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The Faint Sound of the Coast: A Study of the Adaptation of Aru Bay Fishers to Climate Change through the Sustainable Livelihood Framework Approach

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Abstract: Climate change has had a significant impact on the sustainability of coastal communities, particularly small-scale fishers who depend on the stability of marine ecosystems for their livelihoods. This study aims to understand the forms of adaptation undertaken by fishing communities in Aru Bay, South Kalimantan, and examine how these adaptations relate to existing institutional support and policy frameworks. Using a qualitative case study approach and analysis based on the Sustainable Livelihood Framework (SLF), this study explores ive forms of livelihood capital human, social, natural, physical, and financial that shape fishers' adaptation strategies. Data were obtained through in-depth interviews with nine key informants, including active fishermen, fishermen's families, and the local village head. The results show that fishermen's adaptation process occurs autonomously and is heavily influenced by local experiences, social relations, and their interpretations of seasonal changes and extreme weather. Adaptation occurs through adjusting fishing times and locations, diversifying income, and establishing informal social networks. However, limited access to technology, financing, and social protection remains a significant barrier. These findings are expected to form the basis for developing more contextual and inclusive policies in response to the challenges of climate change in the small-scale fisheries sector

Keywords: Climate Change, Fishermen Adaptation, Aru Bay, Sustainable Livelihood Framework (SLF), Social Resilience, Livelihood Capital.

INTRODUCTION

Climate change has become an unavoidable global challenge. The complexity of the current problem not only impacts the resilience and sustainability of ecosystems but has also significantly altered the well-being of millions of communities whose livelihoods depend on

the stability of natural conditions. This includes coastal communities, particularly small-scale fishers, who are on the front lines of these changes.

This aligns with the Intergovernmental Panel on Climate Change (IPCC)'s Climate Change 2023 Synthesis Report, which highlighted that coastal areas are among the most vulnerable to the impacts of climate change. Rising sea temperatures, shifting wind and current patterns, storm intensity and seasonal uncertainty, shifts in fish migration patterns, and declining coastal ecosystems are logical consequences of declining fisheries productivity and increasing risks to the livelihoods of coastal communities (Kazzan et al., 2023).

Furthermore, Pörtner (2022), as cited by the European Environment Agency (EEA) in How Climate Change Impacts Marine Life (2023), states that changes in the marine environment, such as increasing temperatures, seawater acidification, and reduced oxygen levels, have disrupted the structure of marine ecological communities. This condition places significant pressure on the survival of various fish and invertebrate species, resulting in habitat degradation, population decline, threats of local to global extinction, and shifts in patterns in marine food webs (Pörtner et al., 2022). This is a condition unprecedented for thousands of years, resulting in significant impacts on marine life and coastal areas (EAA, 2020).

The same challenge is also reflected in a report released by the Food and Agriculture Organization (FAO) in collaboration with the Fisheries and Marine Ecosystem Model Intercomparison Project (FishMIP) at the 36th Committee on Fisheries (COFI) forum in 2024, that global projections of exploitable fish biomass show a potential decline of ±10% by the end of this century in most countries. In a higher emission scenario with an estimated global warming of 3–4°C. The potential decline increases significantly beyond 30% in 48 countries, including Indonesia (Blanchard, & Novaglio, 2024). In fact, a report entitled "Hot Water Rising," prepared by the World Bank in collaboration with the Indonesian Ministry of Maritime Affairs and Fisheries and the University of British Columbia, confirms that total economic benefits from the fisheries sector in Indonesia's exclusive economic zone are projected to decline by 15% under a low-emission scenario and by 26% under a high-emission scenario by 2050 (Kazan et al., 2023).

In order to emphasize the urgency of the impact of climate change on the future of fishermen and coastal communities in developing countries, it can be seen from the results of an analysis of a study entitled Poverty Line Income and Fisheries Subsidies in Developing Country Fishing Communities (Teh, LSL, et al. 2024), which states that of the 6.96 million fishermen analyzed from 30 countries, with an estimate that each fisher supports an average of four to five family members, it is estimated that 33.2 million people whose lives depend on the fisheries sector are living below the poverty line.

In a more specific context in Indonesia, Prof. Dr. Ir. Rokhmin Dahuri, MS in his speech at the Coordination Meeting on Capture Fisheries Management in May 2024 , stated that the number of people working in the capture fisheries sub-sector, both directly and indirectly, is 6.4 million people. . If we use the same estimate as in the study above, that each person working in the fisheries subsector supports an average of five family members, then it can be estimated that the welfare of 30.2 million Indonesians is at stake.

