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Fishermen's perceptions of climate change impacts on livelihoods: A Weighted Average Index (WAI) Analysis in Bangkalan, Madura Island

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ABSTRACT

Climate change presents a global challenge with significant implications for livelihood sustainability, particularly in coastal communities. This study explores fishermen's perceptions of climate change and its impacts on their livelihoods in Bangkalan Regency, Madura Island, Indonesia, a region where communities are directly affected through altered weather patterns, rising sea temperatures, and disrupted fishery ecosystems. Employing a quantitative approach, data were collected from 94 fishermen in Banyusangkah Village, Tanjungbumi Sub-district, selected via simple random sampling. The Weighted Average Index (WAI) method was used to analyze perceptions. The results indicate a high level of awareness among fishermen regarding certain climate phenomena, such as increased sea temperatures and the frequency of heavy rainfall, which they perceive as directly affecting fish catches and fishing safety. However, awareness of slower-onset, long-term impacts, such as tidal flooding and coastal erosion, remains low. These findings underscore the critical need for targeted educational outreach and policy interventions designed to foster community-based adaptation strategies, thereby enhancing the resilience of fishing communities in the face of increasingly uncertain environmental changes.

Keywords: Climate change perception, Coastal area, Fishermen, Madura Island

INTRODUCTION

Over the past 65 years, the global climate has undergone significant transformation, with further changes projected throughout the 21st century due to global warming. Climate change presents a multi-faceted challenge, impacting ecological, environmental, socio-political, and economic systems worldwide (Raihan, 2023; Feliciano et al., 2022). Its effects—including long-term shifts in temperature and precipitation, melting ice sheets, rising sea levels, and increased frequency of extreme weather events—pose severe threats to global stability (Massey, 2023; Abbass et al., 2022).

The burdens of climate change are not distributed equally. Developing nations, due to socio-economic vulnerabilities and constrained adaptive capacity, bear a disproportionate share of climate-related risks. Within these countries, marine sectors and coastal communities are particularly exposed. Climate-induced disruptions to fish stocks and fishery operations directly threaten livelihood security for small-scale fishers, whose vulnerability is acutely manifested through reduced resource access, declining productivity, and the impacts of

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ocean warming and acidification (Signed & Mbaye, 2022; Mendenhall et al., 2020; Islam et al., 2020). This confluence of biophysical changes jeopardizes the foundations of coastal life, including food security, cultural practices, and economic stability (Sarkar et al., 2022). This vulnerability is often compounded by a lack of financial capital and technical capacity, severely limiting resilience and increasing susceptibility to impoverishment (Galappaththi et al., 2019).

Within this context, understanding local perceptions is a critical determinant of adaptive behavior. Fishers' perceptions directly shape their risk assessment and influence their willingness to adopt adaptive measures (Maltby et al., 2021). When perceive climate change is perceived as a tangible threat, communiti they are more inclined to take action; conversely, a lack of awareness or a sense of helplessness can foster inaction, increasing overall susceptibility (March & Pierre, 2022). Therefore, systematically analyzing these perceptions is a fundamental step in designing effective, targeted adaptation strategies.

The Weighted Average Index (WAI) was employed to quantify the perceptions of fishing communities regarding the impacts of climate change on their livelihoods. This method is particularly advantageous in remote and developing regions, where the scarcity of reliable secondary data—due to limited accessibility, incomplete databases, and protracted governmental approval processes—often constrains research. The WAI has been widely applied to evaluate public perceptions on environmental issues; for instance Hoang et al. (2022), used it to assess the perceived importance of adaptation strategies among farmers in Bangladesh, while Ndamani & Watanabe (2015) utilized it alongside the Problem Confrontation Index (PCI) to rank barriers to climate adaptation in Ghana.

Bangkalan Regency, a coastal region of Madura Island, Indonesia, exemplifies a socio-ecological system where high livelihood dependence on fisheries intersects with significant climate vulnerability. Key challenges include sea-level rise and coastal erosion Sukandar et al. (2016), which threaten both the integrity of marine ecosystems and the stability of the fishery-based economy. This dynamic renders local communities highly susceptible to infrastructure damage and severe economic losses (Salarieh et al., 2023)

A recurring finding in the regional literature is the discrepancy between the experienced impacts of climate change and the conceptual understanding of it among coastal communities in Indonesia. Research by Nurhayati et al. (2020) highlight that while populations report direct observations of climatic shifts, their overall perception and knowledge of climate change remain low, a factor that impedes the development of robust adaptation strategies. This pattern is evident in locations such as Popoh Bay, East Java, where community awareness has not translated into a deep understanding, thereby limiting adaptive responses. Further illustrating this point, research from Osi Island, Maluku, demonstrates that fishermen's perceptions are primarily informed by empirical experience and traditional knowledge, allowing them to identify specific alterations in weather, sea conditions, and fishing seasons that threaten their livelihoods (Nurhayati et al., 2020; Isdianto & Muzaky Luthfi, 2019; Rais et al., 2024). This collective evidence underscores that reliance on experiential learning alone, without complementary scientific information, can result in adaptation gaps.

