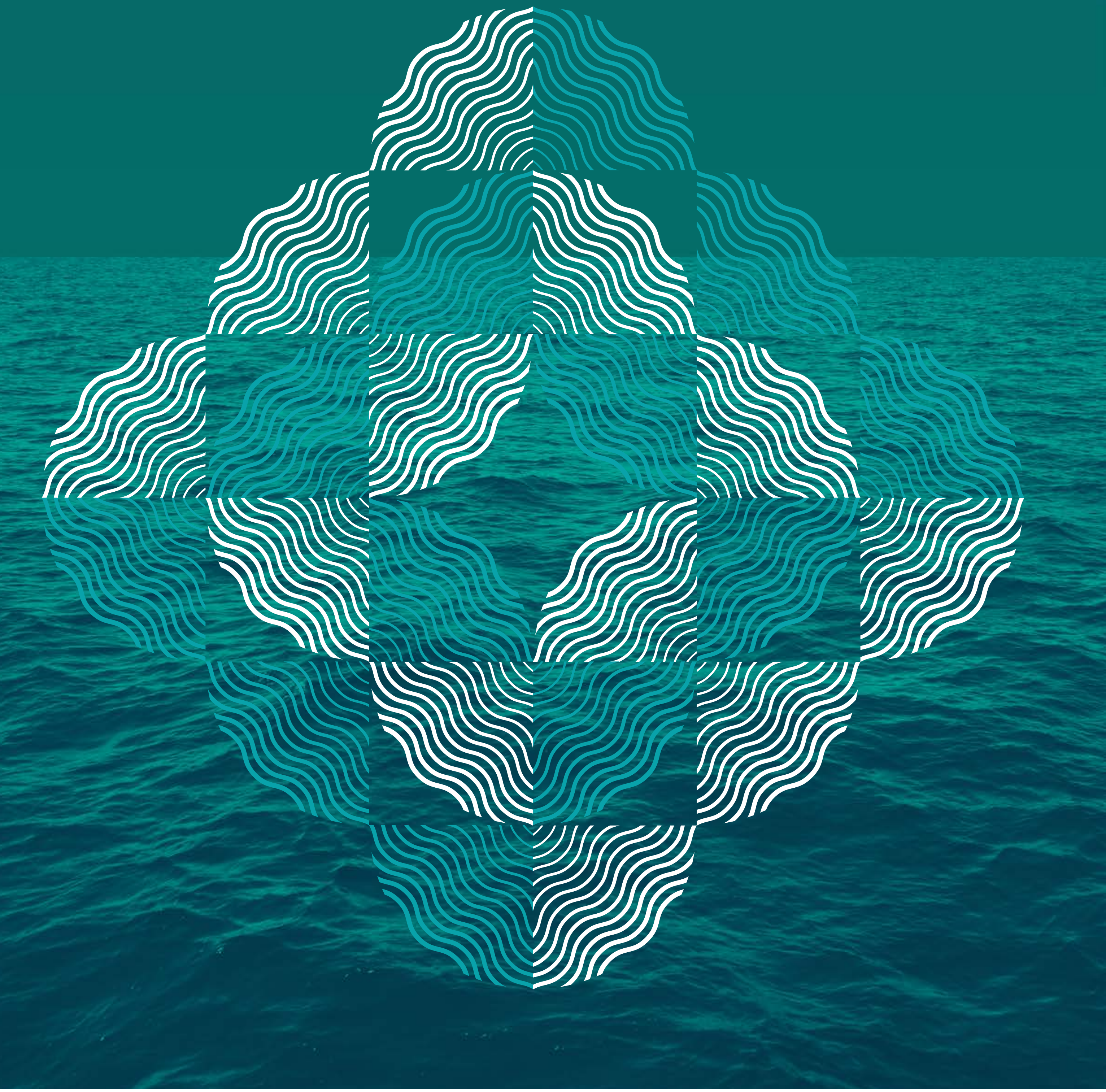
Hot Water Rising

The Impact of Climate Change on Indonesia's Fisheries and Coastal Communities



MINISTRY OF
MARINE AFFAIRS AND FISHERIES
REPUBLIC OF INDONESIA

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Suggested Citation:
Kaczan, D, Nurhabni, F, Cheung, W, Frölicher, T, Kuswardani, A, Lam, V, Muawanah, U, Puspasari, R, Reygondeau, G, Sumaila, U, and Teh, L (2023). Hot Water Rising: The Impact of Climate Change on Indonesia's Fisheries and Coastal Communities. The World Bank, Washington, D.C.

A collaborative partnership:

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Foreword

Victor Gustaaf Manoppo

Director General for Marine Spatial Management
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As a tropical country, Indonesia would face more severe climate change impacts than other regions, particularly the fisheries sector. Climate change will adversely impact our fishery resources, threatening food security, fishers' safety, conservation and biodiversity, and will affect the economy generated by the marine and fisheries sector. Therefore, Indonesia needs effective management strategies to reduce climate change impacts in the fisheries sector. Specifically, we need management that is based on science and considers broader socioeconomic and ecosystem components.

Unfortunately, only a few studies are intended to address climate change impacts on the fisheries sector in Indonesia. Recognizing such issues, this report provides assessment and policy recommendations to tackle climate change impacts on fisheries and coastal communities in Indonesia. Specifically, it finds that the maximum catch potential in 2050 is projected to decrease by 20-30 percent under a high-emission scenario and by 5-20 percent under a low-emission scenario compared to 2010. Consequently, economic income from fisheries is projected to decline by 15 to 26 percent in the absence of adaptation measures. This study also provides a vulnerability assessment of Indonesia's coastal communities based on an analysis that integrates fisheries modeling results with socioeconomic indicators. A series of policy options to support resilience in Indonesia's fisheries and coastal communities are presented to complement these analyses.

We expect that this study can support the mainstreaming of climate change control actions in the implementation of Indonesia's blue economy policy. This policy includes five priority programs: (1) expansion of marine protected areas; (2) quota-based capture fisheries; (3) development of coastal, marine, and inland aquaculture; (4) sustainable management of coastal and small islands; and (5) marine plastic waste management.

Ultimately, this report is a tangible manifestation of the Government of Indonesia's commitment to encouraging the inclusion of ocean issues in climate change (*ocean-climate nexus*) towards achieving the Indonesian *Nationally Determined Contribution* (NDC) adaptation target. Specifically, the report can provide input for stakeholders in implementing climate change adaptation actions and contribute to improving the resilience of coastal and small island communities, especially fisheries communities.

I express my utmost appreciation to the team from the Indonesian Ministry of Marine Affairs and Fisheries, the University of British Columbia (UBC), and the World Bank, with support from the David and Lucile Packard Foundation, for this study.

Victor Gustaaf Manoppo
Jakarta, October 2022

We need management that is based on science and considers broader socioeconomic and ecosystem components to reduce climate change impacts in the fisheries sector.

Acknowledgments

This report was prepared by a joint research team from the World Bank, the Ministry of Marine Affairs and Fisheries of the Republic of Indonesia (MMAF), and the University of British Columbia (UBC), with the support of the David and Lucile Packard Foundation (Packard) and the PROBLUE Multi-Donor Trust Fund.

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Reviews were gratefully received from Yadranka Farida (Natural Resources Management Specialist), Andrew Harvey (Senior Fisheries Consultant), Charlotte De Fontaubert (Sr. Fisheries Specialist), Diji Chandrasekharan Behr (Sr. Environmental Specialist), Gunilla Greig (Sr. Fisheries Specialist), Julien Million (Sr. Fisheries Specialist), Berengere Prince (Lead Natural Resources Specialist), and Jacqueline Alder (Sr. Marine and Fisheries Consultant) all of the World Bank.. Additional technical input was provided by Zahra Didarali (Climate Change Consultant), Neel Inamdar (Blue Finance Consultant), and Stephanie Tam (Senior Climate Specialist). Sandra Sari (Program Assistant) and Shella Adelina (Team Assistant) provided team support. Report preparation and finalization was by Zubair Qamar (Editor), Reidinar Wardoyo (Communications Specialist), and David Irianto (Visual Designer).

From the MMAF, the team thanks Muhammad Yusuf (Director of Coastal and Small Islands Utilization), Barnard Ceisaro Purba (Sub Coordinator of Climate Change Adaptation), Rini Widayanti (Climate Change Adaptation Analyst), Marselius Fransiskus Talahatu (Climate Change Adaptation Analyst), and Eko Wibisono (Climate Change Adaptation Analyst) for their support. The team also would like to thank Muhammad Firdaus Agung Kunto Kurniawan (Director of Marine Conservation and Biodiversity) for his review.

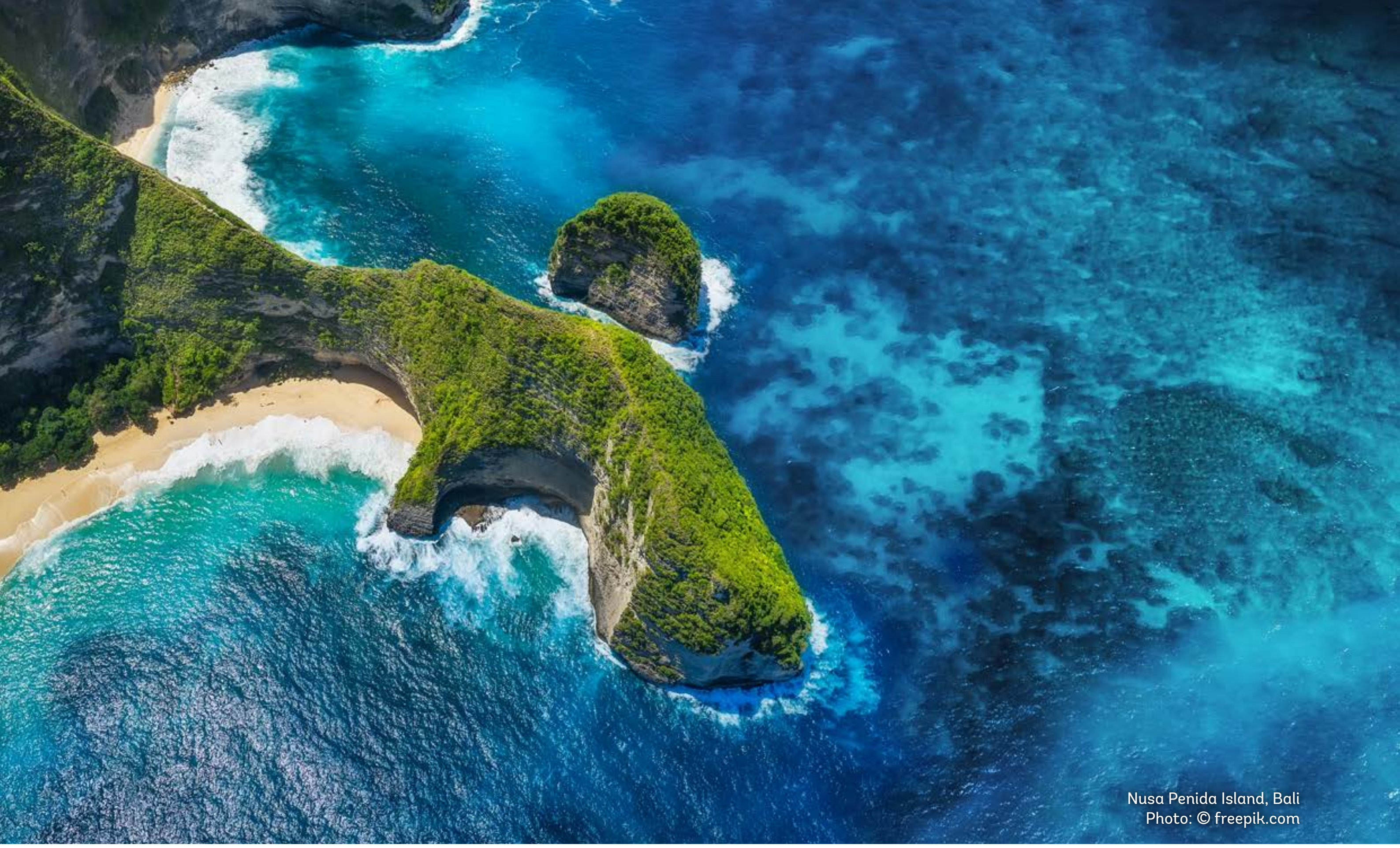
From the World Bank, the team thanks Satu Kristiina Kahkonen (Country Director, Indonesia), Bolormaa Amgaabazar (Operations Manager, Indonesia), Ann Jeannette Glauber (Practice Manager), Giovanni Ruta (Lead Environmental Economist), Andre Rodrigues Aquino (Program Leader) and Ambroise Brenier (Senior Natural Resource Management Specialist) for guidance and support.

The David and Lucile Packard Foundation provided the primary funding for this work. Additional funding was provided by the PROBLUE Multi-Donor Trust Fund administered by the World Bank. This product was developed in support of the Oceans for Prosperity (*Lautan Sejahtera*, LAUTRA) project, an investment by MMAF in Indonesia's coastal ecosystems and communities in Eastern Indonesia, with the support of the World Bank, PROBLUE, and the Government of Canada.

Any errors or omissions are the responsibility of the authors.

Acronyms

AMDAL	Environmental Impact Assessment
BLU	Badan Layanan Umum
BMKG	Badan Meteorologi, Klimatologi, dan Geofisika
BRIN	Badan Riset dan Inovasi Nasional
CCDP	Coastal Communities Development Project
CIMP6	Coupled Model Intercomparison Project, Phase 6
CMMAI	Coordinating Ministry of Maritime Affairs and Investment
COAST	Caribbean Ocean and Aquaculture Sustainability Facility
COREMAP	Coral Reef Rehabilitation and Management Program
DTKS	Data Terpadu Kesejahteran Sosial
EEZ	Exclusive Economic Zone
FAD	Fishery Aggregating Device
FAO	Food and Agriculture Organization of the United Nations
FMA	Fisheries Management Areas
FPAT	FAO Fishery Performance Assessment Tool
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIA	Geospatial Information Agency
GPS	Global Program on Sustainability
IFC	International Finance Corporation
LAUTRA	Oceans for Properity Project
LPP	Lembaga Pengolaan Perikanan
MCP	Maximum Catch Potential
MMAF	Ministry of Marine Affairs and Fisheries
MoEF	Ministry of Environment and Forestry
MoF	Ministry of Finance
MPA	Marine Protected Area
MPWH	Ministry of Public Works and Housing
MSY	Maximum Sustainable Yield
MTCE	Ministry of Tourism and Creative Economy
NDC	Nationally Determined Contribution
NPP	Net Primary Productivity
NR	Natural Resources
PKH	Program Keluarga Harapan
PKPT	Pengembangan Kawasan Pesisir Tangguh
RCP	Representative Concentration Pathway
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RFMO	Regional Fisheries Management Organization
RPJMN	Rencana Pembangunan Jangka Menengah Nasional
SBT	Southern Bluefin Tuna
SDG	Sustainable Development Goal
SISNERLING	Integrated System of Environmental-Economic Accounts
TNC	The Nature Conservancy
TURF	Territorial Use Rights in Fisheries
UPP	Unit Pengelola Perikanan
VMS	Vessel Monitoring System
WPP	Wilayah Pengelolaan Perikanan



Nusa Penida Island, Bali
Photo: © freepik.com

Executive Summary

Rising ocean temperatures are a challenge for Indonesia and many countries worldwide.

Oceans underpin Indonesia's prosperity but will be impacted by climate change

With 17,504 islands, 108,000 kilometers of coastline, and three-quarters of its territory at sea,[1] Indonesia's prosperity is deeply entwined with its oceans. Yet the future for Indonesia's oceans, like those worldwide, is increasingly uncertain. Climate change is driving increases in water temperatures, storm severity, and sea level rise, causing shifts in coastal ecosystems and fisheries. These trends pose challenges for Indonesia's ocean economy and the people it supports.

Indonesia's fisheries are on the front line

Indonesia's fisheries are at the center of these challenges. The fisheries sector contributes US$26.9 billion annually to the national economy (around 2.6 percent of GDP), 50 percent of the country's protein, and over 7 million jobs (World Bank 2021). The impact of climate change on the fisheries sector will thus have important implications for livelihoods, food security, and economic growth. While this is true around the world, few countries have fishery resources as vast as Indonesia's or depend as much as Indonesia does on fisheries for jobs and protein.

Indonesia recognizes the importance of a resilient ocean economy

As this report highlights, the importance of ensuring productive and sustainable fisheries in the face of a changing climate is well-recognized. The Government of Indonesia is taking steps toward a climate-resilient marine and coastal economy through investment in infrastructure, technology, capacity-building, and governance. Strategies and actions are outlined in the Enhanced *Nationally Determined Contribution* (NDC), the *Climate Resilient Development Policy 2020-2045*, and the *List of Priority Locations and Climate Resilient Actions* prepared by the Ministry of National Development Planning (Bappenas). Climate resilience is being prioritized by the Ministry of Marine Affairs and Fisheries (MMAF).

1 Statistics from 2018 reference data by the Coordinating Ministry of Maritime Affairs and Investment (CMMAI).

Research is needed to guide planning and investments

Yet the knowledge base for climate-resilient policy and investments remains relatively thin in Indonesia and worldwide. Research is needed for managers to predict changes in fish stocks and fishery value chains and make informed responses. Governments need to be able to pinpoint the coastal communities that are most vulnerable. The private sector needs to understand trends and risks to make sound investments. This report aims to provide such knowledge through a world-first sub-national, species-specific assessment of climate change impacts, drawing on cutting-edge oceanic modeling techniques (Box E.S.1).

Climate-induced changes in ocean conditions will drive shifts in Indonesia's fisheries.

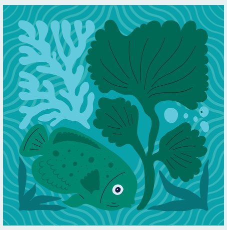
Indonesia's sea surface temperatures are expected to warm by 1.39 - 3.68 °C by end-century relative to preindustrial times

Indonesia's oceans have warmed by around 0.18°C per decade over the past 30 years, a total of over half a degree Celsius (C). The warming will continue. Sea surface temperatures are expected to increase by 1.39 ± 0.39 °C under a low global emissions scenario (SSP1-2.6), and by 3.68 ± 0.86 °C under a high global emissions scenario (SSP1-8.5), by end-century relative to 1850-1900. This long-term warming trend will be punctuated by short-term and localized extremes. Marine heatwaves—temporary hot spikes in ocean temperature—are expected to increase in duration from the typical 1-6 months seen today to 11-12 months by 2050.

Advanced modeling techniques are used to determine the implications for fisheries

This study analyzes the impacts of these temperature rises on the economics of the fishery sector. Four complementary analyses are applied to a selection of 54 "focal species," chosen because of their critical role within Indonesia's industrial and artisanal fisheries. These include shrimp, tuna, varied reef fish, and sardinella species (see Annex 1). The first stage of the analysis determines which species are most vulnerable, given their biological characteristics and projected changes in ocean conditions. The second stage determines how species' ranges will change, i.e., where those species are expected to migrate. The third stage estimates change in maximum catch potential (i.e., fish harvests) given the shifting species distribution and abundance. Finally, the economic implications—costs, revenues, and profits—are projected under different climate and management scenarios.

Box 1. E.S: Objectives of this Report



Drawing on recent climate and ecological modeling advances, this report provides a world-first sub-national and species-specific assessment of the impact of climate change on fisheries and marine habitats. The report assesses how projected temperature changes will alter ocean conditions and the abundance and distribution of key species across Indonesia's waters. Based on these results, it estimates changes in fish catch and economic outcomes at different levels of fishery management performance. The report then integrates fishery modeling results with socio-economic indicators to quantify the vulnerability of Indonesia's coastal communities across the archipelago.

Based on these findings, a set of policy options is offered for a more resilient future for Indonesia's fisheries and coastal communities. These options aim to support governments, the private sector, and civil society adapt to climate impacts and maintain progress towards development goals. The policy options are selected not only to help Indonesia's fisheries and coastal communities survive in a climate-impacted world but to thrive. That is, even if the predicted climate impacts are less severe than expected, the suggested options should still deliver benefits. For this reason, the report focuses on the institutions and systems that underpin the fishery sector's management and productivity and the broader economic conditions of coastal communities.

The report results from a scientific partnership between the Ministry of Marine Affairs and Fisheries, the University of British Columbia, and the World Bank, supported by the David and Lucile Packard Foundation and the PROBLUE Trust Fund.

Source: Authors.

Average maximum catch potential could decline by 20-30 percent under a high climate change scenario

The modeling shows that atmospheric carbon dioxide and temperature increases are driving changes in ocean conditions, with ocean pH, oxygen levels, and salinity levels all declining. The most impacted species are demersal species (those that live or feed near the bottom) in shallow waters and some pelagic species. In aggregate, maximum catch potential is projected to decrease by 20 to 30 percent under the high emissions scenario by 2050 relative to 2010.[2] The low climate change scenario sees declines of up to 20 percent in some regions, and 5-15 percent in most regions, by 2050 (Figure E.S.1). The most affected species include some of those critical to artisanal and industrial-scale fisheries, including yellowstrip and Bali sardinella (*Sardinella gibbosa* and *S. lemuru*), torpedo scad (*Megalaspis cordyla*), mackerels (*Scomberomorus commerson and S. guttatus*), and skipjack tuna (*Katsuwonus pelamis*).

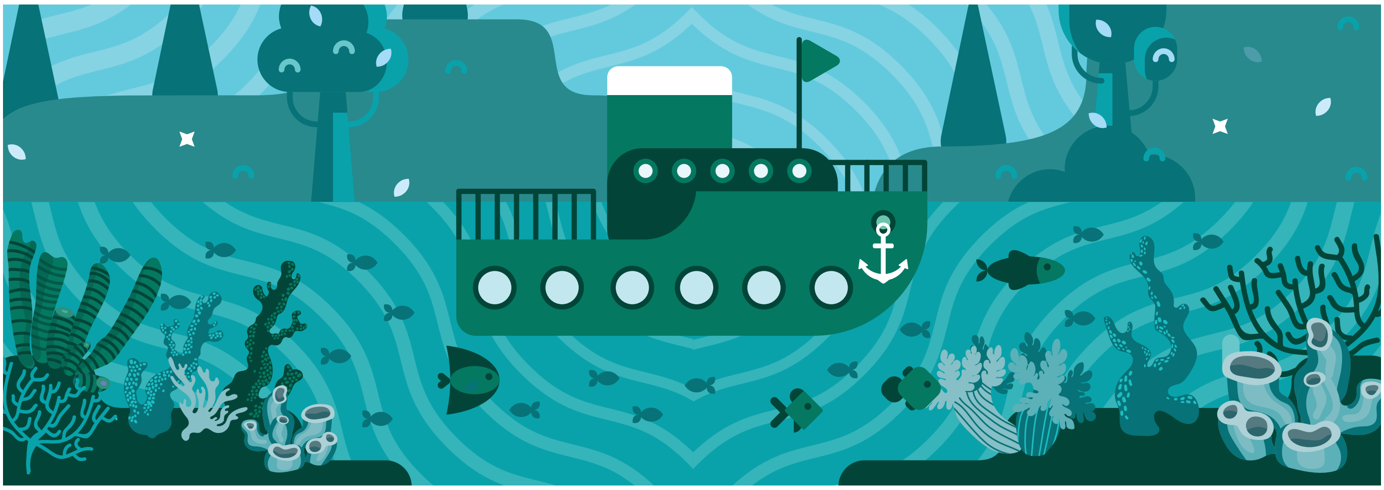
Reductions in catch reduce revenues, but strong management can offset losses.

Climate change could decrease economic returns to fisheries by 15-26 percent by 2050

In line with the projected reductions, total economic returns (considering changes in both revenues and costs) are projected to decrease by between 15 and 26 percent under low emission and high emission scenarios, respectively, across the Indonesian exclusive economic zone (EEZ), by mid-century. Impacts are slightly worse for the small-scale sector (17-19 percent reductions under the low emissions scenario) than for the large-scale sector (13-14 percent) mostly because species caught by the small-scale sector are more vulnerable than those caught by the large-scale sector.

Climate effects interact with fishery management effectiveness

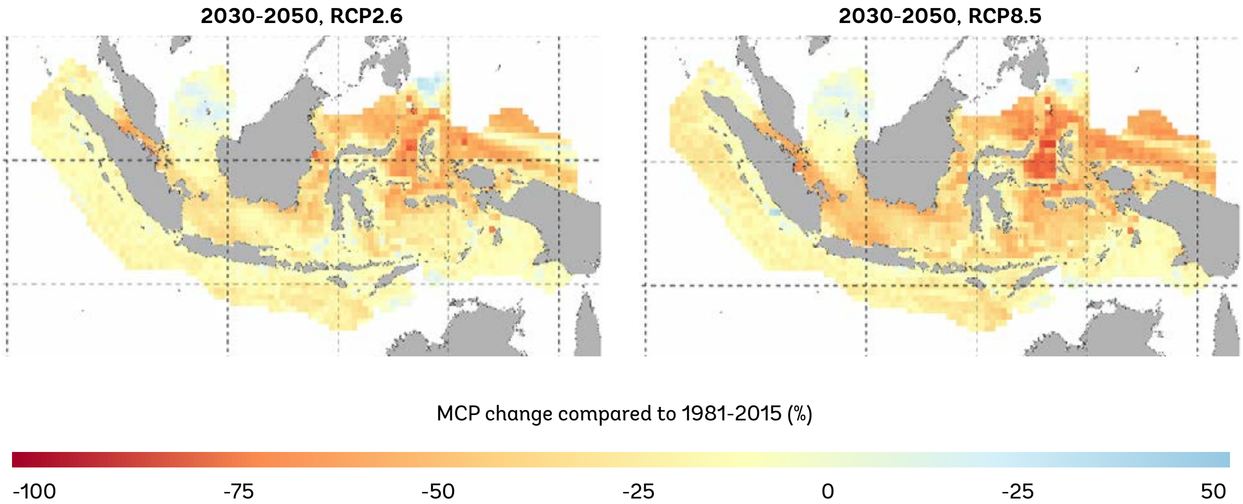
While these effects are substantial, climate change is not the only or even the main determinant of a fishery's productivity. Fishing effort levels, which are controlled by the management regime, are also critical. Overfished stocks can be expected to see a greater reduction due to negative climate change impacts. This contrasts with outcomes for underfished stocks, which have a "buffer" against climate change. Projected economic losses under poor management (i.e., 20 percent overfishing) suggest incremental losses in the small-scale sector of 28-30 percent in 2050 relative to the present (low emissions scenario). More severe overfishing could lead to losses of up to 60 percent. Stocks in such a scenario are placed under severe pressure by climate change; overfishing then pushes these stocks to the point of collapse. However, this is a worst-case scenario. Given improvements in Indonesia's fishery management system over recent years (and provided these trends continue), overfishing is unlikely to reach such levels.