Imagine if life depended entirely on the sea, but the sea became increasingly unpredictable, even for the fishermen who had been sailing it for generations. For these fishermen, climate change does not appear in graphs or numbers, but rather in boats that are stuck for longer periods due to extreme weather, empty nets due to shifting fish migrations, and cold weather that begins to disrupt their kitchens. Small-scale fishermen live in a wave of uncertainty, torn between inherited local knowledge and increasingly extreme weather changes. Furthermore, they are not only facing ecological threats but also disruptions to the livelihood systems they have built across generations. At this point, adaptation is no longer an option for them, but rather an instinct in facing the daily crises that are slowly but surely eroding their

survival. This discourse then raises a more fundamental question: How and in what ways can they adapt, amidst all the existing limitations?

As a country with the second-longest coastline in the world and a water area reaching 3,257,483 km² or ±70% of the total territory (BIG, 2013 in Simatupang & Khomsin, 2016), Indonesia's narrative as a maritime nation or global maritime axis seems to be increasingly tested by more complex pressures than ever before. Responding to the dynamics of climate change, various adaptation discourses have actually been placed as a special focus in various national policy documents. Some of these are as follows. :

1. Enhanced Nationally Determined Contributions (ENDC) Indonesia 2022 which emphasizes the importance of coastal development and marine ecosystem protection as part of the national climate agenda.
2. The National Action Plan for Climate Change Adaptation (RAN-API) 2013–2025, for example, has become an initial framework that emphasizes the importance of strengthening adaptive capacity in vulnerable sectors, including maritime affairs and fisheries.
3. The 2020–2024 National Medium-Term Development Plan (RPJMN) prioritizes sustainable development, climate resilience, and coastal community protection.
4. Law Number 7 of 2016 concerning the Protection and Empowerment of Fishermen expressly mandates the state to protect small-scale fishermen from the threat of climate change and ensure the sustainability of their livelihoods through business protection, capital assistance, and the provision of easily accessible climate information.

However, the adopted approach remains macro-oriented and dominated by technocratic and aggregate methods, which tend to obscure social dynamics and adaptation experiences at the community level. Programs such as improving business facilitation, technology development, financing, human resource innovation, and marine research generally reflect a top-down, formal-system-based development approach. This is reflected, for example, in Ministerial Decree No. 52 of 2024 concerning the Climate Change Mitigation Roadmap, where the approach taken focuses solely on technical and ecological aspects rather than the socio-economic dimensions of coastal community adaptation. A similar trend is also found in Government Regulation No. 11 of 2023 concerning Measured Fishing (PIT), which, while regulating the use of measured catch quotas, opens access to fishing areas up to 12 nautical miles to legal entities, including foreign investors, in strategic zones. This has the potential to restrict the mobility of small-scale fishers and make it difficult to compete fairly with large businesses that have significantly higher capacity, capital, technology, and competitiveness (Adhiem, M. A., & Sawalman, 2024).

Various studies and preliminary observations indicate that small-scale fishers' adaptation efforts often occur intuitively and are based on local experiences. Findings from research conducted in several fishing communities and coastal communities in Mamuju Regency (Ansaar, 2019), Pangkep Regency (Kasri et al., 2024), and Konawe Regency (Dewiyanti et al., 2019), for example, explain that adaptation patterns for fishers and coastal communities are carried out autonomously, such as adjusting fishing patterns, shifting fishing locations, diversifying livelihoods, or establishing supportive social networks at the community level. Therefore, this condition reflects a potential mismatch between national policy direction and actual adaptation strategies implemented at the community level. In other words, little is known about how these national adaptation programs are internalized, translated, or even perceived by small-scale fishers. In fact, the Food and Agriculture Organization (FAO) highlights that fully centralized fisheries management by the state has been a major cause of failure in fisheries governance in many developing countries (FAO, 2022). In contrast, co-management approaches, involving resource users, including small-scale fishers, have developed in response

to legitimacy crises, government budget constraints, and resource degradation in many coastal areas (FAO, 2022). This model is considered crucial for improving management effectiveness and bridging the gap between formal policies and local dynamics.