Research specifically examining fisher households' perceptions of climate change in Madura, particularly in Bangkalan Regency, using the Weighted Average Index (WAI) method remains

limited. This region's coastline faces threats common across Indonesia, including sea-level rise, altered weather patterns, and an increased frequency of natural disasters, all of which directly impact fishing communities. As understanding local perceptions is critical for formulating effective adaptation strategies, there is a pressing need for focused research in this area. This study, therefore, aims to analyze the perceptions of fishers in Bangkalan Regency regarding the phenomena and impacts of climate change using the WAI method. The findings are essential for developing targeted strategies to mitigate risks and enhance community resilience in the face of increasingly uncertain environmental changes.

RESEARCH METHODS

Study Areas and Research Time

This study was conducted in Banyusangkah Village, Tanjungbumi District, Bangkalan Regency, Madura. The location was selected purposively based on two primary criteria. First, Bangkalan Regency accounts for approximately 25% of the total fish catch on Madura Island, demonstrating its high significance to the regional capture fisheries sector (BPS East Java, 2024). Second, within Bangkalan, Tanjungbumi District is the largest contributor to fish production, with Banyusangkah Village serving as a central hub. Field data collection, comprising structured interviews using a questionnaire, was carried out over the second and third weeks of September 2024.

Types and Data Sources

This study utilized data from both primary and secondary sources. Primary data were collected directly from 94 fishermen in Bangkalan through questionnaire-based surveys and in-depth interviews. These instruments were designed to gather information on fishermen's perceptions of climate change, as well as household-level socioeconomic variables, fishing catches, and income. Secondary data were obtained from published literature, official reports from the Marine and Fisheries Service, and the Meteorology, Climatology, and Geophysics Agency (BMKG). From the BMKG, climatic and environmental data were sourced, including records on the duration of droughts, intensity of rainfall, shifts in wind patterns, storm frequency, sea-level rise, coastal erosion, sea surface temperature, and flash flood events. From the Marine and Fisheries Service, data on the total number of fishermen and aggregate fish catches were acquired.

Sample Determination Method

This study was conducted in Banyusangkah Village, Bangkalan Regency, Madura Island, Indonesia. The population included 1,340 fishermen, encompassing crew members, fishing masters, and *juragans* (Fishing Boat Owner/Captain). A simple random sampling method was employed to select fishing households as the sampling unit. Using the Slovin formula (Amin et al., 2023), a sample size of 94 households was determined:

$$n = \frac{N}{1 + N\,(e)^2} = \frac{1340}{1 + 1340\,(10\%)^2} = 93{,}056 \approx 94 \quad (1)$$

Data Collection Methods

Data were collected through structured interviews with fishermen, using a questionnaire. The instrument was designed to gather information on household characteristics, perceptions of climate change phenomena and their impacts, and key socioeconomic variables.

Data Analysis

1. Descriptive analysis

This study employs a quantitative descriptive analysis to characterize fishing households and their climate change adaptation strategies. The purpose of this analytical approach is to summarize the field-collected data descriptively rather than to infer generalizable or causal conclusions.

2. Weighted average index (WAI) analysis

To evaluate fishermen's perceptions of climate change impacts on their livelihoods, we employed the Weighted Average Index (WAI). The WAI is a methodological approach that incorporates weighting factors for different perception responses, allowing for a more nuanced analysis (Gunawan & Pasaribu, 2020).

$$\mathrm{WAI} = \frac{\sum(\mathrm{Si.\,Fi})}{\sum \mathrm{N}} \qquad (2)$$

WAI: Weighted Average Index
Si: The value of the scale given to its priority (1 to 5)
Fi: The frequency of respondents for the value of the scale
N: Total number of observations

The measurement of attitude data was calculated using the likert scale technique scale scale 1-5: 1=very weak; 2=weak; 3= enough; 4=strong and 5=very strong. Climate change perception variables include the impact of long droughts, heavy rains, changes in wind direction and storms, sea level rise, coastal erosion or coastal intrusion, increase in sea surface temperature, and flash floods.

