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Identification Study of Fishermen's Vulnerability Indicators and Capital Assets in Facing the Impacts of Climate Change

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ABSTRACT

Climate change is an impact of global warming, characterized by high waves, extreme weather, floods, droughts, and disturbances in marine ecosystems. In Bengkulu City, climate change is evident through climate variability, including rainfall, strong winds, and storms, which impact the livelihood patterns of fishermen. Uncertain weather conditions and prolonged climate change events make fishermen socially and economically vulnerable. Vulnerability is influenced by exposure to extreme weather and sensitivity due to climate change pressures. Efforts to reduce vulnerability involve optimizing the use of capital assets to ensure the sustainability of fishermen's livelihoods. This study aimed to identify vulnerability indicators and capital assets that fishermen use to cope with the impacts of climate change. The research employed a qualitative method, complemented with a literature review approach and expert discussions. After identifying indicators through literature analysis, the findings were discussed with relevant experts to validate the results, gain new perspectives, and deepen the understanding of the research topic. The study results identified 30 vulnerability indicators and capital assets that affect fishermen's adaptation to climate change. Fishermen's vulnerability was influenced by exposure, sensitivity, and adaptive capacity, while capital assets include human, physical, natural, financial, and social assets. Identifying these indicators enables the government and stakeholders to design inclusive and participatory adaptation programs that align with the needs of fishermen. Collaboration among stakeholders can enhance the effectiveness of adaptation programs for fishermen in addressing climate change.

INTRODUCTION

Scopus

Indexed in

Climate change has become a significant issue in many regions worldwide. Climate variability pressures have the potential to impact fishery resources, including sea surface temperature, salinity, pH, dissolved oxygen, and chlorophyll. China's domestic marine fisheries, which account for more than 80% of the total marine catch, face numerous challenges due to ocean warming and climate change. Nearly 67 fish species in China are at risk of extinction due to environmental degradation caused by climate change, including the inability to adapt to ocean acidification, vulnerability of fish stocks, narrow temperature ranges, and limited larval dispersal capacity, all of which increase species

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vulnerability. The ability of species to adapt to environmental changes is also disrupted by climate change (Jiang et al., 2017a). Institutional governance and regulations concerning fishing limits and designated fishing areas serve as strategic indicators for supporting fishermen's adaptation. Additionally, the involvement of non-government actors and community participation plays a role in climate-resilient fisheries management (Jiang et al., 2017b). Climate change pressures also threaten the sustainability of capture fisheries in Palawan, Philippines. Several pelagic fish species, such as scad, mackerel, and tuna, are projected to experience a significant decline in abundance in most parts of Palawan from 2040 to 2060. Thus, climate change poses a potential threat to food security and the livelihoods of coastal communities that depend on capture fisheries. Without efforts to enhance the resilience of development systems against climate change, the sustainability of fishermen's livelihoods will be at risk. Strengthening fishermen's adaptive capacity to withstand climate pressures will help reduce their vulnerability. In Indonesia, the impacts of climate change have been felt both directly and indirectly. Physical effects include shifts in weather patterns, changes in rainy and dry seasons, and alterations in the hydrological cycle, as well as the expansion of the tropical zone. Other physical effects include changes in ENSO (El Niño-Southern Oscillation), increased frequency of tornado occurrences, extreme weather events, and high waves (Aldrian, 2011). These changes in the duration of rainy and dry seasons significantly affect fishermen's economy. It is well known that fishing activities are closely related to climate and weather conditions. Indicators of climate change include global warming, which has led to a trend of increasing air temperatures and sea surface temperatures. Climate components also exhibit shifts in rainfall patterns, leading to longer dry seasons, shorter rainy seasons, and alterations in peak rainy season periods.