One coastal area experiencing similar challenges is Aru Bay in Kotabaru Regency, South Kalimantan. Small fishing communities in this region are also not immune to the pressures of climate change. According to the 2018-2022 report on marine capture fisheries production within the Fisheries Management Area (WPP), several areas experienced a significant decline of 37%, namely Aru Bay, the Arafura Sea, and the Eastern Timor Sea (WPP 718) (Setiawan et al., 2024 in Vikalian et al., 2024). Interestingly, the Aru Bay area itself is included in a national marine conservation area as stipulated in the Decree of the Minister of Maritime Affairs and Fisheries No. 69/2020. Despite lacking a complete understanding of the term "climate change," they have implemented various forms of adaptation based on experience, intuition, and local knowledge. This phenomenon raises important questions: How does this adaptation process actually occur, and what factors shape their adaptation patterns. Therefore, the Aru Bay area is a relevant space for understanding the dynamics of adaptation of small-scale fishermen's livelihoods contextually, while also observing the extent to which policy interventions truly address the needs and realities of coastal communities.

Various existing studies have made important contributions to understanding the dynamics of climate change and its impacts on the livelihoods of small-scale fishers. However, most approaches tend to be quantitative and technocratic, relying, for example, on spatial models, climate data, or aggregate-based policy analysis. Therefore, research using such approaches often falls short of capturing how fishers individually and collectively interpret climate change, respond to ecological uncertainty, navigate resource constraints, and develop adaptation strategies within their complex socio-economic context.

Yet, a deeper understanding of the lived experiences, social resilience, and local knowledge of fishers is crucial for shaping more responsive policies. Therefore, researchers believe it is necessary to develop an alternative lens that allows us to examine how adaptation strategies are truly shaped by the interaction between available resources, the external pressures they face, and the institutional support or limitations surrounding them. It is at this point that the Sustainable Livelihood Framework (SLF) approach can play a significant role as an analytical perspective centered on real-life actors and practices.

Using a case study approach and the Sustainable Livelihood Framework (SLF) as an analytical framework, this research aims to map not only technical adaptation strategies but also highlight the social, economic, institutional, and resource aspects that underpin their livelihoods. It is hoped that the results of this research can contribute to the development of more contextual and participatory environmental communication policies or strategies, strategies that not only originate from the top but also emerge from an understanding of adaptation practices that have long grown from the grassroots.

METHOD

This research uses a qualitative approach with a case study strategy. This approach was chosen to explore in-depth the experiences, strategies, and dynamics of small-scale fishers' adaptation to climate change at the community level. Case studies allow researchers to understand social realities contextually and holistically, taking into account the economic, cultural, and institutional backgrounds that shape coastal communities' livelihood strategies.

This research was conducted in the coastal area of Aru Bay, Kotabaru Regency, South Kalimantan Province. It is important to note that Aru Bay is located in the administrative area of Pulau Laut Kepulauan District, Kotabaru Regency, which is included in the scope of the Pulau Laut-Pulau Sembilan Marine Conservation Area, as stipulated by the Decree of the Minister of Maritime Affairs and Fisheries No. 69 of 2020. This status normatively indicates the importance of the area in the agenda of ecosystem protection and strengthening socio-

ecological resilience, although in practice it still faces various adaptation challenges at the local level. Aru Bay is also one of the areas experiencing climate change pressures as well as socio-economic complexities in the small-scale fisheries sector. The location selection was based on considerations of the socio-economic characteristics, livelihoods, and relatively small scale of the Aru Bay community, making it suitable as a case study unit in the SLF approach. Its local complexity can represent the dynamics of small coastal communities living under environmental pressures and macro policies.

The study involved 10 subjects, consisting of small-scale fishers, members of their families, and a village head with a deep understanding of the socio-economic dynamics of coastal communities in Aru Bay. The participants were selected using purposive sampling, taking into account their experience, involvement, and knowledge of climate change issues and local adaptation strategies.

Subject selection took into account not only their position as direct participants in fisheries activities but also their role as part of social and institutional networks that influence livelihood adaptation processes. This aligns with a qualitative approach that emphasizes depth of information over the number of participants.

The presence of family members in this study was crucial to capture how fishermen's adaptation strategies often involve the household dimension—both in economic decision-making, livelihood diversification, and domestic roles in adjusting to daily needs. Meanwhile, the village head played a role in providing perspective on local institutional dynamics, social support, and the relationship between the community and external programs that address climate change or coastal livelihoods.

Data were collected through semi-structured interviews, allowing flexibility in data collection while maintaining focus on key themes. Interviews were conducted on-site, using an interview guide developed based on components of the Sustainable Livelihood Framework, such as livelihood assets, coping strategies, and access to institutional support. In addition to interviews, participant observation and field notes were used to enrich the context and add dimensions to understanding the daily practices of fishers.

