



# The Future of Indonesian Fishing Communities Amidst Climate Change

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## Abstract

This study explores the future of Indonesian fishing communities in the face of climate change, focusing on the intersection of environmental, social, and economic challenges. Indonesia, an archipelagic nation with a significant reliance on marine resources, is particularly vulnerable to the impacts of climate change, including rising sea levels, changing fish migration patterns, and extreme weather events. The study employs a multi-disciplinary approach, combining climate science, fisheries management, and socio-economic analysis, to provide a comprehensive understanding of the challenges and potential solutions for these communities. Key findings highlight the disproportionate effects of climate change on small-scale fishers, who are often the most vulnerable to environmental shifts due to limited adaptive capacity and reliance on declining marine resources. Novel contributions include the identification of community-driven adaptation strategies and the role of traditional ecological knowledge in enhancing resilience. Furthermore, the paper emphasizes the urgent need for policy interventions that integrate both local and global efforts to mitigate the impacts of climate change on Indonesia's fishing sector.



This research contributes to the ongoing discourse on sustainable fisheries management by offering practical recommendations for enhancing the adaptive capacity of Indonesian fishing communities, ensuring food security, and preserving marine biodiversity. The findings underscore the necessity for a holistic approach, combining scientific, social, and economic considerations to safeguard the future of these communities amid the growing climate crisis.

**Keywords:** Climate Change, Environment, Fishing Communities, Indonesia, Community Resilience

## Introduction

Indonesia, recognized as the world's largest archipelagic state, comprises more than 17,000 islands and possesses one of the longest coastlines globally. Its maritime geography situates the country at the intersection of the Indian and Pacific Oceans, rendering marine ecosystems central to national development and cultural identity (Cribb & Ford, 2009). Fisheries constitute a vital economic sector, contributing significantly to food security, employment, and export revenues. Small-scale fisheries, in particular, employ millions of Indonesians and sustain coastal livelihoods through artisanal fishing, aquaculture, and related value chains (FAO, 2022). These communities depend not only economically but also socially and culturally on marine environments, embedding fishing practices within customary law (*adat*), communal traditions, and intergenerational knowledge systems (Adhuri, 2013).

However, Indonesia's geographic characteristics also heighten its vulnerability to climate change. Rising sea levels, increasing sea surface temperatures, ocean acidification, and intensifying extreme weather events pose profound risks to marine ecosystems and coastal settlements (IPCC, 2022). Coral bleaching, shifting fish migration patterns, and declining fish stocks threaten the sustainability of small-scale fisheries, while coastal erosion and storm surges endanger housing and infrastructure (Hoegh-Guldberg et al., 2017). These environmental stressors are compounded by pre-existing socioeconomic inequalities, limited access to capital, and weak institutional support in many coastal areas (Allison et al., 2009). Consequently,

Indonesian fishing communities stand at the frontline of climate impacts, navigating ecological uncertainty within fragile socioeconomic systems.

Climate change disproportionately affects small-scale fishers, who typically lack diversified income sources, savings mechanisms, and political representation. Unlike industrial fishing enterprises, artisanal fishers rely on nearshore ecosystems that are highly sensitive to temperature fluctuations and habitat degradation (Cinner et al., 2012). Declining fish catches not only reduce household income but also intensify food insecurity in communities where fish constitute a primary protein source. Structural inequalities—including insecure tenure rights, limited access to formal credit, and inadequate infrastructure—further constrain adaptive capacity (Béné, 2009). As a result, climate vulnerability intersects with poverty, marginalization, and governance deficits.

Despite Indonesia's commitments under international frameworks such as the Paris Agreement and national adaptation strategies embedded within its Nationally Determined Contributions (NDCs), gaps persist between policy design and local realities (Republic of Indonesia, 2021). Climate adaptation policies often emphasize technological solutions or macroeconomic resilience while insufficiently addressing localized knowledge systems and community participation. Furthermore, fragmented coastal governance and overlapping institutional mandates complicate implementation (Armitage et al., 2012). These discrepancies underscore the need for integrated analyses that bridge environmental science, social vulnerability assessments, and governance studies to better understand how climate change reshapes fisheries-dependent communities.

This study is guided by three interrelated research questions. First, how is climate change transforming the livelihoods of Indonesian fishing communities? This question seeks to examine ecological shifts—such as altered fish distribution, coral reef degradation, and extreme weather variability—and their socioeconomic consequences. Second, what socio-economic vulnerabilities intensify climate risks? Here, attention is directed toward factors including income inequality, gender disparities, limited educational access, and weak institutional support that amplify exposure and sensitivity to climate stressors (Adger, 2006). Third, what adaptive strategies—both local and institutional—can strengthen resilience among small-scale fishers? This inquiry encompasses community-based adaptation practices, diversification strategies, co-management initiatives, and state-led interventions aimed at enhancing long-term sustainability (Pomeroy et al., 2007).

By addressing these questions, the study situates climate change not merely as an environmental issue but as a multidimensional challenge encompassing social justice, governance, and development. The analytical framework integrates vulnerability theory, resilience thinking, and sustainable livelihoods approaches to provide a holistic understanding of climate impacts on fisheries-dependent populations (Scoones, 1998; Folke, 2006).

The primary objective of this research is to assess the environmental and socioeconomic impacts of climate change on Indonesia's small-scale fisheries. This involves analyzing empirical data on temperature trends, fish stock fluctuations, and coastal hazards alongside socioeconomic indicators such as income variability, employment patterns, and food security. By integrating ecological and social dimensions, the study seeks to reveal how environmental change translates into livelihood instability.

A second objective is to examine community-based adaptation strategies. Local responses—including adjusting fishing seasons, diversifying income through aquaculture or tourism, adopting sustainable gear, and participating in marine protected area management—offer valuable insights into grassroots resilience (Cinner et al., 2018). Understanding these strategies can inform scalable and context-sensitive adaptation policies. The final objective is to propose integrated policy recommendations that align national climate frameworks with local governance structures, emphasizing participatory decision-making, equitable resource distribution, and sustainable marine management.

This study contributes to scholarly discourse on climate adaptation and sustainable fisheries by foregrounding the experiences of small-scale fishers within an archipelagic developing state. Existing literature often prioritizes macroeconomic or ecological analyses; however, localized perspectives illuminate the human dimensions of climate change, highlighting how vulnerability and resilience are socially constructed (Adger, 2006). By centering Indonesian fishing communities, the research expands comparative understanding of climate impacts across the Global South.

Policy relevance is equally significant. Indonesia's coastal governance frameworks must reconcile economic development with ecological conservation and social equity. Strengthening adaptive capacity in fisheries supports not only livelihood security but also national food security and maritime sovereignty. Moreover, the findings offer broader insights into resilience-building in archipelagic

states facing similar climate threats. By integrating environmental science, socioeconomic analysis, and governance perspectives, this study underscores the urgency of holistic adaptation strategies that protect both marine ecosystems and the communities that depend upon them.