The concept of vulnerability was introduced in the early 1990s by Adger, who emphasized the fishermen's exposure to climate change. Vulnerability is influenced by an individual's ability to access resources, income diversification, and social status within a community (**Cutter** *et al.*, 2003). Moreover, it is also a function of exposure and sensitivity due to external pressures (Lee, 2014). Consistent with previous studies, vulnerability is determined by three variables: exposure, sensitivity, and adaptive capacity. Exposure refers to the physical and non-physical responses of fishermen to climate change pressures that disrupt their livelihoods. The degree of exposure is directly related to the frequency and intensity of climate change impacts. The greater the exposure, the higher the sensitivity and, consequently, the level of vulnerability (IPPC, n.d.; Twigg, 2007; Hidayatulloh, 2021; Zeleke *et al.*, 2021; Villasante *et al.*, 2022; Damasio *et al.*, 2023).

Efforts to reduce fishermen's vulnerability are carried out through livelihood strategy approaches by optimizing the use of livelihood assets. Livelihood assets refer to all forms of capital used to sustain a living (**Yurike** *et al.*, **2022**). There are five types of

fishermen's livelihood assets: human capital, natural capital, financial capital, social capital, and physical capital. Capital assets are used as strategies for fishermen to build resilience against climate anomalies (Chamro *et al.*, 2020). Socioeconomic indicators that influence the adaptive capacity of communities are observed through demographic characteristics, economic conditions, political/governmental factors, natural resource management, and civil society participation (Brenkert *et al.*, 2005). Exposure to climate-related pressures makes fishermen highly vulnerable to the impacts on their primary sources of livelihood. As a result, capital assets become essential resources for traditional fishermen to sustain their way of life.

This study examined vulnerability indicators and capital assets affecting fishermen's adaptation to climate change. Unlike previous studies, this research employed a literature review and expert study approach about climate change adaptation. Literature analysis was combined with expert discussions to identify vulnerability and capital assets indicators, validate findings, identify gaps, and determine the novelty of the research topic. Identifying vulnerability and capital assets to anticipate the impacts of climate change, serving as a basis for designing climate-resilient adaptation strategies.

MATERIALS AND METHODS

This study employed a literature review and expert study approach related to fishermen's adaptation to climate change. Data sources consist of secondary data from scientific publications and primary data from in-depth interviews with fishery extension officers, experts, practitioners, and traditional fishermen. Three experts were consulted: a climate change impact specialist, a fisheries management specialist, and a sociologist. Climate change experts provided a scientific basis for local climate change predictions and their risks to the fisheries sector and fishermen's productivity. Meanwhile, fisheries management experts provided analysis of changes in fish migration patterns due to climate change, the effectiveness of fishing gear and modernization of fisheries technology, and sustainable fisheries management policies. Sociology experts examine the socio-economic impacts on fishermen related to the sustainability of their lives.

The research process began with a literature review of vulnerability indicators and capital assets using academic publication search engines, such as Google Scholar, LibGen, Publish or Perish, Dimension, and Maps Open Knowledge. The data were then collected through a literature review, which involved reading, examining, and conducting an in-depth analysis of relevant journals and publications. The data obtained from the results of the literature search were identified and screened, and 26 journals were obtained that were related to the vulnerability and capital assets of fishermen's adaptation to climate change (Table 1).