Data analysis was conducted thematically using the Thematic Analysis approach (Braun & Clarke, 2006). The analysis process was carried out in several stages:

a. Initial coding of interview transcripts,
b. Grouping of codes based on the five types of livelihood assets in the SLF (human, natural, social, physical, and financial capital), as well as the structural-institutional dimensions and vulnerability context,
c. Extraction of key themes to identify adaptation strategies used by fishermen in responding to climate change,
d. In-depth interpretation by linking empirical findings and local context into the SLF framework.

This analysis allows researchers to understand adaptation strategies not as separate actions, but as complex processes formed from interactions between resources, social structures, ecological pressures, and institutional support..

RESULTS AND DISCUSSION

1. Dynamics of Strategy and Adaptation: A Portrait of Aru Bay Fishermen Facing Climate Change

As with fishing communities and coastal communities in many places, climate change is not an abstract concept for the fishermen of Aru Bay, Kotabaru Regency, South Kalimantan. It is present in its most tangible forms: unpredictable seasons, increasingly unpredictable waves, high winds that make fishing difficult, and declining catches. For most fishermen in this region, extreme weather conditions and changing ocean dynamics have significantly altered their way

of life, requiring adjustments in fishing practices, household economic strategies, and daily risk management.

Interviews with nine participants revealed that fishermen's adaptive responses varied. Some chose to remain fishermen, relying on experience and observations of natural and weather signs. Others began to turn to alternative occupations such as gardening, farming, and even laboring on oil palm plantations. Livelihood diversification is a key form of adaptation, especially for fishermen who can no longer rely on daily income from their catch.

Some fishermen, like Kaswin and Jalamin, have chosen to switch careers, including farming, gardening, or managing small businesses. This diversification emerged not from formal training programs or interventions, but rather from long experience with unpredictable weather and declining catches. As noted by researchers, Kaswin stated, "I've been farming more rubber and cloves for the past four years. Seafood is no longer predictable." Similarly, Jalamin also stated, "When there's no catch, fishermen rely on their own crops. Some also work for palm oil companies." This demonstrates that adaptation doesn't always take the form of technological innovation, but also involves reorganizing their lives and developing survival strategies based on locally available resources. Meanwhile, some fishermen continue to rely on limited seafood for their livelihoods. Despite the significant risks, these fishermen persist in fishing by adapting their fishing strategies based on local knowledge of weather changes and determining their fishing schedules.

Researchers have observed that awareness of climate change has actually grown among fishermen. This can be seen in their awareness of the shift in the west and east monsoons, which are no longer predictable as they used to determine fishing times. They noted that in recent years, the west monsoons have become longer and more erratic, with strong winds hindering fishing activities. Fishermen have also noticed changes in fish behavior, such as shifts in the locations and seasons of certain species. Tuna, mackerel, anchovies, and shrimp are now more difficult to find, or must be caught farther from the shore, which automatically increases operational costs. They have even recently observed dolphins increasingly frequenting and residing in areas where they usually fish. These dolphins often eat fish caught in fishermen's nets, damaging them. Meanwhile, repairing nets and fishing equipment is not cheap.

However, adaptation isn't simply a matter of reading the weather or changing shipping routes. It also involves the ability to survive within limited resources. Most fishermen in Aru Bay rely on small, mastless boats with rudimentary engines, limiting their optimal fishing distance and time. Meanwhile, in interviews, several fishermen stated that support in the form of fuel subsidies, fishing gear subsidies, and adaptation training have not fully and equitably reached their needs.

Another challenge arises from the catch distribution system, which is not yet fully profitable for fishermen. Fish caught are generally sold to middlemen at fluctuating prices, while direct access to markets remains limited. Furthermore, operational costs for a single trip to the sea can reach Rp 100,000 to Rp 300,000, with no guarantee of an adequate catch. In certain situations, fishermen must be content if their catch only barely covers their costs, or even resort to drying fish as a survival strategy when selling fresh fish is not feasible.

In facing these conditions, social networks between fishermen and families become a crucial support. Some fishermen provide capital to fellow fishermen, then share the catch. Others form fishing groups to submit proposals for assistance, although the results often do not meet expectations. The values of mutual cooperation and solidarity appear to be crucial forces in responding to this increasingly vulnerable situation. Interestingly, not all forms of adaptation are based on external intervention. In many cases, adaptation stems from local knowledge, self-observation, and even traditional myths that are still practiced. Thus, the experiences of the Aru Bay fishermen demonstrate that adaptation is not a linear process directed from above, but rather a complex, dynamic, and highly contextual survival effort driven by the urgency of life,

social ties, and efforts to maintain honor as fishermen even though the sea is no longer as familiar as it once was.

