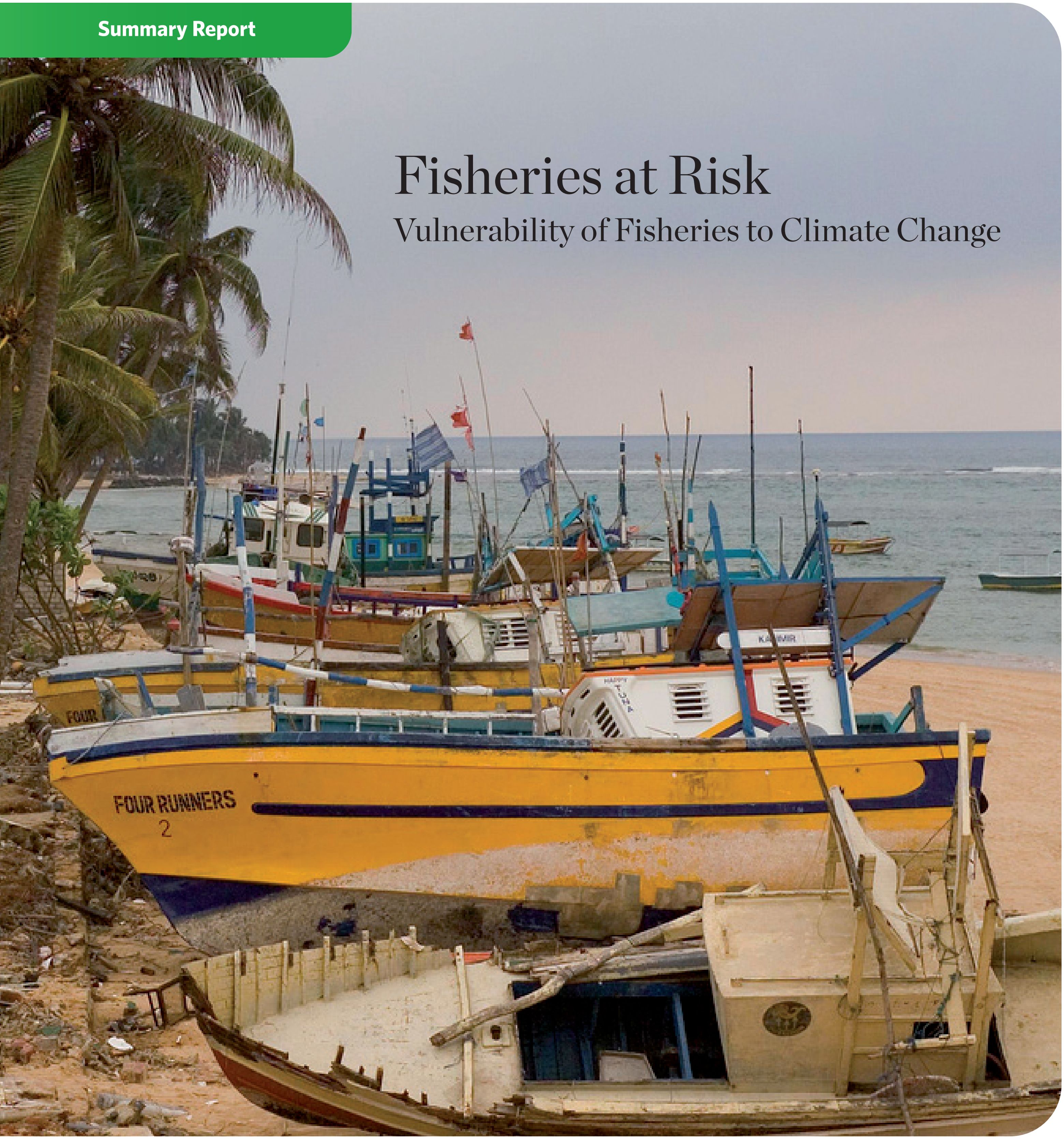
Summary Report

Fisheries at Risk

Vulnerability of Fisheries to Climate Change



The Nature Conservancy Europe

University of California Santa Cruz

Bündnis Entwicklung Hilft
Gemeinsam für Menschen in Not.