2 The baseline period for comparative analysis is the average of conditions between 1991-2010.

Figure 1. E.S: The projected catch of fish species in Indonesian waters under climate change

Change in maximum catch potential (MCP) by mid-century (2030-2050) under RCP 2.6 and RCP 8.5 scenarios.



Notes and source: MCP change is relative to recent historical catch (1985-2015). RCP = Representative Concentration Pathway. RCP8.5 should be considered a high bound on climate impacts, and RCP2.6 a low bound. Estimation by authors.

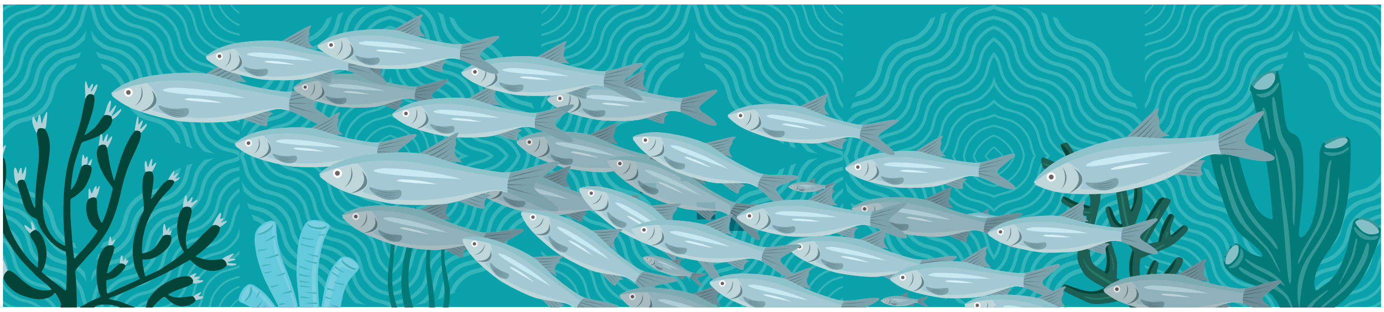
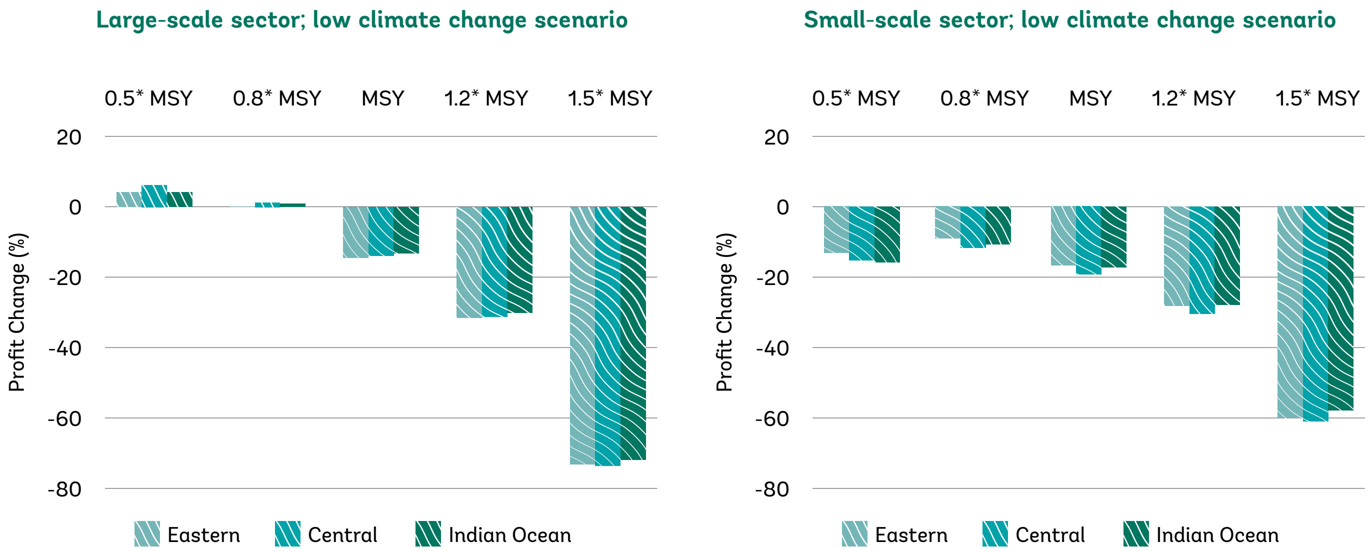


Figure 2. E.S: Projected change in economic returns for small-scale and large-scale fishing sectors

Percentage change in economic returns (revenues less costs) by 2050 relative to current returns by sub-sector (small and large scale), region (Indonesia's eastern, central, and Indian ocean waters) and management scenarios.



Source: Estimation by authors. The small-scale sector refers to vessels relying on sail or outboard engines for propulsion and fishers operating gear without a boat. Low climate change scenario represented by SSP1-RCP2.6. MSY = Maximum sustainable yield. Harvesting above MSY implies overfishing (which, for modeling purposes, is assumed to be sustained, causing the fishery to become overfished).

Fortunately, good management can substantially offset many climate change losses

By contrast, climate losses are partially mitigated under strong management performance. Maintaining total fishing effort at 80 percent of the maximum sustainable yield (MSY) (as Indonesia's fishery managers aim) would shift climate losses from 17 to 19 percent down to 9-10 percent for the small-scale sector. The same conservative management would completely offset losses in the large-scale sector, with economic returns projected to be 4-6 percent greater than those received today under the strictest management under the low emission scenario (Figure E.S.2.).

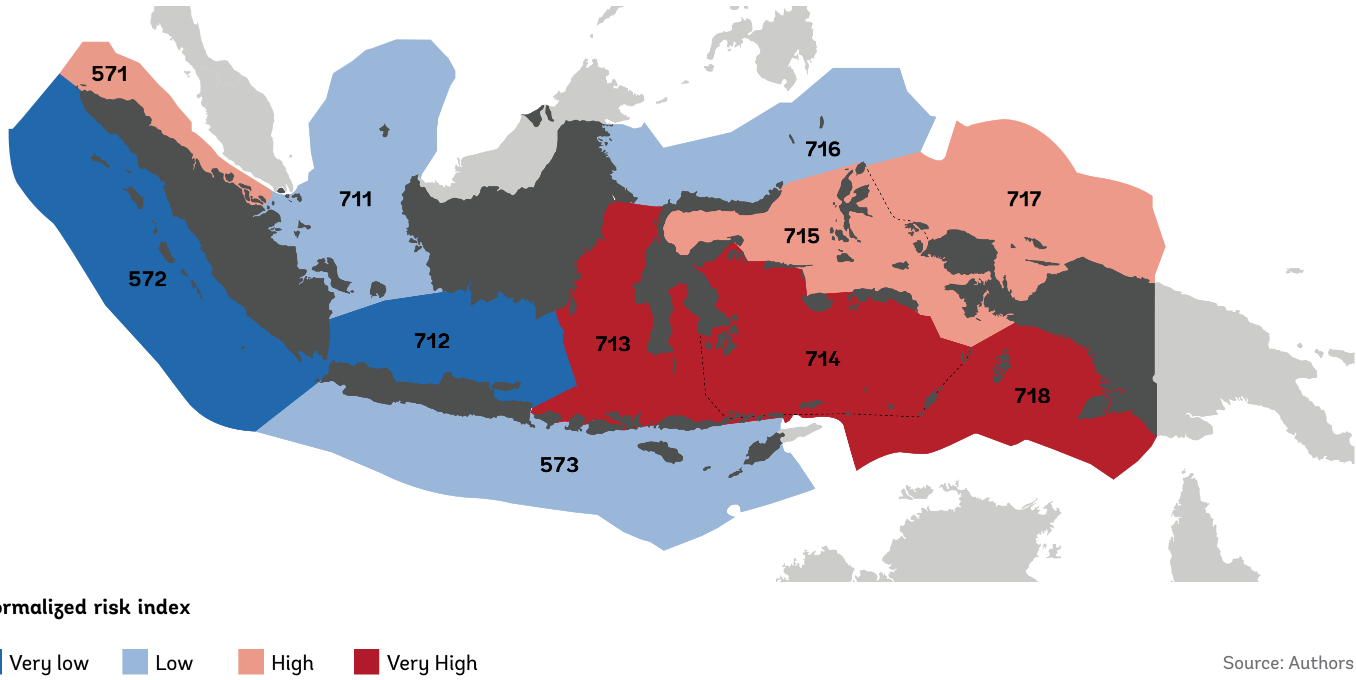
The vulnerability of coastal communities to these changes varies across Indonesia.

In aggregate, Fishery Management Units 713, 714, and 718 are most vulnerable to climate impacts on fisheries, although further research is needed

This report next turns to consider the vulnerability of Indonesia's coastal communities. This includes broader socio-economic factors, such as dependency on the fishery sector, infrastructure, social services, and other forms of adaptation capacity. In aggregate, communities in Fishery Management Units (*Wilayah Pengelolaan Perikanan, WPP*) 713, 714, and 718 appear to be the most vulnerable to the impacts of climate change (Figure E.S.3). These areas combine larger projected changes in fishery resources, with high levels of fishery dependence and still-developing adaptive capacity (infrastructure and social services). In line with these findings, these regions are already high priorities for MMAF investments and programming, including transportation and logistics (connectivity), fishing-village support, and social protection programs.

Figure 3. E.S: Comparison of aggregate vulnerability to climate impacts on fisheries by WPP

Relative vulnerability as a function of climate change exposure (and hazard), sensitivity, and adaptive capacity.



Source: Authors

Climate change is a threat, but Indonesia's strategic and sustained interventions will lessen impacts.

Fishery sector adaptation measures are a national priority

Indonesia has made important progress in improving climate resilience in a range of areas, including strengthened disaster risk management, financing for contingent liabilities, and an expanded social protection system. National and sub-national governments are investing heavily in infrastructure, including ports and fishing villages. Marine and fishery sector adaptation is seen as a key priority (Bappenas 2021). Overall, Indonesia aims to limit climate damages to below 2.87 percent of GDP in 2050.[3]

Measures will be needed in three complementary areas

Building further marine and coastal resilience will require a combination of measures in three categories: (1) coastal ecosystem protection, (2) sustainable fishery management, and (3) measures to strengthen coastal communities and local economies. These three areas are complementary, and MMAF programming is often designed to address these three areas together. Underpinning these interventions is a need for (4) financing mechanisms that can ensure resources are available and channeled to where they are needed. This report proposes measures in all these areas based on stakeholders' perspectives, existing programs already underway, and new approaches trialed globally. Over one hundred stakeholders from NGOs, the fishing industry, the government, and academia participated in this study's workshops to define policy priorities.

These include interventions for coastal ecosystem protection….

Coastal ecosystem protection conserves the foundations of the fishing industry

The first set of measures addresses the foundation of Indonesia' fishery sector – protection for ecosystems such as mangroves, seagrass, and coral reefs. The Government is investing significantly in these ecosystems through programs such as the *Coral Reef Rehabilitation and Management Program* (COREMAP) and investments in mangrove restoration (towards a national target of 600,000 hectares restored or receiving enhanced protection by 2024). These investments will help protect ecosystems against the worst effects of climate change by reducing compounding stresses such as coastal clearing or damage from fishing vessels. They will also help fortify coastal communities, given the storm protection and erosion benefits that reefs and mangrove offer (Guannel et al. 2016).

… climate adaptive fishery management….

Robust and adaptive fishery management helps the sector respond to long- and short-term changes

The second set of measures is robust and adaptive fishery management. Fishery management under climate change must anticipate and respond to faster and more significant changes than has been the case previously. These changes will be both long-term trends as well as more dramatic swings season-to-season or even day-to-day, such as marine heatwaves. The WPP system, when fully operational, will provide a basis for localized and responsive management, while the recently introduced policy of sustainable quota-based fishing (an output-based quota system) will provide greater flexibility on when and how much fishers harvest. These systems, provided they are supported by strong enforcement, will be the "first line of defense" against climate-change impacts, by preventing overfishing (which compounds climate stresses) and allowing for season-to-season adjustment in harvests. Over time, Indonesia may also look to develop *dynamic management* measures and short-term forecasting that informs temporary closures to avoid patches of low productivity or high bycatch on a daily or weekly basis.

3 Government modelled losses in the absence of adaptation (MoEF, 2021).

… and can be supported through research and incentive design

Adaptive and dynamic management measures necessitate greater levels of data. Indonesia has high scientific capacity, and continued investments in fisheries modeling capacity will strengthen them further. Efforts could be directed toward remaining data gaps, such as species-specific stock assessments and low-data methods (which provide cost-effective approximations in the absence of detailed data). Investing in the capacity of local universities (those universities that participate in WPP advisory bodies) will also be important. Management could also be supported by incentive mechanisms. For example, quota adjustment that favors provinces (or firms) with the best track records on licensing and enforcement. Such mechanisms will require detailed design work and research.

… stronger coastal communities and ecosystems…

Diverse and vibrant local economies underpin climate resilience

The wellbeing of coastal communities under climate stresses will be determined in large part by the economic opportunities they have access to. The strength and diversity of local economies as well as their connectivity to markets and services determine communities' adaptation capacity. On current trends, Indonesia's economic growth will lift millions out of poverty in the coming decades, and coastal communities will benefit from some of these trends. Yet, economic opportunity in coastal communities, most notably those in rural and isolated locations, will not be delivered by growth trends alone. Climate impacts will inflict economic and physical losses on the most vulnerable and least adapted communities. The isolation and higher costs of services provision in more remote coastal communities could create a development divergence between relatively more-resilient urban or peri-urban areas and less-resilient and poorer rural coastal areas.

Investments are most effective when they support broad economic development

MMAF is investing in coastal livelihoods, skills, and infrastructure through initiatives such as the Oceans for Prosperity (*Lautan Sejahtera, LAUTRA*) Project, the Coastal Communities Development Project (CCDP), and the Coastal Resilience Village Development Program, among others. A key focus has been on eastern Indonesia. This report shows that this region is relatively more vulnerable to climate change impacts. These programs have been implemented successfully in Indonesia and provide lessons for future programs. One lesson is that measures that provide finance, business skills, and equipment (i.e., measures that support broader employment options) appear more successful than measures (such as fishing equipment) that encourage and deepen individuals' investments in fishing itself.

Continued improvements to social protection and inclusive finance programs will help

Further measures for consideration could include climate-indexed insurance programs, which cover fishers' losses from storms or marine heatwaves, with insurance payouts made automatically after an event. Launched in 2019, this approach was first used in the Caribbean Ocean and Aquaculture Sustainability Facility (COAST). Coastal village economies could be strengthened through further support for micro, small- and medium-sized enterprises. Increased use of dedicated financing facilities could provide finance to businesses that have been previously excluded. This could include non-collateralized loans, loan guarantees (or unconventional forms of collateral, such as fishing boat deeds), and invoice and cash flow-based lending products.

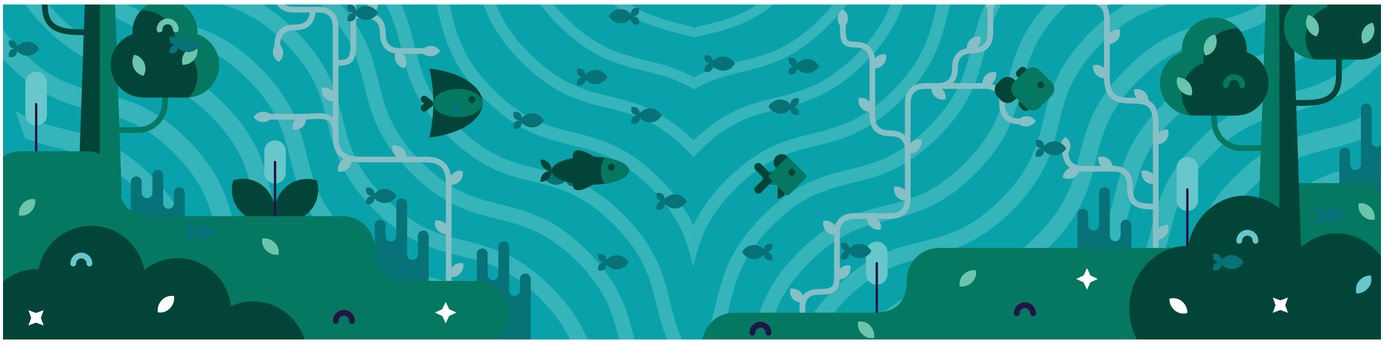
Resilience goes hand in hand with gender equality and inclusion

Another critical consideration for economic opportunity is the impact of gender disparities. Equitable and inclusive communities are typically more resilient to external economic and physical pressures and less likely to see community members 'left behind' during a disaster or downturn. Coastal resilience and development projects internationally are increasingly targeting women-owned seafood businesses with training and finance (in Tonga and Mauritania), requiring project participants to meet gender targets in hiring or civic participation (Caribbean), or supporting coastal households in making equitable financial and domestic decisions (Mozambique). Indonesia also has experience in such interventions, which could be scaled up.

… and new sources of finance.

Building resilience require new sources of financing

These interventions will require increases in both public and private investment. The estimated needs considerably exceed conventional funding sources (Tirumala and Tiwari 2020). There is considerable interest from the private, philanthropic, and development sectors in providing financing for marine and coastal activities, as demonstrated by recent market research. These sources of funds may be channeled via a range of 'blue' finance instruments, most of which involve some level of blending between public and private sources. While some instruments have been piloted, the field is relatively nascent. Possible instruments include blue bonds and impact funds, concessional loans, as well as equity and debt funds supported by guarantees. These opportunities require considerable policy and design work before funds can flow.



Integration and local decision-making underpin adaptation success.

An integrated response across ecosystems, fisheries, and communities, is needed

Given their complementarities, programs should work across the core areas of need—ecosystems, fishery management, and communities— in an integrated way wherever possible. To give one example of these complementarities, economic diversification through household finance and business support makes it feasible for households to reduce their reliance on marine and coastal ecosystems, facilitating their protection. For this reason, MMAF typically takes an integrated approach to the design of coastal interventions. The Oceans for Prosperity (*Lautan Sejahtera, LAUTRA*) Project is a good example of an integrated approach, with investments in businesses, livelihoods, and coastal small infrastructure, MPA strengthening, and measurement and management of coastal fisheries.

Community participation is also important

Community participation is also key. The diversity of Indonesia's coastal communities and the complexity of its fisheries and geography means that climate-resilience measures must be highly localized in their design and implementation. Fishery outcomes are much stronger in locations where site-level co-management is practiced (Fidler et al. 2022). This is not surprising. Habitat protection supported by education and awareness efforts, and backed by trusting and empowered community members, is likely to benefit from higher stewardship (and management capacity) than efforts without these elements. Expansion of customary marine tenure could further facilitate such localized approaches.

Climate resilience promotes development goals

Ultimately, climate resilience should not be considered separate from the wider development needs of coastal communities. Many activities recommended by this report contribute to Indonesia's short-term goals—including improving fisher's income, national fish exports, and stock status—while contributing to longer-term development aspirations. The ambition of the policy options is thus to help Indonesia's fisheries and coastal communities not only to *survive* but to *thrive*. That is, recommendations are chosen that provide benefits even if climate change impacts are less severe than expected. For this reason, they focus on the fundamental institutions and systems that underpin the fishery sector's management and productivity. Climate resilience will take time to develop. This report presents short- and medium-term actions toward this long-term goal. These actions can be refined over time through further research and on-the-ground experience.

Summary of Policy Options for Resilience

	Policy Option	Timeline *Key Government Agencies*
	Marine and Coastal Ecosystems Resilience	
1	**Adaptive and monitored spatial planning**: Beyond MPAs, spatial planning underpins coastal protection. Develop a scorecard to monitor and evaluate spatial plan implementation (akin to the MPA management effectiveness scorecard, EVIKA) that considers social, economic, and environmental outcomes. Develop an integrated system that links business permitting to spatial plans at the provincial level. Establish technical and financial support (incentives) for accelerated implementation of spatial plans (and longer-term spatial cadastres) by provinces, along with institutional arrangements for adapting spatial plans over time.	**Short-term priority** *MMAF, Bappenas, Provinces*
2	**Design options for climate resilience in the MPA network**: Identify climate refugia locations (i.e., high biodiversity or fishery productivity sites that will be relied upon by large numbers of species as habitat suitability shifts). These could be priority areas for future MPAs, which in addition to management upgrades in existing MPAs and broader spatial planning, will be the cornerstone for marine and coastal conservation. Explore legal and practical options for use of dynamic spatial planning in which MPA boundaries are shifted as species' key habitat areas move.	**Medium-term priority** *MMAF, MoEF*
3	**Data and research on ecosystems and climate change**: Establish and systematize long-term monitoring with defined sampling protocols for coral reefs, mangroves, and seagrasses that continue beyond any one individual monitoring project. This could utilize or build on the indices recently developed by BRIN. Complement physical measures with economic valuation of key coastal ecosystems and include valuation data within the Indonesian System of Environmental-Economic Accounts (SISNERLING). Further develop research capacity on climate change impacts on ecosystems. Assess the joint impacts of climate change with other human stressors (such as pollution and shipping) on Indonesia's marine ecosystems.	**Short- and medium-term priority** *MMAF, MoEF, BRIN, Provinces*
4	**Mangroves protection**: Expand the scope of license issuance moratorium in primary forest and peatlands to include mangroves and include mangroves in the national REDD+ framework to support carbon financing. Some exceptions to the mangrove moratoria could be made for high-value public interest development (e.g., critical infrastructure). However, these should be minimized. Ensure the value of mangroves is recognized in environmental impact assessment (AMDAL) preparation.	**Short- and medium-term priority** *MoEF, MMAF, Bappenas, Provinces*
5	**Systems for conservation financing**: Develop a provincial (pilot) or national-level system for collection of visitor fees in high-visitation MPAs, with transfer of a proportion of revenues to support MPAs that are unable to generate their own revenues (while allowing site management to keep a proportion of revenues to incentivize performance). This could be supported by transforming select MPA management units into Public Service Entities (Badan. Layanan Umum, BLU), similar to that used in Raja Ampat. A national or provincial endowment fund could further support MPA financing. The fund could be used to receive and distribute locally raised funds and additional contributions from philanthropy, development assistance, and private sector contributions.	**Medium- and long-term priority** *MTCE, MMAF, MOF, Provinces*
	Robust and Adaptive Fisheries Management	
6	**Fisheries management institutions**: The fishery management system—specifically the WPP system—is the "first line of defense" against climate impacts on fisheries. Continue advancing WPP operationalization by identifying and defining the full suite of roles and responsibilities within the system, update regulations, and increase budgets and human resources for its components (including implementing agencies, executive coordinator, and advisory bodies such as the *Lembaga Pengolaan Perikanan, LPP*).	**Short-term priority** *CMMAI, MMAF, Bappenas, Provinces*
7	**Harvest control rules and quota allocations**: A system that can quickly and fairly adjust fishing efforts in response to changes is fundamental to fishery management. Accelerate development and implementation of harvest control rules (including clearly defined limit and target reference points and input/output control mechanisms) based on the best available data. Continue developing sustainable quota fisheries, with allocations informed by harvest control rules (and subject to consolidation limits to prevent unfair quota accrual among a few operators). Explore options for quota allocations that reward provinces (or firms) with the best track records (e.g., high reporting compliance or bycatch minimization).	**Short-term priority** *MMAF, Provinces*

	Policy Option	Timeline *Key Government Agencies*
8	**Data and research on fisheries and climate change**: Continue expanding data collection on fisheries, including geographical and fleet coverage, and refine species information (notably species-specific stock assessments). Continue consolidating the existing multiple information systems within MMAF, including within *Pusat Data Statistik dan Informasi*. Invest in the capacity of local universities to collect and interpret fishery data (particularly those that participate in the WPPs). Explore low-data decision-making tools such as "fish baskets" and the FAO Fishery Performance Assessment Tool (FPAT), in which indicator species are used to determine the condition of a multi-species stock. Analytics on value-chain impacts (i.e., impacts on markets and processors beyond fish stocks themselves) may also be needed.	**Medium- and long-term priority** *MMAF, BPS, BRIN, Provinces*
9	**Dynamic fishery management**: While season-to-season quota allocations responding to changing stock conditions (adaptive fishery management) will be the basis for a well-managed fishery sector, dynamic measures—short-term forecasting of fish stock conditions that guides fishers in daily or weekly fishing decisions—will become increasingly important. This is a long-term capacity requirement that can be strengthened through international research collaboration.	**Long-term priority** *MMAF, BRIN*
10	**Safety at sea**: Further develop early warning weather forecasting capability, with a focus on systems for delivering regular weather updates to fishers through handphone text messages and satellite- or GSM-based vessel monitoring systems (VMS). Forecasting may require increased deployment of remote monitoring buoys. Low-cost weather and text communications systems can be incorporated into VMS. This provides opportunities to improve management and safety simultaneously: VMS inform management and enforcement activities (by monitoring fishing activity), with their use potentially incentivized through the delivery of free weather and communications for smaller vessels that otherwise lack these capabilities. They also provide a means for locating vessels in emergencies.	**Medium-term priority** *MMAF, BRIN, BMKG*
11	**Cost recovery mechanisms**: Well-designed mechanisms can raise revenues while also incentivizing behaviors aligned with fishery management outcomes. These include using auctions for allocating fishing privileges and raising revenues, supporting management objectives, e.g., preferential allocation to vessels meeting certain criteria (e.g., independently verified sustainability credentials), or taxing undesirable fishing gears due to their environment impact. Research and design work on such mechanisms would be valuable.	**Medium-term priority** *MMAF, MOF*
	Coastal Communities and Economies	
12	**Coastal livelihoods and business support**: Promote diversified livelihoods and business growth in coastal communities through business skills-building and access to finance programs. Training and business promotion in activities outside of fishing could support efforts to reduce pressure on marine or coastal resources. Design support programs that diversify, rather than deepen, fishing dependency. Expand unconventional financing opportunities for small businesses and households, including those based on non-collateralized loans and loan guarantees (or loans based on unconventional forms of collateral, such as fishing boat deeds) and invoice and cash flow -based lending products.	**Short and medium-term priority** *MPWH, MMAF, MOF, Provinces*
13	**Customary marine tenure**: Explore options for a legal framework that can define marine resources privileges and responsibilities at the local level to expand the current *Hak Pengelolaan Perikanan* approach beyond traditional communities. Integrate customary marine tenure within spatial planning and permitting systems to the extent the current legal framework allows.	**Medium- and long-term priority** *MPWH, MMAF, MOF, Provinces*
14	**Social protection for fishers**: Explore options for parametric insurance (paid on expected losses rather than assessed losses) for fishers' losses from storms. Launched in 2019, this approach was first used in the Caribbean Oceans and Aquaculture Sustainability Facility (COAST). The parametric approach could be expanded to pre-registered fish vendors and processors over time, and long-term could also consider marine heatwaves. In the short term, continue expanding social security access for fishers through existing programs.	**Medium- and long-term priority** *MPWH, MMAF, MOF, Provinces*

1

Introduction

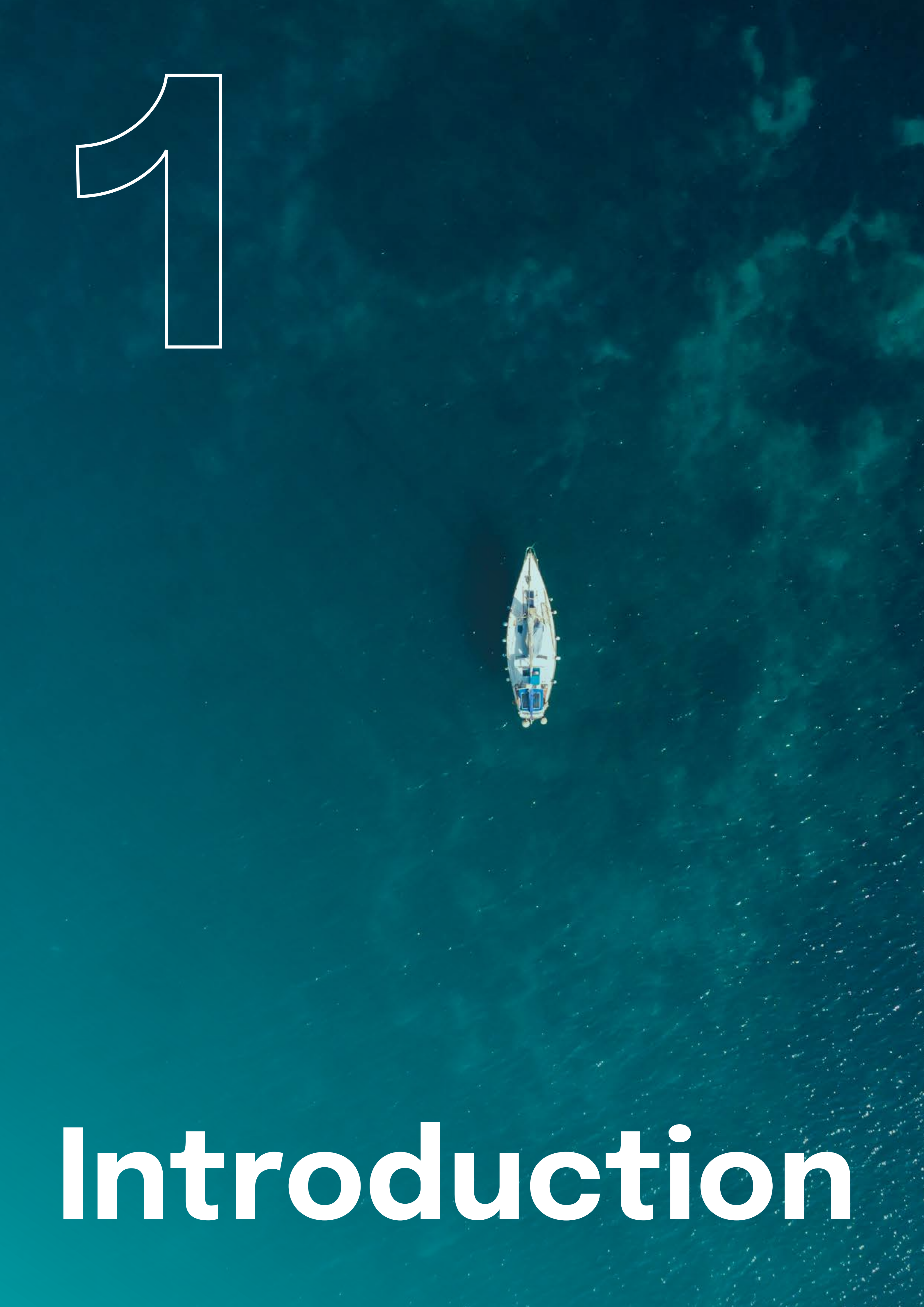



Photo: ©freepik.com

Mentawai Island, West Sumatra
Photo: © freepik.com

1. Introduction

Climate change will play a large part in determining the future of Indonesia's ocean economy.

