Adaptation Strategies of Small-Scale Fishermen Households to Climate 1 **Change Impacts: Evidence from North Lombok, Indonesia** 2 3

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Abstract 4

Climate change has significantly affected the livelihoods of small-scale fishermen households in 5 North Lombok Regency, the region with the highest poverty rate in West Nusa Tenggara Province, 6 Indonesia. This study aims to identify the livelihood sources of small-scale fisher households and 7 assess the impacts of climate change on those sources, as well as to formulate adaptation strategies 8 to cope with the impacts of climate change. A mixed-methods approach was applied. Data were 9 collected through structured interviews with 100 respondents. Data were analyzed using the 10 Analytical Hierarchy Process (AHP). The results show that household livelihoods rely mainly on 11 fishing activities (by husbands), contributing the highest income (IDR 1,837,908/month), followed 12 by non-fishing activities (IDR 598,250/month). Additional income is generated by wives and 13 children, averaging IDR 796,650 and IDR 361,000 per month, respectively. Climate change has 14 reduced fishing activity and income, threatening the sustainability of these livelihoods. In 15 response, adaptation strategies include diversification of fishing gear and techniques, development 16 of alternative income sources, use of fishing information technology, access to government 17 support, adjustment of fishing times and locations, mangrove and coral reef restoration, social 18 network utilization, and use of household assets and savings. These strategies reflect the adaptive 19 efforts of small-scale fishermen households to maintain and strengthen their livelihoods amid 20 climate-related challenges. 21

Keywords: Adaptation strategies, Small-scale fishermen households, Climate Change, AHP. 22

1. Introduction

Indonesia is highly vulnerable to the impacts of climate change. This vulnerability is closely 25 related to the country's geographical characteristics-comprising mostly ocean, with a sea area of 26 5.8 million km², a coastline of 81,000 km, and 17,508 islands (Nursan et al., 2022). Indonesia 27 ranks 37th out of 182 countries most affected by climate change (Eckstein et al., 2017). Among 28

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the 323 regencies and cities in Indonesia, 23 regions are significantly affected by climate change 29 (Suroso et al., 2011). 30

Climate change in Indonesia has already posed serious threats to human lives (Rondhi et al., 2019; 31 Steffen et al., 2015), the global environment (Čadro et al., 2019; Simunic et al., 2019) and 32 biodiversity (Kroeker et al., 2013; Wenger et al., 2011). It contributes to food shortages, migration, 33 heatwaves, droughts, tidal floods, storms, forest fires, and degradation of marine ecosystems 34 (IPCC, 2013; Rahman & Rahman, 2015; Zougmoré et al., 2019). These changes reduce the 35 availability of marine resources and organisms (Comte & Olden, 2017; Knouft & Ficklin, 2017). 36 significantly affecting small-scale fishermen households-many of whom are still poor (Nielsen 37 et al., 2018) and heavily reliant on the sea for their livelihood and food supply (Lauria et al., 2018). 38 The fisheries sector, though critical for household livelihoods and food security, remains highly 39 vulnerable to climate change (Galappaththi et al., 2022).

To understand how fishing communities respond to climate pressures, it is essential to apply 41 relevant theoretical perspectives. Human adaptation theory explains how individuals and 42 43 communities adjust behaviorally and structurally to environmental changes (Ojea et al., 2020). The Sustainable Livelihood Framework (SLF) underscores five categories of capital-natural, 44 financial, human, social, and physical-that collectively influence the adaptive capacity of 45 households (Afrin & Islam, 2023). Meanwhile, the Progressive-Integrative Social Structure (S2PI) 46 47 model highlights the dynamic interaction between individual agency and social institutions in shaping community responses, aligning with integrative approaches to climate adaptation (Fedele 48 et al., 2019). These frameworks are conceptually relevant for examining how small-scale 49 fishermen adapt within their specific socio-ecological contexts. 50

51 Social structures such as patron-client systems, kinship networks, and community-based organizations strongly influence decision-making processes and resource access. These social 52 structures can either constrain or enable adaptation strategies, depending on how inclusive and 53 responsive they are to change. Recognizing these dynamics is crucial in identifying realistic and 54 sustainable adaptation pathways for fishermen households. 55