3. Perception Index

The perception index was used to evaluate the level of fishers' perception of the impact of climate shocks at the research site. There are five levels measured: very strong, strong, medium, weak, and very weak.

$$WAI = \frac{(5.f1 + 4.f2 + 3.f3 + 2.f4 + 1.f}{N} \qquad (3)$$

$\mathbf{f_1}$: First scale preferred frequency (very powerful)
$\mathbf{f_2}$: Second scale option frequency (strong)
$\mathbf{f_3}$: Third scale (medium) preferred frequency
$\mathbf{f_4}$: Frequency of the fourth scale (weak) choice
$\mathbf{f_5}$: Frequency of the fifth scale selection (very weak)
N: Total responden

The WAI value is in the range of $1 \leq \mathrm{WAI} \leq 5$, where higher numbers indicate a stronger perception of the impacts of climate change.

RESULTS AND DISCUSSION

Respondents Characteristic

Table 2 presents the socio-economic and demographic characteristics of the fishermen respondents. The average household size was 3.7 members (±1.17). Respondents had a mean age of 40.8 years (±12.23) and an average of 21.6 years (±13.02) of fishing experience, indicating a seasoned and middle-aged sample population. In terms of education, the average formal schooling was 6.5 years (±3.37), which typically corresponds to primary education. The majority of fishermen held the position of ABK (crew member), as indicated by a mean value of 0.3 for job position (where 0 = ABK and 1 = non-ABK).

Economically, household income from fishing showed considerable variation, with a mean of approximately IDR 100.4 million per month and a very high standard deviation of IDR 216 million, suggesting significant income disparity within the sample. Exactly half of the households reported having credit (mean = 0.5). Fishing patterns were intensive, with a mean of 6.7 trips per week (±0.59), and each trip lasting an average of 9.6 hours (±3.76). The proximity to fishing grounds was relatively close, with the average distance from

home to the sea being 430.2 meters (±296.55).

Fishermen's Perception of Climate Change Phenomena Using the WAI Method

Based on the results of table 3 which illustrates that there are 8 indicators that are measured to understand the extent of fishermen's perception of the phenomenon of climate change. The data obtained through interviews with a questionnaire reference was tested for validity. The test was carried out by calculating the correlation coefficient between the score of each item and the total score using the Pearson Product Moment Correlation formula at a significance level of 0.05. Khoiroh et al. (2024) , an instrument is considered valid if the calculated RR value is greater than the table RR, the obtained table RR value is 0.197. The overall validity value in table 2 exceeded 0.197, so it can be said that the question instrument used was valid to measure fishermen's perception of the impact of climate change. To find out whether the question instrument is reliable or not, it is by looking at the price of Cronbach's Alpha.

Table 2 Characteristics of Respondents

Variable	Information	Mean	Std Dev
Number of household members	The number of household members is calculated in units (people per household)	3,7	1,17
Age	Age of respondents in units (years)	40,8	12,23
Marital Status	Respondent's marital status (0 = if married, 1 = if unmarried)	0,9	1,17
Education	Total time to take formal education of respondents No school = 0 SD = 6 years Junior high school = 9 years old High school = 12 years	6,5	3,37
Fisherman's job position	Job position of fishermen in boats (0 = Abk, 1 = Non-abk)	0,3	0,47
Fisherman's household income	Revenue earned from the total number of subscribers earned in units (IDR per month)	100.4 22.22 2,2	215997119,5
Fishing trips per week	Number of fishing trips in one week	6,7	0,59
Fishing trips per day	Duration of fishing trips in one day in units (hours)	9,6	3,76
Fisherman's household credit	Fishermen's household credit ownership (0 = if they have, 1 = if they don't have)	0,5	0,50
Fisherman's experience	Experience working as a fisherman in a unit (years)	21,6	13,02
Distance from the house to the sea	Distance from home to access the sea as a place for fishermen to work in units (meters)	430,2	296,55