The ocean's economic contribution will be impacted by climate change

With more than 17,500 islands, 108,000 kilometers of coastline, and three-quarters of its territory at sea,[4] Indonesia's prosperity is intimately connected to its oceans. Indonesia's oceans support more than US$180 billion of economic activity annually (PENSEA 2018).[5] Yet, with the effects of climate change set to increase, the future of Indonesia's oceans is uncertain. Low-lying areas across Indonesia are susceptible to storms and sea level rise while rising temperatures damage coastal ecosystems of high economic and ecological value. These and other effects of climate change pose challenges to the ocean economy across the vast Indonesian archipelago.

Climate risks are heightened by the important role of Indonesia's fisheries

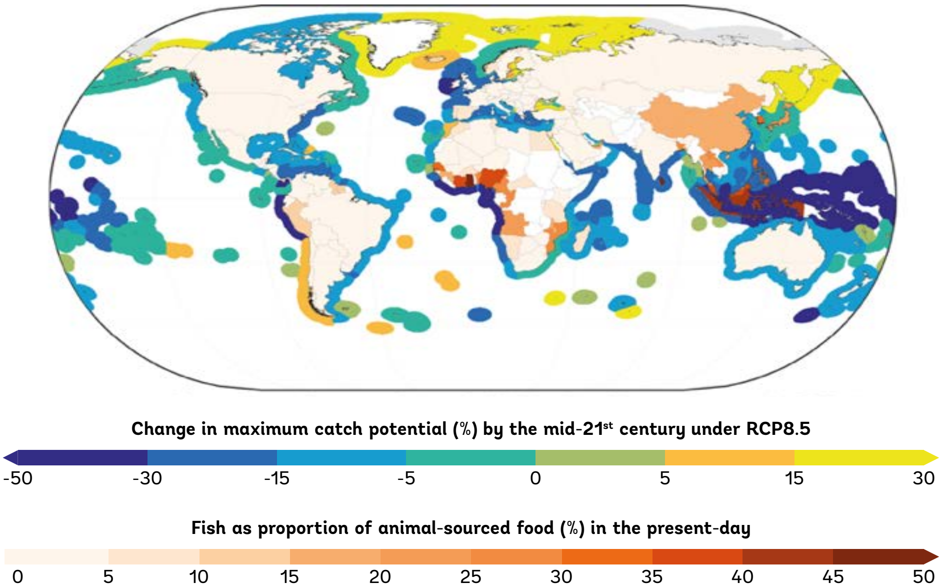
Indonesia's fisheries are at the center of these challenges. The sector contributes US$26.9 billion annually to the national economy (around 2.6 percent of GDP) (BPS 2020), supplies over 50 percent of the country's protein, and contributes over 7 million jobs (WTTC 2020; World Bank 2021). This dependence on fisheries means that climate change impacts on the sector will have implications for livelihoods, food security, economic growth, and the well-being of coastal communities. In global assessments, Indonesia ranks among the highest of all countries on the national importance of its fisheries. At the same time, Indonesia ranks among the highest countries for the predicted impacts of climate change on those fisheries (Cheung et al. 2016; Barange et al. 2018; Lam et al. 2020) (Figure 1).

4 Statistics from reference data by the Coordinating Ministry of Maritime Affairs and Investment (CMMAI).

5 Based on 2015 data. Sectors comprising this total include fisheries, marine and coastal tourism, sea-based transport, energy and minerals, marine manufacturing (e.g., shipbuilding, salt production), marine and nearshore construction, and government oceans-related expenditure. The sector has likely grown significantly since this assessment.

Figure 4: Estimated climate impacts on fisheries and dependence on fisheries for food security globally

Projected changes in maximum catch potential by 2050 (2041-2060) relative to 1986-2005 under a high emission 'no mitigation' scenario, and the dependence of countries on fish as a source of food.



Source: Golden et al. (2016). Representative Concentration Pathway (RCP) 8.5 represents the high emissions scenario. RCPs are trajectories for greenhouse gas concentrations adopted by the IPCC. RCP8.5 should be considered an upper bound on climate impacts (see Box 3).

Climate challenges are inherently development challenges

A productive fishery sector is a key development imperative. Indonesia has laid out ocean-related development goals in the national medium-term development plan *(Rencana Pembangunan Jangka Menengah Nasional*, RPJMN 2020-24) in line with the country's long-term aim of reaching high-income status by 2045. The government seeks to contribute to this goal in the fisheries sector through increased production, sustainably managed stocks, and higher value-add through public and private investment. Meanwhile, coastal communities will require diversified income opportunities and protection from climate change's physical and economic impacts. The challenge of trying to increase productivity, sustainability, and livelihoods in the context of climate change is a challenge faced by many sectors, as well as by many countries of all levels of income (Box 1).

Indonesia is responding with climate-sensitive policy and strategy

This development imperative is well-recognized in Indonesia. The government is taking steps towards a more climate-resilient future for its marine and coastal economy through investment in infrastructure, technology, capacity building, and governance. Strategies and actions underway are outlined in the *National Climate Adaptation Roadmap*, the *Enhanced Nationally Determined Contribution* (NDC), and the *List of Priority Locations and Climate Resilient Actions* by the Ministry of National Development Planning (Bappenas). Implementation of these actions is being prioritized by the Ministry of Marine Affairs and Fisheries (MMAF), including actions that improve resilience through healthier ecosystems and stronger communities. Many of these actions also contribute to Indonesia's "blue-economy" strategy, articulated by the Oceans Policy of 2017 and the RPJMN 2020-24. A blue-economy strategy is an integrated approach to ocean policymaking based on science and data, coordination across ocean sectors, and the participation of diverse stakeholders (World Bank 2017a).

Lampung, Sumatra
Photo by Devi Puspita Amartha Yahya on Unsplash

This report provides the first national-level assessment of climate risks to fisheries…

Translating these development strategies and goals into specific adaptation measures relies on detailed and reliable evidence. Research is needed that can predict changes in fish stocks and inform management steps to reduce risks. Similarly, businesses and other stakeholders must understand trends and risks to make sound investments. This report aims to provide this knowledge. The report begins by introducing Indonesia's fisheries, its governance structure, and the ecosystems that sustain them. These are the building blocks of a productive and climate-resilient fishery sector. Drawing on advances in climatological and ecological modeling, the report then quantitively links projected climate changes to Indonesia's ocean conditions, and fishery abundance and distribution. It does so by drawing on cutting-edge oceanic modeling techniques—applied previously at global and regional scales by researchers at the University of British Columbia, the World Bank, and partner institutions (see World Bank 2019)—and now applied at sub-national scales for the first time.

… and provides policy options that contribute to both economic and climate goals.

These impacts are explored in the context of differing fishery management approaches, and differing levels of community development and vulnerability levels across Indonesia. The report emphasizes that climate resilience is just one outcome of robust fisheries management, i.e., a co-benefit of institutional investments that deliver more economically productive fisheries irrespective of climate outcomes. Well-managed stocks (i.e., with biomass within target ranges) are those that are most productive and can be fished at the lowest costs, as well as those best able to adapt to the effects of climate change. Continued investment in Indonesia's fishery management capacity and institutions—a process already well underway—thus represents a 'no-regrets' policy direction. Reflecting this finding, the report provides policy options for a transition to a climate-resilient future for Indonesia's fisheries and coastal communities, supported by examples from international experience.

Box 2. Indonesia's Climate Vulnerability and Readiness: A Global Comparison

While global comparisons suggest areas for improvement, Indonesia is gradually trending upwards in climate readiness. The Notre Dame-Global Adaptation Index (ND-GAIN) summarizes countries' vulnerability to climate change and other global challenges and their readiness to respond to impacts. It draws on global datasets for an internationally comparable (although approximate only) indication of where countries stand. It quantifies vulnerability through indices that capture climate impacts in six areas: food, water, health, ecosystem service, human habitat, and infrastructure, while it captures readiness (i.e., the country's ability to leverage investments and convert them to adaptation actions), by considering indices of economic performance, governance, and social systems.

The ND-GAIN Index ranks Indonesia as the 73rd most vulnerable to, and the 106th most ready for, climate change, with a vulnerability score of 0.446 and a readiness score of 0.31 (Figure B1.1 and B1.2). These scores place Indonesia around the global median. However, vulnerability is higher, and readiness is still lower than in many peer countries (those countries with similar economy size, income levels, and population). Since 2014, Indonesia's vulnerability has decreased slightly (in line with peers), while its readiness has been increasing (faster than peers).

Figure B1.1: Indonesia's vulnerability to climate impacts

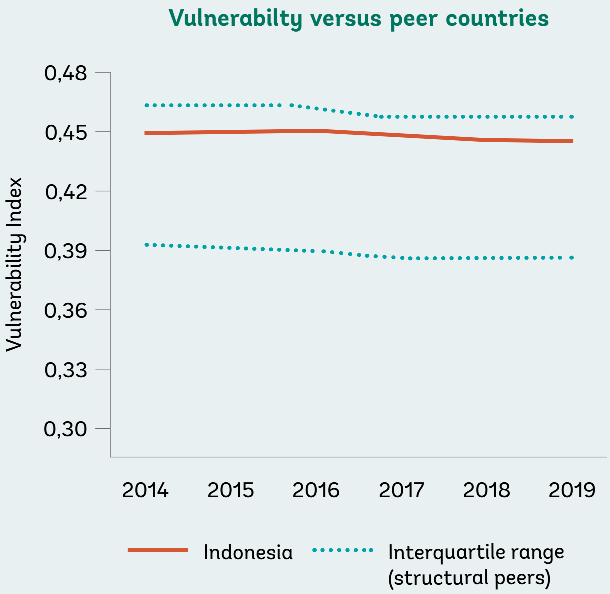
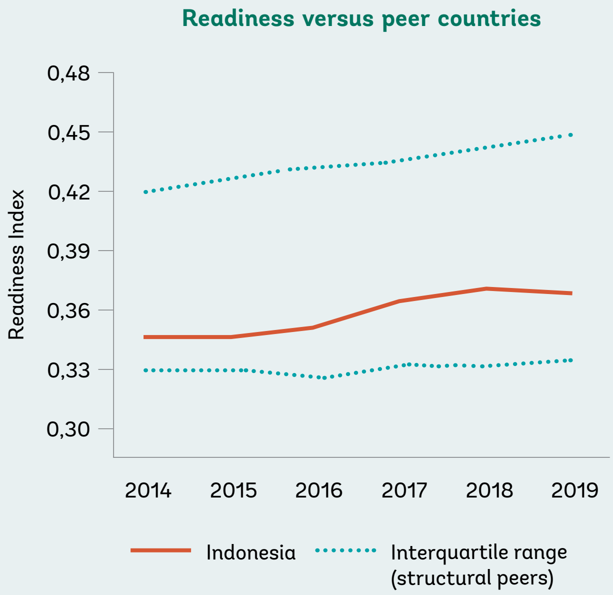


Figure B1.2: Indonesia's readiness for climate impacts



Notes and Source: Structural peers are Brazil, China, India, Thailand, Philippines, Mexico, Egypt, Russia, Iran, Nigeria, and Ukraine. These countries were selected for this analysis as they are the most statistically similar to Indonesia based on three variables: GDP per capita and total GDP (World Bank data). Vulnerability and Readiness data are from the Notre Dame Global Adaptation Initiative (2022).

Sectors that are most vulnerable to climate change include agriculture, water, health systems, and as shown in this report, fisheries. It should be noted that the breadth of the ND-GAIN Index means it cannot capture all dimensions of individual countries' vulnerability and readiness. In areas such as social protection systems and disaster risk management and financing, Indonesia has been making significant improvements that are not reflected in these numbers.

Source: World Bank Staff based on data from the Notre Dame Global Adaptation Initiative (2022) (link).

2

Indonesia’s Fisheries


Photo by Jakob Owens on Unsplash

Belitung, Bangka Belitung Islands
Photo by Vive Vio on Unsplash

2. Indonesia's Fisheries

2.1. A Complex and Critical Sector

Indonesia relies on its fisheries for economic growth and coastal livelihoods.

Indonesia's fisheries are complex and economically important

Fisheries play an important role in the national economy. Indonesia has the sixth-largest ocean area (as measured by its Exclusive Economic Zone, EEZ). Depending on the year, it has the second or third largest marine fish catch after China and Peru, at over 6 million metric tonnes (Figure 5). Aquaculture contributes a further 4.95 million tonnes (FAO 2019). The harvest supports exports valued at over US$4 billion per year—an important source of foreign exchange—while also sustaining livelihoods and food security domestically. Capture fisheries employ approximately 2.7 million workers, while an additional 1 million workers are employed in the processing and marketing of fisheries products (CEA 2018). Fish contribute 52 percent of all animal-based protein in the national diet (FAO 2011; Oktavilia et al. 2019).

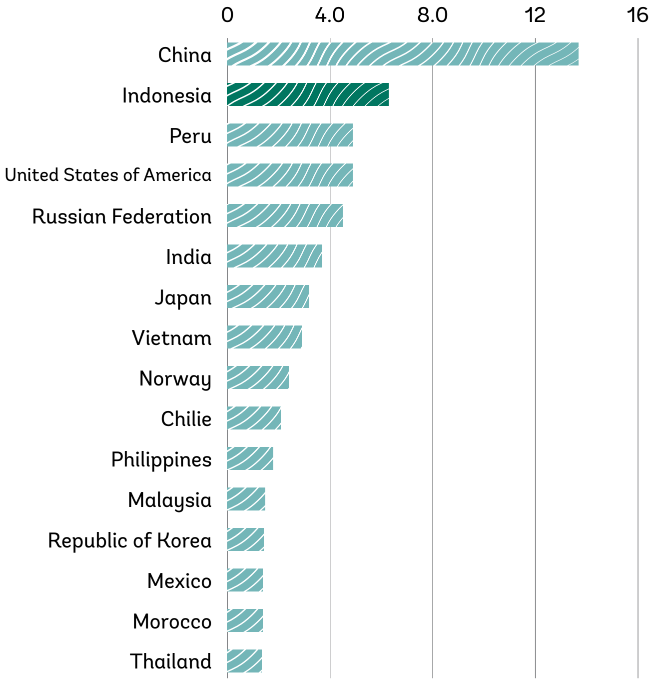
The small-scale sector dominates a complex socio-economic system

The sector is highly complex in terms of both fisheries and people, with hundreds of species caught and traded by a vast armada of small and large vessels. Small vessels (less than 10 gross tonnes) account for over 90 percent of the total ~600,000 vessels, and contribute around half the total catch (CEA 2018).[6] A significant portion (~71 percent) are considered non-motorized and are either small craft with outboard engines or no engine at all. The gears used and the species caught vary widely. The small-scale fleet targets small and large pelagic and demersal species, reef fishes, mollusks, and shellfish. The large-scale commercial fleet is relatively small (~4 percent of the total fleet) but contributes significantly to overall production. The most important commercial species, skipjack tuna (*Katsuwonus pelamis*), account for the largest portion of Indonesian fisheries' landings and value.

6 Law 7/2016 on the Protection and Empowerment of Fishermen, Fish Raisers and Salt Farmers defines small-scale fishers as those who catch fish for daily needs, without or with vessels smaller than 10 gross tonnes.

Figure 5: Global marine capture production by major producer countries

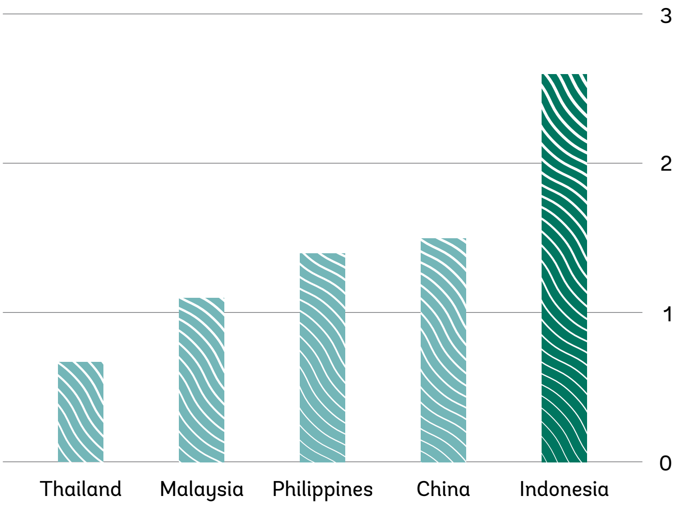
2015-18 avg. annual marine capture production, million tonnes



Source: FAO 2019.

Figure 6: Fisheries as a proportion of GDP versus regional peer countries

Fisheries sector value as a percent of total GDP



Sources and note: China, Indonesia, and Thailand (2016) from CIEC 2019; Philippines and Malaysia (2015) from SEAFDEC 2019.

Figure 7: Spatial variation in Indonesia's catch

Areas of highest and lowest catch throughout the Indonesian archipelago.

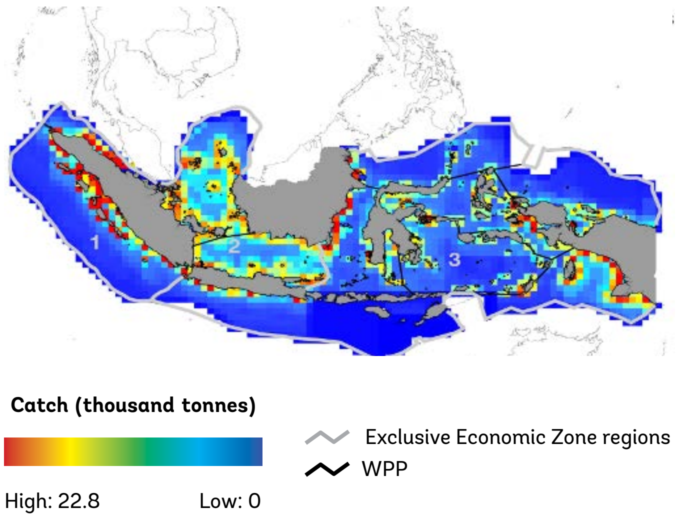
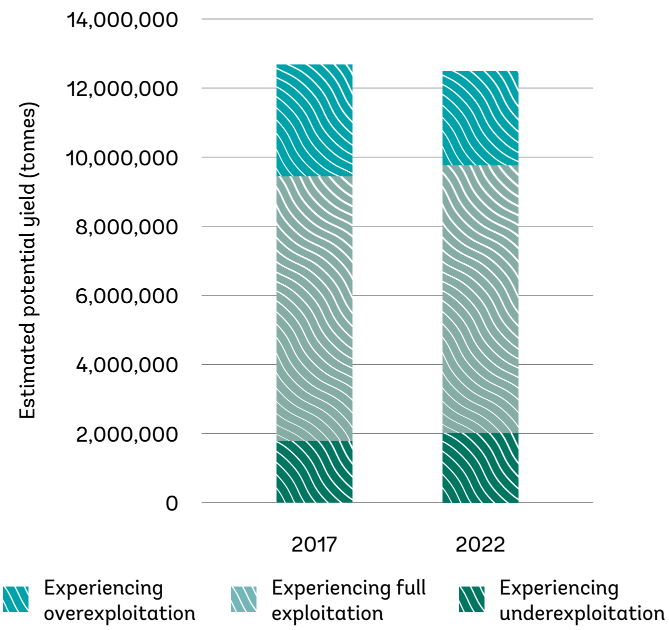


Figure 8: Status of Indonesia's fisheries, 2017-2022

Volume of stocks (estimated annual potential yield) by stock status classification.



Notes and Source: Stock status data from MMAF (50/KEPMEN-KP/2017; 19/KEPMEN-KP/2022), compiled by authors. Reconstructed catch data by location from Sea Around Us (SAU) database based on data from FAO and MMAF. This represents large-scale catches for which vessel monitoring system and logbook data are available. Small-scale catches are not reflected.

Management of such a complex sector is challenging, but improving

The complexity of Indonesia's fisheries means that management is highly challenging and likely to become more so under climate change. The resource is vast and varied. Stocks and vessels cross jurisdictions, and different classes of vessels fall under the responsibility of different levels of government. Small vessels are exempted from licensing and sometimes go unregistered and unmonitored. While under the jurisdiction of provinces, small vessels sometimes operate beyond provincial waters. As a result of these and other challenges, some fish stocks continue to suffer from overfishing, which undermines fisheries revenues, export earnings, and coastal community livelihoods (Pomeroy et al. 2007; Muawanah et al. 2012). In 2022, 35 fisheries were considered to be experiencing overexploitation, while 44 were being fully fished (exploited at their maximum productivity) (Figure 8). However, the trend since 2017 shows an improvement, with a reduction in fisheries experiencing overexploitation stocks and an increase in fully exploited stocks. Management improvements and enforcement actions against illegal foreign fishing have contributed to these improvements.[7] As explored in section 3.3, stock status is critical in the context of climate change, with impacts relatively more severe on stocks facing overexploitation.

The decentralized system for management is being strengthened

Institutional improvements to fishery management are progressing. As discussed in sections 3 and 4 of this report, these improvements will be central to boosting climate resilience. Recognizing the challenges of fishery management coordination across provincial boundaries, in 2014, the MMAF launched the system of *Wilayah Pengelolaan Perikanan (WPP)* or Fisheries Management Areas (FMA).[8] Each WPP contains multiple provincial governments plus industry and community stakeholders. These groups are represented within the Fishery Management Unit *(Unit Pengelola Perikanan (UPP)*, responsible for advising management decisions within that WPP. This structure aims to empower local governments, researchers, NGOs, communities, and the private sector in data collection and decision-making and balance interests between levels of government (Jaya et al. 2022). Such area-based management approaches have successfully achieved high levels of sustainable production in Canada, New Zealand, Australia, Peru, and the United States, among other countries (Hilborn et al. 2021). Indonesia's system is still being built by MMAF and other stakeholders, with a budget for operations and staff, offices, and equipment gradually increasing. Fishery management plans (*Rencana Pengelolaan Perikanan, RPP*) have been developed. A key next step will be to develop harvest control rules that link stock conditions to the level of permissible fishing effort (with specific reference points). Lines of authority within the WPP structure are being clarified over time, along with the co-management arrangement between provincial authorities and the central government. Full operationalization of this system is a commitment in the RPJMN, and as discussed further in section 3.3, will be the first line of defense against climate change impacts in the fishery sector.

7 Actions taken by the MMAF to combat illegal foreign fishing led to an estimated 25-40 percent reduction in total effort on fish stocks in Indonesia's waters between 2014-19 (Cabral et al. 2018).

8 Marine and Fisheries Ministerial Decree 18/PERMEN-KP/2014 defines the structure of and roles within the fisheries management area system. (link)

Gili Trawangan, Gili Indah, North Lombok Regency
Photo by Uber Scuba Gili on Unsplash

2.2. Fisheries' Foundation: Marine and Coastal Assets

The productivity and climate resilience of the fishery sector is a function of Indonesia's sensitive ecosystems.