NO	Authors	Title	Year	Source
1	Adger, W. N., Hughes, T. P.,	Social-ecological resilience	2005	Science, 309(5737), 1036-
	Folke, C., Carpenter, S. R., &	to coastal disasters.		1039.
	Rockström			
2	Brenkert, Antoinette L.	Modelling vulnerability and	2005	Journal Climate Change, Vol:
	Malone, Elizabeth L.	resilience to climate change:		72, Issue:1-2, page: 57-102
		A case study of India and		
		Indian states		
3	Barnett, B. J., & Mahul, O.	Weather Index Insurance for	2007	American Journal of
		Agriculture and Rural Areas		Agricultural Economics,
		in Low-Income Countries.		89(5), 1241-1247.
				https://doi.org/10.1111/j.1467-
				<u>8276.2007.01091.x</u>
4	Twigg, J.	Characteristics of a disaster-	2007	Disaster Risk Reduction, 1(1),
		resilient community.		1-20.
5	IPPC	ClimateChancello	2007	
3	IFFC	7. Imposto Adoptot	2007	
		ion on d V u ln o ro bility		
6	Streep L D		2008	Agnigulturg Finguage Deviau
0	SKEES, J. K.	(2008) Challenges to the	2008	68(1) 107 217
		Use of Index Based Weather		https://doi.org/10.1108/00214
		Insurance in Lower-Income		660880001226
		Countries		00000001220
7	Skees, J. R., Barnett, B. J., &	Agricultural Insurance:	2008	Dalam buku "Climate Change
,	Collier. B.	Background and Context for	2000	and Adaptation" (hlm, 181-
		Climate Adaptation		200).
		Discussions.		Earthscan.https://doi.org/10.43
				24/9781849770805
8	Allison, et al	Vulnerability of national	2009	Fish and Fisheries Journal,
		economies to the impacts of		Vol:10, Issue: 2, Page: 173-
		climate change on fisheries		196
9	Joesidawati, M I	Climate Change Modeling in	2012	Agriekonomika
		Tuban Regency Using		Journal,
		Magicc Scengen		https://journal.trunojoyo.ac.id/
				agriekonomika/article/view/35
				2
10		Analysis of Criteria and		eprints.undip.ac.id
	Efendi, M	Indicators of Community		http://eprints.undip.ac.id/3761
		Vulnerability to Climate		4/
		Change Based on Watershed		
		(Case Study of Garang Hulu		

Table 1. Identification of studies via publication search engine

		Sub-Das)		
11	Fauziah, A. N.	Climate vulnerability assessment: A reassessment in the coastal area of Semarang City.	2014	<i>Jurnal Ilmu Lingkungan</i> , 10(3), 316-329.
12	Greatrex, H., Hansen, J., Garvin, S., Diro, R., Le Guen, M., Blakeley, S., & Osgood, D.	Scaling Up Index Insurance for Smallholder Farmers: Recent Evidence and Insights.	2015	<i>CCAFS Report.</i> Copenhagen: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). <u>https://cgspace.cgiar.org/handl</u> <u>e/10568/68907</u>
13	Wibowo, A Satria, A	Fisher's Adaptation Strategies in small islands to the impacts of Climate Change (A case study in Pulau Panjang Village, Subi District, Natuna Regency, Riau	2015	Sodality: Jurnal Sosiologi Pedesaan
14	Cinner, J. E., Huchery, C., Hicks, C. C., Daw, T. M., Marshall, N., Wamukota	Building Adaptive Capacity to Climate Change in Tropical Coastal Communities	2018	Nature Climate Change, 8(2), 117-123. https://doi.org/10.1038/s41558 -017-0065-x
15	Grafton, R. Q. (2010).	Adaptation to Climate Change in Marine Capture Fisheries	2020	Marine Policy 34(3), 606-615. https://doi.org/10.1016/j.marp ol.2009.11.011
16	Jiang, H. J., Underwood, T. C., Bell, J. G., Ranjan, S., Sasselov, D., & Whitesides, G. M.	Social-Ecological Vulnerability and Risk of China's Marine Capture Fisheries to Climate Change	2017	Proceedings of the National Academy of Sciences, 114(34), 8031-8036. https://doi.org/10.1073/pnas.1 617933114
17	Marshall, N. A., Marshall, P. A., Tamelander, J., Obura, D., Malleret-King, D., & Cinner, J. E.	A Framework for Social Adaptation to Climate Change: Sustaining Tropical Coastal Communities and Industries. <i>IUCN</i> .	2010	
18	Deressa, Temesgen Hassan, Rashid M. Ringler, Claudia	Measuring Ethiopian farmers' vulnerability to climate change across regional states		IFPRI Discussion Paper, Vol :806, issue : January, page : 32
19	Ostrom, E.	A general framework for	2009	Science, 325(5939), 419-422.