Fisheries at Risk: Vulnerability of Fisheries to Climate Change

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Pg 4: Local residents of Honda at the local fish market, Colombia. © Juan Arredondo
Pg 6: A fisherman cleans his catch at the Grenville Bay harbor, Grenada. © Marjo Aho
Pg 13: Workers unload boats from the Irrawaddy River with catfish, tunnel fish, palm pomfret and carp, making their way to Sanpya Fish Market in Yangon, Myanmar. © Michael Yamashita
Pg 14: A fisher holds out small gray angelfish caught in his traps at Pedro Bank, Jamaica. © Tim Calver

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Executive Summary

Fishing is vital to the lives and livelihoods of coastal communities and countries around the world. Yet, marine fish stocks and fishers face many growing challenges from coastal hazards and climate change. At-risk countries and communities need support to build resilience and adapt to these challenges effectively. This study examines the impacts of climate change on fish, fisheries and fishers and informs targeted strategies to support effective adaptation and risk reduction for fishing communities. It refines previous global fisheries risk assessments by:

+ focusing on overall risk, including exposure and vulnerability, and
+ separately examining multiple aspects of coastal hazards such as waves and storms, as well as climate-related aspects such as warming and acidification that differentially affect fish and fishing communities.

We provide an assessment of near-term and future risk, based on expected changes in sea surface temperature, ocean acidification, and sea level rise. We show how these differences in exposure of fish and fishers to climate change should be reflected in the strategies developed to reduce these risks.

Key Findings and Recommendations:

+ **The study results indicate geographically different exposure profiles.** The effects of warming and acidification have greater impact on fish catch for countries at higher latitudes (e.g., Greenland). Growing climate-related coastal hazards such as flooding and inclement wave conditions for harbors, in turn, have greater impact on fishers in more tropical countries (e.g., Myanmar) where these impacts are more likely to adversely affect fishing communities.
+ **Long-term adaptation strategies and policy changes that address shifting fish stocks are required** to reduce risks to fish and catch. Where climate change puts fish stocks at risk, policies should be implemented to limit overfishing as stocks decline and to encourage diversification of stocks that are fished. Otherwise, fishers will have to increase their capacity to "follow the fish", which can be difficult for small-scale fisheries.
+ **Investments in fishery disaster preparedness and hazard mitigation are required** to reduce the risk of climate impacts on fishers and fishing communities. Pre-hazard actions are particularly cost effective for risk reduction. However, there is generally limited funding available for these actions. More disaster recovery funding should be directed towards improving resilience and adaptive capacity of fishers, for example, to diversify fisheries, promote less destructive gear, and provide opportunities for alternative livelihoods and income diversification.
+ **Non-climate stressors should be reduced.** These stressors could be reduced by using area-specific policy measures that minimize impacts on critical fishery habitat (e.g., banning bottom trawling), implementing appropriate fishery closures, ensuring the enforcement of designated regulations, and reducing pollution sources.
+ **Micro- and parametric insurance mechanisms can be expanded** to help prevent fishers from spiralling into poverty with the loss of their boats and gear. These mechanisms could also help reduce pressure and enhance recovery of collapsing stocks.


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1. Introduction

Marine fisheries are vital for coastal nations as an important food source and as a source of employment (Johnson and Welch 2009, McClanahan et a. 2015). Globally, marine fisheries supply about 80 million tons of protein for direct human consumption per year (Da Silva 2016, FAO 2017). Marine fisheries also support national economies with an estimated annual gross revenue of US$ 80–85 billion (Sumaila et al. 2017, Sumaila et al. 2011) and provide full-time and part-time jobs to an estimated 260 million people, with a large fraction of fishers engaged in small-scale fisheries (FAO 2017, Teh and Sumaila 2013).

Marine fisheries are subject to multiple anthropogenic threats which reduce their productivity, including overfishing, habitat loss and pollution (Noone et al. 2013). Climate change poses an additional threat to marine fisheries and to fishing communities. Climate change is already altering chemical and physical conditions of the ocean (Cheung et al. 2010, Allison et al. 2009) such as changing sea surface temperature and ocean acidification, which are likely to affect catch potential of coastal fisheries in the future through changes in productivity and distribution of fish species (Barange and Perry 2009, Cheung et al. 2010). These ecological shifts are expected to indirectly affect fishers and fishing communities as a result of altered fishing revenues, higher operation costs, higher insurance costs, and reduced food security (Sumaila et al. 2011, Badjeck et al. 2010, Ding et al. 2017). Sea level rise and extreme weather events leading to business disruption and loss of coastal infrastructure and fish habitats put additional stress on fisheries and fishing communities (IPCC 2014).