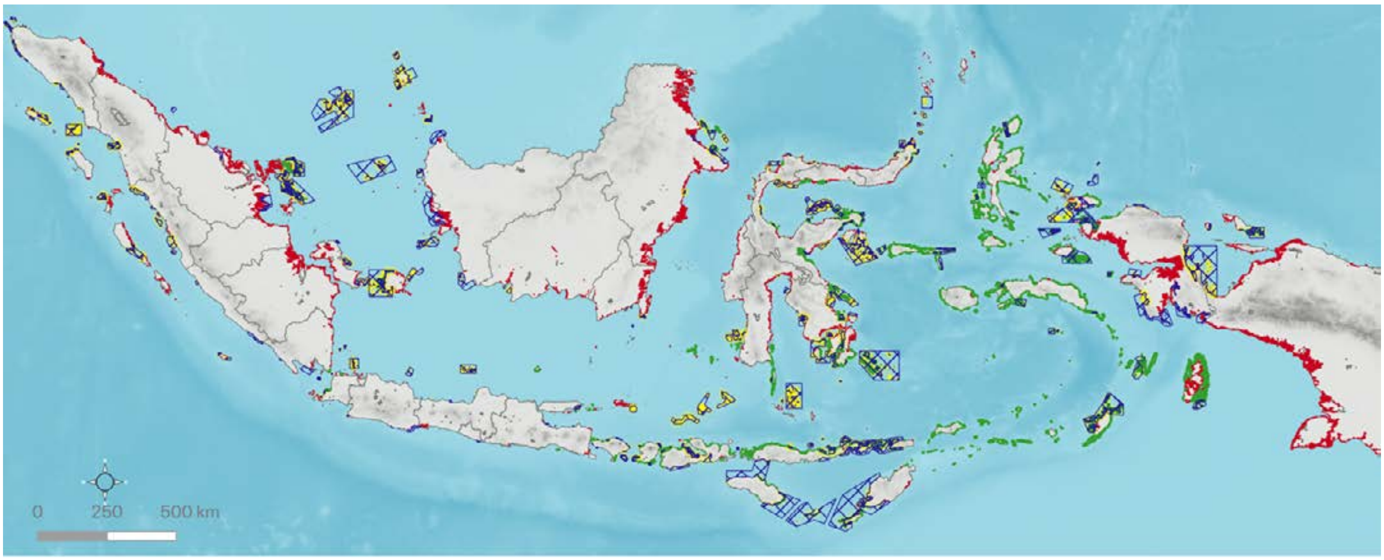
Indonesia's marine and coastal habitats are some of the richest in the world

Mangroves, coral reefs, seagrasses, and other climate-sensitive ecosystems underpin the productivity of Indonesia's capture fisheries and further support coastal communities through tourism, aquaculture, and physical protection of infrastructure. The country's mangrove area is the world's largest and most biodiverse, with 3.31 million hectares accounting for over 20 percent of the global total (MoEF 2019). Reefs span a combined area of over 2.4 million hectares[9] and provide a home to over 3,000 fish species and 590 coral species (the greatest reef biodiversity of any country) (Hutomo and Moosa 2005; Froese and Pauly 2022). While data on seagrasses are limited, these ecosystems too are considered some of the richest and most extensive of their kind worldwide (Unsworth et al. 2018). Across a range of climate-sensitive ecosystem types (Figure 9), Indonesia is a global hotspot of natural ocean wealth.

9 World Bank staff calculations based on LIPI data, with support from the Global Program on Sustainability (GPS).

Figure 9: Key concentrations of marine and coastal ecosystems across Indonesia

Major areas of key coastal ecosystems (mangroves, seagrass, and coral reef) and designated marine protected areas.



Marine protected areas | Mangroves | Coral reef | Seagrass

Sources: Map produced by authors using seagrass data from the Geospatial Information Agency (GIA), National Agency for Research and Innovation (BRIN), The Nature Conservancy (TNC), Coral reef data from BRIN (2007) and GIA (2009), mangrove from MoEF (2018) and marine protected area extents from MMAF.

These assets underpin the fishery sector but are themselves at risk

These ecosystems play a crucial role in fish species' feeding and breeding cycles, which is important for Indonesia's commercial catch and food security. They are also filtration systems, removing pollutants from runoff and remove disease-causing fish pathogens and pollutants from the water (Lamb et al. 2017). While studies to-date are limited, estimates suggest that reefs alone provide a fishery value of over US$2.9 billion per year (UN Environment 2018) to Indonesia. However, these ecosystems are under pressure from coastal development, destructive fishing practices, and land-based pollution. More than half (i.e., 1.82 million out of 3.31 million hectares) of the mangrove areas are currently in degraded condition (MoEF 2019). As much as 40 percent of Indonesia's original seagrass cover may have been lost (Unsworth et al. 2018).

Climate change exacerbates these risks

Climate change is adding to the stresses on these ecosystems. Increased water temperatures cause coral bleaching, with over 80 percent of Indonesia's reefs expected to experience bleaching five years out of 10 by the 2030s (Burke et al. 2012). Increased carbon dioxide concentrations are increasing the acidity of oceans (explored in section 3.1), weakening calcified coral structures. Greater runoff from more intense precipitation is increasing local water pollution and turbidity (Ridwansyah et al. 2020). Marine heatwaves, caused by localized elevated sea surface temperatures, pose threats to mangroves and seagrasses, is also discussed further in the next section.

Management is key to strengthening ecosystem resilience

While the global temperature impacts of climate change are, for the most part, beyond Indonesia's control, management systems can and are working to alleviate some of these compounding stresses. The national and sub-national governments are implementing coastal and small islands marine spatial plans (RZWP3K) as part of the country's broader spatial planning framework (*Rencana Tata Ruang Wilayah, RTRW*). Indonesia's Marine Protected Area (MPA) network is expanding, with over 23 million hectares reserved or gazetted (exceeding the Aichi targets[10]), and is on track to reach 30 million hectares by 2030. MMAF has implemented a scorecard system (EVIKA) across MPAs to provide a consistent means of tracking management effectiveness. Rehabilitation activities are underway towards a national mangrove restoration target of 600,000 hectares by 2024, the largest such effort in the world. These will go some way towards protecting the foundations of productive fisheries in Indonesia and improve resilience to increasing climate impacts. This report returns to further possibilities for climate-sensitive ecosystem management in section 5.

10 Aichi Target 11 of the Convention on Biological Diversity calls for countries to effectively conserve at least 10 percent of coastal and marine areas by 2020.

Indonesia's Marine Protected Area (MPA) network is expanding, with over 23 million hectares reserved or gazetted, and is on track to reach 30 million hectares by 2030.

3 The Climate Challenge

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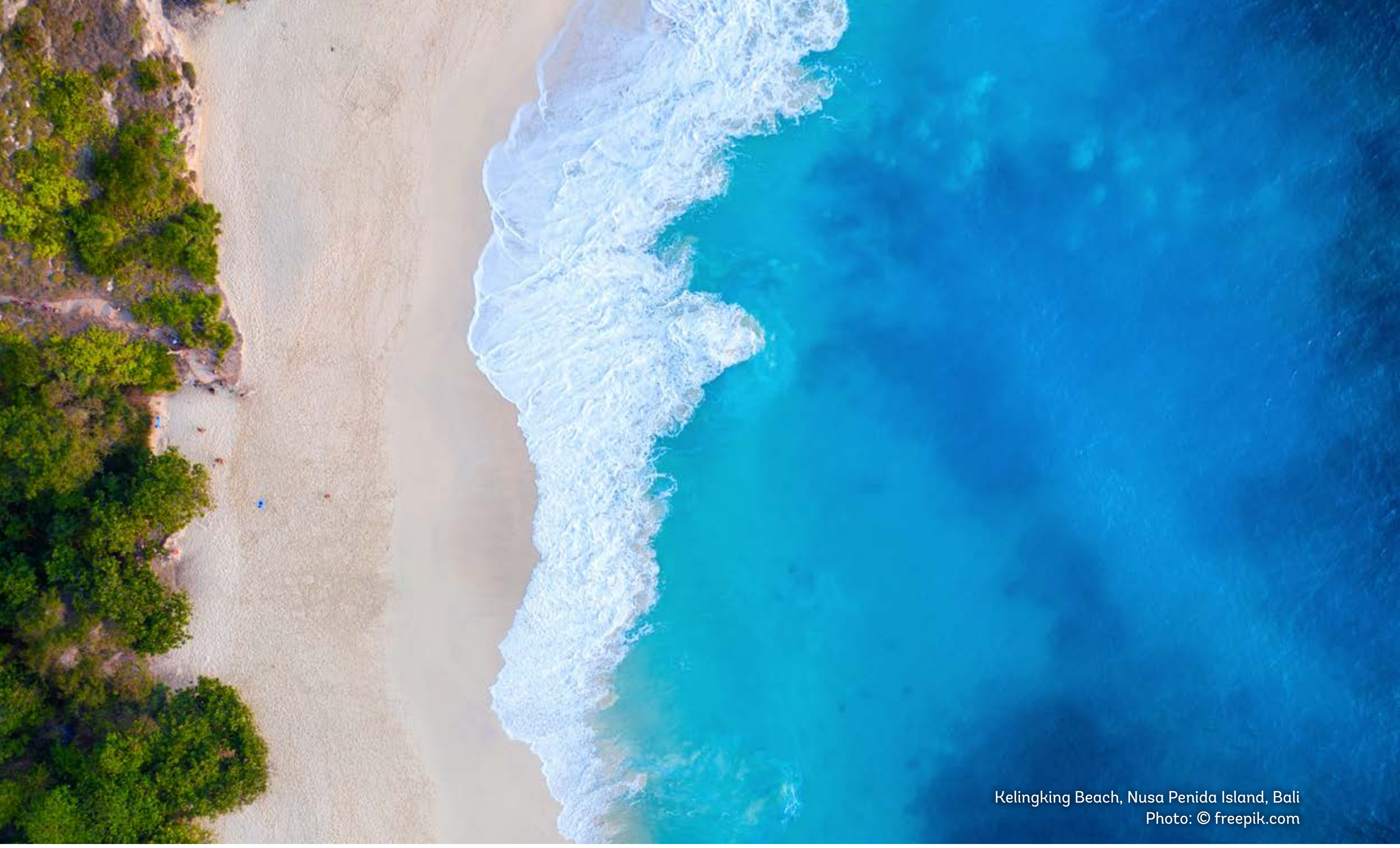


Kelingking Beach, Nusa Penida Island, Bali
Photo: © freepik.com

3. The Climate Challenge

3.1. Impacts on Indonesia's Oceans

As global temperatures increase, Indonesia's oceans are changing.

Indonesia's oceans have warmed by over half a degree C. since the 1980s.

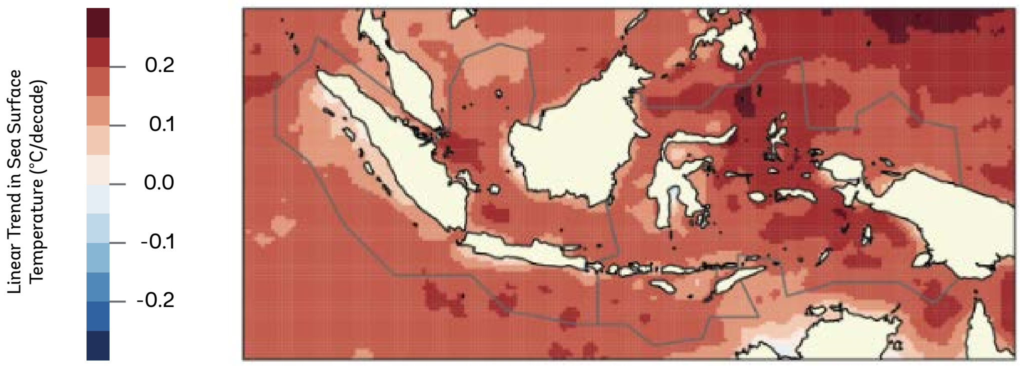
Over the past three decades, Indonesian oceans have warmed substantially. Satellite data analyzed for this report indicate that sea surface temperatures have increased by 0.18°C, 0.16°C, and 0.15°C per decade in Eastern, Central, and Indian Ocean EEZs, respectively, since 1982 (Figure 10). The total observed average temperature change to date is over half a degree Celsius. More severe but temporary spikes are also becoming apparent. During the strong El Niño events of 1997-98 and 2015, sea surface temperatures greatly exceeded the long-run average conditions in all subregions. Sea surface temperatures have increased in all regions, with the strongest increase observed in the open ocean (> 0.2°C increase per decade), with warming in coastal regions relatively less severe (< 0.1°C per decade) (Figure 11).

Figure 10: Temperature increase in Indonesia's oceans

Sea surface temperatures (°C) averaged over EEZ subregions, 1982-2019.

Figure 11: Hotspots of warming in Indonesia's oceans

Map of local linear trends in sea surface temperatures (°C), 1982-2019.



Notes and Source: Authors' analysis based on data from Coupled Model Intercomparison Project, Phase 6 (CIMP6).

Warming is projected to further increase substantially...

The projections for further changes to the temperature of Indonesia's ocean are severe. Averaging across the projections made by the set of climate models used for the IPCC reports,[11] the surface air temperature average over the Indonesian region is projected to increase by 4.2°C ± 0.9 between 1850-1900 and 2081-2100, under the SSP5-8.5 (high global greenhouse gas (GHG) emissions) scenario. This means a change from a historical average of 27°C to more than 31°C. Under a scenario with mitigation measures (SSP1-2.6) (low global GHG emissions), the annual mean surface air temperature is projected to increase by 1.6°C ± 0.4 over this period (Figure 12A). These figures can be considered likely upper and lower bounds on temperature change, respectively (Box 3), and are slightly below the projected global change.[12] The associated sea surface temperature changes are from 1.39 (± 0.39) to 3.68 (± 0.86) °C under the low and high scenario, respectively relative to preindustrial levels.

11 Data are derived from the Coupled Model Intercomparison Project, Phase 6 (CIMP6) which are the basis for global climate change projections in the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC).

12 Global warming is expected to be relatively less severe at high latitudes (Indonesia) and more severe at low latitudes (Canada). However, as this report explains in the next section, this does not imply lesser impacts on fisheries.

… leading to short-term temperature spikes (marine heatwaves)

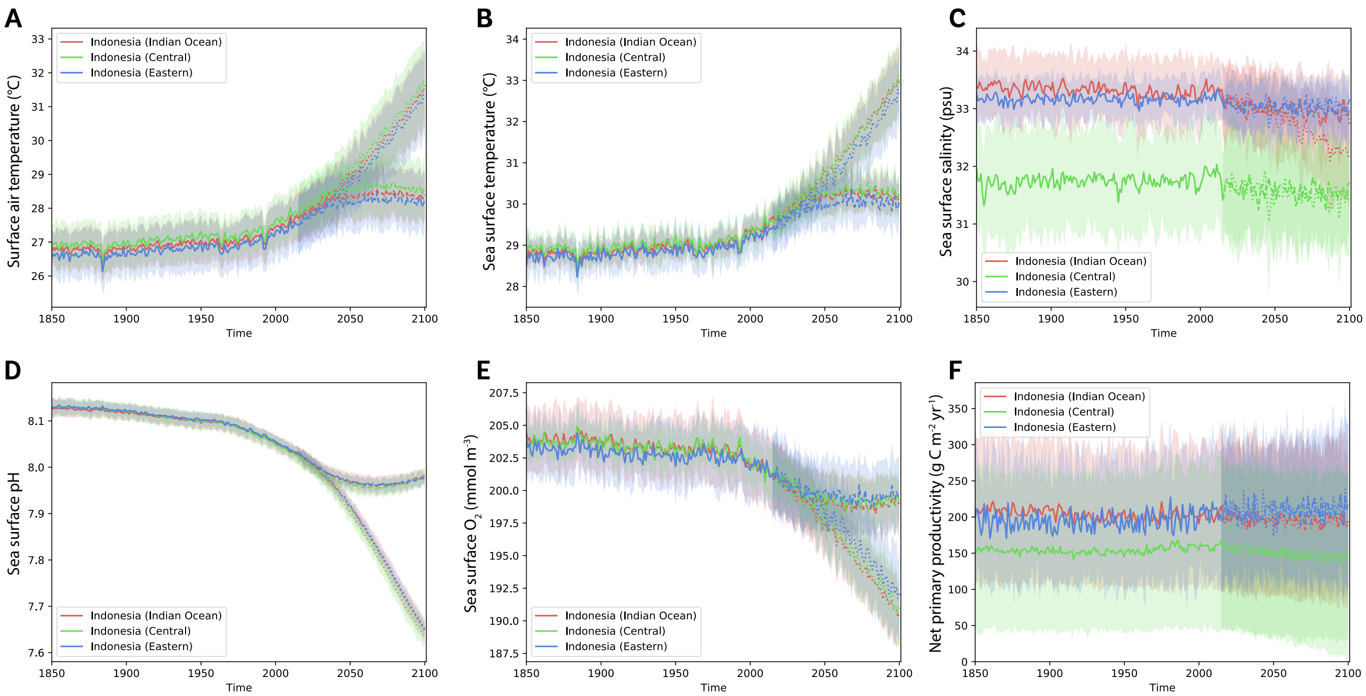
Short-term fluctuations and localized variation, such as those seen in marine heatwaves will punctuate these long-term changes trends. These short-term hot temperature spikes last from a few days to months and globally have roughly doubled in frequency over the past three decades (Frölicher et al. 2018). Defined by a temperature above the 90th percentile of the historical average, marine heatwaves in Indonesia are projected to intensify. Modeling for this report suggests periods of marine heatwave with temperatures of 2-10 degrees C above normal (the climatological mean) by 2030, and up to 16 degrees above normal by 2050, under the high GHG emissions scenario. The length of these heatwaves is expected to increase from a typical 1-6 months in the 2000s to 11-12 months by 2050. Experience suggests that these are likely to arrive during strong El Niño and decreased monsoon activity (as seen in 1998 and 2016) (Iskander et al. 2021). Marine heatwaves place pressure on critical coastal ecosystems, manifesting in symptoms such as the death of marine invertebrates (which play an important role at the bottom of the food chain), coral bleaching, and mangrove dieback, hindering these ecosystems' support for fisheries.

… and changes in Indonesian ocean's oxygen levels, pH, and productivity.

Yet climate impacts are not only about heat. Changes in temperature drive other changes in ocean conditions, with major implications for fisheries. Climate modeling for this report shows that surface-level pH, oxygen, and salinity are declining in Indonesian waters as warmer temperatures reduce the physical exchange of gases between the ocean and atmosphere (Figure 12). Mixing processes within the ocean's depths is changing, leading to reduced salinity and oxygen levels. Meanwhile, higher levels of carbon dioxide concentrations in the atmosphere and water increase carbonic acid formation in the water, reducing pH and damaging coral reef structures and shellfish. These conditions may also undermine the net primary productivity (NPP) of oceans—their basic ability to generate biomass from sunlight and nutrients—although projected changes in this outcome are less certain.

Figure 12: Projected physical and chemical changes in Indonesia's oceans

Changes in (A) surface atmospheric temperature (B) sea surface temperatures, (C) surface ocean salinity, (D) surface ocean acidity (pH), (E) surface ocean dissolved oxygen (O2), and (F) net primary production (NPP) within Indonesia's three different EEZ subregions, 1850-2100.



Notes and source: Surface atmospheric temperature is averaged over 90°W-145°W and 15°S-10°N. Values are anomalies relative to the 1850-1900 reference period. The lines show multi-model annual means, and the shaded areas represent ± one standard deviation across the models. Solid lines show the historical (1850-2014) and SSP5-8.5 scenario time series (2015-2100). The dotted lines indicate the SSP1-2.6 scenario time series from 2015 to 2100.

Box 3. Climate Scenarios used in this Report

To evaluate the pathways associated with potential changes in greenhouse gas (GHG) emissions, two representative concentration pathways scenarios are applied for each environmental variable. The first scenario, RCP2.6, represents a relatively good outcome for the planet, with rapid decreases in greenhouse gas emissions by major emitting countries. Emissions start declining in 2020 and reach zero by 2100, with consequent radiative forcing (the extra energy trapped by the atmosphere for each square meter of land) peaking at 3 Wm-2 before 2100 followed by a decline to 2.6 Wm-2 by 2100. The second scenario (RCP8.5) is a "worst-case" emissions scenario, with emissions rising throughout the century. Radiative forcing reaches 8.5 Wm-2 by 2100.

Neither scenario is likely in itself, but they bookend likely climate outcomes from above and below, thus covering the likely range of outcomes. Global emissions are on track to exceed the RCP2.6 scenario, while the falling cost of renewables and accelerated policy action by governments means that RCP8.5 is also now unlikely (although adverse feedback loops could still cause this outcome). The planet is on track for an outcome between these extremes, with recent estimates suggesting around 3 degrees of warming by 2100 based on the Paris Agreement emissions pledges.

Source: Authors.

3.2. Implications for Indonesia's Fisheries

Climate-induced changes in ocean conditions will drive large shifts in Indonesia's fisheries.

Temperature changes shift fish stocks to new locations

Changes to Indonesia's oceans are directly impacting the biology, ecology, and, ultimately, the catchability of exploited fisheries. The internal temperature of most fish depends on the surrounding water temperature; a change in water temperature influences their internal chemistry and biological processes, such as reproduction and feeding. The geographic distribution of species thus changes as stocks attempt to remain in locations suitable for each species. The impact of temperature change on species distribution and abundance is particularly dramatic in tropical countries such as Indonesia, which have waters already at the high end of global temperatures. High initial temperature implies adjustment by the movement of stocks towards cooler waters, leading to a net decrease in fisheries abundance in Indonesia without inflows of new (higher temperature) species from elsewhere.

Impacts are observable on some fish stocks already

Impacts on fisheries are already being observed. Indonesia's bigeye tuna catch decreased between 1997 and 2010 consistent with climate impacts, thought to be due to a reduction in phytoplankton abundance (Lumban-Gaol et al. 2012). Productivity of the *Sardinella lemuru* fishery in the Bali straight has decreased significantly over the past decade, with the largest dips in catch-per-unit effort seen following the high ocean temperature conditions in 2010 and 2016. Again, the abundance of phytoplankton appeared to be the critical pathway (Puspasari et al. 2019). The fishing area for flying fish (Exocoetidae Sp.) appears to be migrating from Sulawesi to West Papua. The trends are complex at local scales, with short-term countervailing outcomes. For example, the positive Indian Ocean Dipole event of 2019 increased phytoplankton biomass and small pelagic fish production in Indonesian waters (Lumban-Gaol et al. 2021). Localized and short-term increases in some fisheries have and will continue to occur even in the face of longer-term projected decreases.

Box 4. Climate Impacts on Fisheries: A Summary of Modeling Methods

This study uses three complementary methods to analyze the effect of changing ocean conditions on fish stocks. These are applied to a selection of 54 "focal species" of 47 fish and 7 invertebrates, including shrimp, skipjack tuna, and sardinella species critical to the industrial and artisanal fisheries of Indonesia. Species were selected based on the 40 species with the greatest catch volume, cross-referenced with databases of commercially important species within Indonesia (see Annex 1).

1. **Assessment of climate risk on individual species.** The first stage of analysis determines those species most vulnerable using a fuzzy logic climate index. Climate risk is determined by three components: exposure, sensitivity, and capacity to adapt. Exposure is the distribution of a given species (across ocean conditions—temperature, oxygen levels, pH, net primary production). Sensitivity is the degree to which that species' biological function is affected by those condition changes (maximum length, temperature preference, and taxonomic group). Adaptive capacity is the ability of species to respond and adjust (proxied by fecundity, bathymetry range, latitudinal range, and habitat specificity). Exposure variables are sourced from earth systems model projections (see section 3.1); sensitivity and adaptive capacity parameters are drawn from life-history and ecological data in the *FishBase*, *SeaLifeBase*, and the *Sea Around Us* databases. These determine a relative-risk value from 0 to 100 for each species, with 100 indicating a species with the highest risk of disappearing from Indonesian fisheries (see Cheung et al. 2018; Jones and Cheung 2018 for detail on the index).
2. **Assessment of change in species distribution.** The second stage of analysis considered how species' distribution would change within Indonesia's waters. The future distributions of the focal marine species are modeled using an environmental niche approach (Austin 1985) that quantifies environmental preferences of marine species (based on their current observed distribution and average environmental conditions within that distribution from 1971 to 2000). This is used to project their potential distribution following environmental change, quantified by a Habitat Suitability Index (HSI) following established methodologies (Reygondeau 2019). The HSI ranges from 0 (the species cannot survive) to 1 (the species is in its optimal environment) and is calculated for each species in each spatial cell. To address uncertainty, a multi-model approach is adopted to best approximate the environmental niche of each species. Pelagic species are modeled using surface variables, benthic species using sea bottom environmental variables, and demersal species using both sets of environmental data (gathered from *FishBase*).
3. **Assessment of impacts on fishery harvests.** The third stage of analysis projects changes in maximum catch potential for exploited marine fishes and invertebrates. A Dynamic Bioclimate Envelope Model (DBEM) simulates changes in distribution, abundance, and potential catches of species based on the ecological niche and biology of the species (see Cheung et al. 2016 for details). Population carrying capacity in each spatial cell varies with habitat preference (see HSI calculation, described above). The model simulates changes in relative abundance of a species in each grid cell at each time step based on changes in population carrying capacity, intrinsic population growth, and the advection-diffusion of adults and larvae in the population driven by ocean conditions projected from the Earth system models. Maximum catch potential (a proxy of maximum sustainable yield, MSY) from each population is predicted by applying a fishing mortality rate at the level required to achieve maximum sustainable yield. Changes in total annual maximum catch potential by mid-century (2050: 2041-2060) and relative to 2000 (1991-2010) under SSP1-2.6 and SSP5-8.5 is calculated for each subregion, based on averaged projected conditions from the three Earth system models.

Source: Authors.

Shallow water demersal species will be most affected

Longer term, all species assessed for this report (a total of 47) are projected to be affected by climate change to some extent, with some species more affected than others. The projected most impacted species are demersal species (those that live or feed near the bottom) and neritic-pelagic species (the top ocean layer close to the coastline), and include Mangrove red snapper (*Lutjanus argentimaculatus*), Toli shad (*Tenualosa toli*) and Indo-Pacific king mackerel (*Scomberomorus guttatus*) (Table 1). Their narrow distribution and specialized ecology make them highly sensitive to climate variation. These are important stocks for artisanal and industrial-scale fisheries in Indonesia. The risk of disappearance of these species from local waters[13] is projected to be very high for key Indonesian species compared to globally exploited species.

13 Disappearance within Indonesia's waters, not total extinction. Species' range is expected to shift to cooler climates.