		analyzing sustainability of		https://doi.org/10.1126/science
		social-ecological systems.		.1172133
20	Surminski, S., Bouwer, L. M., & Linnerooth-Bayer, J.	How insurance can support climate resilience	2016	Nature Climate Change, 6(4), 333-334. https://doi.org/10.1038/nclima te2979
21	Boer, Rizaldi	Basic Introduction to Climate Risk and Vulnerability Analysis	2018	Ccrom Seap Ipb
22	Villasante, S., Macho, G., Silva, M. R. O., Lopes, P. F. M., Pita, P., Simón, A., et al.	Resilience and social adaptation to climate change impacts in small-scale fisheries.	2022	Frontiers in Marine Science, 9, 802762. https://doi.org/10.3389/fmars. 2022.802762
23	World Bank	Weather Index Insurance for Agriculture: Guidance for Development Practitioners.	2011	World Bank Group. https://openknowledge.worldb ank.org/handle/10986/2408
24	Hidayatulloh, Muhammad Fikri	Analysis of economic vulnerability and adaptation strategies of fishing communities due to climate change in Paciran sub- district, Lamongan	2022	Program Studi Ilmu Kelautan Fakultas Sains Dan Teknologi Universitas Islam Negeri Sunan Ampel Surabaya 2021
25	Yurike, Y., Syafruddin, Y. S., Mulyani, O., & Sari	Analysis of community livelihood assets in two mangrove area conditions.	2022	Jurnal Sosial Ekonomi Kelautan dan Perikanan, 17(1), 63-72. https://doi.org/10.15578/jsekp. v17i1.10934
26	Azizi Komarudin, Nursahbani	Analysis of livelihood vulnerability of fisherman dealing with climate variability (case Muara Village Blanakan sub- district, Subang District)	2021	Jurnal Akuatek Vol. 2, No. 2, Desember 2021: 140-147
27	Sarwanti, A Fahlevi, K G Areva Sugraha, A Putra, F	Strategi Pembangunan Berketahanan Iklim Dan Green Growth Program Di Indonesia Dan Di Negara Asia Lainnya Climate	2022	Bspjisamarinda.Kemenperin.G o.Id

Source: Literature Review and Expert Discussion (FGD), 2025.

To identify research gaps, objectives, and the novelty of the article's theme, a bibliometric analysis was also conducted using the VOSviewer application. VOSviewer is a software designed to build and visualize bibliometric networks. These networks include journals, researchers, or individual publications, which can be mapped based on citations, bibliographic coupling, co-citations, or co-authorship relationships.

The bibliometric study using VOSviewer revealed that the theme of fishermen's adaptation to climate change has gained significant attention in recent years. The bibliometric network visualization analysis revealed that topics such as "fishermen's adaptation," "climate change," and "food security" frequently appear in the scientific literature. Yellow visualizations indicate that these themes are highly prevalent in academic publications, whereas blue and purple colors represent less popular but still relevant topics for further research. The bibliometric analysis also highlighted that research on fishermen's adaptation to climate change tends to focus on three main areas: (1) the impact of climate change on fishery resources, (2) technology-based and socioeconomic adaptation. However, research on the adaptation of traditional fishermen remains relatively limited, especially in developing countries like Indonesia. The findings of the bibliometric study are illustrated in Fig. (1).



Fig. 1. Visualization of climate change data network (Source: Scopus database processed by the authors using VOSviewer)

Data were analyzed using quantitative descriptions to identify adaptation indicators, vulnerability factors, and capital assets. The findings offer insights into the adaptation variables of traditional fishermen. The stages of the analysis method are illustrated in Fig. (2).



Fig. 2. Data collection steps (Source: Processed by the author)

RESULTS

Based on a literature review, vulnerability variables include exposure, sensitivity, capital assets, and adaptive capacity. Exposure refers to the extent to which fishermen are affected by the impacts of climate change, such as extreme weather, natural disasters, and changes in marine ecosystems. Sensitivity measures how vulnerable fishermen are to the impacts of climate change, based on their dependence on marine resources and socioeconomic conditions. Capital assets encompass the resources that fishermen possess to adapt, including human, natural, physical, financial, and social assets. Adaptive capacity assesses how well fishermen can cope with the impacts of climate change through adaptation strategies such as livelihood diversification, technological utilization, and participation in training programs.