## **Climate Change and Marine Ecosystems in Indonesia**

### *A. Rising Sea Levels and Coastal Erosion*

Indonesia's extensive coastline renders it acutely vulnerable to sea-level rise, a phenomenon driven by thermal expansion of seawater and glacial melt associated with global warming. As an archipelagic state characterized by low-lying coastal plains and densely populated deltaic regions, Indonesia faces heightened exposure to coastal flooding, shoreline retreat, and land subsidence (IPCC, 2022). Empirical studies indicate that several Indonesian coastal cities, including Jakarta and Semarang, experience compound risks arising from sea-level rise and anthropogenic subsidence, intensifying inundation events and infrastructure degradation (Ward et al., 2011). For fishing communities, whose settlements are often located in proximity to landing sites and estuaries, these processes threaten housing, storage facilities, and fish-processing infrastructure, undermining livelihood security and social stability.

Coastal erosion further exacerbates vulnerability by reducing habitable land and damaging mangrove ecosystems that function as natural buffers against storm surges. Mangroves, seagrass beds, and tidal wetlands provide essential ecosystem services, including carbon sequestration, nursery habitats for fish species, and shoreline stabilization (Alongi, 2008). However, rising sea levels and increased wave energy contribute to habitat degradation, diminishing the ecological resilience of coastal zones. Saltwater intrusion into freshwater systems compounds these challenges by contaminating drinking water supplies and agricultural land, thereby intensifying food and water insecurity (Nicholls & Cazenave, 2010). For small-scale fishers, whose livelihoods intersect with both marine and terrestrial resources, the cumulative effects of erosion and salinization represent not only environmental disruptions but also multidimensional socioeconomic stressors.

### *B. Ocean Warming and Acidification*

Ocean warming constitutes one of the most profound climate-induced transformations affecting Indonesia's marine ecosystems. Elevated sea surface temperatures disrupt ecological balance, particularly within coral reef systems located in the Coral Triangle region, an area recognized for its exceptional marine biodiversity (Veron et al., 2009). Increased thermal stress triggers coral bleaching events, wherein symbiotic algae are expelled from coral tissues, reducing reef productivity and structural complexity (Hoegh-Guldberg et al., 2017). Repeated bleaching episodes weaken reef resilience, resulting in biodiversity loss and diminished fish habitat availability. Given that many Indonesian small-scale fisheries depend on reef-associated species, coral degradation directly translates into reduced catch volumes and declining household incomes.

Ocean acidification, caused by increased absorption of atmospheric carbon dioxide, further undermines marine ecosystems by altering carbonate chemistry and impairing calcifying organisms such as corals, mollusks, and certain plankton species (Doney et al., 2009). Acidification affects fish physiology, including sensory functions and reproductive success, potentially disrupting spawning cycles and larval development (Munday et al., 2009). In Indonesia, where fisheries contribute substantially to national protein consumption, these ecological changes pose risks to food security and nutritional stability (FAO, 2022). The intersection of warming and acidification thus constitutes a systemic threat to marine biodiversity, ecological services, and the sustainability of fisheries-dependent communities.

### *C. Changing Fish Migration Patterns*

Climate change also alters oceanographic conditions that influence fish distribution and migration. Variations in sea temperature, salinity, and currents affect spawning grounds and feeding habitats, leading to spatial shifts in commercially important species (Cheung et al., 2013). In Indonesian waters, such changes contribute to seasonal unpredictability, complicating traditional ecological knowledge systems that guide artisanal fishing practices. Fishers who historically relied on generational knowledge of monsoon cycles and fish behavior now confront increasing uncertainty, as climatic variability disrupts established patterns.

Shifting fish stocks generate significant economic consequences for small-scale fishers, who often lack the technological capacity to pursue migrating species over long distances. Unlike industrial fleets equipped with advanced navigation and refrigeration systems, artisanal fishers operate within limited geographic ranges and depend on nearshore resources (Allison et al., 2009). Reduced catch reliability diminishes income stability, increases indebtedness, and may prompt occupational shifts or migration. Furthermore, intensified competition over declining resources can exacerbate social tensions within and between communities. Consequently, climate-induced changes in fish migration patterns not only transform ecological systems but also reconfigure socioeconomic relations, underscoring the urgent need for adaptive governance frameworks that integrate environmental monitoring with community-based management strategies.

## **Socio-Economic Vulnerabilities of Fishing Communities**

### *A. Dependence on Marine Resources*

Indonesian small-scale fishing communities exhibit a profound dependence on marine resources, which underpins both their economic livelihoods and cultural identity. In many coastal villages, fishing is the primary source of household income, nutrition, and intergenerational knowledge transmission, creating a high degree of exposure to ecological variability (Cinner et al., 2012). Artisanal fishers generally operate small boats in nearshore waters, harvesting species such as tuna, mackerel, and reef-associated fish. The reliance on local fish stocks renders these households particularly sensitive to natural fluctuations, including seasonal variability, overfishing, and climate-induced disruptions such as coral bleaching, ocean warming, and shifts in fish migration patterns (Hoegh-Guldberg et al., 2017; Cheung et al., 2013). These ecological stressors directly impact income stability, food security, and the long-term resilience of coastal households, particularly in areas where fish constitute a primary source of protein.

The mono-dependence on marine resources is further exacerbated by the limited availability of alternative livelihoods. Many fishing communities are geographically isolated, which restricts access to markets, vocational training, and

education opportunities, reducing the feasibility of diversification (Allison et al., 2009). While some households attempt supplementary activities such as small-scale aquaculture, seaweed farming, or tourism-related services, these initiatives often require technical skills, infrastructure, or capital that are beyond the reach of most artisanal fishers. Consequently, ecological shocks such as declining fish stocks or extreme weather events immediately translate into economic stress, with limited options for recovery.

Furthermore, dependence on marine resources interacts with ecological vulnerability to reinforce long-term insecurity. The degradation of coral reefs and other marine habitats diminishes fish availability, which has direct consequences for both catch volumes and household nutrition (Hoegh-Guldberg et al., 2017; Veron et al., 2009). Fishers' livelihoods are therefore highly sensitive not only to short-term climatic events but also to cumulative environmental change. As these stressors accumulate, communities face a cascading set of challenges, including reduced income, food insecurity, and intergenerational vulnerability.

This dependence also intersects with traditional knowledge systems. Artisanal fishers rely on long-standing ecological knowledge, including monsoon cycles, fish migration patterns, and reef indicators, to plan fishing activities. Climate variability and environmental degradation disrupt these knowledge systems, undermining their effectiveness and creating uncertainty for younger generations who inherit both ecological risks and economic constraints (Adger, 2006). The erosion of knowledge further diminishes resilience and complicates adaptive responses.