2. Analysis of Aru Bay Fishermen's Adaptation through the Lens of the Sustainable Livelihood Framework (SLF)

The Sustainable Livelihood Framework (SLF) approach allows for a more systematic mapping of community survival strategies through five forms of livelihood capital: human capital, social capital, natural capital, physical capital, and financial capital, and how these interact with existing institutions and environmental vulnerabilities. The following analysis explores the dynamics of adaptation of Aru Bay fishers through the SLF lens:

1) Human Capital: Local Knowledge and Adaptive Capacity

Like other traditional fishing communities in Indonesia, which rely on local knowledge to interpret seasonal patterns and determine fishing strategies, the fishermen of Aru Bay do the same. The knowledge and skills of the fishermen of Aru Bay are inseparable from the accumulated experience passed down through generations. The majority of fishermen demonstrate an intuitive ability to read natural phenomena, such as wind direction, waves, changes in air temperature, and even the color of the sky and clouds. In terms of seasons, they possess a fairly detailed knowledge of the west, east, southeast, and even south monsoons, which directly influence fishing schedules/duration, fishing gear types, fishing locations, and risk assessments.

During the east and south monsoons, which generally last from June to September, sea conditions are considered relatively calm and the weather tends to be sunny. During this period, fishermen feel more free to go out to sea, even over longer distances. Fishing activity also tends to be higher because catches are more abundant and fish like tuna and mackerel are more readily available. Conversely, the west monsoon, which lasts from December to March, presents its own challenges. This season is characterized by heavy rainfall, strong winds, and unstable sea waves. Many fishermen choose not to go out to sea or significantly limit their activities due to the high safety risks and decreased catch productivity. Meanwhile, the southeast monsoon is usually considered a transitional period that demands flexibility because sea conditions can change drastically in a short time. This knowledge not only shapes the decision to go out to sea but also influences the schedule and duration of fishing activities themselves. As Jalamin explained, "During the west monsoon, we usually leave at 5 p.m. and return at 6 a.m.. During the east monsoon, we usually leave at dawn and return at night."

However, this adaptive capacity has not been significantly strengthened by support from formal systems, such as scientific data-based weather training, education on the use of weather forecasting technology, or digital literacy to access information from the Meteorology, Climatology, and Geophysics Agency (BMKG). Some fishermen, like Alan, admitted to only knowing weather conditions from the BMKG's Instagram account or asking fellow fishermen. Even when they receive a Fisherman's Card, which is normatively intended as a form of social protection and access to subsidies, most of them don't understand how to use it, let alone experience its real benefits. This situation doesn't take into account physical limitations and age. Mr. Jalal, for example, can no longer go to sea due to a stroke, without an adequate social protection system to ensure his survival. This indicates that human capital in fishing communities is tested not only by ecological knowledge but also by personal vulnerability factors, such as health and age, which should be included in more inclusive policy adaptation schemes. In other words, local knowledge is a key strength for resilience, but this capacity is increasingly under pressure from extreme climate change, while adaptive training and social security systems are unable to fully address their basic needs.

2) Social Capital: Solidarity, Patronage, and Local Institutions

In the dynamics of life in the coastal communities of Aru Bay, social capital plays a central role in maintaining sustainable livelihoods, especially amidst increasingly uncertain environmental conditions. In Aru Bay, relationships between fishermen are framed in a patronage system based on trust and social cohesion. Fishermen with more resources—such as engines, nets, or access to fuel—often provide capital to other fishermen to go to sea, with a profit-sharing system as a form of reciprocity. As one participant explained: "We are also fishermen, collectors too. Sometimes the profit is only 25,000, sometimes it's three times that... We take care of 20 fishermen, providing them with capital. We pay them with our catch, and the profits are split in half." (Interview with Mochtar and Rohana, 2024). Practices like this demonstrate the high level of horizontal trust among community members. This social capital is also manifested in the form of close-knit local community ties, as expressed by Alan: "In this area (Jalan Raya Tanjung), the fishing community here has more than 20 members, and it can be said that they are quite close-knit and have good relationships."

In the literature, this is known as Bonding Social Capital (Putnam, 1993 in Patulny & Svendsen, 2007), a form of solidarity that grows from emotional closeness, recurring patron-client relationships, and the values of mutual cooperation that persist within the social structure of fishing communities. However, the role of formal institutions such as fishing groups has not been fully optimized. Efforts such as forming fishing groups and preparing aid proposals have not always yielded positive results. Although almost all fishermen have fisherman cards and are members of groups, many feel that aid is still unevenly distributed or the process is not transparent. One participant said, "I never get aid, the aid is not evenly distributed. What is the distribution like? It should be equitable. Even though I have taken care of all the paperwork, there is still no aid." (Interview with Rohana, 2024). Alan expressed a similar sentiment, "We've even made proposals, but they're always skipped. The government usually provides oil subsidies, and in other areas, there are even engine subsidies."