The vulnerability of fisheries and fishing communities to the effects of coastal hazards and climate change needs to be better understood to enable fisheries and fishing dependent communities to adapt to long-term changes in environmental conditions (e.g. ocean acidification), seasonal events (e.g. El Niño), and severe weather events (e.g. hurricanes). Considering these impacts is critical for reducing the overall risk to fisheries from both long-term and short-term impacts.

This study, therefore, refines previous efforts and provides a vulnerability assessment that accounts for climate-related effects on fisheries due to long-term changes in coastal ecosystems and extreme climate events that are likely to increase in duration and frequency in the future. In contrast to previous studies, we make a distinction between **exposure of fish** to change in marine ecosystems (sea surface temperature, ocean acidification), and direct **exposure of fishermen** to climate-related effects (hurricanes, sea level rise). This separation is important to identify direct risk to people versus indirect risks to people via impacts on marine ecosystems. The separation is also critical for developing targeted recommendations for reducing risk, which consider impacts on people and impacts on ecosystems.

The study uses a widely used risk-based framework which allows us to comprehensively view fisheries risks from a coastal hazards and climate change perspective. This framework and the Fisheries@Risk Index recognize this resource sector as a social-ecological system in addressing the following questions:

+ How at risk are coastal nations to climate change impacts on their fisheries?
+ What strategies can help to reduce risk, looking across the near-term and long-term impacts of climate change on fish and fishing communities?

The findings of this study provide critical information to regional, national and international decision-makers about the risks that fisheries and fishing dependent communities and nations face; the factors that contribute to risk for fisheries; and the role that social, economic, and governance factors play in reducing current and future climate risks to fisheries.

2. Methods

The study uses a composite indicator for assessing the current and near future risk that coastal nations face with respect to climate change impacts on their fisheries and fishing dependent communities. For this assessment, an IPCC risk-based framework is used which offers an integrated approach for exploring the complexity of variables that shape vulnerability of fisheries to climate-related risks including short-term and long-term climate events (IPCC 2014). This framework calculates risk as a combination of hazard, exposure, and vulnerability (IPCC 2014). For this report, hazard and exposure are combined into one variable, following the methodology of the WorldRiskIndex (Bündnis Entwicklung Hilft / IFHV 2019). Thus, the overall risk is calculated based on exposure and vulnerability.

The indicator-based risk estimation uses a range of available environmental, social, and economic global data sets, that capture risk to fisheries across exposure, sensitivity, and adaptive capacity. Building from earlier work on risk of nations to natural hazards, namely the WorldRiskIndex and the Coast@Risk reports, this study includes several new fishery specific indicators to examine risk to fisheries, which sharpens our ability to assess industry specific strategies that help reduce risk in coastal areas.

The Fisheries@Risk Index is calculated by combining the indicators under exposure and vulnerability. Exposure of fish catch (landing in tonnes) were calculated based on hazards that affect fish, including sea surface temperature and ocean acidification, multiplied by reported landings. Exposure of fishers was calculated based on hazards that directly affect fishers (sea level rise (SLR), storms, wave actions). Projections of future exposure until the mid-century were the intermediate and high climate change scenarios from the IPCC (more formally, the representative concentration pathways RCP4.5 and RCP8.5). Sensitivity was calculated as the dependency of coastal nations on fisheries for food, employment, and economic income. Sensitivity of the fish resource is based on non-climate stressors that render the ecosystem more vulnerable to climate impacts. Adaptive capacity was assessed based on 1) the presence of marine livelihood alternatives, 2) fisher's capacity and mobility, 3) fishery management and governance, and 4) the generic adaptive capacity (GDP, literacy rates, World Governance Indicators of the World Bank). The combined vulnerability score (the aggregate of the sensitivity and adaptive capacity scores) was then multiplied with exposure to get a final risk index rating.


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3. Results

3.1 Global Assessment

Fisheries risk is a multi-dimensional phenomenon caused by exposure to coastal hazards and climate change as well as the vulnerability of nations to fisheries impacts. Based on data availability, 143 Exclusive Economic Zones (EEZ) of coastal countries are included in the analysis. We examine key indicators below and then present the overall Fisheries@Risk Index.