Table 1: Focal species at the highest risk of disappearance from Indonesian fisheries

Species		Risk Index		
Scientific name	Common name	Central	Eastern	Western
Tenualosa toli	Toli shad	93	92	92
Lutjanus argentimaculatus	Mangrove red snapper	90	85	90
Scomberomorus guttatus	Indo-Pacific king mackerel	90	85	90
Carcharhinus limbatus[a]	Blacktip shark	89	85	90
Epinephelus tauvina	Greasy grouper	89	84	89
Aphareus rutilans[b]	Rusty jobfish	89	83	89
Lutjanus malabaricus[c]	Malabar blood snapper	89	87	89
Euthynnus affinis	Kawakawa	88	84	88
Scomberomorus commerson	Narrow-barred Spanish mackerel	87	83	88
Megalaspis cordyla	Torpedo scad	88	86	88
Plectropomus leopardus	Leopard coral grouper	87	-	88
Dussumieria acuta	Rainbow sardine	87	82	87
Rastrelliger brachysoma	Short mackerel	87	81	87
Epinephelus areolatus[d]	Areolate grouper	85	78	86
Selaroides leptolepis	Yellowstripe scad	84	78	85
Thunnus tonggol	Longtail tuna	85	82	85
Parastromateus niger	Black pomfret	83	80	84
Thunnus alalunga	Albacore	84	75	-
Thunnus maccoyii	Southern bluefin tuna	84	84	-
Thunnus obesus	Bigeye tuna	83	74	84

Notes and source: Risk assessment by authors based on a fuzzy logic climate index (see Box 4). Risk is assessed under SSP5-8.5 but expected to be similar in relative terms (but lower in absolute terms) under more moderate climate scenarios.

Arafura, Timor, and Banda seas will be most affected

There is variation in the degree of impact among different regions. More negative impacts in habitat suitability and, thus, higher species turnover is projected in the Arafura, Timor, and Banda seas and the Indian Ocean coast by mid-century and beyond, relative to recent historical levels (1981–2000) (Figure 13). The environment in these regions will be less favorable for species with narrow distributions, which will consequently need to migrate as climate conditions change. Relative to other regions, no or few climate-driven invasive species are expected to move into these regions, as there are no or few species tolerant of the more extreme ocean conditions projected for these regions. No regions within Indonesia's waters are projected to see a net increase in habitat suitability.

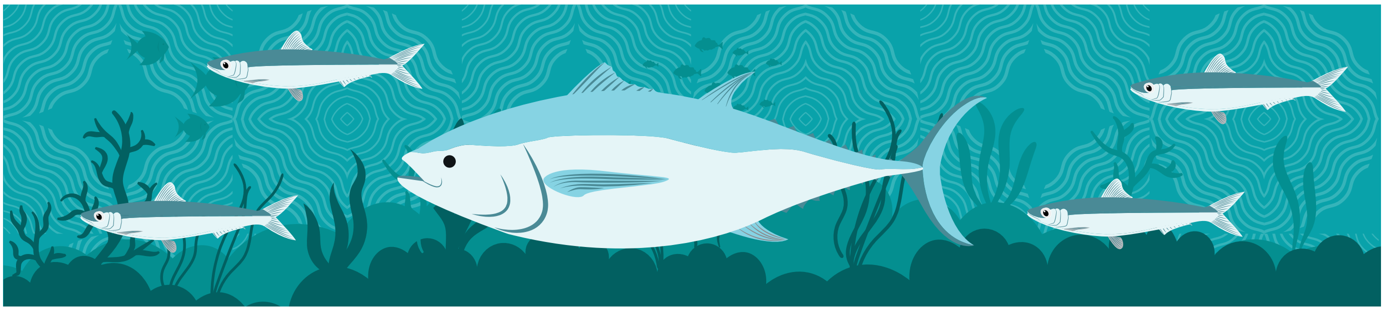
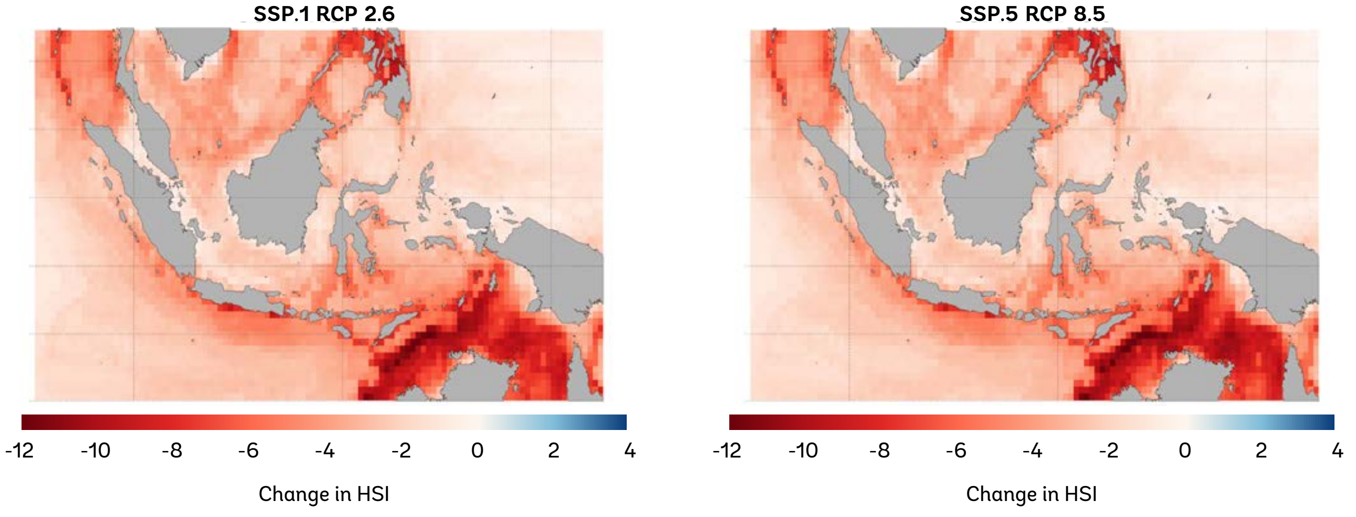


Figure 13: Change in habitat suitability for fish species in Indonesia's waters

Change in the sum of the habitat suitability index (HSI) by mid-century (2041-2060) under SSP1-2.6 (left) and SSP5-8.5 (right) scenarios.



Notes and source: Map of the change in the sum of the HSI (averaged across Earth system models and species distribution models). HSI is normalized by current species richness.

Average maximum catch potential is projected to decline by 20-30 percent under a high climate change scenario.

Decreased habitat suitability is projected to reduce the overall productivity of Indonesian fisheries (Figure 14). The total maximum catch potential of the focal species is projected to decrease by 20 to 30 percent under the high emissions scenario relative to 2010 (1991-2010) across the three subregions by 2050. Maximum catch potential declines further after 2050 under the high emission scenario. Affected species include those critical to small-scale pelagic fisheries such as yellowstrip and Bali sardinella (*Sardinella gibbosa* and *S. lemuru*), which are projected to have more than 30 percent declines by mid-century under the high emission scenario. Several large pelagic species of importance to commercial catches are also projected to have large declines, including torpedo scad (*Megalaspis cordyla*), mackerels (*Scomberomorus commerson* and *S. guttatus*), and skipjack tuna (*Katsuwonus pelamis*).

Declines under a low climate change scenario are also considerable before 2050.

Notably, these declines are not confined to a high climate change scenario only. The low climate change scenario (SSP1 RCP2.6) has large impacts on total catch potential by 2050 (up to 20 percent decreases, and 5-15 percent decreases in most regions). Impacts of this scenario level off as the global climate stabilizes, with mild further decreases in the subsequent decades. Some commercially important species are relatively more resilient, too, with a smaller risk of impacts and declines in maximum catch potential. For example, silver pomfret (*Pampus argenteus*) is amongst those species with relatively mild projected declines. Overall, the long-term declines in maximum catch potential under high and low scenarios have important implications for economic outcomes (explored in the next section) and food security, given Indonesia's dependency on fisheries for protein.

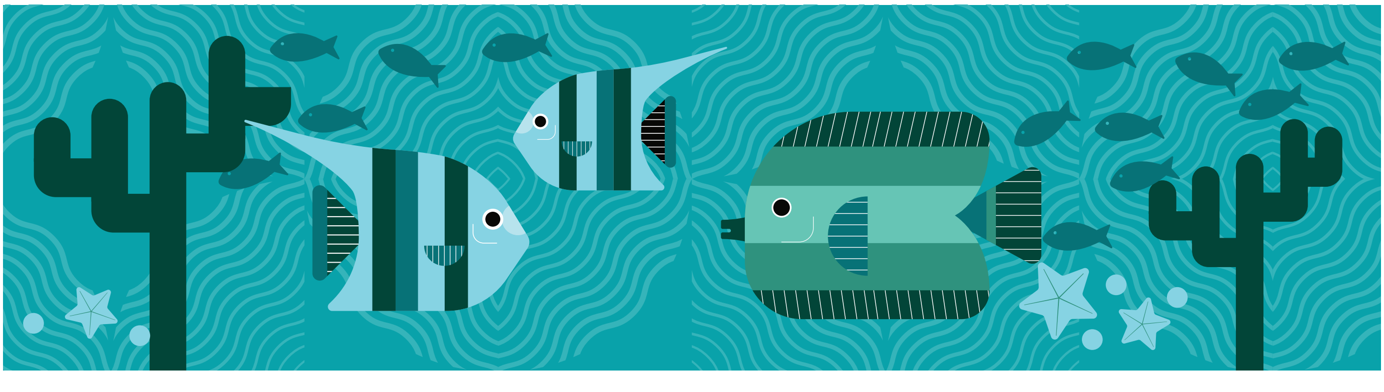
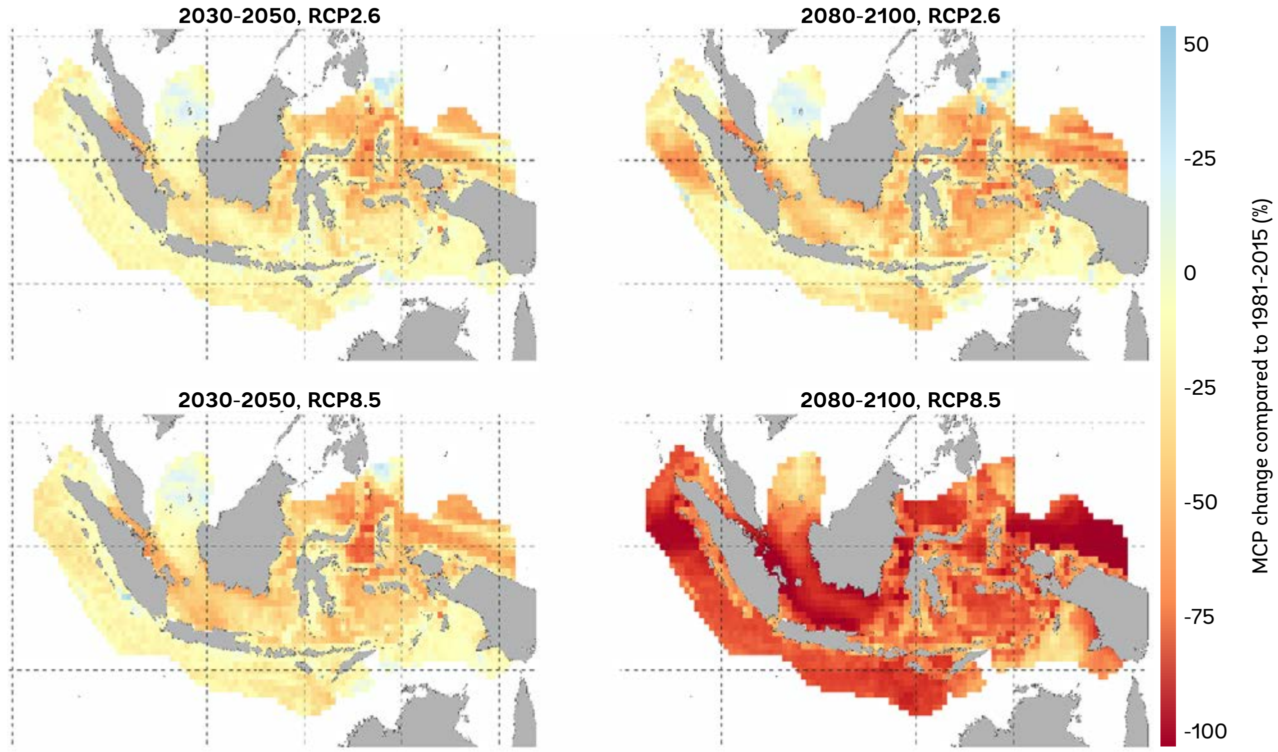


Figure 14: The projected catch of fish species in Indonesian waters under climate change

Change in maximum catch potential (MCP) by mid-century (2041-2060) and end-century (2080-2100) under SSP1-2.6 (top) and SSP5-8.5 (bottom) scenarios.



Notes and source: MCP change is relative to recent historical catch (1985-2015). Estimation by authors.

3.3. Economic Effects of Climate Change on Fisheries

Reductions in catch potential reduce revenues but strong management can offset some losses.

Climate change is expected to decrease economic returns to fisheries by 15-26 percent by 2050.

The impacts of climate change on fisheries can be calculated in economic terms.[14] This report estimates the change in fisheries revenues,[15] variable fishing costs,[16] and overall economic returns under different climate change and management scenarios. In line with the projected reductions in catch discussed in the previous section, total fisheries revenue across the Indonesian EEZ is projected to drop by 15 and 27 percent under the low (SSP1-2.6) and high (SSP5-8.5) emissions scenarios, respectively, by 2050, in the absence of climate adaptation measures in management (explored further below). Falls in catch drive lower costs as well as lower revenues (due to decreased fishing activity), with the variable cost projected to drop by 10 and 21 percent under low emission and high emission scenarios, respectively. The resulting total economic returns (the difference between revenues and costs) are projected to decrease by 15 and 26 percent under low emission and high emission scenarios, respectively, with only minor differences between eastern, central and western regions (Figure 15 and Table 2).

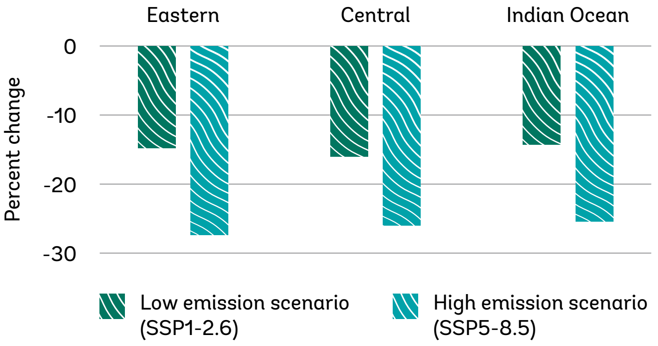
14 The method used for these calculations is elaborated in Lam et al. (2016).

15 Revenues are calculated as the product of the species' ex-vessel price and projected maximum catch potential (reported in section 3.2). Real ex-vessel price (i.e., after adjusting for inflation) is kept constant throughout the projection period given uncertainties in future price projections. Real ex-vessel fish prices have remained relatively stable since 1970 (Swartz et al. 2012) although may increase in the future.

16 The variable costs of different fleet types in Indonesia were obtained from a literature review. Since fishing cost data comes in a variety of formats (cost per year or cost per trip, etc.), the variable cost to landed value ratio was calculated in each fishing sector (large-scale and small-scale), considering the fleet size and tonnage of the fleet (0.532 for large-scale, 0.399 for small-scale). Ratios were applied to the landed values of each taxon to calculate the fishing cost.

Figure 15: Projected change in economic returns to Indonesia's fisheries by region

Percentage change in economic returns (revenues less costs) by 2050 relative to current returns by region and climate scenario.



Source: Estimation by authors.

Table 2: Projected change in catch, fishing revenue, costs, and economic returns

Projected change relative to current conditions by 2050 (%), all Indonesian waters and fisheries.

	Catch	Revenues	Fishing Cost	Profit
Low emission scenario (SSP1-2.6)	-13.1	-14.8	-14.6	-15.0
High emission scenario (SSP5-8.5)	-25.7	-26.5	-26.4	-26.6

Source: Estimation by authors.

The small-scale fleet will be affected slightly more than the large-scale fleet

Impacts differ slightly between large-and small-scale fleets. Economic returns for the small-scale sector drop by 17-19 percent under the low emissions scenario, and 28-29 percent under the high emissions scenario, across the three regions by 2050 relative to returns at present. These estimates conservatively assume that fishing effort remains at a level conducive to maximum sustainable yield throughout this time, i.e., there is no overfishing. Economic returns within the large-scale fishing sector drop by 13-14 percent under the low emissions scenario and 24-27 percent under the high emissions scenario across the three regions.

Climate effects interact with fishery management effectiveness

While these effects are substantial, climate change is not the primary determinant of a fishery's productivity. Fishing effort levels, which are controlled by the management regime, are also critical. High effort levels (overfishing) cause short-term increases in catches and thus increased revenues, but over the long term, reduce the size of the stock and thus its productivity. Effort levels also affect fishing costs, with greater effort leading to higher costs. Similarly, depleted stocks imply higher fishing costs as the few remaining fish become harder to find. Management directly affects these factors. Management determines the objective of the fishery—for example, to maximize the volume of production for food security or maximize economic returns—and provides the tools to enforce fishing effort levels consistent with that objective. Most fisheries in Indonesia are benchmarked against the maximum sustainable yield (MSY, equivalent to maximum potential catch). As described in section 1, many of Indonesia's key stocks are close to this target because gradual improvements to Indonesia's fishery management systems in recent years. Some are still experiencing overfishing.

Well-managed stocks have a buffer against climate impacts

These management outcomes interact with climate change. Overfished stocks can be expected to see a greater reduction due to negative climate change impacts than those currently underfished. A reduction in the maximum catch potential due to climate change reduces the optimal effort level relative to current effort levels, implicitly increasing overfishing. This is thought to have contributed to the collapse of the Northwest Atlantic cod (*Gadus morhua*) off the US and Canadian east coasts in the 1990s. Overfishing may have been occurring for years despite the fishery operating within harvest limits because those limits did not account for climate-associated declines in productivity (Pershing et al. 2015). This contrasts with an underfished stock, which has a "buffer."

Overfished stocks face large climate losses...

Projected economic losses under climate change are thus much worse under poor management. Overfishing by 20 percent above MSY causes projected losses in the small-scale sector of 28-30 percent in 2050 relative to present. This is under the low global emissions scenario. Losses are even greater under the high emissions scenario, or under more severe overfishing. Given the improving trends in Indonesia's fishery management outcomes (see Figure 8), and provided these trends continue, overfishing is unlikely to reach extreme levels. Yet, the results highlight the importance of avoiding even mild overfishing given the interaction that occurs between overfishing and climate change. Essentially, stocks are placed under severe pressure by climate change, even under the low emissions scenario, as demonstrated in section 3.2. Overfishing then pushes these stressed stocks to the point of near economic collapse.

... while conservative fishery management can partially offset losses in the small-scale sector...

By contrast, climate losses are partially or fully mitigated under highly conservative management. Keeping the total fishing effort in the small-scale sector at around 80 percent of MSY (in line with Indonesia's target catch rate) would shift climate losses from 16.7-19.3 percent down to 9.1-10.7 percent under the low emissions scenario. Notably, management improvements alone appear unable to fully offset small-scale losses (see Table 3, where more extreme restrictions do not improve outcomes further). Other measures will thus be required to offset losses in economic terms: a focus on small-scale value-add (i.e., improved market access and product quality), cost efficiencies in harvesting, and cash transfers for those who can exit the sector. Such policy options are elaborated in section 5.2.

... and fully offset losses in the large-scale sector under a low emissions scenario

In the large-scale sector, conservative management can, in principle, completely offset climate losses under the low emissions scenario. Economic returns are projected to be 4-6 percent greater than those received today under the most restrictive management regime, or on par with today's returns under a more modest management regime (Table 3 and Figure 16). An important consideration not fully accounted for in the modeling is spillover effects between the large-scale and small-scale sectors. If management quality improves significantly in the large-scale fleet, but corresponding improvements are not made in the small-scale fleet, small-scale fishing efforts may rise to take advantage of the "space" left by the restrictions on large-scale vessels. This would partially undermine the value of the management action. This applies only to stocks shared between the fleets. Management enhancements in both fleets together is thus important.

Table 3: Projected change in economic returns for small-scale and large-scale fishing sectors

Percentage change in economic returns (revenues less costs) by 2050 relative to current returns by sub-sector (small and large scale), region (Indonesia's eastern, central, and Indian ocean waters), climate, and management scenarios (fishing effort).

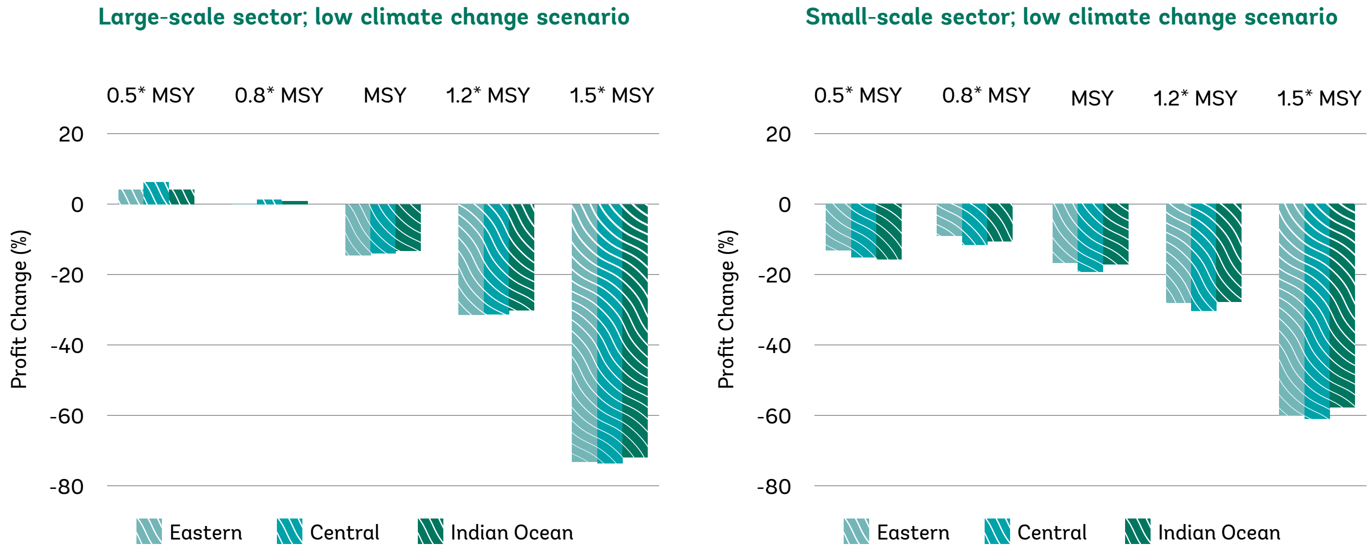
	Low emission scenario (SSP1-2.6)					High emission scenario (SSP5-8.5)				
Management Scenario (effort)	**0.5*MSY**	**0.8*MSY**	**MSY**	**1.2*MSY**	**1.5*MSY**	**0.5*MSY**	**0.8*MSY**	**MSY**	**1.2*MSY**	**1.5*MSY**
Small-scale fishing sector economic returns (revenues-costs)										
Eastern	-13.2	-9.1	-16.7	-28.1	-59.9	-25.0	-21.5	-28.0	-38.0	-65.5
Central	-15.2	-11.7	-19.3	-30.4	-60.9	-26.1	-22.9	-29.3	-39.1	-66.0
Indian Ocean	-15.8	-10.7	-17.2	-27.8	-57.7	-27.1	-22.5	-28.1	-37.2	-63.1
Large-scale fishing sector economic returns (revenues-costs)										
Eastern	4.2	0.1	-14.4	-31.4	-73.1	-11.5	-15.0	-27.2	-41.8	-77.2
Central	6.2	1.3	-13.9	-31.2	-73.5	-7.9	-12.2	-25.3	-40.5	-77.1
Indian Ocean	4.2	0.9	-13.2	-30.1	-71.8	-9.3	-12.2	-24.4	-39.1	-75.4

Source and Notes: Average fishing effort at present is assumed to be F_{MSY} (effort associated with MSY). Harvest above MSY implies overfishing (which for modeling purposes is assumed to be sustained, causing the fishery to become overfished). Author estimations.

Juwana, Pati Regency, Central Java
Photo by Alfi Hilman on Unsplash

Figure 16: Projected change in economic returns for small-scale and large-scale fishing sectors

Percentage change in economic returns (revenues less costs) by 2050 relative to current returns by sub-sector (small and large scale), region (Indonesia's eastern, central, and Indian ocean waters), and management scenarios.



Source: Estimation by authors. Low climate change scenario represented by SSP1-RCP2.6.

Climate change is expected to decrease economic returns to fisheries by 15-26 percent by 2050 in the absence of adaptation measures.

4

The Vulnerability of Coastal Communities

Kelingking Beach, Nusa Penida, Bali
Photo by Reinis Birznieks on Unsplash

Gili Trawangan, Gili Indah, North Lombok Regency
Photo: © freepik.com

4. The Vulnerability of Coastal Communities

The vulnerability of Indonesia's coastal communities is a function of environmental change and socio-economic conditions.

The way in which climate and fisheries impacts people depends on the socio-economic context

This report has so far considered a specific type of climate vulnerability: the physical and economic impacts of oceanic changes on fisheries. Indonesia's dependence on fishery resources—for export revenues, coastal livelihoods, and food security—means that this source of vulnerability is significant. However, the impact that changes in fisheries will have on the community and household well-being depends on many factors. Some communities will be able to weather dramatic changes in income and livelihood changes arising from one sector due to a diversified local economy, strong local institutions, good public services and infrastructure, high income, and education levels, or tight community bonds. Others lacking in one or more of these factors will feel the impacts of diminishing fisheries more severely.

Risk-factors include the level of dependency on fishery resources, diversity of the economy, and development level

Building on the results presented above, this report now considers those broader socio-economic factors to identify the most vulnerable areas of Indonesia. Vulnerability is commonly described as being a function of four dimensions: hazard, exposure, sensitivity, and adaptive capacity (IPCC 2007; Allison et al. 2009; Blasiak et al. 2017). (1) Hazard is the severity of climate change itself (e.g., temperature change or sea-level rise); (2) Exposure is the presence of people and ecosystems likely to be affected by climate impacts (e.g., coastal population, presence of major fisheries); (3) Sensitivity is the degree to which the exposed people will be impacted (e.g., due to dependency on fisheries for food security); and (4) Adaptation is the capacity of people and communities to adjust (e.g., functional village governance, high education levels). The combination of these factors determines climate vulnerability (Box 5).

Box 5. Quantifying Climate Vulnerability at National and WPP scales

This study quantifies relative vulnerability at national and fishery management area (Wilayah Pengelolaan Perikanan, WPP) levels. It uses a risk assessment framework from the IPCC Working Group II Fifth Assessment Report adapted for a specific focus on fisheries. The selected variables represent hazard, exposure, sensitivity, and adaptation capacity. A similar set of variables is used for national and WPP level assessments, with some substitutions based on data limitations when required.