North Lombok Regency in West Nusa Tenggara Province is one such coastal area impacted by 56 climate change. Migration of fishing communities from this region has already occurred due to 57 climate-related pressures (Hidayati et al., 2021; Latifa & Romdiati, 2017). Moreover, North 58 Lombok is the only region in the province still designated as a "3T" area (underdeveloped, frontier, 59

and outermost). It has the highest poverty rate in the province, with 61,700 people (27.04%) living
in poverty. The poverty depth index is 5.69, and the severity index is 1.66. Additionally, 1,043
individuals (0.41%) fall into the extreme poverty category out of a total population of 256,438
(BPS North Lombok Regency, 2022). The extremely poor population is predominantly composed
of fishermen and farmer households, who are highly vulnerable to climate impacts on their
livelihoods. Adaptation strategies are needed for small-scale fishermen households to overcome
the impacts of climate change.

Climate change adaptation policies in the fisheries sector remain largely sectoral and short-term, 67 often neglecting the role of local social structures and community-based capacities. In fact, small-68 scale fishing communities possess unique social systems and adaptive strategies that can inform 69 more context-specific and responsive policy design. This study introduces a novel approach by 70 integrating the Analytical Hierarchy Process (AHP) with three conceptual frameworks: human 71 adaptation theory, the Progressive-Integrative Social Structure (S2PI) model, and the Sustainable 72 Livelihood Framework (SLF). This integration enables a multidimensional analysis of adaptation 73 strategies, considering not only economic impacts but also the influence of social relations, social 74 capital, and institutional support in enhancing household resilience to climate change. 75

This study aims to assess the impacts of climate change on these sources and formulate adaptationstrategies for small-scale fishermen households.

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2. Materials and methods

This research uses mixed methods of quantitative and qualitative. The research was conducted in four villages in North Lombok Regency: Gondang Village in Gangga District, and Jenggala, Sigar Penjalin, and Tanjung Villages in Tanjung District. These villages were purposely selected due to their exposure to extreme weather events. The locations are shown in Figure 1.

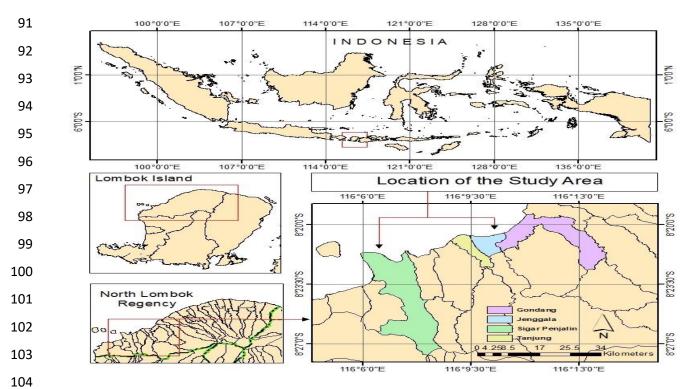


Figure 1. Regional Map of Study Location (North Lombok Regency, Lombok Island, Indonesia).

Data collection was conducted from June to September 2024. A total of 100 respondents were 107 selected from a population of 412 small-scale fishing households using Slovin's formula, with an 108 error margin of 8.7%. The sample was proportionally allocated across four purposively selected 109 coastal villages: Gondang (36), Singgar Penjalin (23), Jenggala (25), and Tanjung (16). 110 Respondents were chosen using simple random sampling based on an official household list. Data 111 were collected through structured interviews and focus group discussions (FGDs), and analyzed 112 using the Analytic Hierarchy Process (AHP) with Criterium DecisionPlus (CDP) Program to 113 prioritize adaptation strategies. AHP analysis is a decision analysis technique based on various 114 alternatives, criteria and objectives (Büyüközkan et al., 2019; Dehghanimohammadabadi & 115 Kabadayi, 2020). The following are the steps in AHP analysis (Saaty, 1980): 116

117 1. Conducting problem analysis.

118 2. Carrying out pairwise comparisons (*pairwise comparison*). The hierarchical weighting is119 presented in Table 1.