Source : Primary data processed, 2024

Fatayah et al. (2022) , if the price of Cronbach's Alpha ≥ the threshold of Cronbach's Alpha (0.60) and has a positive value then the test instrument is reliable but if the price of Cronbach's Alpha < the threshold of Cronbach's Alpha then the test instrument is not reliable. The overall reliability value for all indicators in this study reached 0.603 which exceeded the threshold of 0.6 so it can be said that the instrument used is reliable enough to measure fishermen's perception of climate change phenomena. The results of the analysis using WAI in table 3 show variations in fishermen's perception of the climate change phenomenon. The indicator that has the highest WAI is the change in sea surface temperature with a value of 4.3 which is categorized as "Strong". In line with temperature data in East Java province from 2005, this significant temperature change reflects the impact of climate change, especially on the extreme fluctuations that occurred in 2006. The highest temperature fluctuation occurred in 2006 with a difference between the maximum and minimum temperatures of 17°C, indicating significant instability. These findings provide strong evidence that temperature change is not only a scientific indicator, but also a phenomenon directly perceived by coastal communities. In addition, the frequency of heavy rains, changes in storms and changes in wind speed were also recognized as significant impacts with WAI values of 4.1 each. Changes in marine ecology such as changes in rain intensity, changes in wind direction, high sea waves, and storms cause fishermen's seagoing intensity to decrease. Then, the frequency of the current long drought also received the perception of "Strong" with a WAI value of 4. which emphasized that fishermen felt that the intensity of the phenomenon had increased compared to 2005. Long droughts are often caused by climatic anomalies such as El Nino, which tend to reduce rainfall in tropical regions including East Java. Based on the average length of solar irradiation from 2020 to 2022, there is a significant increase in the duration of daily irradiation indicating a longer duration of sunlight received in the East Java region (Hasibuan et al., 2017) (East Java Province in Numbers, 2023).

However, there is an indicator with a perception value of "Moderate", namely the change in sea level height which has a WAI of 3.5. This shows that although sea level rise is felt, the impact is not as strong as other indicators that have a more direct effect on fishermen's daily activities. Interestingly, the frequency of problems such as coastal erosion and flash floods had the lowest WAI, 2.7 and 1.8, respectively, categorized as "Weak" indicating that fishermen may not be directly or not very affected by the impacts of coastal erosion and flash floods in their areas. The high perception of temperature changes, heavy rain, and wind indicates that fishermen are more worried about phenomena that affect their catch and safety when going to sea. On the contrary, the low perception of the problem of flash floods and coastal erosion indicates that fishermen are not fully aware of the potential long-term threat of the phenomenon.

Fishermen's Perception of the Impact of Climate Change Using the WAI Method

Based on the results of table 4 which illustrates that there are 10 indicators measured to understand the extent to which climate change affects fisheries activities on the Madura coast. The overall validity value in table 3 exceeds 0.197, so it can be said that the instrument used is valid to measure fishermen's perception of the impact of climate change. The overall reliability value for all indicators in this study reached 0.632 which is above the minimum threshold of 0.6 so it can be said that the instrument used is quite reliable

to measure fishermen's perception of the impact of climate change.

Based on table 4, the highest WAI value is 4.4, which is found in the indicator of temperature change causing the fish population in the sea to decrease. This value shows a very strong perception of fishermen towards the significant impact of these two phenomena. Changes in ocean temperature affect the survival and migration patterns of fish, which ultimately impacts catches. Supported by research that each species of fish has a tolerance of certain temperature values that are preferred to live so that it affects the existence and distribution of fish in the waters Zulkhasyni (2015).

Table 3
Perception of Climate Change Phenomena

Indicator	Validity	WAI	IP
Current Long drought frequency (compared to 2005)	0,634	4	Strong
Current frequency of heavy rains (compared to 2005)	0,588	4,1	Strong
Current storm changes (compared to 2005)	0,540	4,1	Strong
Changes in current wind speed (compared to 2005)	0,591	4,1	Strong
Changes in current sea level elevation (compared to 2005)	0,519	3,5	Keep
Frequency of problems such as coastal erosion in coastal areas today (compared to 2005)	0,535	2,7	Weak
Changes in current sea level temperatures (compared to 2005)	0,552	4,3	Strong
Current flood frequency (compared to 2005)	0,588	1,8	Very Weak
Reliability Test		0,603	