Hazard (H)	Exposure (E)	Sensitivity (S)	Adaptation Capacity (AC)
• Projected turnover of marine species • Projected marine heatwaves • Climate disaster incidence	• Coastal population (no.) • Coastal villages (no.) • Projected change in max. catch potential (%) • Coral reef-dependent species (%) • Overfished stocks (%) • Presence and condition of mangroves	• Employment in fishing sector • Fish consumption per capita • Malnutrition rate (%) • Poverty rate (%) • Fishery value (% GDP) • Catch (tonnes)	• Health care centers (No.) • Schooling length (years) • University participation (%) • Governance index • Employment diversity index • Motorized fishing vessels (%) • Road development • Disaster preparedness

Scores for each variable were normalized to one and summed to arrive at a score for each of the four categories (Vulnerability = H+E+S-AC). No assumptions are made regarding the relative importance of each factor (i.e., each has the same weighting). Data at provincial level (e.g., coastal population) was aggregated to the national or WPP level. A country or WPP with a high vulnerability score is assumed to have (i) high exposure to climate change; (ii) high level of fisheries contributions to its economy and food security; and (iii) low ability to respond and adapt to climate risks.

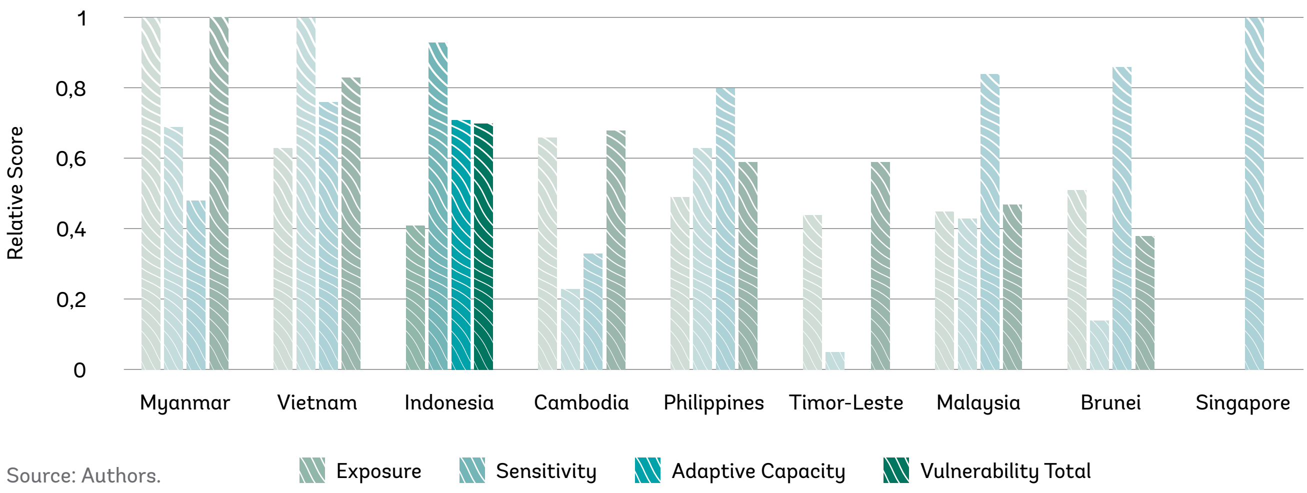
Source: Authors.

Indonesia ranks third in the Southeast Asian region for coastal climate and fisheries vulnerability

National level vulnerability assessment utilizes an existing national-level climate-fishery assessment drawing on the same techniques used in this report (but with a lower level of species and spatial specificity) (see Cheung et al. 2016a). These findings are integrated with published socio-economic indicators (see Box 4). Aggregated scores suggest that Myanmar, Vietnam, and Indonesia are the top three most vulnerable countries in the region (in that order) to the impacts of climate change on fisheries. The overall relative vulnerability of Indonesia is driven particularly by sensitivity (i.e., the importance of fisheries for livelihoods, meeting the country's protein needs, and export value). Indonesia's adaptive capacity (health, GDP level per capita, and governance) is mid-ranked against regional peers and has improved in recent years.

Figure 17: Regional comparison of vulnerability to climate impacts on fisheries

Relative scores (0-1) for exposure (and hazard), sensitivity, adaptive capacity, and vulnerability.
The top ranked country in the region receives a 1, the lowest a 0.



Source: Authors.

Climate hazard is greatest in WPP 714, 718 and 713

Country-level analysis provides a broad benchmark but little of the granularity required for policymaking. A more targeted approach considers the same variables at a WPP level, again combining the indices of hazard, exposure, sensitivity, and adaptative capacity to determine overall relative vulnerability for each WPP.[17] Doing so provides broad geographic guidance toward hotspots of climate concern. WPPs 713, 714, 571, and 573 appear to face some of the greatest underlying climate hazards (see Section 3.2), with hazards driven by a high rate of species turnover (particularly WPP 573 and 714), projected marine heatwave intensity and duration (particularly WPP 571 and 573), and elevated presence of climate disasters (particularly WPPs 714 and 713). These are areas where the greatest ecological change can be expected. Improved protection for marine and coastal ecosystems under stress and strengthening coastal infrastructure and local disaster risk management systems will be important in these areas.

Climate exposure appears greatest in WPP 711, 713 and 714

WPPs 711, 713, and 714 appear to face some of the greatest exposure to climate hazards based on these metrics. Scores are driven by high coastal population (WPP 713), high coastal population proportion (WPPs 714 and 715), elevated presence of overfished stocks (WPPs 711, 713, and 717), and dependency on coral-reef associated stocks (WPP 711, 713 and 714). Loss of maximum catch potential is projected to particularly affect WPPs 718 and 711, but also affects WPP 571 and 572 (zones that face less exposure on other metrics). Resilience will require continued focus on improved fishery management and measures to diversify coastal economies over the long-term.

Climate sensitivity appears greatest in WPP 714, 715 and 718; these areas' also have low adaptive capacity

WPPs 713, 714, and 718 appear to have elevated sensitivity to climate change. This is seen particularly in terms of elevated numbers of fishing households, income dependence on fisheries, and high fish consumption per capita (all evident in WPP 714, 715, and 718), along with the incidence of malnutrition (particularly WPP 714) and poverty (WPP 714 and 718). Adaptive capacity mirrors these results to some extent, with WPPs 717, 718, and 711 showing relatively low adaptive capacity. Yet results are mixed. Measures of adaptive capacity are broad and extend well-beyond coastal and fishery-related metrics and should be considered rough proxies of adaptation capacity only, generally reflecting regional development status. Health measures (health care centers in the village; life expectancy at birth) are relatively low in WPPs 717, 718, and 571, along with education metrics (length of schooling, university participation rates). WPPs 717 and 718 also stand out for low road development and disaster risk mitigation systems.

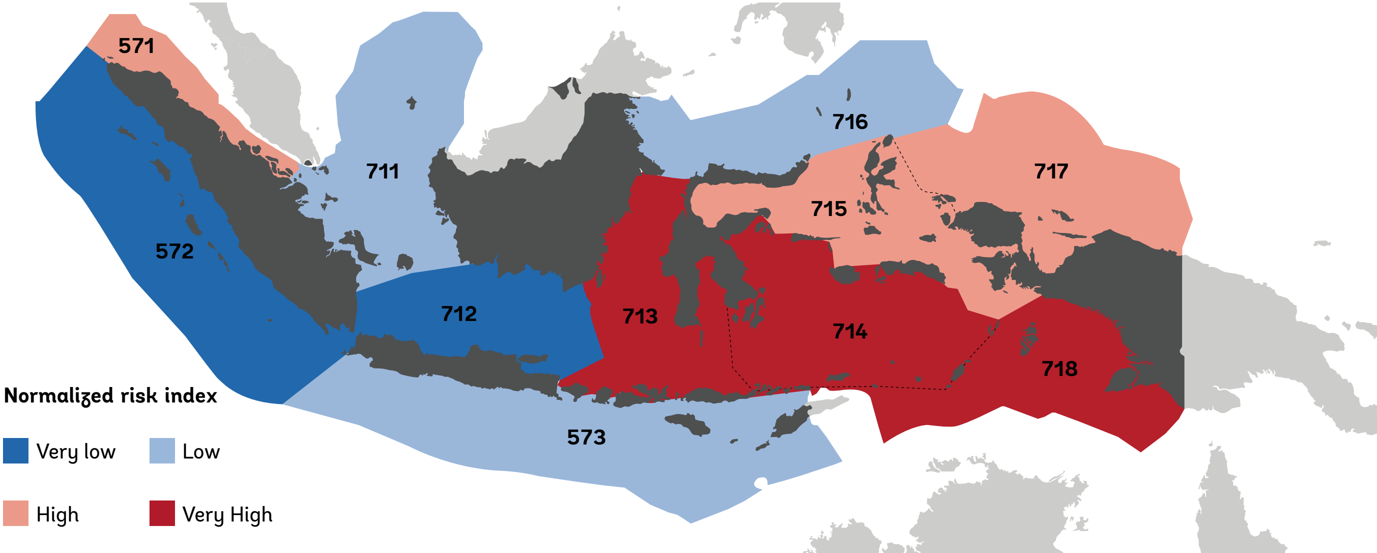
In aggregate, WPP 713, 714, and 718 are most vulnerable to climate impacts, although further research is needed

The combination of these factors suggests that WPP 713, 714, and 718 are the most vulnerable to the impacts of climate change on fisheries in Indonesia (Figure 18). These areas combine larger rates of projected change in fishery resources with high levels of dependence and reduced adaptive capacity. It is important to note that vulnerability assessments take a variety of forms, and the conclusions of any study depend on the indicators chosen to represent each vulnerability component. It is also important to note that the selected indicators reflect processes occurring on varied timescales, with socio-economic indicators signaling current conditions and fishery indicators reflecting a combination of current (e.g., overfishing) and future projected conditions (maximum catch potential). Development conditions will change as a function of economic growth, and Indonesia's long-term development goals and differentiated rates of development will eventually change the rankings presented in this section. Yet measures to increase adaptation capacity and reduce sensitivity and exposure are generally long-term propositions. Relative results based on current conditions indicate where investments and programs are most needed to drive development in ways that help mitigate both present and future vulnerability.

17 WPPs are ocean areas and thus not themselves vulnerable in a socio-economic sense. Our analysis uses WPPs as shorthand for the provinces and communities that border these WPPs and utilize their resources. The analysis combines ecological risks facing the WPP areas themselves (i.e., fisheries) with socio-economic risk factors of communities along their shores.

Figure 18: Comparison of aggregate vulnerability to climate impacts on fisheries by WPP

Relative vulnerability as a function of climate change exposure (and hazard), sensitivity, and adaptive capacity.



Source: Authors

Box 6. Impacts of Sea Level Rise on Indonesia's Coastal Communities

Indonesia is particularly exposed to sea-level rise (SLR), ranked fifth highest in population inhabiting low elevation coastal zones (Church, et al. 2013). By 2050, global sea levels are expected to rise between 0.24 m (0.17-0.32 m) under a low global emissions scenario (RCP2.6) and 0.32 m (0.23-0.40 m) under a high emissions scenario (RCP8.5) (Oppenheimer et al. 2019). This will accelerate erosion and flooding in Indonesia's coastal areas, possibly damaging mangrove ecosystems, aquaculture, agriculture, and infrastructure. Studies suggest health impacts from increased disease (e.g., malaria and dengue fever) are also possible, along with increased pressure on sanitation systems (Marfai 2014; Bappenas 2021).

The number of people exposed to coastal flooding is projected to grow. By the 2030s, around 9 million people in Indonesia could reside in a 100-year flood plain (an area exposed to 1 in 100-year coastal floods), growing to 14 million people by the 2060s (this compares to a baseline of 5.4 million people in 2000) (Neumann et al. 2015). These estimates assume a 10 cm SLR by 2030 and 21 cm SLR by 2060. Over 20.5 million people in almost 80 cities already live in high flood-risk areas (Figure B5.1). Flood damage modeling predicts flood damage costs of US$17 billion in 2030 (0.55 percent of GDP) and US$47 billion by 2050 (0.73 percent of GDP), up from US$1.2 billion (0.13 percent of GDP) in 2010.

Figure B6.1: Coastal flood risk map for Indonesia

Low	Low-medium	Medium-high	High	Extremely high
(0 to 9 in 1,000,000)	(9 in 1,000,000 to 7 in 100,000)	(7 in 100,000 to 3 in 10,000)	(3 in 10,000 to 2 in 1,000)	(more than 2 in 1,000)

Source and notes: Adapted from WRI Aqueduct Model (2019). Coastal flood risk measures the proportion of the population expected to be affected by coastal flooding in an average year, accounting for existing flood protection standards.

5

The Path Forward

Padar Island, West Manggarai Regency
Photo by Bagir Bahana on Unsplash

Halmahera, North Maluku
Photo by Kanenori on Pixabay

5. The Path Forward

5.1. Possibilities for Indonesia's Fishing Future

Climate change is a severe threat, but the worst of its effects are not inevitable.

Some level of climate change impacts are locked in

This report has presented a difficult diagnostic. Climate change impacts on fisheries in Indonesia are projected to be some of the most severe in the world, with decreases in catch potential of 20 to 30 percent under a high emissions scenario and 10-15 percent under a low emissions scenario. Indonesia's tropical ocean geography means that its fisheries already occupy the upper end of the temperature spectrum-ecological niche combination. There are thus relatively few species that can increase their abundance in a warmer world. Indonesia is also one of the world's most fishery-dependent large nations in terms of per capita consumption, livelihoods, and economic contribution, as could be expected given the richness of the country's fishery resources. Moreover, the fundamental challenge of temperature is mostly beyond Indonesia's control: significant temperature rise is baked in from past emissions, while the emissions choices of the global collective will determine the extent of additional rises.

Yet adaptation actions will be critical in determining outcomes on the ground

Yet significantly different outcomes remain possible. As a top-five global emitter and a top-twenty global economy, Indonesia has some influence over the global emissions trajectory. Indonesia's ability to meet its medium-term NDC target—a 32 to 43 percent reduction below business-as-usual projections—and its willingness to drive emissions to net zero in the long term will influence choices made by other nations. However, more importantly, adaptation and resilience measures remain firmly in Indonesia's control. The combination of global action and local adaptation will determine Indonesia's climate future.

'Blue-Fish' climate-resilient policies are the focus of this section

This report now turns to a set of options that can drive extensive local adaptation and thus offset many climate impacts. We call this future a 'Blue-Fish' world. Catch potential declines in line with the impacts described in section 3, but Indonesia mitigates economic losses through robust and adaptive fishery management systems. Ecosystems show adverse climate impacts (such as coral bleaching) but spatial planning and coastal ecosystem protection help mitigate effects. The alternative is a 'Brown-fish' world, in which climate change compounds fragile ecosystems, stressed fish stocks, and vulnerable communities. Moving Indonesia as close as possible towards 'Blue-Fish' outcomes through policy and programming measures—while recognizing that not all 'Brown-Fish' realities are avoidable—given the global nature of climate change is the focus for the remainder of the report.

5.2. Strategies for a 'Blue-Fish' World

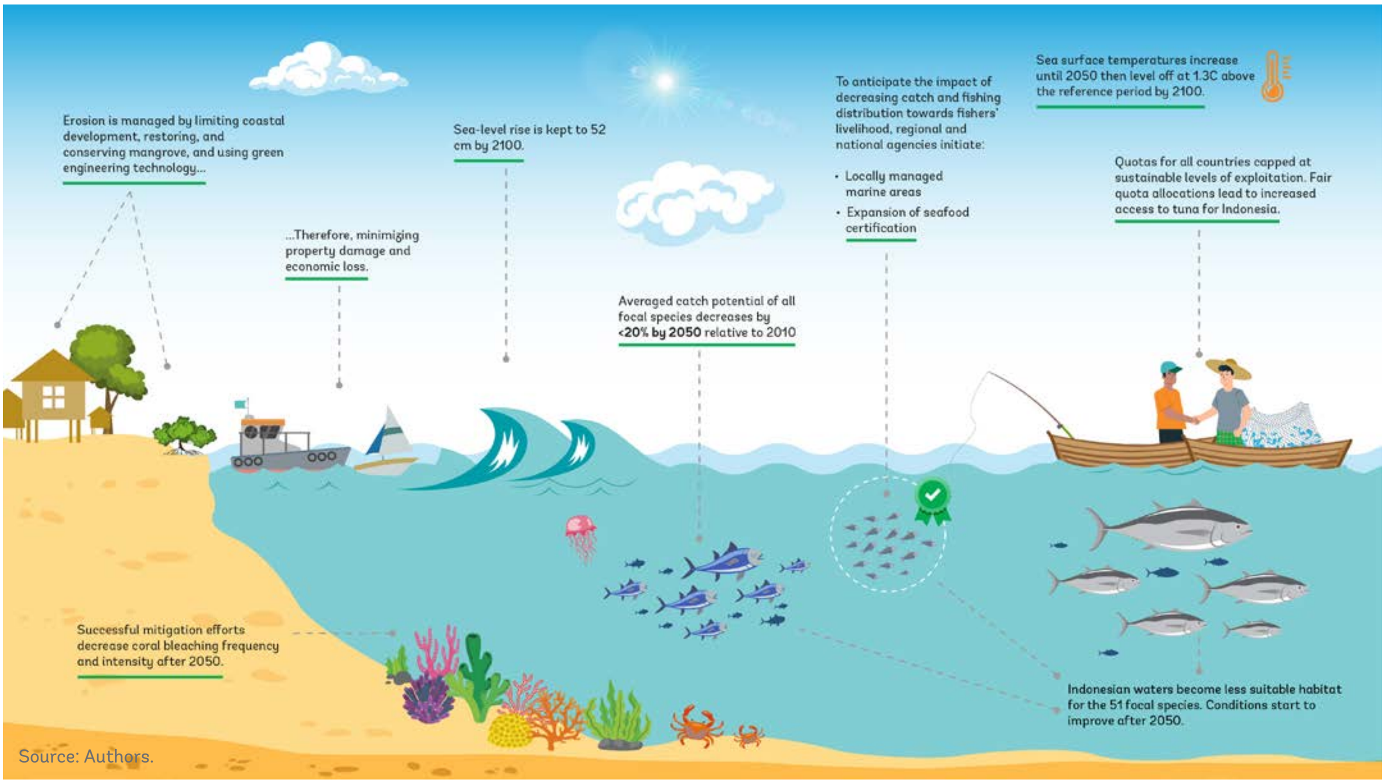
A policy framework for climate resilience strengthens ecosystems, fisheries, and communities.

Design and implementation of fishery sector adaptation measures is at a nascent stage globally

Countries with high climate risk are increasingly implementing adaptation actions across their economies, although measures specifically for fishery sector adaptation are relatively nascent. Indonesia has made important progress in a range of areas. The government recognizes the importance of marine and fishery sector adaptation and is working to develop strategies for its Roadmap for Climate Adaptation.

Figure 19: A stylized depiction of Indonesia's future under a 'Blue-Fish' world

A future in which extensive local adaptation efforts offset impacts to the extent possible and global emissions are rapidly curtailed (SPP1-2.6).



Source: Authors.

Measures will be needed in three complementary areas: (1) coastal ecosystem protection…

'Blue-fish' world outcomes will require a combination of mutually complementary outcomes. The foundation of Indonesia's fishery sector is the natural assets that provide habitat for stocks: mangroves, seagrasses, and coral reefs. Adaptation will require protecting these ecosystems against the worst effects of climate change, in many cases, by reducing compounding anthropogenic stressors such as coastal mangrove clearing or damage from fishing vessels. Given the storm protection and erosion benefits reefs and mangroves offer, these actions will also help fortify coastal communities in some locations (Guannel et al. 2016).[18] These benefits will likely grow as coastal areas become more developed and climate change becomes more severe (providing coastal urbanization pressures do not place ecosystems at further risk).

… (2) robust and adaptive fishery management, and (3) stronger coastal communities.

Building on a foundation of resilient ecosystems is robust and climate-adaptive fishery management. Even with healthy fish nurseries and other habitats, overfishing can still undermine fish stocks' productivity as demonstrated in the previous section. This is true irrespective of climate change but becomes more important as climate change becomes more severe. Finally, communities will increasingly need to look beyond fishing for incomes and livelihoods and will need assistance to bring about the local economic transformation required. This is recognized by the Government of Indonesia, which is investing in coastal livelihoods, skills, and infrastructure, through programs such as Oceans for Prosperity (*Lautan Sejahtera, LAUTRA*), the Coastal Communities Development Project (CCDP), and the Coral Reef Rehabilitation and Management Program (COREMAP). Continued investments, along with support for community-level governance capacity and economy-wide efforts to promote productivity will be needed. The measures put forward below draw on the perspectives of stakeholders (Box 7), successful existing programs in Indonesia, complemented by new approaches being trialed globally.

Box 7. Engaging Stakeholders to Inform Adaptation Strategies

Adaptation requires actions from diverse stakeholders—including government, industry, academia, and civic society—whose knowledge and perspectives on the best path forward differ. The joint study team held participatory stakeholder consultations to gather perspectives on adaptation strategies and exchange knowledge. The first workshop focused on identifying the perceived severity of climate impacts and broad adaptation strategies. The second workshop concentrated on specific adaptation measures and assessing their risks and benefits. MMAF extended invitations to national and provincial government agencies, non-governmental organizations, including industry groups representing fishers, and academia.

The first workshop focused on three sub-topics: impacts and strategies for fisheries management, socio-economic wellbeing, and marine and coastal ecosystems. The second workshop built on findings from the first to propose adaptation strategies for fisheries management, erosion and flood mitigation, and coral bleaching. Guiding questions aided by live polls were used to encourage discussion, while online questionnaires gathered data. Findings have informed the recommendations presented in this report.

Perceived climate impacts. Participants expressed the greatest concern about extreme weather (including heavy rainfall and floods), followed by coral bleaching and degradation of corals, and changes in fisheries abundance and location. Coastal erosion and sea-level rise attracted mid-level concern.

Perceived most effective types of adaptation responses. Participants nominated three categories of adaptation actions as most important: (1) Investments in social capital, including capacity-building, education, improving social cohesion, and social assistance for coastal communities (e.g., financial savings and training programs); (2) restoration and sustainability actions for coastal ecosystems, including rehabilitating mangrove and corals, protecting watersheds and forests (to reduce runoff, flood risks, and land-based pollution), and stronger natural resources management (e.g., MPAs); and (3) improved governance, including increased cooperation between government and non-government agencies; multi-stakeholder dialogues, and inclusion of adaptation actions in development plans (Figure B6.1).

18 Reefs and mangroves lessen damage from storm surge and tsunamis. Less dramatically but more frequently, they moderate wind-waves and swells, reducing chronic shoreline erosion. Recent studies indicate that Indonesia's coral reefs protect coastal areas from flood damage worth at least US$639 million annually (Beck et al. 2018), while mangrove protection is worth a further estimated US$250-500 million (Menéndez et al. 2020). It should be noted that mangroves, seagrass, and reefs provide protection most effectively as intact systems rather than as single habitat types due to their complementary characteristics. Integrated management is thus important.

Perceived most effective adaptation actions.

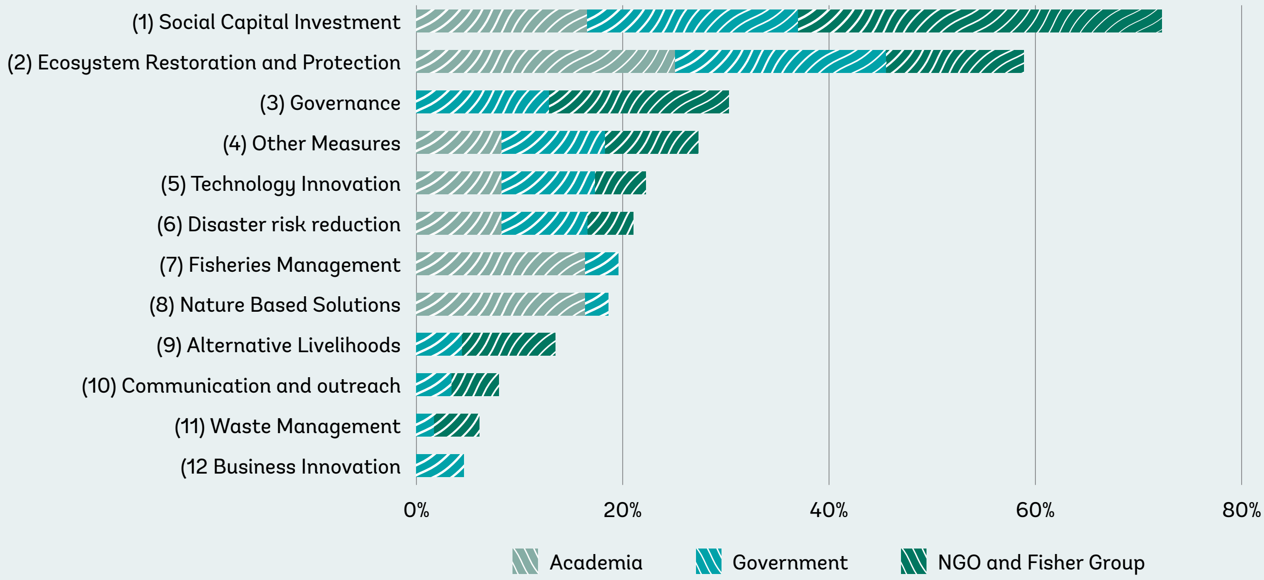
- Preference for adaptation strategies for coastal erosion and floods were evenly divided between "Brace for the storm" actions (those that reduce personal, property, and financial damages) and "fortify defenses" actions (those that protect coastal ecosystems and buffer against storms), reflecting participant's recognition of the complementarity between these categories. Building seawalls, for instance, is reinforced by coastal habitat protection, early warning weather systems, and evacuation shelters, and indirectly, by education for greater awareness of storm and erosion risks. Mangrove rehabilitation was seen as a particularly valuable "fortifying" activity, although participants raised a need for regulations to implement and enforce rehabilitation. "Get out of harm's way" type strategies (retreat from areas of exposure, develop new towns and cities, provide social assistance) were the least favored strategy, possibly due to negative experiences with past relocation projects.

- Preference for actions to protect reefs favored "stress reduction" activities, such as stronger protections for reefs (including MPAs), fishing gear restrictions, anchoring restrictions, and jetty construction to avoid damage to coral reefs from boats. "Climate proofing" strategies—actions that build resilient corals through coral "gardening," assisted migration and colonization, assisted genetics, and microbiome manipulation—were less favored, possibly partially due to lower levels of familiarity with these approaches (many of which are at the proof-of-concept stage only, see Rinkevich et al. 2019).

- Preferences for actions within fishery management favored diversifying fishing practices, such as diversifying fish catch composition, changing fishing grounds and gear, and investing in new equipment. A contrasting view opposed relying on technology-centered adaptation and instead focusing on strengthening community fishing associations and capacity and improving market access. Measures to reduce reliance on fishing were relatively less preferred among stakeholders, with perceptions that it would entail economic hardship on fishers.