122	Tabl	e 1. Weight Values for Each Hierarchy Level.
	Weight	Definition
	1	Both elements are equally important
	3	One element is slightly more important than the others
	5	One element is more important than the other
	7 9	One element is clearly more important than the others One element is absolutely more important than the others
	2, 4, 6, 8	Values between two adjacent results
123	Source: Saaty (1980).	
124	3. Calculating eigenval	ues and eigenvectors.
125	4. Checking the consist	ency of the comparison matrix.
126	5. Summarizing prioriti	ies to make decisions.
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128	3. Results and Discuss	lions
129	Sources of Livelihood for S	Small-scale Fishermen Households
130	The sources of livelihood for	r small-scale fishermen households in North Lombok Regency comes
131	from the main activity of fisl	hing, businesses in the fisheries sector and outside the fisheries sector.
132	The largest household incom	ne for small-scale fishermen comes from the main source of income,
133	i.e., fishing (by husband) an	nounting to IDR 1,837,908 per month, then non fishing (by husband)
134	of only IDR 598,250 per m	nonth. The income of wives and children to support the household
135	economy of small-scale fis	hermen households is IDR 796,650 and IDR 361,000 per month.
136	Fishing is an activity that pro	ovides the largest contribution to household income compared to other
137	activities, as also found by N	Apemba and Mombo (2019).
138		
139	The Impact of Climate C	Change on the Source of Livelihood of Small-scale Fishermen
140	Households	
141	The impact of climate chan	ge on the livelihoods of small-scale fishermen households in North
142	Lombok Regency can be see	en from the case of activity and the amount of fishing caught over the
143	last 10 years. The results of	the analysis are presented in Table 2.
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149	Table 2. The impact of climate change on the livelihoods of Small-scale Fishermen Households in
150	North Lombok Regency (2024).

No	Description	Percentage (%)
	Climate change causes fishing activities to be:	
1	Easy	0
2	Difficult	89
3	No difference	11
	Amount	100
	Climate change cause result of fish catch to:	
1	Increase	0
2	Decrease	76
3	No difference	24
	Amount	100

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The majority of fishermen (89%) reported that fishing activities have become more difficult over 152 the past 10 years due to climate change, while 11% reported no change. Additionally, 76% of 153 fishermen stated that their catches have decreased as a result of climate change, whereas 24% saw 154 no difference. This difficulty and reduction in catches are caused by shifts to more remote fishing 155 areas and decreased fishing intensity due to longer periods of not fishing, driven by climate-related 156 events such as rising sea levels, storms, floods, and coastal erosion (Barange et al., 2018). 157 158 Therefore, climate change that has occurred in North Lombok Regency has had an impact on reducing the income of small fishermen from their main source of income, the fishing. These 159 results are in line with research by (Shaffril et al., 2017) who found that climate change has reduced 160 fishing intensity by up to 90% a month during the northeast season and reduced fishermen source 161 162 of livelihood and income (Bah et al., 2018; Chan et al., 2023).

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164 Small-scale Fishermen Households Adaptation Strategy to Climate Change

There are 8 alternative strategies used by Small-scale fishermen Households to overcome the impacts of climate change in North Lombok Regency. The details of these alternative strategies are presented in Table 3, and then each strategy is explained in more details.

168	Table 3. Adaptation strategies of Small-scale Fishermen Households in overcoming the impacts
169	of climate change in North Lombok Regency.

No	Adaptation Strategy	Code	Percentage (%)
1	Receiving Government Assistance	S1	100
2	Diversification of fishing equipment and techniques	S2	100
3	Change of Capture time and region	S 3	58
4	Use of information technology in fishing	S4	38
5	Diversification of household income sources	S5	59
6	Utilization of Assets and Savings	S6	61
7	Social network	S7	46
8	Planting Mangroves and Coral Reefs	S8	26

Receiving government assistance 170 Small-scale fishermen households in North Lombok Regency are tackling the impacts of climate 171 change with assistance from the local government, which provides 10 kg of rice per family. This 172 support is universal among households and is complemented by the provision of fishing 173 equipment, such as nets and boats, along with training on climate-resilient coastal practices. While 174 these government interventions help mitigate risks and vulnerabilities, challenges remain, 175 176 including insufficient aid and distribution delays, raising concerns about dependency due to a lack of capacity-building initiatives. To improve the situation, government policies should focus on 177 increasing the adequacy of aid, ensuring timely and transparent distribution with community 178 oversight, and implementing sustainable empowerment programs. Furthermore, these policies 179 180 align with the findings of Celliers et al. (2013) for integrated support systems to help vulnerable coastal communities adapt to climate change effectively. 181 182