Institutional and governance factors play a critical role in shaping dependence on marine resources. Limited access to marine tenure rights, inadequate regulation of industrial fishing, and the absence of community-based management frameworks reduce local agency and exacerbate vulnerability (Pomeroy et al., 2007). Without legal safeguards and enforcement mechanisms, small-scale fishers are exposed to overexploitation by industrial fleets and illegal fishing activities, further constraining their ability to secure stable livelihoods.

The cultural dimension of dependence on fishing cannot be overlooked. Fishing is deeply embedded in social and cultural practices, influencing communal structures, rituals, and local identity (Adhuri, 2013). This cultural embedding makes alternatives to fishing complex, as households must navigate economic needs alongside social norms and values. Effective adaptation strategies, therefore, require

interventions that account for both ecological realities and cultural significance, reinforcing resilience while maintaining community cohesion.

### *B. Poverty, Debt, and Market Pressures*

Economic precarity in Indonesian fishing communities is a pervasive structural vulnerability shaped by poverty, indebtedness, and market dynamics. Many households operate at or below subsistence levels, relying almost entirely on daily or seasonal catches to meet basic needs such as food, education, and healthcare (Béné et al., 2016). This marginal economic base is often exacerbated by intermediaries, such as middlemen, who control access to markets and set prices, limiting fishers' negotiating power and reducing the financial returns from their labor (Jentoft & Chuenpagdee, 2009). The dependence on middlemen is particularly acute in remote areas, where access to alternative buyers or cooperative structures is constrained, perpetuating cycles of economic vulnerability.

Debt cycles are a common feature of these communities. Many fishers take loans from patrons or informal lenders to finance boats, fuel, nets, and other equipment, often entering agreements that restrict the sale of their catch to the lender (Allison et al., 2009). While such arrangements provide necessary liquidity, they often result in chronic indebtedness and limit fishers' economic autonomy. When catches are low or environmental shocks occur, the inability to repay loans exacerbates financial insecurity and creates compounding stress, leaving households trapped in precarious economic positions.

Market pressures, including price volatility for key species and competition with industrial fishing operations, further heighten vulnerability. Fluctuations in supply and demand at local, regional, and global scales directly influence household income, often with little warning (Cinner et al., 2012). During periods of environmental stress, such as fish migration shifts or coral degradation, households experience disproportionately low income, intensifying food insecurity and undermining social well-being. The interplay of market forces and ecological stress highlights the multidimensional nature of vulnerability.

Limited access to formal financial services compounds these challenges. Many artisanal fishers lack access to microcredit, insurance schemes, or cooperative funding mechanisms, leaving them unable to buffer against shocks (FAO, 2022). The absence

of insurance for equipment, boats, or lost catch forces households to absorb the full cost of environmental and economic disruptions, increasing the likelihood of long-term poverty. These institutional gaps underscore the importance of targeted financial interventions to enhance resilience in fisheries-dependent communities.

The interaction of poverty, debt, and market pressures also has social consequences, influencing household decision-making, migration, and community cohesion. Young fishers may leave their villages for urban centers in search of alternative employment, resulting in the erosion of local knowledge systems and demographic imbalances (Adger, 2006). Social tensions may rise when resources become scarce, particularly in highly dependent communities, highlighting the interconnectedness of ecological, economic, and social vulnerabilities.

Addressing these challenges requires integrated governance approaches. Policies must promote equitable market access, regulate intermediaries, and provide financial tools tailored to the realities of small-scale fisheries (Pomeroy et al., 2007). Without such interventions, poverty and market pressures will continue to undermine the resilience of fishing communities, perpetuating a cycle of vulnerability that is difficult to disrupt.

### *C. Gender Dimensions of Fisheries*

Gender constitutes a critical lens through which the vulnerabilities of fishing communities can be understood. In Indonesian coastal contexts, men are typically responsible for offshore fishing, while women undertake processing, marketing, and domestic management roles (Kristiansen et al., 2018). Women's labor is essential for household survival and for linking production to local markets, yet their contributions are often marginalized in governance, planning, and policy frameworks. The undervaluation of women's roles limits recognition of their adaptive capacities and constrains their participation in decision-making processes.

Environmental and climate stress disproportionately affect women. Extreme weather, sea-level rise, and declining fish stocks increase household burdens, forcing women to compensate for reduced income and maintain food and health security (Neis et al., 2016). Destruction of local markets, fish processing facilities, or storage infrastructure directly undermines women's livelihoods, highlighting the gendered dimensions of ecological vulnerability. Furthermore, women in remote villages may

face mobility restrictions, limiting their ability to seek alternative income or training opportunities.

The social structures within fishing communities often exacerbate these gendered vulnerabilities. Traditional norms may restrict women's access to leadership positions, credit, and resource management forums, reducing their capacity to influence adaptation strategies (Kristiansen et al., 2018). These limitations persist despite evidence that women often possess specialized knowledge of local ecosystems, marketing networks, and household-level risk management strategies, which are crucial for community resilience.

Despite constraints, women demonstrate innovative responses to vulnerability. Many engage in small-scale aquaculture, cooperative marketing, or value-added processing to enhance income security (Cinner et al., 2018). Such adaptive strategies indicate the potential of gender-inclusive approaches to enhance both household and community resilience. Recognizing and supporting these initiatives is essential for sustainable fisheries governance.

Gendered vulnerability intersects with other social inequalities. Female-headed households, for example, face heightened risks due to limited access to resources, market exclusion, and social marginalization (Adger, 2006). Climate change magnifies these inequities, disproportionately impacting women and children and highlighting the importance of intersectional approaches to vulnerability assessment.

Global and national frameworks increasingly emphasize gender equity in climate adaptation and fisheries management. Programs that enhance women's access to credit, training, and participatory governance contribute to more inclusive, resilient, and socially equitable coastal communities (FAO, 2022; Neis et al., 2016). Integrating gender perspectives into socio-economic vulnerability analyses not only improves adaptation outcomes but also strengthens the overall sustainability of small-scale fisheries.

## Traditional Ecological Knowledge and Local Adaptation

### *A. Indigenous Marine Knowledge Systems*

Indigenous marine knowledge forms the backbone of resilience in Indonesian fishing communities, providing locally adapted strategies for resource use and risk management. Traditional knowledge encompasses seasonal forecasting techniques, such as observing wind patterns, lunar cycles, and marine currents to predict fish migration and spawning periods (Cinner et al., 2012). These practices have been transmitted across generations and are embedded in customary laws that govern fishing behavior, seasonal closures, and gear restrictions. The combination of observational science and cultural norms allows communities to regulate extraction sustainably while safeguarding critical habitats, illustrating the sophistication of indigenous marine knowledge systems.