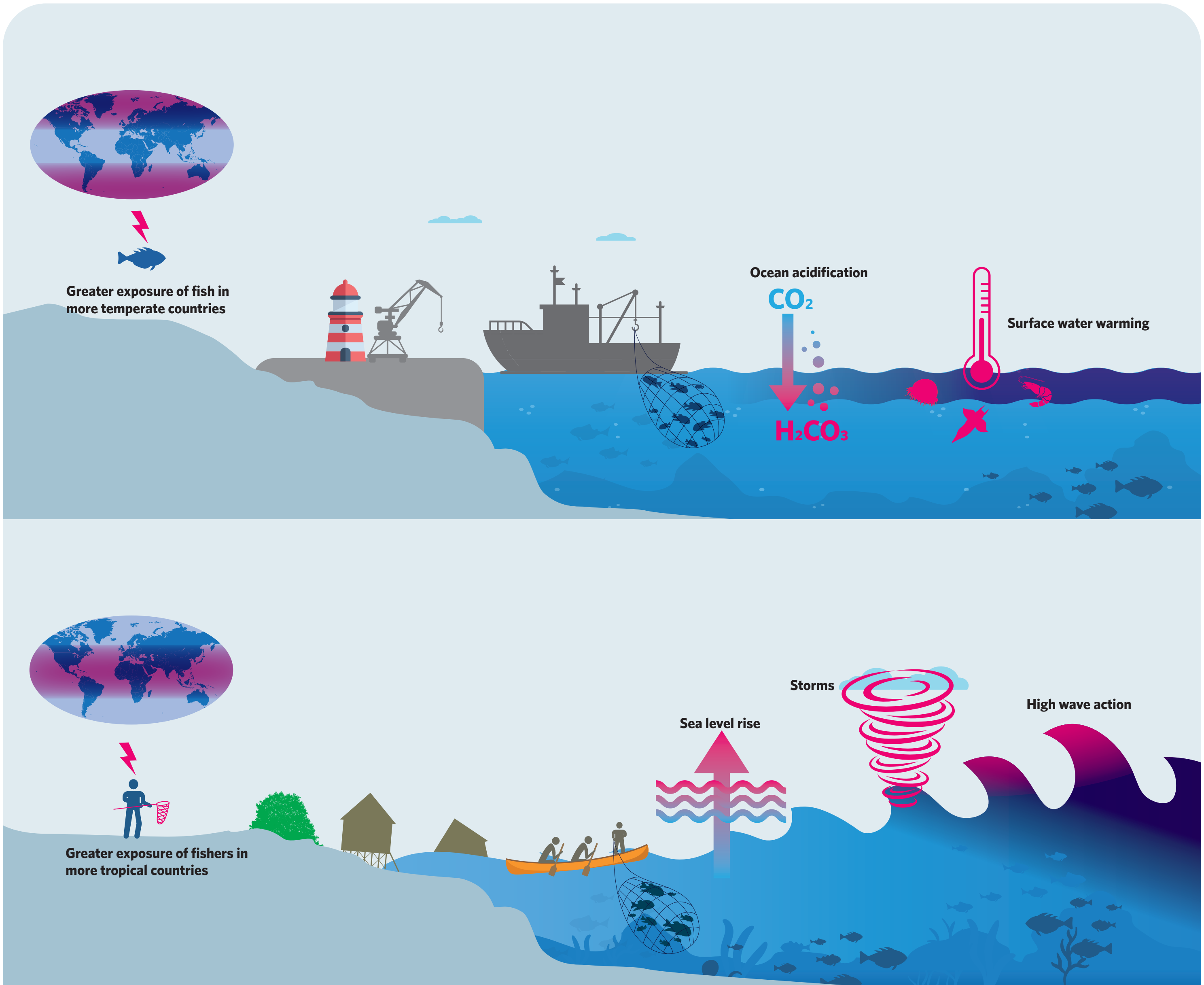

Figure 1: Differences in exposure across geographic regions

Exposure

When disaggregating the different components of exposure, we see latitudinal differences in the underlying nature of exposure (Fig. 1). Namely, higher latitude countries will be more exposed to climate impacts on fish, for example through ocean acidification and surface temperature warming, tropical or lower latitude countries will be more exposed to climate impacts on fishers through storms, sea level rise and greater wave action. Figure 2 shows that the climate-related impacts on fish, due to changes in sea surface temperature and ocean acidification, will most likely exacerbate fisheries risk in more northerly latitudes. Conversely, the fishers and fishing communities of tropical countries are more likely to be exposed to and face risks from direct impacts of coastal cyclones, high wave action and sea level rise (Fig. 3). Combined exposure of fish and fishers to climate impacts is highest in Greenland, Iceland, Micronesia, Norway, the British Virgin Islands, Philippines, Mauritius, Turks & Caicos, Vanuatu and Sint Maarten.