Table 2	Vulnerability	and capital	assets	indicator	based	on l	iterature	review	and	expert
	discussion									

Vulnerability and capital assets variables indicator by literature review		Vulnerability and capital assets variables indicator with expert FGD	
Exposure	Extreme weather	Frequency and intensity of extreme weather events (such as storms and high waves)	• Early Warning System: Develop an early

	Frequency of Fishing	Frequency of fishing accidents	warning system for
	Accidents/Shipwrecks	(shipwrecks, missing, or	extreme weather that
	_	fatalities at sea)	fishermen can access via
	-	Decline in the diversity of	mobile phones or radio.
		commercial fish species	Climate-Resilient Port
	Changes in Fish	Changes in fish migration	Infrastructure: Design
	Migration Patterns	patterns	and build ports with
	Rising Sea Surface	Increase in air temperature and	and build points with
	Temperature	sea surface temperature	Safety facilities to protect
	Frequency of Rainfall	Changes in rainfall patterns and	Isning boats during
	requeite y or realinant	distribution	severe weather
	Frequency of Flood	Frequency of disasters (floods,	conditions.
	Disasters	earthquakes, coastal erosion)	• Training and
	High Wayas	Rising sea levels and high	Education on Maritime
		waves	Safety
		waves	Weather Insurance:
			Offer climate insurance
			to mitigate financial risks
			for fishermen resulting
			from extreme weather
			conditions.
	-	Number of fishermen affected	Livelihood
Sensitivity		by climate change	Diversification:
~	Alternative Livelihoods	Dependence of fishermen on	Motivate and support
2	Alternative Livelihoods	Dependence of fishermen on marine resources	Motivate and support fishermen to develop
	Alternative Livelihoods Fishing Gear and Boat	Dependence of fishermen on marine resources Level of damage to fishing gear	Motivate and support fishermen to develop secondary businesses
	Alternative Livelihoods Fishing Gear and Boat Damage Levels	Dependence of fishermen on marine resources Level of damage to fishing gear and boats	Motivate and support fishermen to develop secondary businesses such as marine tourism,
	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or
	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's income due to climate change	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or agriculture
	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's income due to climate change	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or agriculture.
	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's income due to climate change	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or agriculture. Non-Fishing Skills Training: Offer training in
	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's income due to climate change	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or agriculture. Non-Fishing Skills Training: Offer training in non-fishing skills including
	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's income due to climate change	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or agriculture. Non-Fishing Skills Training: Offer training in non-fishing skills, including crafting from shells fish skin
	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's income due to climate change	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or agriculture. Non-Fishing Skills Training: Offer training in non-fishing skills, including crafting from shells, fish skin or scales and small-scale
	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's income due to climate change	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or agriculture. Non-Fishing Skills Training: Offer training in non-fishing skills, including crafting from shells, fish skin or scales, and small-scale business ventures
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	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power Education, Age, Sea	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's income due to climate change Human Capital: Skills, health, and education	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or agriculture. Non-Fishing Skills Training: Offer training in non-fishing skills, including crafting from shells, fish skin or scales, and small-scale business ventures. Skills Training Programs: Conduct training on
	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power Education, Age, Sea Experience, and Household Workforce	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's income due to climate change Human Capital: Skills, health, and education	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or agriculture. Non-Fishing Skills Training: Offer training in non-fishing skills, including crafting from shells, fish skin or scales, and small-scale business ventures. Skills Training Programs: • Conduct training on livelihood diversification
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Capital Asset (Livelihoo d Assets)	Alternative Livelihoods Fishing Gear and Boat Damage Levels Purchasing Power Education, Age, Sea Experience, and Household Workforce	Dependence of fishermen on marine resources Level of damage to fishing gear and boats The decline in fishermen's income due to climate change Human Capital: Skills, health, and education	Motivate and support fishermen to develop secondary businesses such as marine tourism, seaweed farming, or agriculture. Non-Fishing Skills Training: Offer training in non-fishing skills, including crafting from shells, fish skin or scales, and small-scale business ventures. Skills Training Programs: • Conduct training on livelihood diversification, such as fish farming, marine tourism, or handicrafts. • Example: Training in seaweed farming or