Note: WAI = *Weigted Average Index,* IP = Indeks Persepsi

Source : Primary data processed, 2024

Indicators with a WAI value of 4.3 also have a strong impact, such as increased wind speed causing sea waves to become higher and unstable, high tidal waves increasing the risk of fishing activities, extreme temperatures causing changes in fishing locations, wind direction and storms can affect shipping routes and safety, as well as important external support for fishermen's adaptation. Wind and storm directions affect fishermen's shipping lanes, increasing their safety risks while at sea. Fishermen using sailboats are closely related to the wind and weather, the wind also determines the direction of the bow and the flutter of the sail, the position of the sail can move whether in the right or left position, depending on the direction to be headed. The government needs to intervene more effectively through various programs, such as direct assistance, mentoring, and improving the welfare of fishermen. Not only the government, but collaboration must also be carried out between academics, and the private sector aiming to create solutions in dealing with the impact of climate change on fishermen. If governments play a role in policy and support for community-building programs, academics can provide research to understand impacts and adaptation strategies, while the private sector contributes through investment in green technologies and market development. This synergy

ensures effective solutions, safeguarding fishermen's livelihoods, and increasing the resilience of coastal communities. The high value on external support confirms that fishers need direct intervention, such as the provision of accurate weather information and fishing gear that is more adaptive to extreme conditions.(Ansar, 2019) (Benamen & Dokolamo, 2024).

Table 4
Perception of Climate Change Impact

Indicator	Validity	WAI	IP
An increase in the amount of rain (rainfall) leads to a decrease in fish catches	0,624	4,2	Strong
Sea level rise causes changes in fish distribution/migration	0,609	3,5	Keep
Temperature changes cause fish populations in the sea to decline	0,611	4,4	Strong
The increase in wind speed causes sea waves to become higher and unstable	0,588	4,3	Strong
High tidal waves cause a high risk of fishing activities	0,603	4,3	Strong
Coastal erosion interferes with fishing activities	0,592	2,8	Weak
Extreme temperatures will cause changes in fishing locations	0,600	4,3	Strong
Wind and storm directions can affect shipping routes and safety	0,593	4,3	Strong
Sea level rise can cause flash floods and coastal erosion	0,638	2,6	Weak
External support is important to help fishers adapt and reduce risks	0,607	4,3	Strong
Reliability Test		0,632	

Note: WAI = Weigted Average Index, IP = Perception Indeks

Source : Primary Data Processed, 2024

Indicators with a WAI value of 4.2, namely an increase in rainfall causing a decrease in fish catches, also have a strong impact. , the highest rainfall occurred in 2021, which was 280.8 mm, indicating an anomaly compared to previous years. High rainfall disrupts marine ecosystems by affecting seawater salt levels and fish reproductive cycles. As a result, fish are difficult to find in large numbers, which negatively affects the productivity of the catch. This perception shows that fishermen feel the effects of climate change directly through changes in seasonal patterns that disrupt the natural rhythm of the sea. Province East Java in Numbers (2021)

Finally, indicators with moderate and weak WAI values, such as rising sea levels causing changes in the distribution of WAI fish 3.5, coastal erosion disrupting the activities of WAI fishermen 2.8, and rising sea levels causing flooding of WAI 2.6, remain relevant even though the impact is smaller than other indicators. Rising sea levels can change the distribution area of fish, although the impact is not immediately felt by all fishermen. In contrast, coastal erosion and flash floods tend to have long-term impacts that fishermen are less aware of because they affect coastal infrastructure more than their fishing activities. Further education and attention to these indicators are important to prevent long-term losses for fishers and coastal communities. Overall, fishers are more aware of the direct impacts that affect their

catches and safety, so there needs to be a more focused adaptation policy on these aspects.

CONCLUSION

This study reveals that fishermen on the coast of Bangkalan, precisely in Banyusangkah Village, have a strong perception of the impact of climate change, especially on indicators directly related to fishery activities. The WAI results show that changes in sea temperature are the most significant impact felt by fishermen, followed by wind and storm direction indicators that affect shipping routes and their safety when going to sea. However, fishermen's perception of long-term impacts, such as sea level rise, flash floods, and coastal erosion, tends to be lower. This indicates the need to increase awareness of cumulative and indirect risks. Therefore, it is recommended to conduct community-based education to increase fishermen's understanding of the long-term impacts of climate change. In addition, support in the form of adaptive technology, accurate weather information, and strengthening coastal infrastructure that is resistant to erosion and flash floods is essential to help fishermen reduce their vulnerability.

Collaboration between the government, academia, and the private sector also needs to be strengthened to create solutions, especially to address the impact of climate change on fishermen's livelihoods. By focusing on adapting to direct impacts such as changes in sea temperature, as well as increasing awareness of long-term impacts, it is hoped that the resilience and welfare of fishermen can be maintained amid increasingly uncertain environmental changes.

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