 62% of small-scale fishing households. The number of family members directly affects the adequacy of food consumption and household expenses. The more dependents in a family, the greater the economic burden, leading to a larger share of family income being used to meet basic needs [10].

Table 1. Characteristics of small-scale fishermen

Category	∑ (people)	%	Average
Age (years)			
28 - 43	37	37	
44 - 59	54	54	47
>60	9	9	
Formal education (years)			
6	34	34	
9	40	40	9
12	26	26	
Household size (person)			
0 – 2	30	30	
3 – 4	62	62	3
5 – 6	8	8	
Fishing experience (years)			
3 – 21	50	50	
22 – 39	40	40	23
40 – 57	10	10	
Boat ownership			
Owned	40	40	
Rented	60	60	

Source: Primary data, 2025

The majority of small-scale fishers who responded had more than 23 years of experience, with the highest percentage being in the 3-21 years range (50%) of small-scale fishers (50 respondents), while the lowest rate was fishers with 40-57 years of experience, at 10% (10 respondents). According to Salim & Widyanti [11], work experience influences a person's skills in using technology, increasing productivity, and resolving work-related obstacles. However, as years of experience as a fisherman increase, there is a tendency for the number of fishers with longer experience to decrease. This is due to age: fishers who have worked longer tend to get older. As they age, their physical abilities decline.

Vessel ownership affects the level of vulnerability of fishing households. Data shows that 40% of fishermen own their own vessels, while the other 60% rent them. Fishermen who own their own vessels tend to be more economically stable because they have complete control over their fishing efforts and are not burdened with rental costs. According to Yuniarti & Sukarniati [12], fishermen who own their own vessels have advantages over those who do not. Fishermen who own vessels tend to have higher incomes because they do not have to pay for vessel rentals. Furthermore, fishermen who own vessels can generate additional revenue by renting them out.

3.2 Livelihood vulnerability of small-scale fishermen

Vulnerability analysis using the Livelihood Vulnerability Index (LVI) assesses exposure to natural disasters and climate variability; household socio-economic characteristics that influence adaptive capacity; and current health, food, and water resource characteristics that determine household sensitivity to climate change [5]. Calculations using the LVI method (IPCC) showed a value of 0.234, indicating a low level of vulnerability (Table 2). This result is influenced by high exposure (1.000) to climate variability, while sensitivity (0.450) and adaptive capacity (0.480) are still low. Although the impacts of climate change are felt, low sensitivity helps mitigate the effects. However, weak adaptive capacity indicates the need for improved fishing technology, income diversification, and supporting policies to strengthen fishers' resilience to climate change. In contrast, findings [1] indicate that small-scale fishers are more vulnerable, with high sensitivity and low adaptive capacity. The main difference lies in sensitivity: in this study, low sensitivity helps mitigate the impacts of climate change, while high sensitivity increases vulnerability. Although both studies noted high exposure and low adaptive capacity, sensitivity was the main differentiating factor.

For fisheries-based livelihoods, exposure is the degree to which a livelihood system is affected by significant climate variations [5, 1]. The exposure experienced by small-scale fishing households in Bengkulu City is a result of the impacts of climate change and variability that affect the fishing livelihood system.

Table 2. Livelihood Vulnerability of Small-Scale Fishing Households Due to Climate Variability Pressure

Dimension	Indeks	Status
Exposure	1.000	High
Adaptive capacity	0.480	Low
Sensitivity	0.450	Low
LVI – IPCC	**0.234**	**Low**

Source: Primary data, 2025

3.3 Determinants of livelihood vulnerability of small-scale fishermen

The vulnerability of small-scale fishermen's household livelihoods was analyzed using a multiple linear regression model. The results of the analysis (Table 3) show an R^2 value of 0.590, indicating that 59% of the variation in the vulnerability of small-scale fishermen's household livelihoods can be explained by age, boat ownership, fishing experience, number of family members, and fishing distance. In comparison, 41% is influenced by other factors not included in the model. The results of the analysis show a significance value of $0.000 < 0.05$. This indicates that, simultaneously, the variables of age, boat ownership, fishing experience, number of family members, and distance influence the vulnerability of small-scale fishermen's household livelihoods.