The above conditions explain that even though the state has provided institutional and administrative instruments, this does not necessarily mean that it can provide truly beneficial support. According to Uphoff (2000), social capital is a combination of two components: the structural component of formal or informal networks, rules, and organizations, and the cognitive component, which includes shared norms, beliefs, and values that encourage collective behavior. Social institutions can be a source of strength or a barrier depending on the quality of interactions and the legitimacy they possess. Both must support each other for social or formal institutions to function effectively. Without shared trust and norms, formal networks cannot function optimally. In the context of Aru Bay, social embeddedness[1]High levels of community support have become the main foundation when the formal system has not been fully able to reach the needs of fishermen adaptively.

Thus, social capital in fishing communities has implications across two spectrums: First, as a force that strengthens resilience through informal networks and solidarity-based patronage practices; and second, as a reflection of formal institutional functions that still require strengthening in terms of transparency, participation, and accountability.

3) Natural Capital: A Sea that is No Longer Friendly

For the coastal communities of Aru Bay, the sea is not just an economic space, but also a living space where values, skills, and dependencies are passed down across generations. However, in recent years, the sea, once a source of livelihood, has slowly become a source of uncertainty. The decline in fish populations—especially of key species like anchovies, tuna, and mackerel—has become a collective narrative shared by many fishermen. They report that

over the past four years, catches have steadily declined, even during seasons previously known as fish harvests.

Changing seasonal patterns and extreme weather are major challenges. Fishing schedules, which previously followed the monsoon cycle, have now become erratic. Fishermen must not only adjust departure times but also consider increasingly distant fishing grounds. Interview data revealed that some fishermen now have to venture as far as 5–7 miles from the coastline, directly increasing operational costs and increasing safety risks. In some cases, they even have to spend the night at sea to make their journeys more economically efficient.

On the other hand, ecological pressures come not only from nature but also from human activities. The presence of large vessels with massive fishing gear such as cangkrang (similar to trawl nets) is often seen by local fishermen as a factor accelerating the decline in catches. One informant stated that "one pull of the large vessel's net can yield the equivalent of a week's catch for local fishermen." This disparity in scale and technology creates anxiety and potential tension at the local level. This disparity in scale and technology creates anxiety and potential tension at the local level.

In some cases, these dynamics have led to social friction, reflecting the fragility of an inclusive management system for various fisheries business actors. Amidst this situation, small-scale fishers have expressed hope for more active monitoring and dialogue mechanisms, particularly to maintain resource sustainability and ensure equitable fishing grounds for all parties. However, as several sources noted, response mechanisms to this situation have not been fully felt at the local level, so perceptions of inequality and uncertainty remain a part of their daily lives at sea.

4) Physical Capital: Limited Access to Tools and Infrastructure

Physical capital is a key pillar in fishermen's adaptation strategies to climate change. However, in Aru Bay, limited access to fishing gear and supporting infrastructure poses a serious challenge, hampering the adaptive capacity of small-scale fishing communities. Most fishermen in this area rely on small, mastless boats with limited capacity and often outdated engines. When extreme weather strikes, these boats offer no guarantee of safety, let alone the ability to reach more distant fishing grounds. Using bamboo or wooden poles for balance is considered safer, but expensive. As Mr. Jalal explained, the cost of adding bamboo poles can reach Rp 15–20 million, and up to Rp 50 million if using wood. This vulnerability is exacerbated by damage to fishing gear, such as nets, which frequently tear due to high waves or interactions with marine species like dolphins. Net repair costs range from IDR 500,000 to IDR 3 million, a significant amount compared to the uncertain income. In some cases, fishermen must use damaged gear or make emergency repairs themselves to continue fishing, despite the risk of reduced catches.

In addition to fishing gear, limited storage infrastructure is also a significant obstacle. The lack of refrigeration facilities or ice storage means that catches must be sold the same day or dried traditionally to extend their shelf life. This is a common survival strategy, but it results in significantly lower fish prices. Without access to fairer distribution chains or competitive markets, fishermen tend to rely on middlemen, who purchase fish at fluctuating and often unfair prices. As a result, operational costs, which range from IDR 100,000 to IDR 300,000 per fishing trip, are often not covered by the catch, especially during unfavorable weather conditions.

