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Vulnerability of Small-Scale Fishermen's Livelihoods to Climate Change in the Coastal Area of Lampung Bay, Indonesia

Muhammad Arhan Rajab[1], Darmawan Salman[2]* and Firdaus W Suhaeb[3]

[1]Department of Marine Environmental Science, Sumatera Institute of Technology, Jati Agung 35365, South Lampung, Indonesia

[2]Department of Social Economics of Agriculture, Faculty of Agriculture, Hasanuddin University, Makassar 90246, South Sulawesi, Indonesia

[3]Department of Sociology, Faculty of Social and Law, State University of Makassar, Makassar 90222, South Sulawesi, Indonesia

*Corresponding Author: darsalman@agri.unhas.ac.id

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ABSTRACT

Climate change in recent years has affected fishing activities in Lampung Bay. This study aimed to analyze the vulnerability of small-scale fishermen's livelihoods to climate change. The vulnerability assessment in this study assesses the livelihoods of Bagan fishermen based on geographic and socio-demographic indicators that impact Bagan fishermen's households consisting of 9 main components and 33 supporting components. This study was conducted during January-June 2024 in Kotakarang District, Lampung Province. Data were collected based on interviews with 57 Bagan fishermen informants consisting of patron and client fishermen. The results of the study showed that client fishermen were more vulnerable than patron fishermen, as calculated based on the LVI-IPCC. Client fishermen were found to be more vulnerable in key components such as human resource capital where fishing experience is less than 10 years, food sensitivity which shows that part of the income is used to meet food needs, health sensitivity related to difficulty in accessing health insurance, and ownership of fishing gear where client fishermen do not have fishing gear assets. Meanwhile, patron fishermen were found to be vulnerable in food sensitivity components such as income which is mostly used to meet household food needs. Based on the findings in this study, the vulnerability of the livelihoods of bagan fishermen can be evaluated. In addition, this study should be the basis for formulating policies to evaluate assistance programs, especially for areas with minimal data so that the LVI scenario is used as a basis for decision making.

INTRODUCTION

The climate change phenomenon has caused various impacts and problems in multiple countries **(Ahmed *et al.*, 2024)**. Another danger posed is the occurrence of extreme weather, which continues and is predicted to continue to occur **(Rahayu *et al.*, 2020)**. The climate change phenomenon effects the ecological environment. This incident also triggered a decline in biodiversity and potential water shortages **(Rankoana, 2018)**.

Climate change also influences the sustainability of the livelihoods of tuna handline fishermen on Buru Island, where fishermen face threats to the sustainable status of fish resources, economic sustainability of fish resources, losses due to disasters, and port industrial activities **(Laitupa *et al.*, 2023)**. Recent studies by **Liu and Masago (2025)** states that climate change impacts are not single but include spatial and temporal impacts on diverse environments. Climate change occurs in almost all countries and is an important issue that can affect human life. The impacts are irreversible and will continue to occur now and in the future, threatening all sectors of life without exception **(Muia *et al.*, 2025)**. This occurs in the socio-economic aspect, where population concentration and various economic activities grow and develop in coastal areas. Massive industrial development activities, sea transportation, and the development of new cities are centered in coastal areas. At least 11%, or the equivalent of 896 million, of the world's population lives and performs activities in coastal areas. This number is expected to increase to more than 1 billion by 2050. This condition can negatively impact the survival of humans who live and carry out activities and depend on coastal and marine areas for their livelihoods **(Khan *et al.*, 2023)**.

One of Indonesia's provinces with significant fisheries resource potential is Lampung Province **(Department of Marine Affairs and Fisheries of Lampung Province, 2023)**. The coastal and marine areas of Bandar Lampung City are the center of fisheries activities in Lampung Province; this is also supported by the potential of marine fisheries, especially small pelagic fish, which are widely used as salted fish. The average capture fisheries production of Bandar Lampung City, Lampung, from 2018 to 2020 continues to decline. In 2020, capture fisheries production was at its lowest point in the last six years, namely only 5,012 tons **(Central Bureau of Statistics of Lampung Province, 2022)**. The decline in capture fisheries production in Lampung Province is greatly influenced by marine water conditions, which are becoming increasingly unpredictable and giving rise to seasonal and weather uncertainty. Climate change parameters make predicting seasonal weather difficult. The uncertainty of seasons and weather is greatly influenced by the blowing wind's speed and the rainfall level. The average wind speed in Lampung Province over the last 3 years shows increasing and decreasing fluctuations. The latest data show that the highest average wind speed in 2022 occurred in December, with a wind speed of 20 knots compared to 2023; the highest wind speed occurred in October, namely 3.8 knots **(Central Bureau of Statistics of Lampung Province, 2024)**.

Climate change that affects the waters of Lampung Bay also negatively impacts the sustainability of fisheries activities, thereby threatening the lives of coastal communities. Most fishing communities who use bagan can be found living in Kotakarang District **(Rajab, 2023)**. In general, bagan is classified into a lifting net, the construction of this fishing gear uses bamboo, wooden blocks or iron as its frame and consists of a rectangular bag that is stretched horizontally in the air. Bagan fishing gear

targets small pelagic fish that are attracted to light (positive phototaxis). The fishing method relies on using light to attract and concentrate fish above the net bag. Once the fish have gathered, the net is slowly lifted using a net rope roller **(Sudirman & Mallawa, 2004, 2013)**. The bagan fishing community operating in the waters of Lampung Bay has existed for many years and has made several modifications to their fishing gear over time. Modifications to bagan fishing gear can be seen through the adoption of technology carried out by fishermen. This is done to adapt fishing gear to the dynamics of the Lampung Bay sea waters, which are experiencing climate change. Climate change in Lampung Bay's waters, such as increased extreme weather, impacts the increasing difficulty of predicting the season and fishing schedule. This condition further complicates the conditions of Bagan fishing households, many of whom live around the coastal areas of Kotakarang District, Lampung Province.