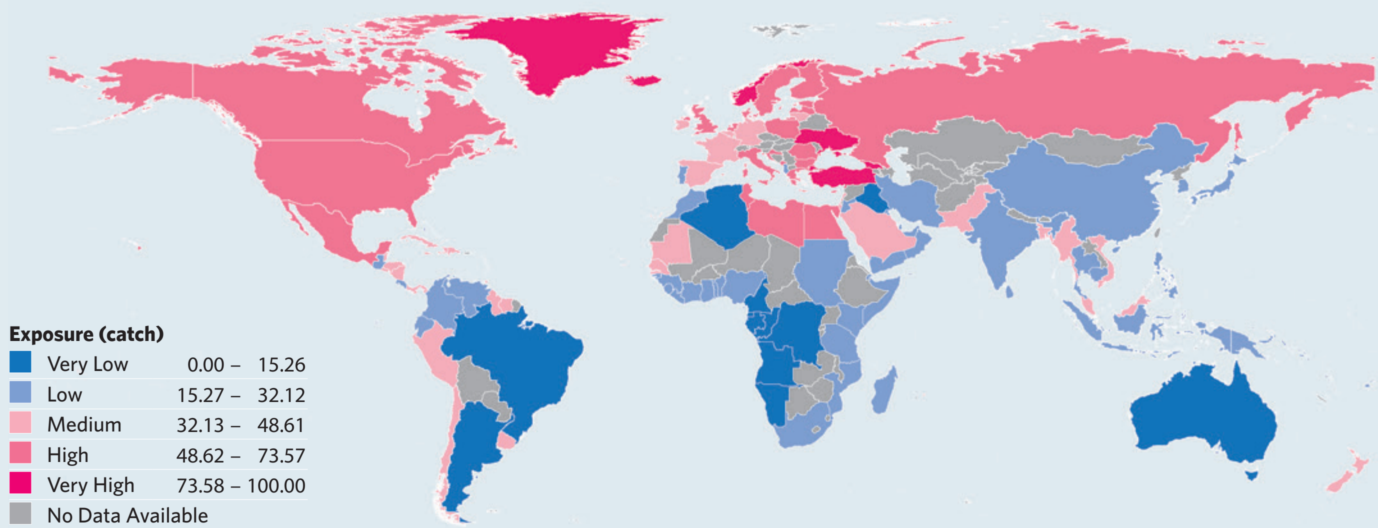

Figure 2: Exposure of catch to sea surface temperature change and ocean acidification