Customary fishing practices also involve intricate social agreements and resource-sharing arrangements, ensuring equitable access to coastal resources among households and villages (Adhuri, 2013). These practices often integrate local taboos, spiritual beliefs, and ecological indicators, creating a framework where environmental stewardship is linked to social cohesion. For instance, certain reef areas may be off-limits during spawning periods to protect juvenile fish, demonstrating how ecological understanding is codified into community governance. Such frameworks enhance ecological resilience by maintaining biodiversity and supporting sustainable livelihoods, even in the face of environmental stressors like climate change and overfishing.

Moreover, indigenous knowledge is dynamic, adapting in response to ecological change. Communities continuously adjust fishing schedules, gear types, and harvest intensity based on observed variations in fish populations, water quality, and climate anomalies (Béné et al., 2016). This adaptive flexibility differentiates traditional ecological knowledge from static conservation rules and allows coastal communities to buffer against environmental shocks. The interplay between long-standing knowledge systems and empirical observations contributes to the resilience of small-scale fisheries in Indonesia.

Customary management is also supported by local leadership structures, such as village councils or elders, who enforce rules and mediate conflicts over resource use (Pomeroy et al., 2007). This decentralized governance allows for rapid responses to ecological disturbances, fostering collective action and enhancing compliance. By embedding ecological knowledge within social institutions, communities can maintain both biodiversity and livelihood security.

The integration of indigenous knowledge into broader resource management frameworks is increasingly recognized as a critical component of climate adaptation strategies. For example, scientific monitoring of fish stocks and coral reef health is more effective when combined with local ecological knowledge, producing hybrid governance models that respect both scientific and traditional perspectives (Hoegh-Guldberg et al., 2017). Therefore, acknowledging and preserving indigenous marine knowledge has socio-cultural implications. These systems underpin local identity, strengthen intergenerational cohesion, and provide a sense of agency in managing environmental change (Adger, 2006). Strengthening the role of traditional knowledge within adaptive management frameworks is thus essential for sustainable fisheries and resilient coastal communities.

### *B. Adaptive Livelihood Strategies*

Fishing communities in Indonesia increasingly employ adaptive livelihood strategies to cope with environmental, economic, and social vulnerabilities. Diversification is a primary response, including the integration of small-scale aquaculture, seaweed farming, and eco-tourism activities (Allison et al., 2009). These alternatives provide supplementary income streams, reducing the economic risks associated with fluctuating fish stocks or seasonal closures. Aquaculture initiatives, for instance, allow households to maintain protein production and cash flow, while eco-tourism offers employment opportunities in guiding, homestays, and local cultural experiences.

Migration is another adaptation strategy, often employed by younger community members seeking alternative livelihoods in urban centers or industrial sectors (Adger, 2006). While migration provides income remittances that enhance household resilience, it can also contribute to social change, including the erosion of traditional knowledge systems and shifting demographics in rural communities. Seasonal migration—where fishers move temporarily to regions with higher fish

abundance—is also common, although it introduces risks associated with unfamiliar fishing grounds, regulatory differences, and potential conflicts with local resource users.

Occupational shifts often complement diversification strategies. Coastal households may engage in small-scale trade, boat maintenance, or construction to supplement fishing income (Cinner et al., 2018). These hybrid livelihoods allow households to spread risk, enhancing adaptive capacity and reducing dependence on a single resource. However, the success of such strategies is often constrained by access to capital, markets, and technical skills, highlighting the importance of supportive policy and training programs.

Local knowledge plays a central role in guiding adaptation strategies. Fishers leverage observations of changing fish behavior, water temperature, and coral health to modify catch techniques, timing, and gear usage, ensuring continued productivity (Hoegh-Guldberg et al., 2017). By combining ecological knowledge with new livelihood strategies, communities demonstrate the dynamic interplay between environmental understanding and socio-economic resilience.

Institutional support is crucial for successful adaptation. Community-based organizations, cooperatives, and non-governmental programs provide training, funding, and technical assistance for alternative livelihoods, strengthening household resilience to both climate and economic shocks (Pomeroy et al., 2007). Policy interventions that recognize and support local adaptive strategies are particularly effective when designed in partnership with communities, ensuring cultural compatibility and practical feasibility. Diversification and occupational shifts contribute to long-term sustainability by reducing fishing pressure on depleted stocks and promoting environmental stewardship (Béné et al., 2016). Adaptive livelihoods thus serve both as resilience mechanisms for households and as instruments for sustainable resource management, demonstrating the interconnection between economic security, ecological health, and cultural continuity.

### *C. Community-Based Marine Conservation*

Community-based marine conservation initiatives have emerged as critical mechanisms for safeguarding ecological and social security in Indonesia's coastal areas. Local marine protected areas (MPAs) are often established under customary

agreements, delineating zones for restricted fishing, seasonal closures, or habitat restoration (Cinner et al., 2012). These MPAs provide multiple benefits, including the preservation of biodiversity, maintenance of fish stocks, and protection of critical habitats such as coral reefs and mangroves. They also reinforce social cohesion, as communities collectively enforce rules and share the benefits of sustainable resource management.

Collaborative governance models are integral to the success of these conservation efforts. Village councils, fisher associations, and NGOs often coordinate to implement monitoring, enforcement, and community education programs (Pomeroy et al., 2007). This approach fosters local ownership and accountability, ensuring that conservation measures are culturally appropriate, socially equitable, and ecologically effective. By embedding governance within social networks, communities enhance compliance while reducing conflicts over resource access.

The ecological benefits of community-based conservation extend to fisheries productivity. Protected or regulated areas act as nurseries for juvenile fish and other marine species, supporting spillover effects that enhance adjacent fishing grounds (Hoegh-Guldberg et al., 2017). This symbiosis between conservation and livelihoods reinforces the dual goals of environmental protection and economic security, demonstrating that ecological stewardship can simultaneously strengthen human resilience.

Local communities also employ traditional knowledge in designing and managing MPAs. Seasonal restrictions, taboos on harvesting specific species, and habitat-specific rules reflect accumulated ecological understanding and culturally embedded conservation practices (Adhuri, 2013). Integrating these practices with modern scientific monitoring enhances the adaptive capacity of MPAs, ensuring that conservation strategies remain responsive to environmental and social changes.

Institutional recognition of community-based conservation has increased through national and international programs. Government and NGO support for locally managed MPAs provides legal frameworks, technical assistance, and funding to reinforce grassroots initiatives (FAO, 2022). By bridging indigenous knowledge, local governance, and formal legal support, these programs enhance resilience against climate-induced disruptions and overfishing pressures.

Community-based conservation contributes to long-term cultural, social, and ecological sustainability. It strengthens local governance, preserves traditional

knowledge, fosters community cohesion, and enhances livelihoods, demonstrating that adaptation is most effective when ecological, economic, and social dimensions are considered holistically (Adger, 2006; Cinner et al., 2018). Such integrated approaches are essential for building resilient fishing communities in the face of climate change and environmental uncertainty.