The most common used bagan operating in Lampung waters is called "*jerrycan bagan*". The construction of this fishing gear is built traditionally. However, it has undergone several modifications, such as using a jerrycan drum that functions as a float for the Bagan frame. This jerrycan drum aims to make it easier for the bagan to move from one fishing location to another. In addition, it allows fishermen to catch the fishing season, which is increasingly difficult to predict from time to time. In its operation, it uses the help of a motorboat to be pulled to the middle of the sea or the fishing location.

The phenomenon of climate change is increasingly exacerbated by the marine pollution that occurs. One reason for marine pollution is that currents carry people's domestic waste through the Way Belau River to the waters of Lampung Bay. Sources of pollution also come from industrial and domestic waste that flows through rivers that empty into the sea along the coast of Lampung Bay **(Regional Research and Development Agency, Lampung Province, 2018)**. The combination of the phenomenon of climate change and the presence of marine debris also has a negative impact. It threatens the sustainability of marine ecosystems, although it depends on the ecological characteristics of waters and local human activities **(Lincoln *et al.*, 2023)**. The impact of climate change and pollution is reflected on fishermen in the Central Region, Ghana and their fishing activities **(Kwadzo *et al.*, 2022)**. Climate change causes rising sea temperatures, ocean acidification, and other ecological impacts. This affects the distribution of fish stocks in the waters, including the abundance and potential of fisheries, which will ultimately have an impact on fishermen's income levels **(Xu *et al.*, 2024)**. Second, regarding economic and socio-cultural aspects, the Bagan fishing community is also vulnerable to economic activities, both types and degrees of economic dynamics, which are limited and small-scale. The livelihood of the majority of residents in the coastal area of Bandar Lampung City is fishermen, namely 1,039 people and 1,933 workers. Therefore, if fishing activities continue without considering carrying capacity, it will put pressure on marine resources along with the dynamics of economic activities. Therefore, studies on climate and the environmental crisis are not only about the issue of

climate change but also cover the vulnerabilities that often occur in coastal areas **(Dewan, 2021)**.

Many studies have been conducted that examine the topic of assessing the impact of climate change through preliminary studies on vulnerability, such as research developed by **Arifah *et al*. (2022)** and **Arifah *et al.* (2023)** in the context of irrigated rice fields, followed by research by **Arham *et al.* (2024)** in the context of coffee farmers in high altitude areas. However, it has not linked this vulnerability to the farmer's livelihood system. In contrast to the agricultural sector, in fisheries activities, especially capture fisheries, the issue of climate change is relatively neglected, which highlights the importance of increasing the knowledge base regarding vulnerability through developing alternative livelihoods. Several studies have been developed in the context of coastal and marine areas, such as research on the vulnerability of fishing communities which has also been carried out by **Ayisi *et al.* (2024)** and **Schwerdtle *et al.* (2024)** regarding fishermen's perceptions of vulnerability due to climate change. According to **Mbaye *et al.* (2023)** and **Filho *et al.* (2025)**, in the context of traditional fishing, the phenomenon of climate change is faced through traditional approaches, religious magic, and modern technology. Additionally, **Ullah *et al.* (2022)** have described various vulnerabilities caused by climate change using a local knowledge approach; however, they did not conduct quantitative assessments of the current level of vulnerability, nor did they explore in depth its connection to the livelihood systems of fishermen. This research will fill this knowledge gap by calculating the level of vulnerability to the impacts of climate change on capture fishing communities and linking the impacts to fishermen's livelihood systems. This research aimed to analyze the level of vulnerability of the livelihoods of small-scale fishing communities in the Lampung Bay Coastal Area, Indonesia.

MATERIALS AND METHODS

1. Research duration and location

This research was carried out from January to June 2024 in Kotakarang District, considering that when the research was conducted it was a productive period or fishing season for bagan fishermen. However, due to climate change, bagan fishermen experienced a decrease in catch due to the difficulty of going to sea and very limited fish resources. In addition, Kotakarang District is a center for fishing activities in the coastal area of Lampung Bay, Indonesia. Therefore, it is very vulnerable to threats and disturbances from natural disasters. Geographically, Kotakarang District is located at 1050 15' 42.3" East Longitude to 1050 15' 52.5" East Longitude and 050 27' 52.2" South Latitude to 050 28' 07.5" South Latitude (Fig. 1).

In 2024, the population of Kotakarang District reached 10,225 people across 2,857 households (**Kotakarang Subdistrict Monograph, 2024)**. The district has a relatively high population density, which is predicted to pose several challenges, including limited

land availability for housing, sanitation issues, and pollution of the coastal and marine environment. Most of the Bagan fishermen in Kotakarang District, who conduct their fishing activities in the waters of Lampung Bay, report experiencing noticeable changes in climate and seasonal patterns, which have affected the intensity and consistency of their fishing activities.