183 Diversification of Fishing equipment and techniques

Small-scale fishermen can mitigate the impacts of climate change by diversifying their fishing 184 equipment and techniques. Previously, fishing was relatively easy, but rising temperatures and sea 185 186 levels have made it more challenging. As a result, small fishermen are compelled to expand the types of fishing gear and methods they use to catch specific fish species. In North Lombok 187 Regency, 100 percent of fishermen have diversified their equipment and techniques to adapt to 188 these changes. This strategy is in accord with Badjeck et al., (2010), that one of the factors that 189 can help fishermen livelihoods in overcoming the impacts of climate change is by changing new 190 191 fishing techniques and tools.

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193 Change of capture time and location

Climate change has compelled fishermen to change their fishing grounds, leading to the loss of 194 traditional areas and a shift to more distant locations. While they often rely on their instincts and 195 experience to discover new fishing spots that might be rich in fish, this adaptation comes with 196 197 challenges. Increased operational costs, such as a 15–20% rise in fuel expenses, along with time wasted on trial-and-error in unfamiliar waters, can result in lower catch volumes-sometimes 198 decreasing by up to 30% during certain seasons. These difficulties can make new fishing areas less 199 profitable, especially due to unfamiliar environments, fewer available species, and heightened 200 competition. In North Lombok Regency, fishermen take into account their past experiences, 201

- weather information, and advice from peers when determining new fishing times and locations,
- with 58 percent having adjusted their practices to adapt to these changes. This strategy aligns with
- 204 findings from Lédée et al., (2012) and Comte et al., (2013), which observed similar spatial
- 205 adaptations in response to climate-driven changes in fish availability. We recommend providing
- 206 fuel subsidies, improving access to weather forecasting, and establishing cooperative planning
- 207 among communities to facilitate this transition.

208 Use of information technology in fishing

Climate change has made it challenging for fishermen to predict weather conditions and fishing 209 210 seasons, which were previously based on natural signs and experience. To adapt, fishermen are now using information technology, such as weather forecasts from BMKG (the meteorological 211 212 agency), television, the internet, cell phones, and information from local governments. However, in North Lombok Regency, access to fish-catching technology information is low, with only about 213 214 38 percent of fishermen utilizing fishing information technology, market information, and fishery product processing technology. Barriers to adoption include limited digital literacy, particularly 215 among older fishermen; high costs of mobile data and smartphone access; and poor internet 216 connectivity in coastal and remote villages. Suggested interventions include digital literacy 217 218 training, subsidized access to fishing-related apps, and infrastructure development in lowconnectivity areas. Research by Galappaththi et al., (2019) and Musinguzi et al., (2016) supports 219 the importance of increasing access to technology and information in enhancing climate resilience. 220

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222 Diversification of household income sources

Diversifying household income sources is a crucial strategy for small fishing households in North 223 Lombok Regency to adapt to the impacts of climate change and reduce reliance on a single income 224 source. This livelihood diversification has been implemented by 59 percent of small-scale 225 fishermen households, who have found additional sources of income beyond fishing. This other 226 source of income is provided by fishermen when they are not fishing and there are extreme weather 227 changes. Fishermen will look for additional work when the non-fishing season starts (Paulus et al., 228 2019; Taufik et al., 2023). Fishermen engage in these activities to support their families and ensure 229 their survival. In North Lombok Regency, fishermen households have various sources of income, 230 including roles as farmers, agricultural laborers, fishing workers, carpenters, air conditioning 231 technicians, livestock breeders, government employees, drivers, builders, and security guards. 232

Additionally, many wives assist their husbands by selling fish and essential goods, while children often take on jobs in the private sector or become migrant workers. Several studies have found that diversifying household sources of income can increase the resilience of coastal communities to climate change (Badjeck et al., 2010; Pinsky & Mantua, 2014; Ojea et al., 2017).

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238 Utilization of Assets and Savings

Small-scale fishermen households rely on assets and savings to meet daily needs and support fishing activities. About 61% adapt by selling items like livestock, gold, or vehicles to fund operations and cope with economic pressures. Research by Berman et al., (2015), found that selling assets and saving can be done to overcome the impact of climate change on households in Western Uganda.