Perceived risks: Stakeholders noted that many strategies entail risk (Table B6.1). Identified risks of concern include the length of time and research needed for technology-centered coral reef adaptations and the need for maintenance and training funding for fortified erosion and flooding control. A common concern was around livelihood impacts. Creating MPAs, for instance, was perceived to reduce resources available to people in the short term (although may increase them longer term). Reducing reliance on fisheries was seen as a risk to livelihoods and income. Also common was concern that adaptation policies could lead to social tension or conflict. This came across particularly strongly in discussions about relocation.

Figure B7.1: Perceived most important adaptation actions



Notes: (1) The cultural norms and relationships that build cooperation among individuals in a community; (2) improving degraded ecosystems to a sustainable level; (3) Formal and informal rules and institutions that underpin NRM and access to NRs; (4) Other measures including climate mitigation; (5) technologies that assist people in adapting to climate change; (6) Interventions that increase people's preparedness to deal with extreme events (e.g., storms and floods) and reduce losses; (7) Formal and informal regulations in place governing fishing; (8) Activities that restore ecosystems while also providing social, economic, and cultural benefits; (9) Programs to reduce reliance on unsustainable resource exploitation; (10) Stakeholder outreach to exchange knowledge and opinions; (11) infrastructure to manage waste and prevent pollution; (12) new and climate-sensitive business models. Data is from participant responses, compiled by Authors. Workshops were held March 9 and June 8, 2021, with 85 and 62 participants, respectively.

Table B7.1: Risks perceived as associated with climate adaptation strategies

Threat:	Coral Bleaching		Erosion and Floods			Fisheries		
Adaptation Actions: / Risks:	*Reduce stress* (ecosystem management and protection)	*Climate proof* (research and technology, eco-engineering)	*Brace* (reduce personal, property, and financial losses)	*Fortify* (protect ecosystems that buffer storms)	*Get out of harm's way* (relocation)	*Maintain* (adjustment to fishing effort, gear, markets)	*Diversify* (change grounds, gear, markets)	*Reduce reliance* (long-term alternatives to fishing)
Insufficient resources (budget, time, training)	+	+	+	+				
Management and implementation failure	+	+				+		
Decreased economic resilience	+					+		+
Decreased access to resources		+						
Social conflict and/or disparities	+				+		+	+
Decreased biodiversity or env. sustainability		+				+	+	

Note: Risks in dark cells are those nominated by participants; risks in light cells are additions nominated by the study team.

5.2.1. Protected Ecosystems

The foundation of climate resilient fisheries and coastal communities are healthy ecosystems.

Resilience requires protecting ecosystems from a range of threats

Ecosystem protection is crucial for climate resilience. Protection is especially pertinent to coral reefs, mangroves, seagrasses, and the fisheries they support, which are projected to be increasingly threatened by increased temperature and marine heatwaves. While ecosystems protection cannot mitigate the direct impacts of climate change, protection from the compounding stress of other sources of human pressure (runoff, fishing, and development impacts) greatly improves ecosystem resilience. Protecting vulnerable and valuable habitats is consistent with Indonesia's Ecosystem Approach to Fisheries Management (EAFM), along with the government's objectives for marine protected areas (MPA), mangrove and coral reef restoration, and community outreach and support for local management.

Indonesia's extensive MPA system is a critical asset towards this goal

MPAs support fisheries management and ecosystem protection goals and are a key tool for improving ecosystems' resilience. (Marcos et al. 2021). Indonesia has made substantial progress in expanding its MPA network to 23.4 million hectares in 2020 (meeting its Aichi target of 20 million hectares).[19] These cover 3 percent of mangroves, 36 percent of seagrass beds, and 43 percent of coral reefs in Indonesia. The country has a further goal of reaching 32.5 million hectares by 2030 (MMAF 2020). Subsequent action could focus on integrating climate resilience

19 Aichi Target 11 of the Convention on Biological Diversity is a call for countries to effectively conserve at least 10 percent of coastal and marine areas by 2020.

in MPA design, e.g., identifying locations that are climate refugia (Ban et al. 2016; Carter et al. 2020), or exploring options for future dynamic spatial planning (where MPA boundaries can be shifted as species' key habitat areas move, see Cashion et al. 2020). Continued investment in the quality of management will also be important through ranger training, increased patrols and enforcement, community engagement, and small infrastructure. Indonesia's scorecard system—EVIKA—provides an outcomes-focused roadmap for these investments. While most national MPAs are close to or have achieved EVIKA "silver" or "gold" status, most provincial-level MPAs remain at significantly lower stages ("bronze").[20]

Sustainable sources of funding will be needed as threats and climate impacts grow

Sustainable funding is necessary to maintain Indonesia's MPAs and other ecosystem protections. Funding for MPAs that are protected from regular budget cycles is an ongoing challenge. One option is to fund MPAs through public budget allocations by transforming the MPA management unit into Public Service Entities (*Badan. Layanan Umum*, BLU), such as Raja Ampat MPA, to produce and manage their own revenues (such as tourism and visitation fees). Another related step—and one more useful for those MPAs unlikely to receive large numbers of tourists—would be to develop national or sub-national conservation endowment funds that can leverage and manage multiple financing streams (including philanthropic, private sector, and international development assistance) for MPA management. This would build on experience at local and regional levels (such as that in the Bird's Head Seascape, West Papua). 'Blue carbon' financing may be another source of revenue that could contribute to such an endowment fund (i.e., proceeds from the sale of carbon credits from seagrass and mangrove conservation). Such financing mechanisms are further discussed in the next section.

Spatial plans can complement MPAs and protect ecosystems in other areas

Ecosystems beyond the boundaries of even an expanded network of MPAs will also need protection. Spatial planning over marine and coastal areas is needed to avoid conflicting uses and destructive areas in high-value ecosystems. Indonesia has developed an advanced set of national and provincial-level spatial plans, including coverage of marine areas, which provide the framework for such protection. Ensuring that these plans boost ecosystem resilience on the ground will require continued investment in monitoring systems and development permitting capacities within provincial governments. This could include a national spatial plan scorecard system (with indicators and targets akin to the EVIKA scorecard system for MPAs) and business permit issuance that fully considers limitations and guidance posed by spatial plans. Longer-term, a marine and coastal cadastre (a spatial title registry identifying property rights over specific areas, including aquaculture sites and tourism facilities) will complement these systems and help manage conflicts.

Mangrove protection underpinned by carbon-financing will strengthen physical resilience of coasts.

Specific ecosystem protections could further complement spatial plans. The GoI has set a commendable target for mangrove restoration—600,000 hectares to be restored or to receive enhanced protection by 2024. This achievement would be well-complemented by measures to prevent mangrove loss. Indonesia has a moratorium on land conversion for Indonesia's primary forests. This could be extended to mangroves given their similarly high ecological, carbon, and economic value (Murdiyarso et al. 2015). Some exceptions will be needed to account for critical development (in the public interest). Carbon financing can support mangrove protection. Including mangroves in Indonesia's land use emissions baseline would allow mangroves to generate emissions reduction payments in carbon-based schemes such as REDD+. As discussed further in the next section, Indonesia is already taking pioneering steps in this direction.

Systematic data collection underpins climate-resilient management

Data and understanding of Indonesia's ecosystems have improved considerably through recent investments in capacity. The development of reef, mangrove, and seagrass health indices by the National Research and Innovation Agency (*Badan Riset dan Inovasi Nasional*, BRIN) is helping create consistent methods for measurement and harmonizing coastal ecosystem datasets (e.g., Hernawan et al. 2022). Yet there remain apparent data gaps. For instance, very little is known about the extent of and trends in seagrass condition and coverage, despite the importance of this ecosystem (Sjafrie et al. 2018). There is a need for research that assesses the joint impacts of climate change with other human stressors (such as water pollution, shipping activity, and coastal development) to underpin climate resilient management.

20 To achieve the highest levels of effectiveness, strong community participation is necessary. A recent long-term program evaluation of Indonesia's MPAs found robust increases in fishery biomass in MPA's management in those areas with higher levels of community participation in governance (Fidler et al. 2022).

Senggigi Beach, West Lombok Regency
Photo by Tandya Rachmat on Unsplash

5.2.2. Climate-Resilient Fisheries

High performing management systems can offset the worst climate change impacts.

Climate-resilient fishery management is precautionary, efficient, responsive, and integrated across spatial and temporal levels.

As seen in section 3.3., robust and adaptive management will be critical for maintaining the contribution that fisheries make to Indonesia's economy and society. Four characteristics define a climate-resilient fisheries management system: (1) it is precautionary, because it recognizes the stresses climate change places on fisheries and makes conservative decisions accordingly; (2) it is efficient, because it keeps costs for industry low to partially offset potential losses in revenues; (3) it is responsive, because it quickly adjusts fishing activities to changes in stock conditions, and (4) it integrates tools and policies across spatial and temporal scales (Holsman et al. 2019). In essence, a climate-resilient fishery management system must anticipate and respond to faster and greater changes in fisheries. These changes will be both the long-time trends assessed earlier in this report (2050 and beyond) and more dramatic swings season-to-season or even day-to-day (such as those due to marine heatwaves). The system must be able to make short-term adjustments while ensuring long-term alignment between fishing effort, stock conditions, and the fishery management objective (Box 8).

MMAF's plans, including operationalizing WPP management, and implementing quota, will support climate-resilience

Several building blocks for such a climate-resilient system are already in place in Indonesia. The WPP system, for instance, decentralizes decision-making and incorporates diverse stakeholders' views, providing a basis for localized and responsive management. The recently introduced plans for sustainable quota-based fishing will provide fishers with allocations (initially limited to the large-scale sector). Such "catch-share" systems are used by many countries to give fishers flexibility in how and when they harvest their catch and to reduce rent-dissipating competition. Indonesia has endorsed the ecosystems-based approach to fisheries management (EAFM),[21] which includes adaptive and precautionary approaches as core tenets (Muawanah et al. 2018). Once fully implemented, these systems will provide a strong foundation for climate-resilient fisheries. Safety at sea—important in a context of increasing storm and wave activity—is being strengthened through vessel monitoring systems (VMS) (Box 9). Yet further actions will be needed.

21 In 2003, FAO defined EAFM as "an approach to fisheries management and development that strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries."

Tightly defined harvest control rules are the first "line of defense"

Climate-readiness of Indonesia's fishery management system would benefit from adaptive measures that ensure responsiveness to mid-term changes in conditions while gradually building capacity for dynamic measures. Harvest control rules with target reference points, which trigger license renewal and/or quota allocation, will be the basis for sound adaptive measures. These are the "first line of defense" against climate-change impacts, preventing overfishing (which compounds climate stresses) and allowing for season-to-season adjustment in harvests, as climate and non-climate factors demand. In the long term, Indonesia can look to utilize "dynamic" measures and short-term forecasting that informs rules or advice for avoiding patches of low productivity or high bycatch. These measures complement strong adaptive and fixed measures (see Box 7).

Box 8. What Makes Climate-resilient Fisheries Management Different?

A climate-resilient fishery must have stocks and harvest levels maintained at sustainable levels. This is generally achieved through well-defined harvest control rules that ensure permitted harvests are aligned with the fish stock's condition. However, in some cases this will be insufficient for climate-resilience, which must consider greater changes and faster timescales to traditional fishery management.

Most fishery management systems are a collection of overlapping policies, regulations, and other measures. These measures can be placed in three categories based on their temporal characteristics. (1) Measures that are "fixed"—they are only revisited on decadal or longer timescales. These include WPP boundaries, MPA locations, and legislatively mandated policies in Indonesia, such as vessel licensing requirements. (2) Measures that are "adaptive"—these are periodic (1-5 years) updates to harvest quotas, or target biomasses, such as MMAF's total allowable catch (*jumlah tangkapan ikan*) and licenses provided to vessels. (3) measures that are "dynamic"—those that respond within days or weeks to changes in conditions. They include continuous bycatch monitoring, within-season adjustments to harvest levels, and temporary zone closures. They use near-real-time ecological data and fisher surveys to inform rapid and more spatially targeted interventions.

Dynamic measures are relatively new (see Box 10 for an example). Approaches include grid-based hot-spot closures, move-on rules, and oceanographic closures. Hotspot closures entail restricting access to small cells (as small as 50 km2) of the ocean when localized bycatch or harvest thresholds are exceeded. Move-on rules are similar restrictions to access, based on a requirement for fishers to move a set distance from a location when a bycatch or harvest threshold in that hotspot is exceeded. Oceanographic closures respond to environmental conditions, such as marine heatwaves, implemented daily or weekly. All are highly targeted, short-term measures that ensure fishing is responding in near real-time to ocean and fishery conditions, with the potential to dramatically increase the efficiency of fishery management (Dunn et al. 2016).

In summary, climate resilient fisheries management, relative to ordinary fisheries management, makes greater use of such dynamic measures while drawing on robust adaptive measures. It also ensures that fixed measures are not overly constraining (or updated too infrequently) in the context of expected climate trends.[22] To facilitate adaptive and dynamic measures, climate-resilient fisheries will need to have richer data collection (species-specific stock and landings data, socio-economic data on fishers), often drawing on community data collection efforts. Finally, climate-resilient management relies on multi-stakeholder participation. Complexities and management variation under climate change means trust and transparency via stakeholder participation are critical to ensure buy-in.

Source: Authors' elaboration. See also Karr et al. (2021), Hobday et al. (2016).

These may require mechanisms to align incentives across levels of government…

While the principle is simple, implementing adaptive and dynamic measures within Indonesia's decentralized system remains challenging. Many (although not all) licenses are granted by provincial governments (specifically, vessels 10-30 GT in coastal waters, less than 12 nautical miles offshore). Provincial governments have their own incentives for issuing licenses that are not always perfectly aligned with the long-term interests of the WPP (which covers multiple provinces) or national-level considerations. When fully operational, the WPP structure provides a forum for discussion and decision-making among varied stakeholders, which will go some way to establishing consensus. Operationalization of WPP and LPP with staff and capacity—an MMAF priority—is thus an important step. Longer-term incentive mechanisms could be considered. For example, quota adjustment supports provinces with the best track records on licensing within limits, as well as the best track record on enforcement.

…and between managers and firms.

National or provincial governments could consider a similar incentive mechanism for individual firms, with those in full compliance rewarded with prioritized license renewal or quota. Such mechanisms would require detailed design work and research but can draw on international experience for lessons. The EU Common Fisheries Policy provides an example, which requires sustainability considerations in fishing allocations.[23] A fishery-level example, and one tied to a dynamic fishery management measure, is the Scottish "Conservation Credits" scheme. This involves short, real-time closures of the cod fishery in high-pressure locations,[24] combined with gear requirements. Participants in good standing were rewarded with additional days at sea (i.e., quota) (WWF 2009).

Varied approaches will be required for the small-scale fleet, reflecting its diversity

Given its numerical importance, the small-scale fleet will need continued special attention (over 90 percent of vessels and around half of the total harvest). Output-based approaches can, in some circumstances, apply to small-scale fisheries, particularly when there are well-organized cooperatives that can hold quota on behalf of their members and provide sufficient oversight of their actions (reducing transaction costs for managers). Community-based approaches (locally devised regulations within a nationally recognized framework) will be more suitable in other situations. These can potentially be supported by expanded registration and monitoring, for instance, through the e-logbook program (Sari et al. 2021) which MMAF is pursuing. This report returns to the community and spatially-based systems in section 5. Input controls (gear, location, and season) restrictions will remain standard tools for management.

Enriched and integrated data underpin climate-resilient fisheries

Adaptive and dynamic management measures necessitate greater levels of data to enable managers to make re-occurring decisions on harvests, gear, timing, and spatial restrictions that match effort to changing stock conditions. Indonesia has high scientific capacity within Ministries, designated agencies such as BRIN, and universities. Continued investments in their fisheries modeling capacity will strengthen them further. This could include investment to fill remaining data gaps, such as species-specific stock assessments (rather than assessments of broad fishery categories) and localized stock predictions.[25] Yet provincial levels have limited capacity to apply detailed data and modeling results to inform management. Integration of different data and knowledge (e.g., that from public scientific, industry, and traditional sources) is also lacking. Investing in the capacity of regional universities (those that participate in the LPPs) towards these ends will thus be important, along with continued integration of data through Indonesia's OneData Policy, which MMAF is using to streamline its multiple data systems.

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22 Climate resilience requires review of "fixed" measures with greater regularity. Fixed measures are simpler to operate. Once decided, they remain in place. Ongoing data needs are limited, and enforcement is simple. However, they assume that conditions are not changing. There is a thus a tradeoff as "fixed" measures are moved to become adaptive (which places a burden both on managers and fishers).

23 The European Union Common Fisheries Policy's Regulation No. 1380/2013, Article 17, states that "Member States must use transparent and objective criteria, including those of an environmental, social and economic nature when allocating the fishing opportunities available to them, …; whereas those criteria may include the impact of fishing on the environment, the history of compliance…" Article 17 also states that Member States shall endeavor to provide incentives to fishing vessels deploying selective fishing gear or using fishing techniques with reduced environmental impact, such as reduced energy consumption.

24 Closures (of 21 days) are triggered by, for example, changes in species compositions or catch rates/landings per unit effort, indicative of a spike in fishing pressure. See WWF (2009).

25 Recent research has demonstrated opportunities for adaptive management based on ecological forecasting. For instance, the abundance of S. Lemuru in the Bali Strait can be predicted from the concentration of chlorophyll-a four months earlier ((Lumban-Gaol et al. 2012). Positive anomalies in chlorophyll-a (itself a function of changes in the IOD) are associated with greater harvests. Management and processing preparations can be made, and fishers can prepare for lean seasons with some warning.

Low-data methods can be used when detailed data is not available

However, the complexity of Indonesia's fisheries means that perfect information will never be available for all fisheries. Decision-makers can draw on localized and non-standardized data in many cases. Expanding technologies for e-reporting and e-catch documentation will help fill gaps over time (through the expansion of MMAF's e-logbook program). Methods of decision-making designed for low information can help. An example of such a method being trialed in Mexico, Cuba, and Chile is "fish-baskets," which simplifies multispecies management (Karr et al. 2021). A fishery that catches many species is managed by assessing a small subset of indicator species. The full set of species is grouped into management "baskets" of similar vulnerability and stock characteristics. An indicator species representing each basket is used to determine harvest control rules. Another example of a low-data assessment tool is the FAO Fishery Performance Assessment Tool.[26]

Tuna will require particular focus and international collaboration

Tuna will require special attention. Indonesia's three main tuna species are some of Indonesia's most valuable fisheries and are already being impacted by changes in ocean temperature. MMAF is investing in the future viability of the country's tuna stocks through a new nationwide harvest strategy with sustainability provisions, including tighter controls on harvests in overfishing locations and restrictions on fishery aggregating devices (FADs). These provide a sound basis for future climate adaptive and dynamic measures. On the international stage, Indonesia's participation in Regional Fisheries Management Organizations (RFMO) has yielded higher tuna harvests, allowing it to expand the high tuna seas longline fleet. The forum may also serve as a platform for Indonesia to collaborate on international research on climate impacts on migratory tuna stocks, which may inform future quota decisions.

Box 9. Extreme Weather and Fishing Safety

Climate change is expected to increase storm activity and wave height. Greater wave heights threaten smaller vessels and place greater stress on coastal infrastructure. These trends are already being felt, with estimated wave heights increasing in Indonesia by 0.38 to 0.75 cm per year between 1984 and 2003 (an average total increase of 7-14 cm over this period, Zikra et al. 2015). Related studies show this trend continuing in Indonesia. Globally, wave energy has increased at approximately 0.4 percent per year between 1948-2008 and accelerated to 2.3 percent per year since 1994 because of warmer oceans (Reguero et al. 2019). The challenge of more dangerous seas interacts with behavioral changes caused by diminishing fish stocks, specifically longer and more dangerous voyages.

Meanwhile, due to its low latitude, cyclones do not directly impact Indonesia. Still, the country feels the effects of tropical cyclones in the southeastern Indian Ocean between January and April and in the eastern Pacific between May and December, with the country usually impacted by strong winds and heavy rainfall. Increased sea-surface temperatures associated with climate change are projected to increase tropical cyclone intensity globally. However, the implications for Indonesia are not yet well known.

In response to these challenges, Bappenas (2021) analysis has called for: (1) strengthening marine early warning systems, (2) extend the use of automatic tracking systems (vessel monitoring systems (VMS) and automatic identification systems (AIS), especially among smaller vessels which do not currently require such systems, further investment in marine safety infrastructure (marine rescue and coast guard facilities), support for vessel repairs and upgrades (e.g., fiberglass reinforcements on less resilient vessels), as well as insurance mechanisms.

Concerning tracking systems, previous studies suggest opportunities to increase their uptake. A 2018 pilot in Indonesia with 200 vessels found that advanced tracking devices (VMS+) increased efficiency of fishing operations—notably an average 10 percent reduction in fuel use—as well as improved safety through their two-way communications features. Cost-sharing schemes with monthly installment plans could be used to make such systems financially accessible to smaller vessels. Processors may be willing to contribute to costs in some fisheries, given that using VMS aids compliance with international traceability requirements and, thus, market access.

Source: Authors' elaboration.

26 FAO's Fisheries Performance Assessment Toolkit (FPAT)—which is also part of the World Bank's Fisheries Sector Assessment Toolkit, helps managers systematically collect, collate, and curate multi-dimensional fisheries data and information from expert judgment, specifically for data-limited and capacity-limited fisheries analyses, including for harvest strategies.

Box 10. Short-term Forecasts for Climate-resilience: The Case of Australian Bluefin Tuna

While adaptive fishery management is the norm in well-managed fisheries globally, dynamic fisheries management is much more nascent. Eastern Australia's southern bluefin tuna (*Thunnus maccoyii*, SBT) fishery provides an example of the type of measures likely to become more common as climate impacts become widely understood.

SBT are managed by a quota system (an adaptive measure) in a large multi-species fishery. Because they are caught alongside other commercial species, the quota for SBT can constrain fishing activity across several stocks (even when the allowable catch for those stocks allows continued harvest). SBT are also seasonally distributed according to localized ocean temperatures. In 2011-12, temperature changes pushed SBT eastward of their historical fishing ground, increasing fishing costs and causing a localized decline in the stock.

The localized decline in SBT led to a decrease in the catch quota. The lower quota constrained fishers focused on other species, a challenge that traditional management approaches could not overcome. A dynamic approach was used instead. A climate-enhanced habitat model was developed using tagging data revealing the narrow temperature band SBT preferred. The model provided short-term forecast maps (2-4 months), which fishers used to avoid areas where SBT would be, and thus could continue fishing for other species without hitting their SBT quota constraints. The tool has helped the industry manage costs and plan their fishery operations, thus managing climate-driven unpredictability in the region.

Source: Authors based on Hobday et al. (2016)

5.2.3. Empowered Communities

Communities need diverse economic opportunities for climate adaptation.

Diverse and vibrant local economies underpin climate resilience

The well-being of coastal communities under increasing climate stresses will largely be determined by the diversity and quality of their economic opportunities. Diverse economic opportunities mean households have options that reduce their dependency on fisheries and other natural resources and the ability to engage in Indonesia's rapidly growing and modernizing economy. On current trends, Indonesia's economic growth will lift millions out of poverty in the coming decades and provide increasing employment options in higher-wage and productivity sectors. Coastal communities will benefit from some of these trends—such as rapid expected growth in marine and coastal tourism (World Bank 2020) and increased integration into global agricultural and fishery product value chains.

The Government is promoting local economic development through infrastructure and social protection

Yet economic opportunity in coastal communities, most notably those in rural and isolated locations, will not be delivered by growth trends alone. Climate impacts will inflict income and physical losses on the most vulnerable communities. The isolation and higher costs of services provided in more remote coastal communities could create a development divergence between relatively more-resilient urban or peri-urban areas and less-resilient and poorer rural coastal areas. Investment in infrastructure and basic services, social protection programs, and livelihoods support will be needed to offset these disadvantages and mitigate vulnerabilities. A range of investments is proposed or underway—including in fishery harbor, transport, and cold-chain infrastructure in remote locations, as well as livelihood programs targeted to coastal communities such as Oceans for Prosperity (*Lautan Sejahtera*, LAUTRA).

Further opportunities for support include insurance and social security

Social protection measures, including insurance, social security, and income support, can target specific risks posed by climate change to fisheries. An example is seen in the Caribbean, where a climate-indexed insurance program, the Caribbean Oceans and Aquaculture Sustainability Facility (COAST), was launched in 2019. The program provides parametric insurance, paid on expected losses rather than assessed losses, reducing transaction costs. The insurance covers fishers' losses due to storms, with payouts disbursed to pre-identified fishers, crew, fish vendors, and processors made automatically shortly after an event. Such instruments could build on improvements Indonesia has made to social protection systems in recent years, including expanding conditional cash transfers (*Program Keluarga Harapan*, PKH) for the poorest 10 percent and establishing the universal social registry (*Data Terpadu Kesejahteran Sosial*, DTKS). There may also be opportunities to expand social security in the long term. BPS data in 2018 indicates that only 20 percent of fishers had access to work-accident insurance, old-age security, pension insurance, and death benefits. This deficiency—which is not uncommon in non-wage, informal sectors—is currently being addressed by MMAF[27] and could be expanded through community outreach over time (Azhar et al. 2020). Other countries' experience, such as Morocco's, shows this is possible (Box 11).

Diversification will be enhanced by livelihood programs…

Building resilient coastal communities will require continued investment in alternative livelihoods. The ability to transition successfully from fishing to other employment within fisheries or outside the sector relies on alternatives, skills training (e.g., aquaculture techniques, business and finance management), and market development for new fishery products (Gillet 2008). Most fishing households already have at least one additional source of income,[28] so developing these skills augments a trend already underway. Experience with alternative livelihood programs already implemented successfully provide a range of lessons for future programs. One such lesson is the importance of interventions that diversify, rather than deepen, fishing dependency. That is, providing equipment that encourages and deepens an individual's investments in fishing appears less successful than access-to-finance measures, business skills, and equipment that supports broader employment options. There is also a need to complement the supply-side promotion of diversified livelihoods (through business skills-building and access-to-finance programs) with demand-side analyses to determine what sectors can absorb additional labor and where market opportunities lie.

… and facilities that improve financial services for village enterprises

In the short and medium term, coastal village economies could be strengthened through further support for micro-, small-, and medium-sized enterprises. Dedicated financing facilities set up with both public and private capital could offer support services and finance to businesses that have been previously excluded. This could include non-collateralized loans, loan guarantees (or unconventional forms of collateral, such as fishing boat deeds), and invoice and cash flow-based lending products. Facilities would target high-demand areas in coastal communities and channel resources toward priority climate-resilient livelihood opportunities and towards traditionally underserved groups. Tools for raising finance for such programs are discussed in the next section.