## **Policy Frameworks and Institutional Responses**

### *A. National Climate Policies and Fisheries Governance*

Indonesia has increasingly recognized the vulnerability of its coastal and marine ecosystems to climate change and has sought to integrate climate adaptation into fisheries governance. National strategies, such as the *Rencana Aksi Nasional Adaptasi Perubahan Iklim (RAN-API)*, outline measures to enhance the resilience of small-scale fisheries, including ecosystem-based management, habitat restoration, and capacity-building for fishing communities (MoEF, 2021). These policies are aligned with the broader principles of the United Nations Food and Agriculture Organization (FAO, 2022) on sustainable fisheries, emphasizing the need for balancing conservation with livelihoods. From a theoretical perspective, Ostrom's (1990) framework on common-pool resource governance highlights the importance of local engagement and adaptive institutions, which Indonesia attempts to operationalize through decentralized coastal management policies. However, implementation remains inconsistent across provinces due to enforcement challenges, limited human resources, and overlapping regulatory authorities (Cinner et al., 2018).

Indonesia's fisheries governance also reflects principles embedded in Law No. 31 of 2004 concerning Fisheries and Law No. 32 of 2009 on Environmental Protection and Management. These legal instruments establish frameworks for sustainable harvesting, ecosystem protection, and community involvement, yet the practical enforcement at the village level is hindered by limited monitoring capabilities and conflicts with industrial fishing interests (Adhuri, 2013). Scholars such as Pomeroy et al. (2007) argue that while the legal framework is theoretically robust, governance gaps and the absence of integrated institutional mechanisms reduce policy efficacy. Furthermore, climate variability, including ocean warming,

sea-level rise, and extreme weather, imposes additional challenges that were not fully anticipated during the policy design phase, creating a need for flexible, adaptive management systems.

Integration of climate adaptation in fisheries management also intersects with socio-economic theory. Vulnerability frameworks, as described by Adger (2006), emphasize that resilience is determined not only by ecological conditions but also by social, economic, and institutional factors. Policies that fail to address poverty, debt, and market dependency among fishers are unlikely to produce long-term adaptive outcomes. Recent policy innovations, including community-based fisheries management (CBFM) initiatives and participatory coastal planning, attempt to operationalize these theoretical insights by engaging fishers in decision-making processes and monitoring compliance with sustainable practices (Kristiansen et al., 2018; Béné et al., 2016).

### *B. International Agreements and Commitments*

Indonesia's climate and fisheries policies are influenced significantly by international frameworks, including the Paris Agreement (2015) and the United Nations Sustainable Development Goals (SDGs). These agreements provide normative and practical guidance for promoting climate-resilient fisheries, particularly SDG 14 (Life Below Water), which emphasizes the conservation and sustainable use of oceans, seas, and marine resources (UN, 2015). The Paris Agreement's focus on climate mitigation and adaptation encourages the integration of carbon-sensitive planning in coastal areas, including marine protected areas and habitat restoration (Hoegh-Guldberg et al., 2017). By participating in these international frameworks, Indonesia not only secures access to technical assistance and funding but also aligns domestic policies with global commitments to human rights and sustainable development, reinforcing the argument that environmental security is a human rights issue (Knox, 2018).

Regional cooperation in Southeast Asia, particularly under the Association of Southeast Asian Nations (ASEAN) and the ASEAN Fisheries Consultative Forum (AFCF), complements national efforts by promoting joint monitoring, enforcement, and knowledge-sharing for marine resources (Chuenpagdee & Jentoft, 2007). Scholars highlight that transboundary fisheries issues, such as shared fish stocks and

migratory species, require coordination beyond national boundaries, with institutions supporting joint climate adaptation and disaster risk reduction strategies (Allison et al., 2009). The theoretical underpinning aligns with global commons theory, which emphasizes that sustainable management of shared resources necessitates collective action and cooperative governance (Ostrom, 1990).

Indonesia has ratified international legal instruments such as the United Nations Convention on the Law of the Sea (UNCLOS, 1982), which provides legal frameworks for maritime sovereignty, exclusive economic zones (EEZs), and conservation obligations. These legal commitments support domestic measures to protect fisheries and coastal livelihoods, although enforcement remains uneven (FAO, 2022). Scholars such as Adhuri (2013) argue that alignment with international law strengthens normative legitimacy and provides leverage for negotiating resources, technical assistance, and adaptive strategies at the community level. In addition, despite international alignment, the translation of agreements into local action is complex. Local governments often lack the capacity to operationalize commitments due to fragmented jurisdiction, insufficient funding, and limited technical expertise (Cinner et al., 2018; Pomeroy et al., 2007). This underscores the importance of linking global norms with practical, context-sensitive policy implementation that empowers communities while respecting ecological boundaries.

### *C. Gaps in Implementation*

Despite robust policy frameworks at national and international levels, significant gaps in implementation hinder the effectiveness of climate adaptation in Indonesia's fisheries sector. One major challenge is the disconnect between policy design and local realities. National strategies often adopt a top-down approach, which fails to consider socio-economic constraints, local ecological knowledge, and cultural practices (Adger, 2006; Kristiansen et al., 2018). For example, fishing communities may lack technical skills to adopt aquaculture or conservation techniques recommended by policy, limiting adaptive capacity. Additionally, policies often do not address inequities in resource access, credit, and market participation, leaving the most vulnerable households inadequately supported (Béné et al., 2016).

Institutional fragmentation exacerbates these challenges. Fisheries management responsibilities are divided among multiple ministries, provincial authorities, and

village-level governance bodies, resulting in overlapping mandates and weak coordination (Pomeroy et al., 2007). Enforcement of sustainable fishing regulations, habitat protection, and climate adaptation programs is inconsistent, particularly in remote coastal areas. Scholars argue that this fragmentation undermines collective action, reduces compliance, and limits the effectiveness of marine protected areas and community-based initiatives (Cinner et al., 2018; Hoegh-Guldberg et al., 2017).

Financial constraints are another major barrier. Funding for climate adaptation projects, infrastructure development, and community-based monitoring is limited, with reliance on donor programs and short-term grants (FAO, 2022). Without sustained investment, adaptive measures such as mangrove restoration, reef rehabilitation, and livelihood diversification remain vulnerable to interruption, undermining long-term resilience. Furthermore, legal enforcement is hampered by insufficient human resources and weak monitoring mechanisms (Adhuri, 2013).

Theoretical frameworks of adaptive governance suggest that bridging these gaps requires iterative learning, local participation, and multi-level coordination (Ostrom, 1990; Adger, 2006). Successful adaptation depends on co-management models that integrate indigenous knowledge, scientific monitoring, and policy support (Cinner et al., 2012). Scholars emphasize that resilience is socially embedded; adaptation strategies must address structural inequalities, empower marginalized groups, and integrate socio-cultural considerations alongside ecological objectives (Kristiansen et al., 2018).