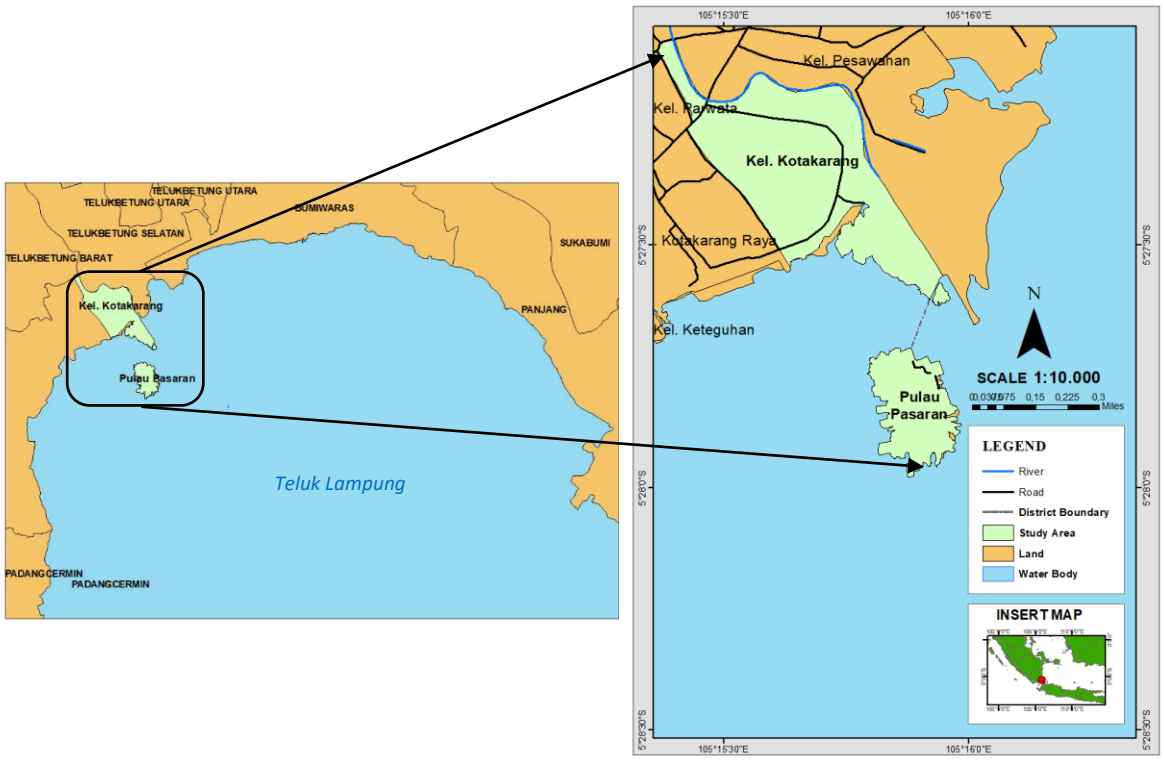

Fig. 1. The map of the Lampung Bay coastal area highlights the research location surveyed in Kotakarang District

2. Sampling and data collection

The informants in this research focused on fishermen who operate fishing gear with fishing locations in the waters of Lampung Bay. Most of the Bagan fishermen are found living in Kotakarang District. The selection of informants was based on the consideration that fishermen had at least many years of fishing experience so that they knew with certainty the changes or natural phenomena that had occurred in the waters of Lampung Bay, which had affected their income so far.

The informants in this research were patron fishermen with the local term "*juragan*" and client fishermen with the local term "*sawi*". A patron fisherman is a person who independently operates fishing gear on his property and has the support of capital sources so that he owns more than one unit of fishing gear. This patron fisherman also has the right to the ownership of the motor boat used by all the fishing gear in the study location, which is used to assist in operating the fishing rod in the fishing location. Meanwhile, client fishermen work to operate the boss's fishing rods.

Twelve fishermen met these criteria as patron fishermen (juragan) and 84 client fishermen (Sawi). Sample calculations in this study refer to the Slovin formula **(Yamane, 1967)**:

$$n = \frac{N}{1+Ne^2} = \frac{12}{1 + 12 \times 0.1^2} = 10.7 \text{ (approximately 11 patron fishermen)}$$

$$n = \frac{N}{1+Ne^2} = \frac{84}{1 + 84 \times 0.1^2} = 45.6 \text{ (approximately 46 client fishermen)}$$

Where, n is the sample size; N is the number of fishing fishermen (patrons and clients) in the research area; and e is 10.00% of N. The sample size is the reason for determining the significance level of 10.00%.

Table 1. Personal information of respondents

Aspects	Mean	Percent (%)
Age (years)	Productive age: 40-60 years	52.6 %
Education	Elementery school	54.4 %
Number of family members persons)	5	58.9 %
Boat owner (persons)	12	21 %
Side occupation	> 1 job	21 %
Trip duration/days (hours)	12 hours	100 %

The survey results showed that out of 57 informants, 11 (19%) were patron fishermen and 46 (81%) were client fishermen (Table 1). Primary data collection in this study was conducted through participant observation and in-depth interviews directly with the research subjects. A literature review was also conducted to support the validity of the collected data, particularly by referencing previous studies and other relevant documents. Generally, data collection took place between 10:00 AM and 2:00 PM, which is the most suitable time to meet heads of households who work as fishermen. Each interview session lasted approximately 40 to 60 minutes per questionnaire.

Meanwhile, secondary data were collected through documentation and additional documents that help carry out the research process. Qualitative descriptive research data indicate that the data are reported in the form of words or pictures rather than numbers **(Creswell, 2009)**. In-depth interviews were conducted with predetermined fishing informants using a semi-structured and open-ended interview questionnaire. In-depth interviews were used to collect data regarding environmental changes that occured.

3. Data analysis

In this study, the vulnerability analysis of the livelihoods of Bagan fishermen in the coastal area of Bandar Lampung City was measured by calculating the Livelihood Vulnerability Index (Table 2). Vulnerability in this context is in the form of external pressure from the ecological environment, hence it requires adjustment or adaptation by

society. Therefore, the vulnerability analysis in this study is a response to disturbances and threats that occur in coastal and marine areas. Furthermore, the explanation of vulnerability is a function of several components, including exposure, sensitivity, and adaptive capacity **(Adger, 2000)**. The LVI assessment has ten main components: socio-demographic profile, livelihood strategies, social networks, health, food, water, houses and land, natural disasters and climate variability, knowledge and skills, and finances **(Huong *et al.*, 2019)**.