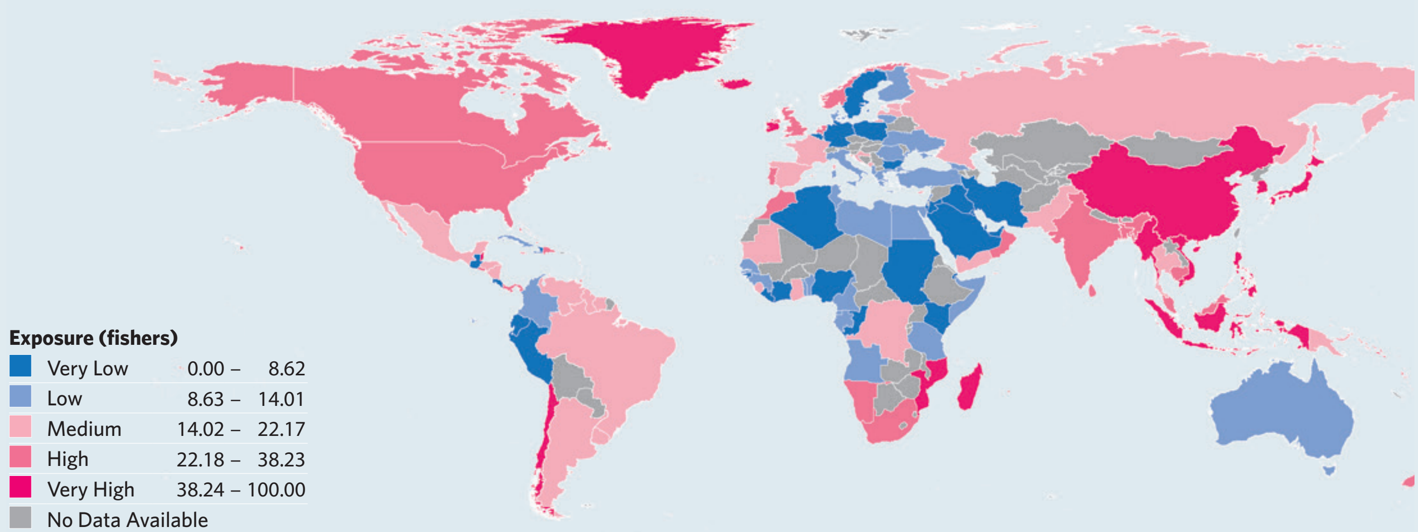

Figure 3: Exposure of fishers to sea level rise, cyclones, and high wave action

Sensitivity

Figure 4 displays the sensitivity of coastal nations to climate impacts. In regions of high sensitivity, many countries rely primarily on small-scale fisheries. These are often considered to be less adaptable to climate change than industrial fisheries. The top 10 most sensitive coastal nations to climate impacts are the British Virgin Islands, Sint Maarten, Sierra Leone, Solomon Islands, Nigeria, Sri Lanka, Togo, Indonesia, Cameroon, and Sao Tome & Principe.

Analysis shows that there are differences in the underlying reasons for the sensitivity of countries to climate change. Factors such as high dependency on fisheries for food security, economic income and employment, or degraded fishery habitats through poor land-use management and fishing practices can all cause nations to be more sensitive to the impacts of climate change. In these cases, non-climate stressors (e.g. pollution) may also have important effects on sensitivity.