Finally, addressing implementation gaps requires legal reinforcement and institutional innovation. Policies such as Law No. 32/2009 on Environmental Protection, Law No. 31/2004 on Fisheries, and the *RAN-API* framework must be operationalized through local ordinances, village-level regulations, and participatory monitoring systems. By connecting legal provisions to community capacities and global commitments, Indonesia can strengthen both ecological and social resilience, mitigating the disproportionate impacts of climate change on small-scale fishing communities (FAO, 2022; Adger, 2006; Cinner et al., 2018).

## Building Resilience: Pathways Forward

### *A. Strengthening Adaptive Capacity*

Strengthening adaptive capacity within Indonesian fishing communities necessitates a multifaceted approach grounded in both infrastructural investment and community empowerment. Adaptive capacity refers to the ability of a system to adjust to climate variability, absorb shocks, and reorganize while undergoing change (Smit & Wandel, 2006). In the context of small-scale fisheries, enhancing physical infrastructure—such as climate-resilient landing facilities, salt-tolerant storage units, and reinforced pier structures—can significantly reduce vulnerability to sea-level rise and storm frequency increases (World Bank, 2018). Climate-resilient infrastructure mitigates the direct impacts of extreme events, protecting both livelihoods and local investments. From a governance perspective, the integration of climate projections into coastal planning aligns with principles of adaptive governance, which stress proactive planning and risk management rather than reactive disaster response (Folke et al., 2005).

In addition to physical adaptations, access to early warning systems is foundational to community resilience. Effective early warning systems, including meteorological alerts and ocean condition forecasts, provide fishing communities with critical information that can prevent loss of life and property during extreme weather events. Research in the Philippines, a comparable archipelagic state, demonstrates that community-based warning systems significantly reduce disaster impacts when combined with local participatory networks (Gaillard & Mercer, 2013). In Indonesia, where artisanal fishers often lack real-time weather information, expanding mobile-based early warning platforms and localized dissemination networks could empower communities to make informed decisions about fishing schedules and evacuation procedures.

Adaptive capacity also hinges on knowledge exchange and collaborative learning. Initiatives that facilitate knowledge sharing between scientists, policymakers, and fishers—such as participatory scenario planning and co-management councils—enhance adaptive learning and support iterative policy adjustments (Armitage et al., 2008). Such collaborative frameworks resonate with social-ecological systems (SES) theory, which emphasizes the importance of cross-

scale interactions and non-linear feedbacks in managing complex environmental challenges (Ostrom, 2009). Strengthening adaptive capacity involves a combination of structural resilience, information accessibility, and institutional learning. Without structural support and knowledge integration, communities remain exposed to climate risks despite formal policy commitments. In this regard, bridging the gap between top-down policies and grassroots adaptive practices is essential for sustainable adaptation pathways.

### *B. Economic Diversification and Social Protection*

Economic diversification emerges as a cornerstone of resilience-building in coastal fishing communities, enabling households to reduce dependence on fluctuating fish stocks and seasonal variability. Diversification strategies include the development of alternative livelihood options such as sustainable aquaculture, agroforestry, handicraft production, and community-based ecotourism (Allison & Ellis, 2001). These economic pathways broaden income sources and create buffers against climate-induced shocks. For example, community-managed seaweed farming cooperatives have shown success in Eastern Indonesia, providing both ecological benefits through habitat restoration and economic returns for local households (Béné et al., 2016).

However, diversification must be supported by inclusive financial services and social protection schemes. Microfinance initiatives tailored to coastal contexts can improve access to capital, enabling fishers to invest in new ventures or adopt climate-smart technologies. Evidence from Senegal and Bangladesh indicates that microcredit programs coupled with training significantly enhance livelihood resilience among coastal fishers (Hossain & Bayes, 2009). In the Indonesian context, microfinance can be embedded within community cooperatives that offer savings schemes, shared credit access, and business support services. Such cooperative models align with asset-based community development principles, which emphasize building on local strengths and resources to enhance socio-economic resilience (Mathie & Cunningham, 2003).

Insurance schemes and social safety nets further protect against climate-related losses. Index-based weather insurance, for instance, offers payouts based on observable climate parameters such as rainfall or sea surface temperature anomalies, reducing administrative costs and improving accessibility for remote communities

(Clarke, 2016). National social protection programs—ranging from conditional cash transfers to emergency relief funds—can complement livelihood diversification by providing temporary income support in the aftermath of extreme events. Research indicates that households with access to safety nets exhibit greater adaptive capacity and lower vulnerability to repetitive climate shocks (Hallegatte et al., 2016).

Nevertheless, the design of social protection systems must be context-specific and cognizant of local socio-cultural norms. Programs implemented without community participation risk exclusion errors and may fail to address the nuanced needs of fishing households. Therefore, participatory program design and ongoing monitoring are essential for ensuring that social protection reinforces resilience rather than displacing traditional coping strategies.

### *C. Sustainable Fisheries and Marine Biodiversity*

Sustainable fisheries management and the protection of marine biodiversity are integral to long-term resilience building within Indonesia's coastal socio-ecological systems. Ecosystem-based management (EBM) offers a holistic framework that considers the interdependence of species, habitats, and human communities, aiming to maintain ecological integrity while sustaining livelihoods (McLeod et al., 2005). By emphasizing multi-species management, habitat conservation, and trophic interactions, EBM contrasts with single-species approaches that fail to account for dynamic ecological feedbacks, particularly under climate change scenarios (Pikitch et al., 2004). In practice, EBM in coastal regions involves establishing spatial management tools, such as marine protected areas (MPAs), habitat corridors, and no-take zones, which have been shown to enhance fish biomass and ecosystem resilience when combined with local stewardship (Halpern et al., 2010).

Combatting overfishing and illegal, unreported, and unregulated (IUU) fishing is another critical component of sustainable fisheries. IUU fishing undermines stock recovery efforts, erodes community resilience, and exacerbates ecological degradation. Indonesia has taken steps to strengthen monitoring, control, and surveillance (MCS) through vessel tracking systems and national enforcement campaigns, yet enforcement remains uneven due to limited resources and jurisdictional complexity (Sumaila et al., 2016). Strengthening legal frameworks—such as implementing stricter penalties, improving port state measures, and

enhancing cross-agency coordination—will be essential for deterring illegal practices. This aligns with UNCLOS provisions and FAO's Port State Measures Agreement (PSMA), which promote global coordination in preventing the entry of IUU-caught fish into legal markets.

Ecological restoration also contributes to resilience. Initiatives focused on mangrove reforestation, coral gardening, and seagrass rehabilitation restore critical nursery habitats and enhance ecosystem services, including carbon sequestration, shoreline protection, and biodiversity support (Alongi, 2008; Mumby & Steneck, 2008). Mangroves, in particular, function as natural buffers against storm surges and coastal erosion, providing both ecological and socio-economic benefits. Integrating restoration activities with community livelihoods—such as linking mangrove conservation to sustainable crab harvesting or tourism—enhances local stewardship and fosters shared incentives for conservation success.