The vulnerability assessment process is a method for systematically combining interactions between humans and the physical and social environment. According to **IPCC (2007)**, vulnerability is defined as:

Vulnerability = Function {Exposure(+); Sensitivity (+); Adaptive Capacity (-)}

The level of exposure shows the degree, duration, and/or significant opportunity for a system to come into contact with shock or disturbance **(Gallopín, 2006)**. Sensitivity is how a system, community, or sector will respond positively or negatively to climate-related hazards. Sensitivity also considers socio-economic context. Adaptive capacity is the system's ability to adapt to stress. This adaptive capacity is related to the resilience level, which is the key to increasing adaptive capacity. Also, resilience is closely related to social capital, including networks and social relationships **(Cutter *et al.*, 2008)**.

According to **Shah *et al.* (2013)**, the LVI method calculation steps consist of 3 stages. The first stage of LVI analysis is a combination of vulnerability indices as follows:

1. The calculation of the index of each sub-component using the following formula:

$$Indeks_{Sd} = \frac{Sd - Smin}{Smax - Smin}$$

Information:
$Indeks_{Sd}$ = Index of each sub-component
Sd = Component sub indikator value
Smin = Minimum value of sub-component
Smax = Maximum value of sub-component

Where, Sd is a region component, and Smin and Smax are each component's minimum and maximum values.

2. After normalizing the sub-component values, the value of each principal component was calculated using the equation:

$$Md = \frac{\sum_{i=1}^{n} Indeks\ sdi}{n}$$

Information:
Md = Value of each significant component
Indeks sd = Index of each sub-component

n = Number of sub-components

3. The final step was to determine the LVI value for each group of fishermen using the formula:

$$LVI_d = \frac{\sum_{i=1}^{8} W_{Mi} \; M_{di}}{\sum_{i=1}^{8} W_{Mi}}$$

Information:

LVI_d = LVI Value in the region

W_{Mi} = Sub-Component Weight

M_d = Assess each major component

This research shows an equal contribution from each main component to LVI. LVI-IPCC scales from 0 (least vulnerable) to 0,5 (most vulnerable) **(Hahn *et al.*, 2009)**.

Table 2. IPCC LVI contribution factor values for Bagan fishermen in Kotakarang District, Lampung Bay, Indonesia

Sub-component	LVI		Major Component	LVI	
	Patron	Client		Patron	Client
Increased intensity of tidal floods and storms	0.75	0.93	Exposure : Social, Economy dan Ecology	0.88	0.89
The house is built on the sea	0.75	0.82			
Catches are erratic	1.00	1.00			
High competition between fishermen	0.67	0.44			
Difficulty getting subsidized fuel	1.00	1.00			
Fluctuating fish selling prices	0.83	0.89			
Increased operational costs at sea	1.00	1.00			
Weather conditions are increasingly difficult to predict	1.00	1.00			
Dependencies in the family are low	0.17	0.78	Adaptif Capacity : Human Capital	0.46	0.50
The education level of the head of the household is at least elementary school	0.58	0.56			
High sea experience > 10 years	1.00	0.56			
The age range of fishermen is above 50 years	0.33	0.11			
Family members who work >1 person	0.08	0.22			
Fisherman as the main occupation	0.58	0.78			
Have more than 1 type of target fish	0.25	0.16	Adaptif Capacity : Natural Capital	0.33	0.39
Have a yard for farming/gardening	0.17	0.00			
The location of the fishing ground changes	0.58	1.00			
Have a side job	0.17	0.33	Adaptif Capacity : Financial Capital	0.35	0.44
Have loans/debts	0.75	0.89			
Have household savings	0.33	0.56			
Obtain assistance from the government	0.17	0.00			
Have communication and information facilities (HP, TV/Radio)	0.25	0.89	Adaptif Capacity : Physical Capital	0.22	0.30
Have fishing tools (Fish finder)	0.17	0.00			
Have more than 1 unit of fishing gear	0.25	0.00			

Join a fishing group	0.25	0.00	Adaptif Capacity : Social Capital	0.33	0.22
Cooperation between fishermen (at sea and on land)	0.42	0.44			
The catch is sold directly	0.83	1.00			
Expenditures for food needs	0.50	0.78	Sensitivity : Food	0.53	0.88
Some of the catch is consumed personally	0.25	0.87			
Distance from health facilities > 1 km	0.33	0.89	Sensitivity : Health	0.33	0.94
Have health insurance facilities (BPJS)	0.33	1.00			
Running a bagan business (not private proverty)	0.00	1.00	Sensitivity : Fishing Gear Asset	0.42	0.50
Bagan ownership is the result of a loan from the bank	0.83	0.00			
Livelihood Vulnerability Index (LVI)				**0.23**	**0.39**

RESULTS AND DISCUSSION

1. Lampung Province's vulnerability to climate change

The vulnerability in Lampung Province is the impact of the climate change phenomenon. The coastal area of Lampung Bay is one of the areas facing threats and disruption from the impact of climate change. In 2022, Lampung Province's greenhouse gas emissions reduction achievement reached 12.9 percent from the target of 6.9 percent **(Regional Development Planning Agency of Lampung Province, 2024)**. The results of another study **(SNV, 2021)** in collaboration with the Bandar Lampung City Government show that Lampung Province is vulnerable to climate change. The risks of climate disasters in Lampung Province include: 1). Flood; 2). Drought; 3). Sea Level Rise; 4). Landslide. Extreme winds and extreme rainfall that coincide can have a more significant impact than if the two hazards occurred separately **(Manning *et al.*, 2024)**, which causes more significant dangers for natural and human systems. Fig. (2) shows rainfall and wind speed data in Bandar Lampung City during 2022-2024. Kotakarang District is extremely vulnerable to natural disasters since it is geographically located in a coastal area and directly faces Lampung Bay. Natural disasters that have hit Kotakarang District in recent years include tidal floods, tornadoes, erosion, and sedimentation. Natural disasters in coastal and marine areas can have negative impacts, one of which is a decrease in the number of people working in the fisheries sector.