Age statistically significantly influences the likelihood of vulnerability among fishermen. This means that the older a fisherman is, the greater the level of livelihood vulnerability they experience. This positive effect indicates that older age tends to increase vulnerability, as older fishermen generally experience decreased physical abilities, which impacts productivity and catch yields. This finding aligns with research by Ariska & Prayitno [13], which found that increasing age among fishermen tends to reduce physical strength, thereby decreasing productivity at sea. Consequently, fishermen's incomes decline, thereby increasing their livelihood vulnerability.

The results of the regression analysis indicate that vessel ownership significantly influences the livelihood vulnerability of small-scale fishing households in Bengkulu City. This shows a strong, significant relationship between vessel ownership and livelihood vulnerability. The regression coefficient (B) of 0.100 indicates that vessel ownership is positively associated with vulnerability. In other words, fishermen who own vessels tend to be less vulnerable in their livelihoods than those who rent boats. Boat ownership provides economic benefits for fishermen because they do not need to pay boat rental fees and can even earn additional income by renting their vessels to other fishermen. Thus, vessel ownership strengthens economic resilience and reduces the level of livelihood vulnerability of fishing households. This finding aligns with research by Yuniarti & Sukarniati [12], which found that fishermen who own vessels have better economic opportunities than those who do not. In addition to cost efficiency, vessel ownership also creates an additional source of income that can improve livelihood stability.

Table 3. Results of analysis

Variables	B	Std. Error	t	Sig
Constant	0.045	0.038	1.199	0.233
Age	0.002	0.001	2.412	0.018*
Boat ownership	0.1	0.01	9.899	0.000*
Fishing experience	-0.001	0.001	-1.079	0.283
Household size	-0.004	0.005	-0.754	0.453
Fishing distance	0.004	0.001	2.95	0.004*
Determinant coefficient (R^2)				0.590
F-test				0.000

Source: Primary data, 2025
*significance at α 5%

The results (Table 3) show that fishing distance significantly influences the livelihood vulnerability of small-scale fishing households. This means that the farther they travel, the more vulnerable they are. This situation can be explained by the realities on the ground, where small vessels limit fishermen's cruising range due to limited fuel capacity, minimal protection against bad weather, and inadequate fish storage facilities. These factors result in smaller catches and increased potential losses, especially when fishermen are forced to fish farther. This finding is supported by Ulfa [14], who stated that climate change forces fishermen to travel longer distances to catch fish. Furthermore, [15] explained that climate change impacts fish production declines, increases fishing costs, reduces the effectiveness of fishing gear, and makes it challenging to determine fishing areas. All of these conditions contribute to increased livelihood vulnerability among fishing households.

4 Conclusion

This study assessed the livelihood vulnerability of small-scale fishing households in Bengkulu City and identified the factors influencing it. The Livelihood Vulnerability Index (LVI) score of 0.234 indicates that fishermen's households fall within the low vulnerability category, although they remain highly exposed to climate variability. Low sensitivity and moderate adaptive capacity help reduce overall vulnerability, yet limitations in technology access, income diversification, and institutional support continue to constrain resilience. The regression analysis shows that age, vessel ownership, and fishing distance significantly influence livelihood vulnerability, while fishing experience and household size do not. Older fishermen and those who must travel farther to fish tend to be more vulnerable, whereas boat ownership reduces vulnerability by providing greater economic stability. Overall, this study contributes to climate-vulnerability research by integrating the LVI–IPCC framework with socio-economic analysis and providing empirical evidence on how climate variability interacts with household characteristics to shape vulnerability. The findings also provide a scientific basis for strengthening coastal adaptation policies to enhance the resilience of small-scale fishers.

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