Policy frameworks must bridge the gap between ecological theory and applied governance. Adaptive co-management approaches, which blend community knowledge with scientific monitoring and regulatory oversight, have demonstrated effectiveness in enhancing both ecological and social resilience (Armitage et al., 2009). By engaging stakeholders at multiple levels, including fishers, researchers, and government agencies, co-management reduces conflict, improves compliance, and enables iterative learning—a process highly relevant under conditions of climate uncertainty. Finally, sustainable fisheries management is not solely an environmental objective but a rights-based imperative. The right to food, livelihood security, and a healthy environment are increasingly recognized within international law and human rights discourse (Knox, 2018). Ensuring that fisheries governance protects these rights reinforces the ethical and legal foundation of resilience-building, highlighting the intersection of ecological sustainability with social justice.

## Case Studies

### *A. Northern Java Coastal Communities*

Northern Java—particularly areas such as Semarang, Cirebon, and Demak—represents a frontline of compounded climate risks where sea-level rise intersects with human-induced land subsidence and socio-economic vulnerability. Sea-level rise in

this region is not solely a consequence of global thermal expansion and ice melt; rather it is exacerbated by excessive groundwater extraction and rapid urbanization, leading to significant land sinking (Syvitski et al., 2009; Nicholls et al., 2008). These processes have tangible impacts on coastal settlements, inundating homes, degrading water quality through saltwater intrusion, and compromising infrastructure critical to small-scale fishing livelihoods, such as piers, fish landing sites, and cold storage facilities. The result is a socio-ecological trap in which environmental stress feeds back into economic insecurity.

Sea-level rise and land subsidence create chronic flooding events that shorten agricultural and fishing seasons, reduce access to safe harbors, and increase maintenance costs for boats and gear. Households facing repeated asset loss and diminished fish catches often allocate scarce resources toward immediate survival rather than long-term adaptation (Hallegatte et al., 2016). This pattern reflects vulnerability theories that emphasize how exposure, sensitivity, and adaptive capacity interact to shape differential outcomes within communities (Adger, 2006). In northern Java, communities with weak access to institutional support and capital are less able to absorb and recover from climate shocks.

Local responses have included incremental behavioral adaptations, such as shifting fishing schedules, modifying gear to target more resilient species, or engaging in informal wage labor during peak flooding seasons. However, these strategies often generate short-term relief without addressing systemic drivers of vulnerability. The persistence of inundation highlights the need for integrative coastal management that tackles both climate hazards and governance deficits. Recent urban planning initiatives in Semarang, for example, are experimenting with sea-dyke construction and ecosystem-based defenses (mangrove buffer zones), aligning with broader ecosystem-based adaptation (EbA) frameworks recognized by the Intergovernmental Panel on Climate Change (IPCC, 2022).

Analytically, the northern Java case underscores how climate impacts become socially mediated through development trajectories, infrastructure deficits, and weak regulatory enforcement. It illustrates that adaptive capacity is not merely technical but deeply embedded in socio-economic and political contexts. Efforts that ignore these intersecting influences risk reinforcing inequality rather than reducing vulnerability (Smit & Wandel, 2006). To enhance resilience, governance systems must strengthen local participation, integrate land-sea planning, and provide sustained financial and technical support to fishing communities.

### *B. Eastern Indonesia (Maluku, Sulawesi)*

Eastern Indonesia, particularly the provinces of Maluku and Sulawesi, exemplifies a contrasting set of climate vulnerabilities where coral reef degradation and artisanal fisheries interact to threaten both ecological integrity and community livelihoods. These regions sit within the globally significant Coral Triangle, a marine biogeographic zone of exceptional biodiversity that supports extensive reef systems and artisanal fishery productivity (Veron et al., 2009). However, rising sea surface temperatures, ocean acidification, and local stressors such as destructive fishing practices have accelerated coral bleaching events, reducing habitat complexity and biomass that sustain reef fish populations (Hoegh-Guldberg et al., 2017).

For small-scale fishers in Maluku and Sulawesi, the degradation of reef ecosystems directly translates into declining catch per unit effort (CPUE), increased fishing effort, and heightened food insecurity. Reef fish, traditionally targeted in nearshore fisheries, are essential both as a primary protein source and as a pillar of local cultural identity. As fish abundance decreases, households shift to lower trophic species, longer fishing trips, or larger inputs, often at greater ecological cost—what scholars term “fishing down the food web” (Pauly et al., 1998). This phenomenon illustrates the feedback loops that link ecological decline to socio-economic vulnerability.

The combined impacts of climate and local stressors have generated socio-ecological mismatches. Reef degradation diminishes ecological resilience, reducing the system’s capacity to absorb shocks and maintain function—a core concern of social-ecological systems (SES) theory (Ostrom, 2009). In turn, communities respond by intensifying fishing pressure in already degraded areas, perpetuating a cycle of resource depletion and livelihood insecurity. Research highlights that artisanal fishers in these regions often lack secure tenure, market access, and capital, compounding their vulnerability to changing ecological conditions (Allison et al., 2009).

Efforts to address reef degradation in Maluku and Sulawesi have increasingly leaned on community-based marine conservation, including locally established marine protected areas (MPAs) and reef restoration initiatives. These programs often integrate traditional ecological knowledge, such as customary no-take zones (*sasi*

*laut*), with scientific monitoring, aligning with adaptive co-management principles that emphasize shared governance and learning (Cinner et al., 2012). While MPAs can enhance biomass recovery and spillover effects when well enforced, their success is conditioned by community buy-in, enforcement capacity, and economic alternatives for displaced fishers (Halpern et al., 2010).

A critical challenge lies in scaling up these local conservation successes into broader policy and governance frameworks that can address systemic drivers, including destructive fishing and inadequate enforcement of marine regulations. Strengthening institutional linkages between provincial governments, community councils, and national agencies is necessary to ensure sustainable fisheries management and biodiversity protection. The Maluku and Sulawesi case underscores that while ecological interventions are vital, they must be paired with socio-economic strategies that support both human and environmental well-being.

### *C. Community-Led Adaptation Initiatives*

Community-led adaptation initiatives highlight the potential for localized resilience when small-scale fishers actively participate in designing, implementing, and monitoring responses to climate change and environmental degradation. These initiatives often emerge from the recognition that external, top-down policies alone cannot address context-specific vulnerabilities without integrating local knowledge systems, cultural practices, and community priorities (Armitage et al., 2008). In Indonesia, several successful examples illustrate how community agency can enhance adaptive capacity and generate sustainable outcomes.

In parts of Lombok and West Papua, fishers have developed collective reef rehabilitation projects that combine traditional ecological knowledge with modern restoration techniques. By organizing reef gardening, coral transplantation, and mangrove planting, communities work to rebuild structural habitat that supports fish recruitment and biodiversity (Mumby & Steneck, 2008). These activities not only enhance ecosystem resilience but also reinforce local stewardship and social cohesion. Community members often rotate leadership roles, share monitoring responsibilities, and integrate adaptive learning into their governance systems, reflecting principles of polycentric governance that scholars like Ostrom (1990) advocate for complex social-ecological systems.