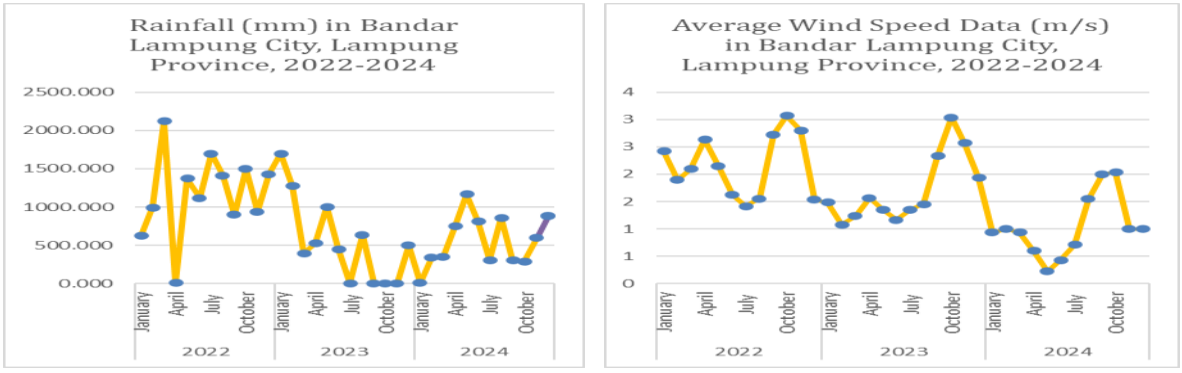

Fig. 2. Wind and rainfall trend from historical climate data during 2022 – 2024 in Bandar Lampung City

Fig. (2) shows rainfall and wind speed data in Bandar Lampung City during 2022-2024. Kotakarang District is highly vulnerable to natural disasters since it is geographically located in a coastal area and directly faces Lampung Bay. Natural disasters that have hit Kotakarang District in recent years include tidal floods, tornadoes, erosion, and sedimentation. Natural disasters in coastal and marine areas can have negative impacts, one of which is a decrease in the number of people working in the fisheries sector.

Climate change also affects the fisheries sector of Lampung Province. Marine capture fisheries production development shows a downward trend yearly (Fig. 3). Based on interviews with fishermen, the impacts of climate change in the waters of Lampung Bay have been felt over the past five years. Fishermen report increasing difficulty in catching fish due to more frequent extreme weather events and the declining availability of fish resources. According to the Ministry of Marine Affairs and Fisheries **(Ministry of Marine Affairs and Fisheries, 2017)**, the potential yield of small pelagic fisheries in Fisheries Management Area (WPP) 712 was reported to reach 364,663 tons.

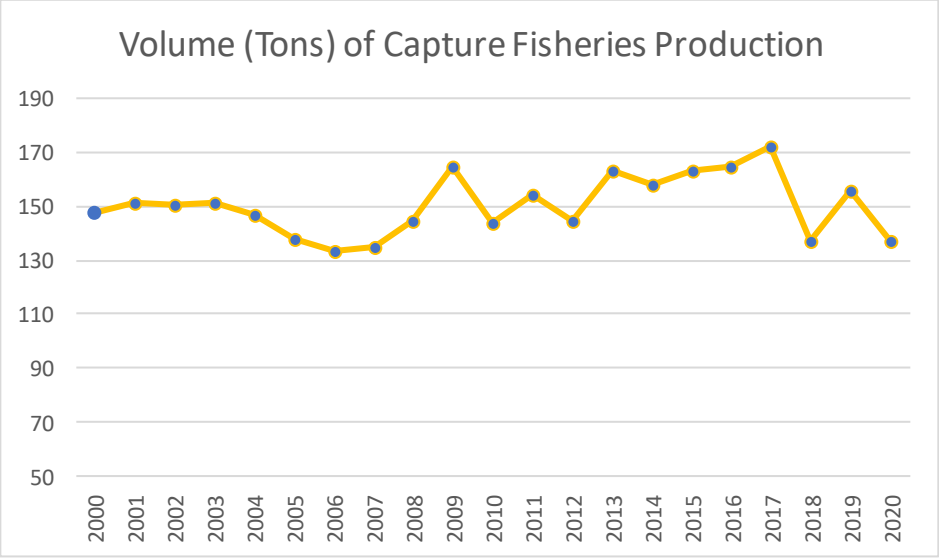

Fig. 3. Capture fisheries production in Lampung Province 2000-2020

Capture fisheries activities in Lampung Bay, Kotakarang District, are dominated by small-scale fisheries, especially Bagan fishermen. The socio-economic conditions of Bagan fishermen are very worrying. This can be seen from the increasing difficulty fishermen have getting fish when at sea; the decline in catches has an impact on their income. The income of Bagan fishermen depends on seasonal conditions, such as climate

and weather, which directly affect fishing trips. The type of fish targeted by Bagan fishermen operating in the waters of Lampung Bay is anchovies (*Stolephorus* sp.). Based on data on marine fish production by type in Bandar Lampung City, anchovy production since 2019 was estimated with an anchovy production volume of 251 tons, 2020 of 257.36 tons, and 2021 of 22,101 tons of the total production volume of captured fisheries 204,169.06 tons **(Central Bureau of Statistics of Bandar Lampung City, 2020)**.