		materials.
		Improved Education
		Access:
		• Provide scholarships or
		non-formal education
		programs for the children
		of fishermen.
		• Example: Vocational
		education programs in
		fisheries or tourism.
		Affordable Healthcare
		Services:
		• Set up mobile clinics or
		community health
		programs in coastal areas.
		Examples include
		vaccination programs.
		routine health check-ups, and
		nutrition awareness
		programs.
Ownership of	Natural Capital: Access to	Management
Farmland/Ponds	natural resources (fish, etc.)	• Establish Marine
		Conservation Areas
		(KKL) involving
		fishermen in their
		management.
		• Example: Coral reef
		restoration and mangrove
		reforestation programs.
		Diversification of Natural
		Resource Utilization:
		• Encourage fishermen to
		utilize alternative marine
		resources, such as fish or
		seaweed farming.
		Example: Grouper or
		seaweed farming programs in
		ponds.
Ownership of (1) Homes,	Physical Capital: Fishing gear,	Modernization of Fishing
(2) Vehicles, (3) Boats,	boats, and infrastructure	Equipment
and (4) Fishing Gear		• assist with more modern
		and eco-friendly fishing
		tools, such as selective
		nets or sustainable fishing

		 rods. Example: Government or NGO assistance programs for fishing gear. Coastal Infrastructure Improvement: Build safe harbors equipped with safety facilities. Example: Construction of docks or early warning systems for extreme weather.
(1) Soving (2) Loong and	Financial Canital: Savings	Crown Souings Drogrom
(1) Saving (2) Loans and Income	Financial Capital: Savings, loans, and income	 Group Savings Program Encourage fishermen to form savings groups or cooperatives. Example: Traditional fishermen's savings and loan programs. Fisheries Insurance Develop affordable fisheries insurance programs for traditional fishermen. Example: Climate insurance or insurance for fishing gear damage. Market Access Improvement: Assist fishermen in marketing their catches through digital platforms or local markets. Example: Online fish marketing programs or integrated fish market development.
(1)Activity in	Social Capital: Social	Strengthening Fishermen
fishormon's	networks institutions and	Croups
nsnermen s	collaborations	Groups:
organizations, access to	conauonauons	• Establish or reinforce
financial institutions (2)		fishermen groups to
cooperation in		enhance collaboration and
dotermining fint		
determining fishing		access to resources.

	locations (3) connectivity		• Example: Creating active
	with social networks (4)		fishermen groups in
	local wisdom in		marine resource
	determining fishing		management.
	locations		Partnership with NGOs
			and Government
			• Encourage collaboration
			between fishermen,
			government agencies, and
			NGOs to develop
			adaptation programs.
			• Example: NGO-supported
			training programs or
			assistance with fishing
			gear.
			Utilization of Local
			Wisdom
			Integrate traditional
			knowledge into marine
			resource management and
			climate change
			adaptation. Example:
			Using local knowledge of
			fish migration patterns or
			weather forecasting.
	Alternative Source of	Livelihood diversification (e.g.,	Government Assistance
	Income;	fish farming, tourism)	Programs:
			• Enhance fishermen's
	(1) Utilization of		access to government aid
Adantive	Information and		programs, including
Capacity	Communication		support for fishing gear,
	technology such as		training, and business
	GPS, fish finders,		capital.
	fishing location		• Example: Support for
	coordinates, radio,		environmentally friendly
	mobile phones, and		fishing gear from the
	digital information		Ministry of Marine
	displays (running		Affairs and Fisheries.
	text)		Strengthening Local
	Replacing traditional		Institutions:
	navigation methods with		Strengthen local
	GPS to determine fishing		institutions such as
	locations, rather than		fishermen's groups
	relying on natural signs.		(KUB) or fisheries

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Training and capacity building to enhance fishermen's ability to use information technology for sustainable fishing	Utilization of information technology (weather forecasting, fish monitoring)	cooperatives. Example: Institutional capacity-building programs through management training.
practices.	Participation in training programs and capacity-building Involvement in fisheries	
Participatory policies on natural resource management tailored to local needs and conditions. (2) Infrastructure that withstands climate impacts (3) regulations to limit large-scale fishing activities (4)	Institutions and policies Strengthening social networks and collaboration stakeholders	

Source: Literature Review and Expert Discussion (FGD), 2025.