Another successful initiative is the community fisheries co-operative model implemented in parts of Bali and Nusa Tenggara, where fishers pool resources, share risk, and engage in joint decision-making. Such cooperatives provide microcredit access, collective bargaining power in markets, and shared investments in safety equipment and early warning communication systems (Hossain & Bayes, 2009; Clarke, 2016). These forms of social organization increase economic resilience and reduce individual vulnerability by distributing risk across the group, consistent with asset-based community development frameworks that emphasize social capital as a resilience resource (Mathie & Cunningham, 2003).

In South Sulawesi, innovative livelihood diversification programs undertaken by youth and women's groups—such as eco-tourism homestays, seaweed processing enterprises, and artisanal crafts—demonstrate how non-fishing income pathways can buffer households against ecological uncertainty. These activities are often supported by partnerships with NGOs, academic institutions, and provincial governments, illustrating how multi-stakeholder collaborations can enhance local adaptive capacity while respecting cultural values and gender roles.

Importantly, community-led initiatives often integrate monitoring and evaluation mechanisms that feed back into adaptive learning cycles. Participatory mapping, community scorecards, and seasonal resource assessments enable fishers to evaluate the effectiveness of conservation measures and adjust strategies in response to ecological change. This aligns with adaptive governance theory, which emphasizes the need for iterative learning and flexibility in managing environmental uncertainty (Folke et al., 2005). Finally, the success of community-led adaptation underscores the importance of enabling environments that support local agency. Legal recognition of customary marine tenure, access to microfinance, inclusion in policy dialogues, and technical training are critical components that allow grassroots initiatives to flourish and link local action to larger governance frameworks. When communities lead adaptation efforts, resilience becomes anchored not only in ecological protection but also in social empowerment and institutional connectivity.

## Conclusion

### *A. Summary of Key Findings*

This study has highlighted the complex interplay between environmental changes and socio-economic vulnerabilities in Indonesian fishing communities. Coastal settlements across northern Java, eastern Indonesia, and other archipelagic regions face multifaceted challenges stemming from sea-level rise, land subsidence, coral reef degradation, and shifts in fish migration patterns. These ecological transformations directly threaten the livelihoods of small-scale fishers, whose economic stability and food security rely heavily on marine resources (Allison & Ellis, 2001; Hoegh-Guldberg et al., 2017). Socio-economic pressures, including limited access to credit, debt dependency, gendered divisions of labor, and market monopolization by middlemen, exacerbate the communities' vulnerability, making adaptation both necessary and urgent (Adger, 2006; Hossain & Bayes, 2009).

The study also underscored the effectiveness of community-based adaptation strategies, including ecosystem-based management, locally managed marine protected areas, livelihood diversification, and collaborative governance. Initiatives integrating traditional ecological knowledge (*kearifan lokal*) with modern conservation techniques have proven successful in enhancing both ecological resilience and social cohesion (Cinner et al., 2012; Mumby & Steneck, 2008). Notably, cases in Maluku, Sulawesi, and northern Java demonstrate that adaptive capacity is not solely determined by environmental conditions but is also shaped by social capital, governance structures, and access to technical and financial resources (Ostrom, 2009; Armitage et al., 2008). These findings illustrate that climate impacts on small-scale fisheries are both ecological and social, requiring holistic interventions that consider human, institutional, and environmental dimensions simultaneously.

### *B. Theoretical Contributions*

From a theoretical perspective, this research contributes to the socio-ecological systems (SES) framework by demonstrating how ecological shocks interact with social structures, governance systems, and economic networks to shape vulnerability and resilience in coastal communities (Folke et al., 2005). By situating small-scale

fisheries within SES theory, the study emphasizes the importance of understanding feedback loops between ecological degradation, human decision-making, and institutional capacity. The research also expands the discourse on climate resilience in developing, archipelagic states, highlighting how localized knowledge systems, community cooperation, and cultural practices mediate the impacts of global environmental change (Adhuri, 2013; Cinner et al., 2018).

Furthermore, the study contributes to climate adaptation scholarship by integrating empirical evidence from multiple case studies, linking micro-level adaptation strategies to macro-level governance and policy structures. It demonstrates the relevance of concepts such as polycentric governance (Ostrom, 1990) and adaptive co-management (Armitage et al., 2008), showing how decentralized decision-making, local participation, and iterative learning can enhance community resilience. By connecting socio-ecological theory to real-world fisheries management, the study offers a model for analyzing climate vulnerability and adaptation in contexts characterized by high ecological diversity and social heterogeneity.

### *C. Policy Implications*

The findings underscore the need for multi-level governance coordination that bridges national, provincial, and local authorities while integrating community participation into fisheries management. Policies should prioritize investments in climate-resilient infrastructure, early-warning systems, and ecosystem-based management approaches that account for both environmental and social dimensions of resilience (Hallegatte et al., 2016; World Bank, 2018). Moreover, enhancing financial inclusion through microfinance, cooperative systems, and insurance schemes can reduce the socio-economic vulnerability of fishing households while promoting sustainable practices.

Strengthening legal frameworks to recognize customary marine tenure and local conservation efforts is also critical. Institutional support for community-led initiatives—ranging from reef restoration to alternative livelihoods—can empower local actors to respond proactively to ecological shocks (Mumby & Steneck, 2008; Cinner et al., 2012). Additionally, regional cooperation through frameworks such as the Coral Triangle Initiative can facilitate knowledge exchange, coordinated

monitoring, and collective enforcement of sustainable marine practices (UNESCO, 2017). These measures collectively suggest that long-term resilience depends not only on technical interventions but also on socio-political structures that enable equitable access to resources and decision-making.

#### *D. Limitations and Future Research*

Despite its contributions, this study has limitations. First, the reliance on secondary data and case studies constrains the generalizability of findings across Indonesia's vast archipelagic regions. Longitudinal fieldwork is needed to track the effectiveness of adaptation interventions over time and understand the dynamic interactions between ecological change, socio-economic adaptation, and governance structures (Halpern et al., 2010). Second, comparative research across Southeast Asia or other archipelagic developing states could provide further insight into best practices and transferable adaptation strategies.

Future research should also explore gendered impacts of climate change, particularly the roles of women in fisheries and household adaptation, as well as intergenerational shifts in livelihood strategies. Investigating the effectiveness of community-led early warning systems, social protection mechanisms, and co-management frameworks under diverse socio-political contexts could yield practical recommendations for policymakers. Finally, integrating climate change projections with fisheries economics and food security models would strengthen the empirical basis for long-term planning, providing actionable insights for achieving sustainable and resilient coastal communities.

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