2. Analysis of fishermen's livelihood capital

The condition of Bagan fishing households in the coastal area of Lampung Bay utilizes livelihood assets/capital to obtain a more decent living. According to **Allison and Ellis (2001)**, a livelihood system is a collection of skills and activities needed for survival, mediated by social relationships and institutions, and includes natural capital, physical capital, human capital, financial capital, and social capital. First, natural capital includes the availability of natural resources that can be utilized to fulfill food needs and become a source of daily income through fishing activities. Second, physical capital, such as the availability of motorboats, fishing gear, and supporting infrastructure when fishing. Third, human capital, such as experience and skills while at sea, and the availability of workers (people). Fourth, financial capital includes the availability of savings that can be converted into cash. Fifth, social capital includes social relationships and work networks among fishermen. Therefore, the role of social capital through the existence of formal and non-formal institutions really helps fishing communities in ensuring their survival.

Fig. 4. Five capitals for fisherman's household livelihoods in Kotakarang District, Lampung Province, Indonesia

Fig. (4) shows that the patron fishermen show five capitals consisting of natural capital, physical capital, financial capital, human resource capital, and social capital, which are classified as high, especially human resource capital, which has the highest contribution to the vulnerability value of 0.46. According to **Ellis (1998)**, a livelihood system is a collection of skills and activities needed for survival, mediated by social relationships and institutions and includes natural capital, physical capital, human capital, financial capital, and social capital. Human resource capital includes the level of education where the average patron fishermen have a low level of education/drop out of school, and the average age of fishermen is over 50 years. However, they have experience at sea> 10 years. In client fishermen, it shows that human resources and social capital have a relatively high contribution to the vulnerability value compared to social, natural, and physical capital. The contribution of the vulnerability value to human resource capital with a value of 0.5 can be seen from the average experience at sea, which is <10 years. In addition, the age distribution of client fishermen was an average of under 50 years. Although they are much younger, this affects their level of understanding and ability to "read nature" natural signs at sea, affecting their performance. Financial capital also contributes to the vulnerability value with a value of 0.44; it can be seen that limited capital is the main obstacle client fishermen face, so they are dependent on patron fishermen. This is further exacerbated by the condition that almost all client fishermen have debts and do not have alternative side jobs, so they are fully dependent on work as fishermen. This condition further enlivens the patron-client relationship in the dynamics of fishermen's lives in the coastal area of Lampung Bay.

Client fishermen experience limitations in capital, so all their needs while at sea depend entirely on patron fishermen. They also do not have savings in the form of cash or gold jewelry. They also admit they prefer to take loans (debts) from patrons because of easy access and time compared to formal institutions such as banks or pawnshops. Based on the survey results, there are quite significant differences between patron fishermen and client fishermen. Ownership of this livelihood capital affects the resilience of bagan fishermen in maintaining their livelihoods from various threats and disturbances in a context of vulnerability.

3. Level of Bagan fishermen’s livelihood

The measurement of vulnerability was carried out using the Livelihood Vulnerability Index (LVI) approach **(Allison & Ellis, 2001)**. This analysis aims to assess the impact of climate change on the vulnerability of fishermen’s household livelihoods. The LVI is based on ten key components: sociodemographic profile, livelihood strategies, social networks, health, food, water, housing and land, natural disasters and climate variability, knowledge and skills, and financial resources. These components form the foundation of the LVI assessment framework **(Huong *et al.*, 2019)**.

In this research, the vulnerability assessment was formulated through a combination of the perceptions of the Bagan fishing community with vulnerability theory. First, exposure in this study refers to 3 indicators: natural exposure, social exposure, and economic exposure (Fig. 5). Exposure to nature means that the livelihood of fishing households is very dependent on coastal and marine resources or the existence of fish stocks in the sea. Therefore, global climate change has a direct negative impact on the livelihood systems of fishermen's households. Second social exposure refer to high competition at sea, with indicators of increasingly frequent conflict incidents between fishermen, especially in fighting overfishing locations. Third, economic exposure is characterized by increasing operational costs at sea, and subsidized fuel prices are becoming increasingly complex, requiring additional costs and fluctuating fish selling prices, thus affecting the income of fishermen's families.

Most of the informants in this study (95.08%) stated that climate change, which is characterized by extreme weather, has disrupted and threatened their income in recent years. Due to frequent bad weather, fishing intensity has decreased, and more activities are on land. In detail, Fig. (5) shows the context of exposure experienced by Bagan fishermen in the coastal area of Lampung Bay.