Overall, these limited physical capital resources not only reduce efficiency and productivity but also erode fishermen's resilience in the face of environmental dynamics. Amidst the demands of adapting to climate change, adequate and adequate physical capital has become a luxury that most fishermen in Aru Bay cannot fully afford.

5) Financial Capital: Economic Dependence and Vulnerability

Of the five capitals within the SLF framework, financial capital is often the most fragile and crucial factor in the adaptability of Aru Bay fishermen. Increasingly extreme fluctuations in catches due to weather changes make fishermen's daily incomes far from stable. As explained in the previous section, a fisherman typically spends between IDR 100,000 and IDR 300,000 per trip, covering fuel, food, and other operational costs. However, the income often falls short of even covering these costs. Interviews with Alan also revealed that the cost of building a boat, complete with engine and fishing gear, ranges from IDR 5,000,000, while the payback period can be up to one year, depending on the catch.

Lack of savings or access to adequate loans restricts fishermen's freedom of movement. Instead of accessing productive loans, many fishermen are trapped in a relationship of dependence on collectors. Some are forced to sell their catch at low prices to collectors, simply because they lack the capacity to store or transport the fish to distant markets. In fact, these collectors not only purchase the fishermen's catch but also often provide initial capital in the form of loans for fuel or equipment. This system gives rise to the practice of profit-sharing, or debt repayment with the catch. While this system certainly reflects strong relationships among fishermen, it also reflects the weakness of structural safety nets outside the community.

The absence of an active fishermen's cooperative in the region also limits financing options. While some, such as Lahudina and Ahyar, have expressed interest in establishing a fishermen's cooperative, such initiatives lack adequate technical and administrative support. Therefore, financial capital in Aru Bay is not just about money, but also about connecting to broader economic support systems, which, unfortunately, have yet to reach many.

Meanwhile, various government programs such as fuel subsidies, fisherman insurance, or equipment assistance may sound promising on paper. However, according to participant testimonies, these programs have not yet been fully realized. Mochtar and Rohana stated that programs like the Fisherman's Card (Kartu Fisherman) are also considered unable to provide concrete benefits. They even noted that many of the fishermen they provide capital to are unaware of the procedures for using the program or submitting claims. This highlights the gap between the availability of programs and fishermen's capacity to access them, whether due to a lack of publicity, low administrative literacy, or lengthy bureaucratic red tape.

Several fishermen also stated that government assistance in the form of fuel subsidies or fisherman's insurance has not fully reached them. The fisherman's card, which serves as an administrative identity, is considered to have provided no concrete benefits, and many even stated they were unaware of the procedures for using it or submitting claims. This demonstrates the gap between the availability of programs and fishermen's capacity to access them, whether due to a lack of public awareness, low administrative literacy, or lengthy bureaucratic chains. This situation demonstrates that fishermen's economic vulnerability is not solely due to climate change or declining catches, but also hampered by access to financial support that should sustain their livelihoods. Without interventions that are more responsive to local realities, financial capital will continue to be the most vulnerable point in the sustainability of their adaptation strategies.

3. Structural Challenges and Adaptation Vulnerabilities

Interviews indicate that while most fishers in Aru Bay have developed adaptive strategies based on experience, such as choosing safer fishing times, changing fishing locations, or temporarily switching to other occupations, despite the fishermen's cognitive and adaptive resilience in the face of climate change, these efforts are evidently hampered by a number of structural challenges that limit their adaptive capital. Challenges such as limited equipment, high operational costs, and limited access to formal assistance make the adaptation process reactive and short-term.

One of the main challenges is limited access to production facilities and adaptive equipment. For example, basic needs like boat engines, weather-resistant fishing gear, or even boat stabilizers are beyond the reach of most fishermen due to the high cost. Mr. Jalal, for example, stated that equipping his boat with a safe wooden mast would cost up to IDR 50 million, a figure that is certainly unrealistic for the majority of small-scale fishermen whose incomes are uncertain.

Limited access to assistance and subsidies is one of the challenges frequently cited by fishermen. In interviews, several informants stated that the distribution of support, such as subsidized fuel, fishing equipment, and insurance, is not entirely equitable. Those living farther from district centers or with limited access to information and administrative channels often feel excluded from these programs. In some cases, even though fishermen possess documents such as fisherman's cards or ship certificates, they still face difficulties accessing available benefits.

This doesn't simply reflect the absence of programs, but rather challenges in policy governance and communication at the grassroots level. Bureaucratic complexity, limited mentoring, and low administrative literacy among some fishermen are likely contributing factors. Therefore, it's important to examine this distribution aspect more contextually, recognizing that in addition to material support, a system capable of bridging the gap between policy and actual needs on the ground is also needed.