DISCUSSION

Vulnerability is influenced by the exposure, sensitivity, and adaptability of traditional fishermen in facing climate change. Capital assets consist of human, physical, natural, financial, and social assets.

• Exposure

Exposure due to extreme weather causes fishermen to be unable to go to sea. Of the 8 indicators obtained from the literature review of previous research in various parts of the world, 7 indicators of exposure were identified from the expert discussion results. The indicator of reduced diversity of commercial fish catches is not an indicator of exposure, but rather, this is a secondary impact of exposure felt by fishermen. Excessive fishing carried out by large vessels with modern fishing gear reduces the catch of traditional fishermen. The exposure of traditional fishermen to reduced fish catches is not caused by climate change. The decline in catches can be caused by overfishing by a large number of fishermen. This indicator is less specific for measuring the exposure of traditional fishermen, such as extreme weather that hinders fishing activities or damages fishing gear. Reduced fish catches are a long-term impact that occurs gradually, rather than an immediate threat (**Adger** *et al.*, **2005**). Expert discussion refers to exposure that directly affects fishermen's activities. The literature review presents global or general

data, while the expert FGD contextualizes the problem in local conditions, highlighting clearer threat priorities.

• Sensitivity

Sensitivity refers to how vulnerable fishermen are to climate change. Of the 4 indicators of the literature review results, only 3 indicators of the expert discussion results are important indicators related to fishermen's adaptation to climate change, namely dependence on marine products, damage to fishing gear, and fishermen's purchasing power. The results of the literature review highlight macro-level indicators, including fishermen's dependence on marine resources, decreased income, and damage to fishing gear. Meanwhile, the results of the expert discussion added alternative solutions that can be done, for example alternative livelihoods that are by field conditions and the level of damage to fishing gear due to climate change, so that the strategy that can be done is to diversify livelihoods (for example, fish farming or marine tourism) to reduce dependence on the sea

- Capital assets are resources owned by traditional fishermen that can be used to increase their resilience and adaptability to the impacts of climate change. These capital assets include human, natural, physical, financial, and social assets. From 17 capital asset indicators identified through a literature review, 23 additional capital asset indicators were developed through expert discussions, which are suspected of influencing fishermen's vulnerability and adaptation to climate change.
- Human assets, as identified in a literature review, include fishermen's education, skills, and health, as outlined in the table. The results of expert discussions specifically describe non-fishing skills that fishermen can adopt.
- Natural assets are indicated by the ability of fishermen to access fishery natural resources, with the threat of climate change that disrupts marine ecosystems. The results of expert discussions detail more broadly the indicators of local wisdom that can be done to adapt to climate change, for example, local natural resource management as an alternative to diversifying livelihoods.
- Physical assets based on literature review, the indicators are fishing gear and the modernization of fishing gear needs. While expert discussions explain the indicators of fishing gear ownership that are very much needed by fishermen, such as GPS to replace compasses, and others. Assets
- Financial assets and social assets, the main differences are identified based on literature review and expert discussions. Expert FGDs identify assets that fishermen have/need (e.g., GPS, mobile clinics), while the literature review is more theoretical. Discussion and results can be in one section. This should explore the significance of the work's results, rather than repeating them, avoiding extensive citations and discussion of published literature.

Identification studies of vulnerability indicators and capital assets are crucial for formulating appropriate adaptation strategies for fishermen. Identification of capital assets can identify the strengths and limitations of fishermen. Thus, helping the government and stakeholders design inclusive and participatory adaptation programs according to the needs of fishermen.

CONCLUSION

Thus, the study of identifying vulnerability indicators and capital assets is important for formulating the right adaptation strategy for fishermen. Identification of capital assets can identify the strengths and limitations of fishermen. Thus, it helps the government and stakeholders design inclusive and participatory adaptation programs according to the needs of fishermen. Validation with expert FGD emphasizes the implementation of local technology and programs, while literature review helps formulate general concepts.

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