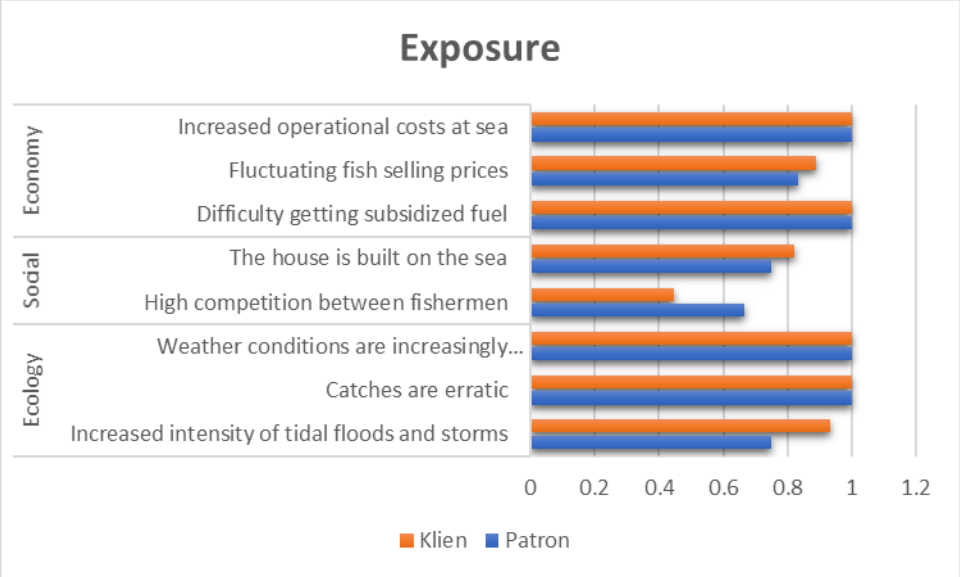

Fig. 5. Level of exposure faced by Bagan Fishermen in Kotakarang District, Lampung Province, Indonesia

The socio-economic and ecological exposure index values of patron fishermen (0.88) and client fishermen (0.89) are very high. The informants of the bagan fishermen experienced several crucial problems related to the pressure and natural threats of climate change in recent years, such as the increasing intensity of tidal floods and storms and increasingly unpredictable weather conditions that ultimately affect fishermen's catches. In addition, most patron fishermen and client fishermen build their homes above the sea. This condition certainly threatens the safety of the lives of fishermen's families if there is

a tidal wave disaster or tidal flood and storms that have the potential to damage and even threaten life safety that occurs every year. This condition also threatens health due to the transmission of diseases through water. Ecological pressure impacts socio-economic pressure, as seen from the fluctuating selling price of fish, increasing operational costs at sea, and difficulty obtaining subsidized fuel (BBM).

The analysis results show that the livelihood exposure index of patron fishermen is 0.88, and that of the client fishermen is 0.89. This value indicates the high impact of climate change on marine resources in Lampung Bay waters. Furthermore, the sensitivity index of client fishermen is higher at 0.79 compared to patron fishermen at 0.44. Meanwhile, the adaptive capacity of the livelihood of patron fishermen is 0.36 or slightly better than that of client fishermen at 0.40. Based on these results, it can be seen that the overall level of vulnerability of fishermen's livelihoods is based on the LVI-IPCC for patron fishermen with a vulnerability index value of 0.23 and client fishermen with a vulnerability index value of 0.39. The vulnerability of fishermen's livelihoods based on the LVI-IPCC is presented in Table (5).

Table 3. LVI-IPCC contribution factor values for Patron fishermen and client fishermen in Kotakarang District, Lampung Province, Indonesia

Contibuting factors	LVI-IPCC	
	Patron	Client
Adaptive capacity	0.36	0.40
Sensitivity	0.44	0.79
Exposure	0.88	0.89
Overall	0.23	0.39

The level of vulnerability to the livelihoods of Bagan fishermen is relatively high. Based on the results of the LVI data analysis, it can be seen that the livelihood level of client fishermen is more vulnerable than that of patron fishermen. This is due to exposure to the natural impacts of climate change affecting all fishing activities. With the increasing intensity of extreme weather in the waters of Lampung Bay, fishermen have difficulty going to sea. The fishing season calendar, which is believed to be a guideline in supporting fishing activities, is no longer valid since it often deviates from the understanding of fishermen. Climate change also causes the distribution of target fish in the waters unpredictable, so most Bagan fishermen have to go out to the sea further to catch schools of fish. This condition requires Bagan fishermen to spend much money amidst the uncertainty of getting the fish they catch. Therefore, if the catch of Bagan fishermen decreases, it will significantly impact fishermen's income.

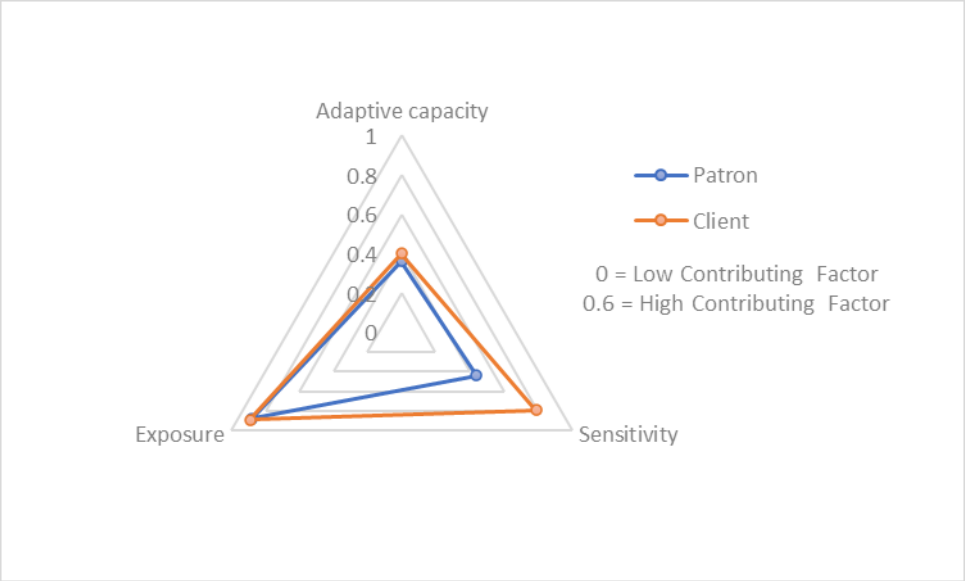

Fig. 6. Triangular diagram of Bagan fishermen's livelihood vulnerability index in Kotakarang District, Lampung Province, Indonesia