On the other hand, dependence on a distribution and marketing system controlled by collectors creates a weak bargaining position for fishermen. They have no alternative markets, and even their small catch must be sold at low prices to collectors who own storage and distribution facilities. This situation places fishermen in a cycle of low production and minimal income.

Another important issue is the lack of outreach and technical support in responding to climate change. Fishermen are not actively receiving weather information, training in adaptive fishing techniques, and risk management. While some extension workers are present, their roles are more administrative or limited to technical aspects of fishing gear, rather than climate knowledge and long-term adaptation.

Overall, the findings of this study indicate that the vulnerability experienced by fishers and coastal communities is not solely a result of ecological changes and pressures, but is also compounded by structural barriers external to the community. Unequal access to assets, the lack of participatory adaptive interventions, and weak social protections have placed them not only vulnerable to climate change but also to increasingly precarious livelihoods.

4. Dynamics of Survival and Livelihood Transformation

Facing multiple ecological and structural pressures, Aru Bay fishermen have not completely surrendered to the situation. Interviews reveal a parallel dynamic of coping and livelihood transformation, though not always under ideal conditions. One dominant form of this dynamic is informal job diversification. Many fishermen have begun to expand into the agricultural sector (such as clove and rubber plantations), become laborers on palm oil plantations, or even utilize agricultural produce and dried fish for household consumption when catches declined drastically. Mr. Kaswin, for example, decided to stop fishing and become a farmer after extreme weather and fuel shortages made fishing unprofitable.

Furthermore, there are forms of social organization based on trust and local networks. Several informants mentioned a profit-sharing system between capital owners and fishermen using boats, as well as the fostering of independently funded fishing groups. These practices demonstrate that social capital remains a crucial support for maintaining livelihood sustainability, especially when formal assistance is unavailable or unevenly distributed. However, efforts to transform livelihoods toward more adaptive and sustainable forms still face numerous limitations. Limited access to entrepreneurship training, microfinance schemes, and

alternative markets limits fishermen's ability to develop new, more promising strategies. Even the idea of changing professions is considered a risky last resort, especially for the older generation who have long depended on the sea.

Some young fishermen have expressed an openness to onshore employment opportunities, but there remains a lack of structural support to collectively develop this livelihood transition. Meanwhile, innovation-based transformations, such as the use of fish aggregating devices (FADs), lift nets (bagan), or alternative fishing gear, continue to occur, but they often emerge from field experience rather than institutional intervention.

Adger et al. (2007) remind us that adaptability is dynamic and influenced by the interconnectedness of many aspects, such as natural resources, economics, social networks, rights, institutions and governance, human resources, and technology. What is apparent in this reality is a high level of resilience, but it is not yet accompanied by structural support that allows for optimal acceleration of the transformation process. As a result, the livelihood strategies of Aru Bay fishermen tend to be limited to reactive and short-term responses. Adaptation is not being undertaken for development, but merely for day-to-day survival. Therefore, it is crucial for adaptation policies and programs at the national and regional levels to focus not only on technical interventions, but also on strengthening local capacity and inclusive structural access, so that the adaptation process can transform into long-term sustainability.

CONCLUSION

The use of the Sustainable Livelihood Framework (SLF) in this research has helped unravel the complexity of fishers' adaptation strategies in Aru Bay through five dimensions of livelihood capital. The SLF allows researchers to highlight not only material aspects such as financial and physical capital, but also the strength of social capital, local knowledge, and human capacity, often hidden in the daily practices of fishing communities. However, reflection on the analysis process shows that in the context of climate change uncertainty, adaptation strategies do not always occur systematically or in accordance with institutional intervention schemes. Instead, adaptation more often emerges as a series of situational, improvisational decisions based on the fishermen's own lived experiences. In this regard, the SLF framework remains relevant for identifying the resources used, but the findings of this study indicate that fishermen's adaptation strategies are not solely derived from calculations of capital availability but are also influenced by social structures, local values, and collective experiences that cannot all be accommodated within a structural approach. Field findings also indicate a difference in perspective and language between formally designed policies and the reality of adaptation at the community level. This gap is not simply a matter of access, but also concerns the framework and ways of understanding change. Therefore, further studies can be directed at developing a more dialogic and participatory approach to bridging policies and local community experiences. Alternative frameworks that capture the narrative, relational, and contextual aspects of adaptation strategies based on social structures, cultural values, and collective experiences can be considered to complement the SLF approach. This effort is important not to replace existing frameworks, but to enrich our understanding of adaptation as a social process lived by communities, not simply designed by policy..

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