Box 11. The Coastal Resilience Village Development Program (*Pengembangan Kawasan Pesisir Tangguh*)

The MMAF started the Coastal Resilience Villages Development Program (Pengembangan Kawasan Pesisir Tangguh, PKPT) in 2012. The program aims to reduce vulnerability and increase the resilience of coastal and small island communities due to disaster, including those caused by climate change. PKPT is one of several concrete actions set out by Government Regulation Number 64 of 2010 on Disaster Mitigation in Coastal Areas and Small Islands.

PKPT stimulates behavior changes within the community, supports basic infrastructure improvements, and builds program sustainability through institutional development. The program's design thus combines structural and non-structural activities within one integrated program. Targeted villages are those most at risk from climate-related disasters, suffering socio-economic disadvantage and coastal degradation, but with economic potential.

Community involvement in all activities is the key to the successful implementation of PKPT. Community involvement starts from designing the actions based on their circumstances and continues into implementation. Women's participation in decision-making processes within supported community organizations is a particular focus. PKPT regards the community as the main actor, increasing their sense of belonging and preparing a good foundation for post-program sustainability.

Source: Authors.

27 MMAF regulation 07/Permen-KP/2016 for the Protection and Empowerment of Fishermen, Fish Raisers, and Sea Salt Farmers.

28 A recent survey by the World Bank and MMAF of 25 coastal villages in 12 provinces found that 90 percent of those who fish have not changed their livelihood in the past five to ten years, however, 74 percent reported an additional source of income besides fishing. Dependency on fishing for fishing villages surveyed in central and eastern Indonesia was higher than for western Indonesia, and dependency on fishing was higher for villages further from the regency capital.

Gender equitable and inclusive communities are more likely to be resilient

Another critical consideration for economic opportunity is gender. Equitable and inclusive communities are typically more resilient to external economic and physical pressures. They are less likely to see community members 'left behind' during a disaster or downturn. Women play a significant role in coastal and marine economies, including fisheries, aquaculture, processing and trading marine products, waste management, coastal tourism, and conservation activities. It is common, however, for gender norms to often prevent women from developing and contributing to their full potential (World Bank 2022a). Women's role in industries like fisheries tends to be informal and less well-paid, preventing their access to social services that increase climate resilience and leadership positions.

Closing gender gaps is becoming a focus of coastal resilience projects internationally

International experience increasingly highlights ways to close gender gaps in coastal development systematically. The 2019 "Tonga Pathway to Sustainable Ocean Project," for example, included an activity for financing and training for women-led oyster farms, along with the provision of seeds, boats, and other tools. This ongoing project aims to increase the share of women-owned oyster businesses by 25 percent. The 2016 "Nouadhibou Eco-Seafood Cluster" project in Mauritania provided women-targeted business training, reaching 659 women-led businesses out of 1,100. Meanwhile, the "Unleashing the Blue Economy of the Eastern Caribbean" project, initiated in 2022, requires that any firm, contractor, supplier, or vendor under the project have a minimum of 10 percent female staff. This project also provides gender-based violence prevention training for contractors and gender capacity building in the workplace.

While local circumstances will determine exact designs, examples show what is possible

Another interesting example comes from Mozambique, where the "Gender Action Learning System" was incorporated into the 2015 Conservation Areas for Biodiversity and Development Project. Facilitators helped households envisage shared goals and equity in decision-making and domestic chores. In the 12 communities where the methodology was implemented, 74 percent of beneficiaries reported progress in behavior change and cohesion within their household. While the design of gender interventions will be highly context-specific, given local norms, customs, and circumstances, these examples offer possibilities and proof-of-concept. Many of these approaches have been harnessed in Indonesia or could be further integrated into coastal resilience development efforts.

Box 12. Social Protection and Formalization for Small-Scale Fishers: The Moroccan Experience.

Social protection measures can incentivize good fishery management practices and formalization. Morocco has increased formalization in the fishery sector through access to social services. The Country's Department of Maritime Fisheries invested in fisheries infrastructure along the coast, providing facilities for improved storage, preservation, compliance with international sanitary standards, and marketing (which increased the value of the catch). These facilities attracted fishers, providing a platform for registering boats and workers who wanted to use them. They also provided a way to offer and administer social insurance and health insurance. The National Office of Fisheries automatically deducts social insurance contributions at the point of sale at the in-port markets, removing the practical barriers to contributing (note that the benefits that small-scale fishers receive are also cross-subsidized by workers in other sectors, meaning that they receive more from the social insurance fund than they contribute). Together, these benefits have incentivized some fishers to formalize their activities, encouraging registration in and contribution to the overall system.

Building on this process, it is now a legal requirement to market catch through the government-run ports, enroll with the National Social Security Fund, and contribute to health insurance. Fisher organizations (cooperatives and associations) have been instrumental in communicating the benefits of formal operation to small-scale fishers. There is still a way to go: the COVID-19 pandemic highlighted gaps in coverage, and fishers are still not entitled to unemployment benefits. Gleaners and the informal workers supporting pre- and post-harvest activities (the very groups who tend to be the most vulnerable) are also not included. Nevertheless, Morocco has achieved relatively high formalization in its fishery sector relative to neighboring countries, creating a more secure industry for workers in the face of regulatory and climate changes.

Source: Authors, based on World Bank (2022b).

5.3. Financing a Resilient Ocean Economy

Significant increases in investment will be needed to build resilience; new financing instruments can help.

The capital needs for building resilience require new sources of financing

There is considerable interest from the private, philanthropic, and development sectors in providing financing for sustainable ocean activities, including those activities which contribute to resilient fisheries and coastal ecosystems disused in this report.[29] Harnessing these sources will be important, given that the conventional funding sources that underpin efforts to improve fisheries and coastal management—including public budgets, development assistance, and private philanthropy—are considerably exceeded by the estimated needs of the blue economy (Dharmapuri and Tiwarib 2020). Although nascent, innovative blue finance instruments have been trialed in limited markets, others are now developing to channel private sector funds (often guaranteed by some public funds) towards sustainable ocean activities.

Indonesia's potential is recognized by markets

Significantly, Indonesia is recognized as Southeast Asia's largest impact investing market,[30] both by capital deployed and the number of transactions. However, limited amounts of this finance are reaching the blue economy due to its relative novelty and the lack of clear guidance. This is not unique: globally, blue finance represented only five percent of climate finance in 2022 (Convergence 2022). At its core, 'blue finance' attempts to pool funds from diverse investors for large public ocean-related projects (implemented by governments) or private ocean-related commercial projects. Blue finance mechanisms thus aim to: (1) raise low-cost financing, (2) deliver financing to sustainable ocean activities, and (3) deliver returns, where possible, to private investors.

Instruments range in structure and uses

Most blue finance instruments developed to-date involve some level of blending between public and private sources. Public funds are used to reduce risks for private investors, crowding in the quantity of resources offered and lowering their costs. Instruments developed to-date include blue bonds, concessional loans (with varying structures of interest and payment), as well as equity and debt funds supported by credit guarantee mechanisms and first loss tranches. In most cases these mechanisms will require considerable further policy and design work before funds can flow. Activities suited for blue financing range from coastal infrastructure to natural resource management. They include sustainable seaweed, tourism, fisheries, aquaculture, and related value chains, as well as commercial products that substitute for harmful plastics or other waste (IFC 2022). These investments may contribute directly to the biophysical resilience of fisheries and ecosystems or, more commonly, to economic opportunities (and thus adaptation) for vulnerable areas.

29 A survey by Responsible Investor of 328 institutional investors in 34 countries in 2019 found that 9 out of 10 were interested in investing in sustainable blue economy projects. See Credit Suis (2020).

30 The Global Impact Investing Network (2018).

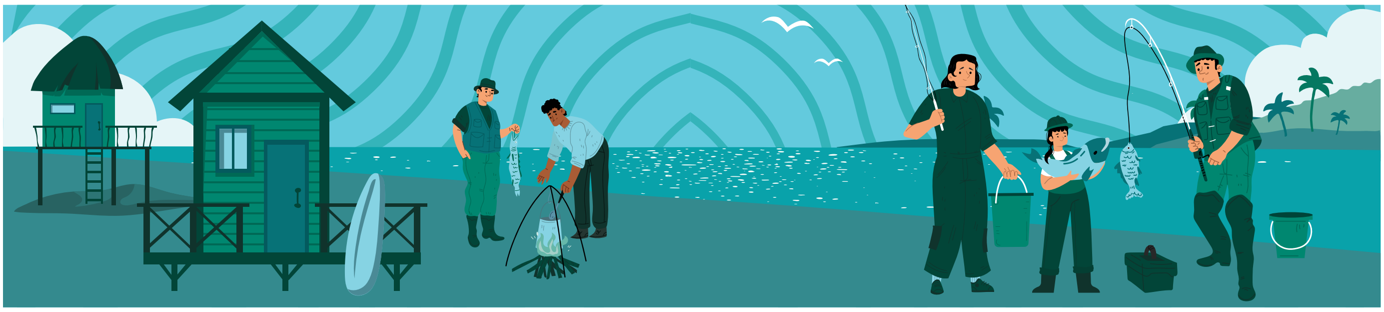
Kedonganan Fish Market, Bali
Photo: © freepik.com

5.4. An Integrated and Community-Focused Approach

Adaptation driven by local decision-making offers the best opportunities for implementation success of development synergies.

An integrated response across ecosystems, fisheries, and communities, is needed

This report has so far argued that continued efforts will be needed in three broad areas to safeguard coastal and fishing communities from climate change impacts: (1) protection for and restoration of ecosystems, (2) adaptive and dynamic (and robust) fishery management, and (3) economic diversification in coastal communities. Programs should work across these domains in concert wherever possible, due to their complementarities. For instance, economic diversification through alternative livelihoods, household finance, and business support makes it feasible for households to reduce their reliance on marine and coastal ecosystems, facilitating their protection (Box 12). For this reason, the Government of Indonesia typically takes an integrated approach to design interventions in coastal areas. The Oceans for Prosperity (*Lautan Sejahtera*, LAUTRA) program currently in preparation by MMAF is a good example of an integrated approach, with investments in businesses, livelihoods, and coastal small infrastructure, MPA strengthening, and measurement and management of coastal fisheries.



Box 13. Building Resilience in 'Packages': Leveraging Complementarities between Investments

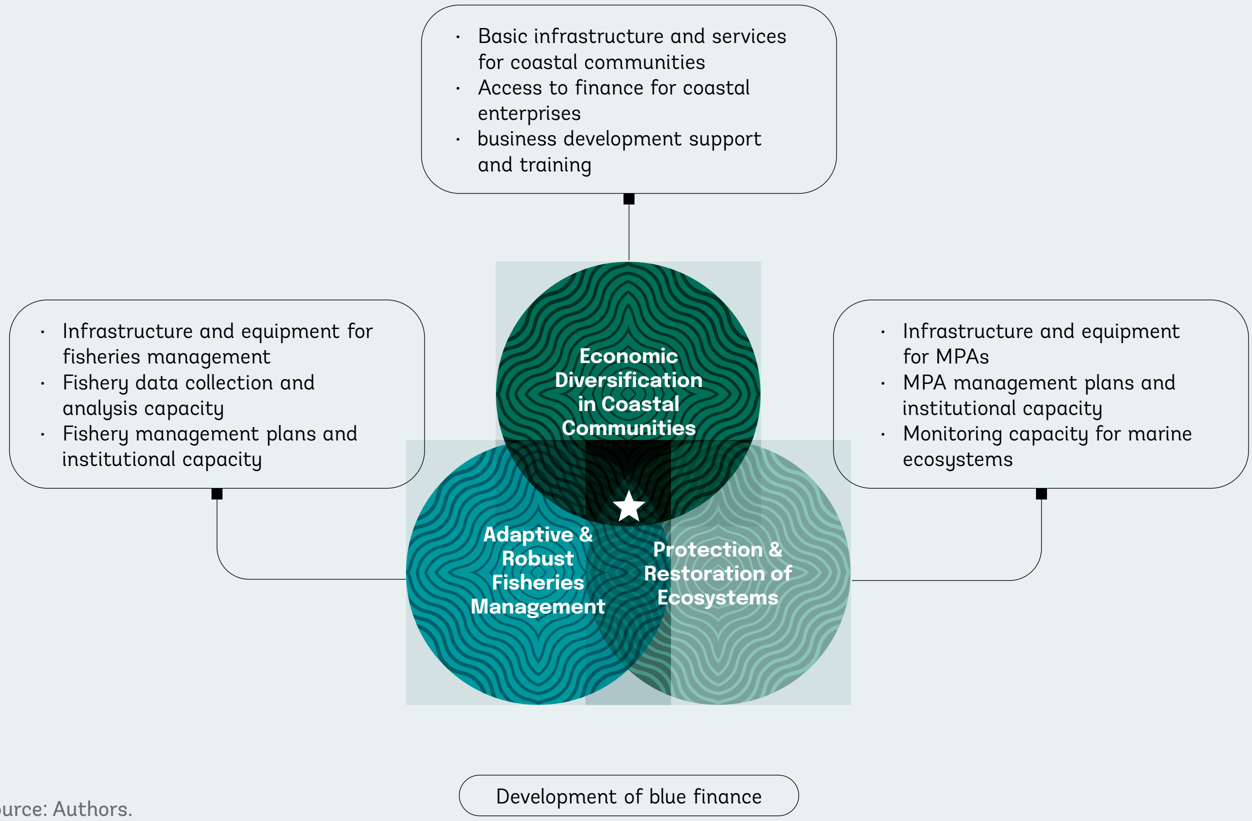
While many policy options are available to governments looking to increase climate resilience, combining them appropriately may be as important as selecting the policies themselves. Policies should be seen in terms of 'packages' which bring complementary characteristics. The whole package may be greater than the sum of its parts.

For example, increasing management effectiveness of MPAs may provide a habitat for charismatic marine fauna or protect high-quality dive sites; coastal development that supports eco-tourism will allow the value of this MPA investment to be realized. This may take the form of basic infrastructure or business development support for sustainable businesses. Both contribute to long-term climate resilience, both economic and physical.

Similarly, investments in MPAs are recognized for their benefits for fish stocks. Investment in fishery institutions—including adaptive and dynamic management systems that can avoid rent dissipation (when too many fishers compete for the same resource, driving up costs), ensure that the economic value of these increased stocks is realized.

Recent investments by MMAF have specifically harnessed this 'packaging' principle. The Oceans for Prosperity (*Lautan Sejahtera*, LAUTRA) program is structured around mutually reinforcing activities that harness complementarities. Investments are targeted in select high-vulnerability locations, ensuring benefits are concentrated enough to have impact. The program is also laying the groundwork for development of blue finance instruments, which could potentially finance future investments. This US$210 million investment, supported by the World Bank and the Government of Canada, is set to begin implementation in 2023.

Figure B13.1: Integrated and complementary activities: The example of the Oceans for Prosperity (LAUTRA) Project



Source: Authors.

Community participation to ensure localized adaptation will also be important

Community participation is also key. The diversity of Indonesia's coastal communities and the complexity of its fisheries and geography means that climate-resilience measures must be highly localized in their design and implementation. High levels of community participation have underpinned the success of Indonesia's past coastal management investments and will be critical for the interventions described in this report. Recent research highlights that fishery outcomes in the Bird's Head Seascape are seen to be much stronger in locations where site-level co-management is practiced (Fidler et al. 2022). This is not surprising. Habitat protection supported by education and awareness efforts, and backed by trusting and empowered community members, is likely to benefit from higher stewardship (and management capacity) than efforts without these elements. Community participation also helps the program to be (perceived as) fair, reducing the risk of social conflict and building broad buy-in. Indonesia is well-placed for community-led approaches to climate-resilience measures, with a robust system for funding village-level decision-making and implementation already in place (*Dana Desa*).[31]

Customary marine tenure supports resilience through a participatory approach

A participatory mechanism used with success in many locations globally is the customary marine tenure system. These help to mitigate fisheries declines by securing the marine resource base for the exclusive use of adjacent communities (Aswani et al. 2007; Halim et al. 2020). These traditional systems exist throughout Indonesia, regulating resource use through traditional practices (*sasi laut*) such as banning the harvest of certain marine resources or temporary seasonal closures. For example, a Territorial Use Rights in Fisheries (TURF) network was designated in Raja Ampat, where user rights to inshore marine waters were conferred to local communities. However, such approaches can currently only be deployed where there are traditionally managed fishing grounds (*petuanan laut*), a small proportion of Indonesia's coastal marine space.[32] The currently used mechanism (*Hak Pengelolaan Perikanan*) is yet to be integrated into the spatial planning or permitting system. A national legal framework for customary marine tenure practices in locations across Indonesia could facilitate expansion, allowing the benefits of community stewardship to be realized in local communities nationwide. However, this is a legally complex reform.

Climate resilience promotes development goals irrespective of global climate outcomes.

Ultimately, climate resilience should not be considered separate from the broader development needs of coastal communities. Activities that restore ecosystem health and improve fishery management have social and economic benefits irrespective of climate change. Many activities recommended in this report contribute to Indonesia's short-term goals—including improving fisher's income, national fish exports, and stock status—while contributing to longer-term development aspirations. Climate resilience will take time to develop. This report presents short-term actions toward this long-term goal. These actions can be refined over time through further research and on-ground experience.

31 It may be possible to encourage villages to draw on village funds (Dana Desa) for coastal management actions by providing technical training and multi-year budgeting flexibility for longer-term interventions. However, decisions on funding use will need to remain with village councils.

32 Traditional and adat communities are very precisely defined under Article 18B of the Constitution. Following a 2011 Constitutional Court challenge, there is not an established legal basis for the granting of fishing privileges beyond these areas. A revised legal mechanism—that maintains a higher degree of government control, protects existing rights of communities, and works for a broader public good benefit—is required and while not simple, is in principle feasible. See Waddell (2012).

> Continued efforts will be needed in three broad areas to safeguard coastal and fishing communities from climate change impacts: (1) protection for and restoration of ecosystems, (2) adaptive and dynamic (and robust) fishery management, and (3) economic diversification in coastal communities.

6 Conclusion


Photo by Hiroko Yoshii on Unsplash

Halmahera, North Maluku
Photo by Kanenori on Pixabay

6. Conclusion

Climate change impacts are significant, but mitigation options will make a big difference.

This report has shown that climate change will have significant impacts on fisheries

The analysis presented in this report suggests that Indonesia's fisheries are likely to be strongly impacted by climate change. As a low-latitude, warm-water country, Indonesian waters are projected to be less favorable for major exploited species currently important to artisanal and industrial-scale fisheries in Indonesia. The results in this report, which are the first sub-national, species-level assessments undertaken anywhere in the world, predict long-term declines in fisheries that are high by global standards: 20-30 percent maximum catch potential reductions under a high emissions scenario, and 12-20 percent under a low emissions scenario, by 2050 relative to 2010. Fisheries revenues may decrease by a similar magnitude. Economic returns decrease by a much larger amount under poor management (i.e., if overfishing increases), but by a reduced amount under conservative management. With the large-scale fleet, returns can improve in the face of climate change, given sufficiently adaptive management.

Mitigation measures can contribute to core sectoral development goals

This report has presented an array of options to support more climate-resilient fisheries and communities. As discussed throughout the report, many of these align with desired development outcomes irrespective of whether low, moderate, or severe climate scenarios eventuate. Protected areas and other ecosystem conservation measures often provide economic benefits in the medium term through more productive fisheries. Harvest control measures that are well-calibrated to stock needs and well-enforced also lead to more productive fisheries. Sustainable quota-based systems, an important adaptive management tool, tend to deliver higher economic returns than input-measure-based fisheries, all else equal (provided equity issues can be addressed). Investments in basic community infrastructure underpin economic opportunity in rural coastal areas. For this reason, the government is significantly investing in many of these measures.

Research, planning, and identification of local solutions will help promote further progress

The ambition of the policy options presented in this report aims to help Indonesia's fisheries and coastal communities not only to survive but to thrive—that is, to provide benefits even if climate change impacts are less severe than expected. For this reason, they focus on the fundamental institutions and systems that underpin the fishery sector's management and productivity. Continued research will be necessary to shape interventions: The relative costs and benefits (i.e., effectiveness) of specific measures in specific places will be needed. This could lead to a ranking of options and inform step-by-step resilience action plans as well as an overarching strategy. Continued basic research will also be required to fill knowledge gaps, while continued identification and evaluation of the most promising localized ideas (many of which are contributed by communities themselves) will provide new ideas for potential scaling. Indonesia's vulnerability to climate change in the oceans sector is high, but so too is Indonesia's potential to build a more resilient oceans future.

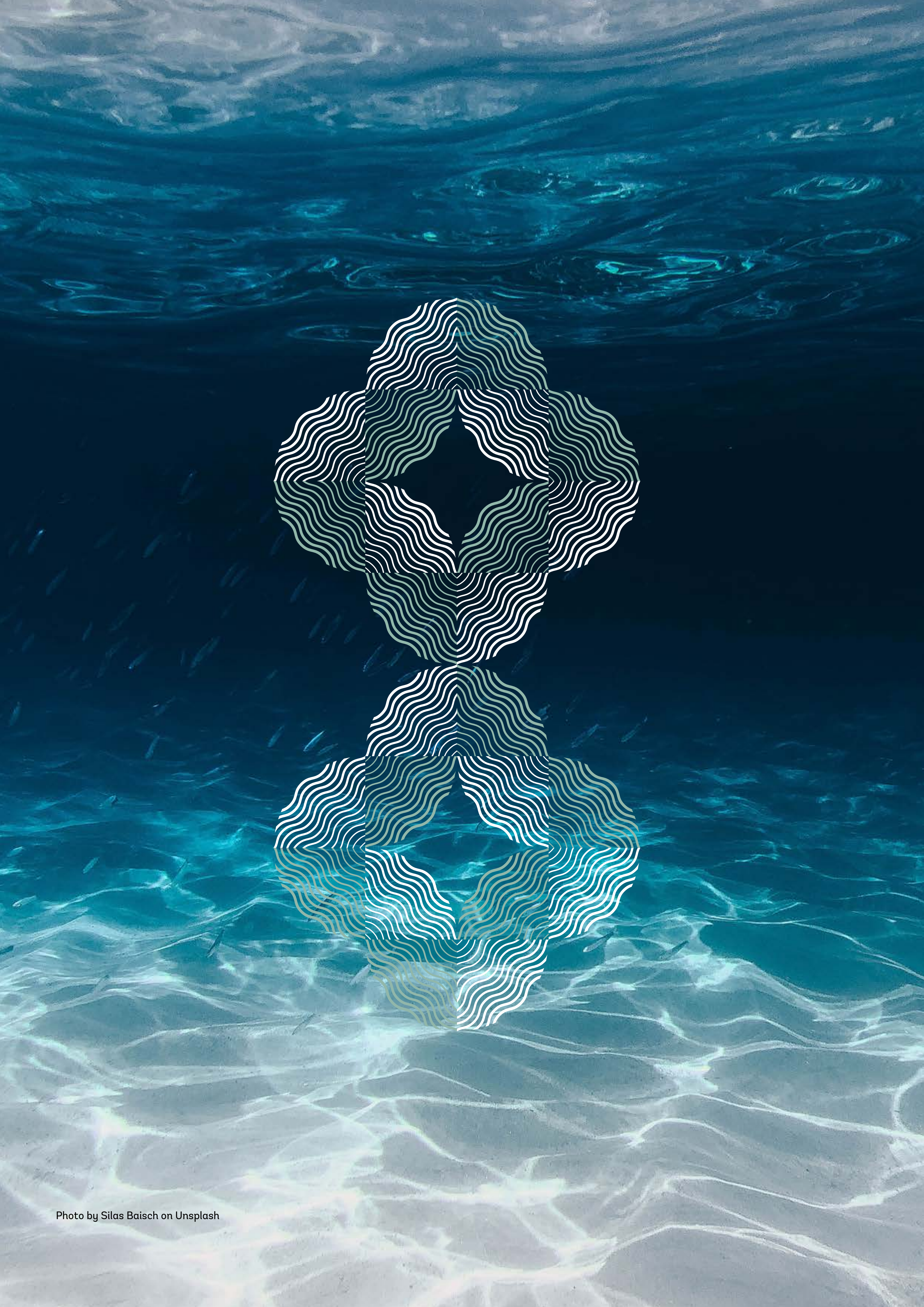


Photo by Silas Baisch on Unsplash

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Annex 1: Focal Species Used in Analysis

Scientific Name	Common Name (English)
Acetes japonicus	Akiami paste shrimp
Aphareus rutilans	Rusty jobfish/Lehi
Auxis thazard	Frigate tuna
Caranx tille	Tille trevally
Carcharhinus limbatus	Blacktip shark
Cephalopholis boenak	Chocolate hind
Chirocentrus dorab	Dorab wolf-herring
Decapterus russelli	Indian scad
Dussumieria acuta	Rainbow sardine
Epinephelus areolatus	Areolate grouper
Epinephelus tauvina	Greasy grouper
Euthynnus affinis	Kawakawa
Fenneropenaeus indicus	Indian white prawn
Fenneropenaeus merguiensis	Banana prawn
Hemiramphus archipelagicus	Jujmping halfbeak
Katsuwonus pelamis	Skipjack tuna
Lates calcarifer	Barramundi
Leiognathus splendens	Ponyfishes
Lethrinus laticaudis	Grass snapper
Lutjanus argentimaculatus	Mangrove red snapper
Lutjanus malabaricus	Malabar snapper
Lutjanus sebae	Red emperor snapper
Megalaspis cordyla	Torpedo scad
Megatrygon microps	Smalleye stingray
Metapenaeus monoceros	Speckled shrimp
Mugil cephalus	Grey mullet
Nemipterus hexodon	Ornate threadfin bream
Netuma thalassina	Giant catfish
Pampus argenteus	Silver pomfret
Parastromateus niger	Black pomfret
Plectropomus leopardus	Leopard coralgrouper
Portunus pelagicus	Blue swimming crab
Pristipomoides filamentosus	Crimson jobfish
Pristipomoides multidens	Goldband snapper
Pristipomoides typus	Red-tailed Opakapaka
Rastrelliger brachysoma	Short mackerel
Sardinella gibbosa	Goldstripe sardinella
Sardinella lemuru	Bali sardinella
Scomberomorus commerson	Narrow-barred Spanish mackerel
Scomberomorus guttatus	Indo-Pacific king mackerel
Selaroides leptolepis	Yellowstripe scad
Sepia latimanus	Broadclub cuttlefish
Siganus sutor	Shoemaker spinefoot
Stolephorus teguhi	Sulawesi anchovy
Tegillarca granosa	Granular ark
Tenualosa toli	Toli shad
Thunnus alalunga	Albacore tuna
Thunnus albacares	Yellowfin tuna
Thunnus maccoyii	Southern bluefin tuna
Thunnus obesus	Bigeye tuna
Thunnus tonggol	Longtail tuna
Trichiurus lepturus	Largehead hairtail
Upeneus vittatus	Yellowstriped goatfish

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