In addition, the sensitivity level also affects the vulnerability level of the livelihoods of Bagan fishermen, for example, in health indicators. Most Bagan fishermen do not yet have access to health insurance services (BPJS). If a family member is sick, they must buy medicine at a stall before finally being taken to the Health Center if their condition worsens. The ownership of Bagan fishing gear also influences the level of sensitivity. Regarding the ownership status of Bagan fishing gear, although patron fishermen have great access to ownership of fishing gear, patron fishermen get capital loans from BANK through People's Business Credit (KUR) to buy Bagan fishing gear. Patron fishermen still have debts/credits that have a certain term. Therefore, fishermen who get capital loans to buy Bagan fishing gear must continue to go to sea even though the weather is bad because they have collateral that is their responsibility where the payment is every month. The availability of food also influences the level of sensitivity. Bagan fishermen sell the fish they catch (target fish) directly to the "pelele" so that none are brought home to meet food needs.

The level of adaptive capacity is seen from the livelihood strategy of fishermen's households, which is assessed from the methods or actions taken in utilizing and managing the livelihood capital they have as a livelihood strategy. The adaptive capacity of patron fishermen is 0.46, and that of client fishermen is 0.50. Indicators in assessing adaptive capacity include human resource capital, such as a high level of experience at sea, where 100% of patron and 56% of client fishermen have had more than 10 years of experience at sea. This high level of experience at sea is because most fishermen have been at sea since childhood with their parents. Hence, the profession of a Bagan fisherman is a family inheritance. Second, natural resource capital, such as fishing

locations, moves from one place to another, which is found in 64% of patron fishermen and 100% of client fishermen. This indicates that both patron and client fishermen practice adaptation by chasing schools of fish to get maximum catches. Third, financial capital. In this financial capital subcomponent, patron and client fishermen have financial constraints. For example, 82% of patron fishermen still have loans/debts to the bank. In comparison, 89% of client fishermen have various loans to patrons and relatives. Fourth, physical capital is characterized by access to and ownership of operational aid technology for fishing, such as fish finders, showing that 18% of patron fishermen and none of the client fishermen have fishing aid technology. This difference is due to the informant's ability to buy these facilities. Fifth, social capital is characterized by strong ties between fishermen, such as cooperation when repairing damaged fishing nets. Patron fishermen have a value of 45%, and client fishermen have a value of 44%.

The Bagan fishing community in the coastal area of Lampung Bay has a fairly high adaptive capacity. This can be seen from the adequate human resources capital, namely with the high experience of going to sea so that all forms of conditions and times are easily recognized by bagan fishermen, including finding schools of fish in the sea, recognizing fishing locations, and reading natural signs. The social capital established among Bagan fishermen also grows rapidly through cooperation movements to repair the Bagan when it is damaged, so that it does not take a long time and can be used immediately to catch fish. Not only on land, cooperative activities are also very close through the dissemination of information. When one of the fishermen gets an abundant fish catch in one fishing ground location, other fishermen will get information and gather it in the fishing ground location. Factors such as social capital determine the scope of action and access to resources closely related to social network structure and dynamics **(Gisevius *et al.*, 2025)**. Therefore, a sense of mutual trust is built, especially among Bagan fishermen who, although informally joining the same motorboat, have high social ties.

In the face of climate change, Bagan fishermen have also begun to adopt technology as a form of renewed understanding of fishing activities. This is a form of adaptive capacity carried out by looking at the condition of target fish, which are increasingly difficult to obtain, so technology such as fish finders can help fishermen predict schools of target fish in the waters. This is also in line with previous research by **Wongnaa *et al.* (2024)** that the fisheries sector will face the impacts of climate change, such as loss of fish seeds, reduced fish stocks, and damage to marine and aquaculture cultivation, therefore in West Africa, climate-smart agricultural technology is developed which is protective of fishing.

The findings of this study provide an overview of how fishing communities in various maritime and island-based countries experience livelihood vulnerability to the impacts of climate change, which also occurs in the coastal areas of Bandar Lampung City, Lampung Province, Indonesia. This is in line with research conducted by

Setyaningrum *et al.* (2024) and **Handayati *et al.* (2025)**, explaining that the livelihoods of small-scale fishermen are greatly influenced by ecosystem degradation and climate change. In this context, previous studies **(Suadi *et al.*, 2022; Castrejón *et al.*, 2024; Chowdhury *et al.*, 2024)** clarified that small-scale fisheries are vulnerable to the impacts of climate change such as decreased catches, longer fishing intensity, increasing operational costs at sea, and increasing competition at sea. Furthermore, communities whose livelihoods depend on the friendliness of the coastal and marine environment are the groups of people most vulnerable to climate change's impacts **(Béné & Friend, 2011; Mudzakir & Suherman, 2020)**.

CONCLUSION

This study applies LVI-IPCC in the process of assessing the vulnerability of small-scale fishermen's livelihoods using bagan fishing gear in the coastal area of Lampung Bay. This study uses an index to assess the level of vulnerability of household livelihoods of bagan fishermen. The results of this study reflect that the level of vulnerability of client fishermen's livelihoods is more vulnerable with an LVI value of 0.39 compared to patron fishermen with an LVI value of 0.23 calculated based on the LVI-IPCC. This study is expected to contribute to providing the necessary input to understand the vulnerability of climate change impacts for Bagan fishing communities. Several limitations in this study can be of concern, especially for further research. The primary data used in this study to assess the vulnerability of fishermen's livelihoods are not only influenced by climate change but also by other factors, such as market mechanisms related to fluctuating fish selling prices. Therefore, assessing the vulnerability of fishermen's livelihoods will allow for the identification of more specific factors in their context.

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