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245 Social networks

To cope with climate change, small-scale fishermen households in North Lombok Regency rely 246 on their social networks as an adaptation strategy, with 46% of fishermen utilizing these networks. 247 These social networks include horizontal connections, such as fishermen's groups, which serve as 248 forums for exchanging ideas about fishing practices. They also involve social borrowing, where 249 fishermen borrow money for daily needs from private moneylenders. Additionally, fishermen 250 engage in vertical networks by receiving government programs and assistance, including food, 251 boats, and fishing gear. Some fishermen also borrow money from banks. Collaborative and joint 252 action strategies are essential to effectively reduce the impacts of climate change (Galappaththi et 253 254 al., 2019).

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Planting Mangroves and Coral Reefs

Fishermen in North Lombok Regency are actively working to restore their environment in 257 response to climate change by planting coral reefs and mangroves. This initiative aims to preserve 258 259 fish habitats and protect coastal ecosystems. While 26% of fishermen recognize the environmental damage, these restoration efforts are also supported by community organizations to enhance 260 ecosystem preservation and attract tourism. However, the adoption of these practices is hindered 261 by high costs, the need for technical knowledge, limited immediate benefits, and uncertainty 262 regarding the survival of the planted corals and mangroves. For many households facing financial 263 constraints, these challenges are significant. To encourage broader community participation, 264

- 265 supportive policies and training programs are essential. Mangroves and coral reefs are crucial for
- reducing the climate vulnerability of coastal areas (Guannel et al., 2016) and play a vital role in
- 267 their sustainable development (Chow, 2017).
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269 Adaptation strategies priority for small-scale Fishermen households to climate change

Determining the priority of adaptation strategies for small-scale fishermen households in
overcoming the impacts of climate change in North Lombok Regency was carried out using AHP
analysis. This analysis was first introduced by Saaty (1980) to assist decision making that involves
many factors and assessment criteria and alternatives.

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275 Determination of adaptation strategy criteria

Determining the criteria for adaptation strategies for small-scale fishermen households in
overcoming the impacts of climate change in North Lombok Regency was carried out by experts.
The selected criteria are economic, social, ecological, policy and technological criteria. The results
of the AHP analysis of priority selection criteria can be seen in Table 4.

Table 4. Determining priority criteria for adaptation strategies for small-scale Fishermen
 households in overcoming the impacts of climate change in North Lombok Regency.

Criterion	Economy	Social	Ecology	Policy	Technology	Eigenvalues	Ranking
Economy	1.000	2.000	1.000	3.000	2.000	0.311	1
Social	0.500	1.000	1.000	0.500	0.333	0.108	5
Ecology	1.000	1.000	1.000	1.000	0.333	0.150	3
Policy	0.333	2.000	1.000	1.000	0.333	0.130	4
Technology	0.500	3.000	3.000	3.000	1.000	0.302	2
CR						0.081	

²⁸²

Table 4 shows that economic criteria are a priority in determining adaptation strategies for smallscale Fishermen households in overcoming the impacts of climate change with a value of 0.311, followed by technological criteria of 0.302, ecology of 0.150, policies of 0.130 and social criteria of 0.108. Assessment by experts regarding the priority of these criteria shows consistent results, indicated by the consistency ratio (CR) value of 0.1 or less, that is 0.081.

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289 Priority Adaptation Strategy for Small-scale Fishermen households

After analyzing the criteria and selecting strategies based on existing criteria, the priority adaptation strategies for small-scale fishermen households can be determined in overcoming the

- impacts of climate change in North Lombok Regency. The results of AHP to determine the
- adaptation priority strategy can be seen in Table 5.

Table 5. Result of AHP to determine priority adaptation strategies for small-scale Fishermen
 households in overcoming the impacts of climate change in North Lombok Regency.

Criterion	S1	S2	S3	S4	S5	S6	S 7	S 8	Model Weights
Economic	0.109	0.199	0.077	0.150	0.272	0.073	0.061	0.059	0.311
Social	0.209	0.070	0.05	0.107	0.141	0.07	0.237	0.116	0.108
Ecology	0.092	0.176	0.085	0.188	0.249	0.049	0.049	0.111	0.149
Policy	0.199	0.215	0.148	0.102	0.099	0.065	0.057	0.115	0.13
Technology	0.121	0.246	0.128	0.201	0.101	0.055	0.047	0.102	0.302
Results	0.133	0.198	0.100	0.160	0.180	0.063	0.074	0.093	
Ranking	4	1	5	3	2	8	7	6	

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297 The AHP analysis for small-scale fishermen households in North Lombok Regency identified S2

as the top priority adaptation strategy with a value of 0.198, followed by S5 (0.180), S4 (0.160),

299 S1 (0.133), S3 (0.100), S8 (0.093), S7 (0.074), and S6 (0.063).

The priority adaptation strategies for small-scale fishermen households in overcoming the impactsof climate change can be seen in Figure 2.

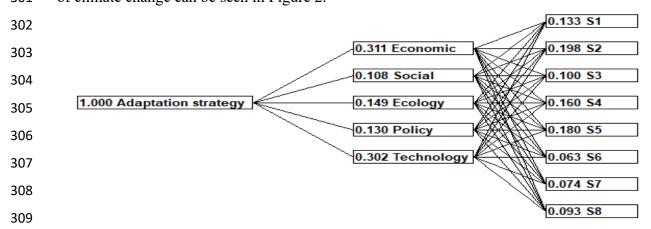


Figure 2. Adaptation strategies priority for small-scale fishermen households.

In order to survive and reduce the impacts of climate change, small-scale households must adopt appropriate adaptation strategies (Pescaroli et al., 2023). In line with this, the findings of this study indicate that fishermen should prioritize adaptation strategies that encompass cognitive, practical, and organizational aspects in addressing the challenges posed by climate change (Samah et al., 2016).

The study identifies eight key adaptation strategies used by small-scale fishing households to cope with climate change, including diversification of fishing gear and income, government aid, use of technology, social network strengthening, and environmental restoration. Quantitative analysis

- highlights diversification as a top priority, but adaptive capacity also depends heavily on socialcapital, savings, and information access, emphasizing the role of institutional support.
- 321 Policy implications call for systemic, long-term approaches that integrate adaptation into regional
- 322 planning, enhance access to adaptive technologies, and support community organizations and
- 323 education. To enhance the effectiveness of government assistance, participatory needs assessments
- 324 should allow fishermen to identify specific support requirements, while digital tracking platforms
- 325 can improve the transparency and efficiency of aid distribution. Furthermore, establishing village-
- 326 based "Climate Information Posts" can provide real-time weather and fishing data, particularly in
- 327 areas with poor internet access. Public funding could also be allocated to subsidize smartphones
- 328 or mobile data packages for low-income fishermen, along with targeted digital literacy training to
- 329 empower them in utilizing these technologies effectively.
- 330 The study also notes that adaptation burdens are unevenly distributed, often marginalizing women
- and children, underscoring the need for inclusive participation in decision-making. These findings
- align with theories of human adaptation that stress the interaction of individual and social factors.
- Additionally, combining local ecological knowledge with scientific data and leveraging strong
- 334 social networks further strengthens community resilience to climate impacts (Coulthard et al.,
- **335** 2011).
- This study has notable limitations, including its focus on just four coastal villages in North Lombok Regency, which may not reflect the diversity of small-scale fishing communities in Indonesia. Additionally, data collection occurred during a specific seasonal period, potentially affecting respondents' recall of climate impacts and adaptation strategies. These limitations suggest the need for future research that includes a broader geographic scope and considers various seasonal contexts for a more comprehensive understanding.

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4. Conclusions

This study examined the impacts of climate change on small-scale fishermen households in North Lombok Regency. The AHP analysis identified diversification of fishing gear and household income as priority adaptation strategies for small-scale fishermen households facing climate change. Other strategies include government assistance, technology use, social network strengthening, and environmental restoration. Adaptability is strongly influenced by social capital, savings, and access to information, highlighting the importance of institutional support. Policy-

- wise, a systemic and long-term approach is needed, embedding adaptation into regional planning, improving access to adaptive technologies, and supporting community organizations and education. The study also emphasizes inclusive participation, noting that women and children are often marginalized in decision-making despite their critical roles.
- 354

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