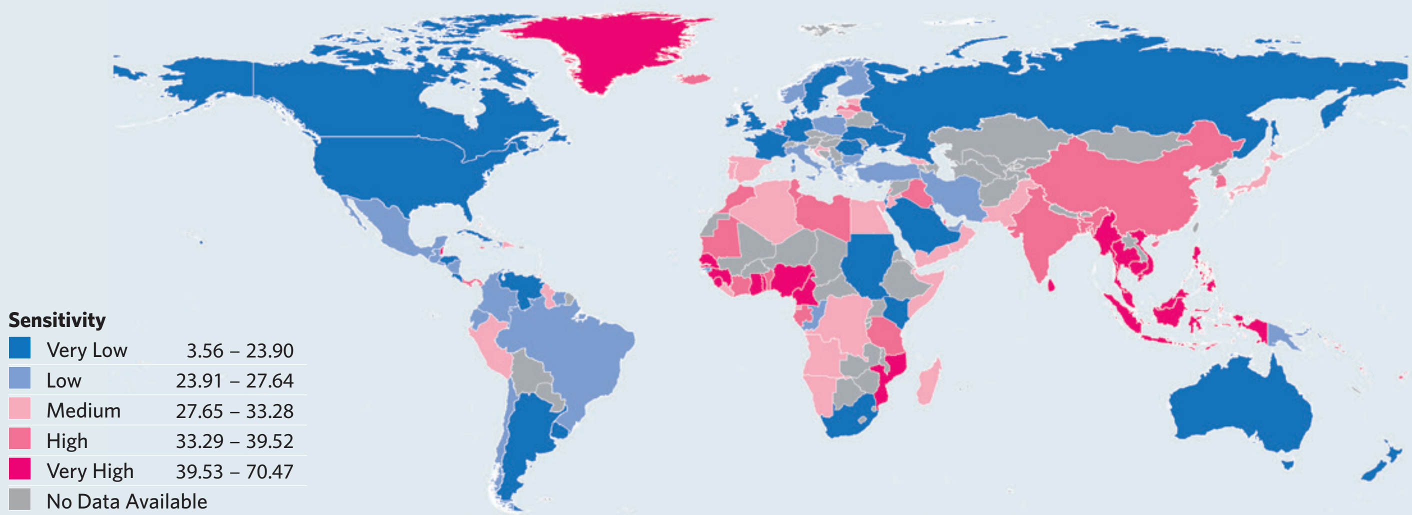

Figure 4: Sensitivity of coastal nations to climate related impacts on fisheries

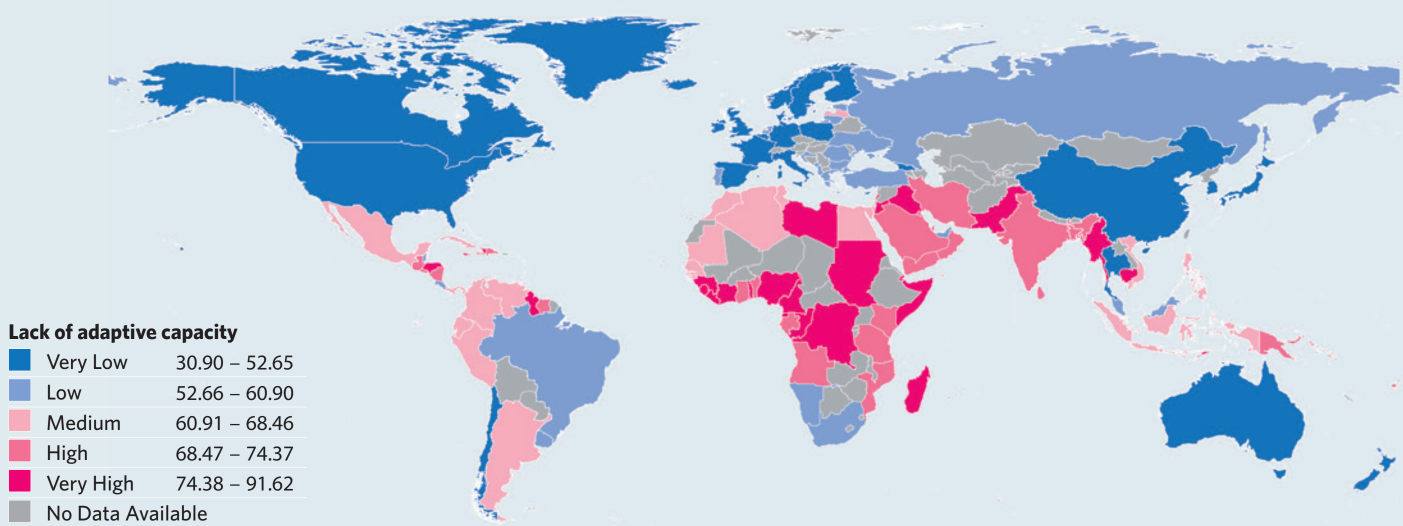

Figure 5: Lack of fisheries adaptive capacity to respond to climate impacts

Lack of Fisheries Adaptive Capacity

Figure 5 highlights geographies that suffer from low fisheries adaptive capacity to respond to climate change. The top 10 countries with the highest lack of fisheries adaptive capacity are Iraq, Djibouti, Haiti, Somalia, Nigeria, Myanmar, Liberia, Lebanon, Cameroon, and Comoros. An analysis of the top 10 countries with very low fisheries adaptive capacity for the different dimensions reveals differences in the types of adaptive capacity that is lacking. The top reasons for limited adaptive capacity are shown to be: (i) a lack of alternative marine livelihoods, (ii) limited mobility and technical capacity of fishers to respond to changes in marine ecosystems, (iii) poor fishery management and governance, and (iv) limited general national adaptive capacity in terms of adult literacy, GDP per capita, and governance. These challenges in fishery adaptive capacity, however, are not regionally specific and do not occur in isolation. Often there is a combination of these factors which limit fisheries adaptive capacity.

Vulnerability

Vulnerability combines sensitivity and adaptive capacity. Figure 6 shows the aggregate results of these indicators. The 10 countries with the highest vulnerability, in order, are Nigeria, Sierra Leone, Cameroon, Togo, Solomon Islands, Sint Maarten, Iraq, Sri Lanka, Cambodia and Myanmar.

Risk

The results of the Fisheries@Risk Index describe the current and potential future risk of fish and fisheries at a national level to climate change impacts. The index is a composite of the above-described underlying factors that shape risk to climate hazards in coastal nations. The aggregated results are mapped (Fig. 7) to facilitate a general understanding and comparison between countries and regions and to show areas which are most at risk. The 10 countries with the highest risk are, in order, Micronesia, Sint Maarten, British Virgin Islands, Philippines, Solomon Islands, Turks & Caicos, Vanuatu, Iceland, Greenland and Tonga.

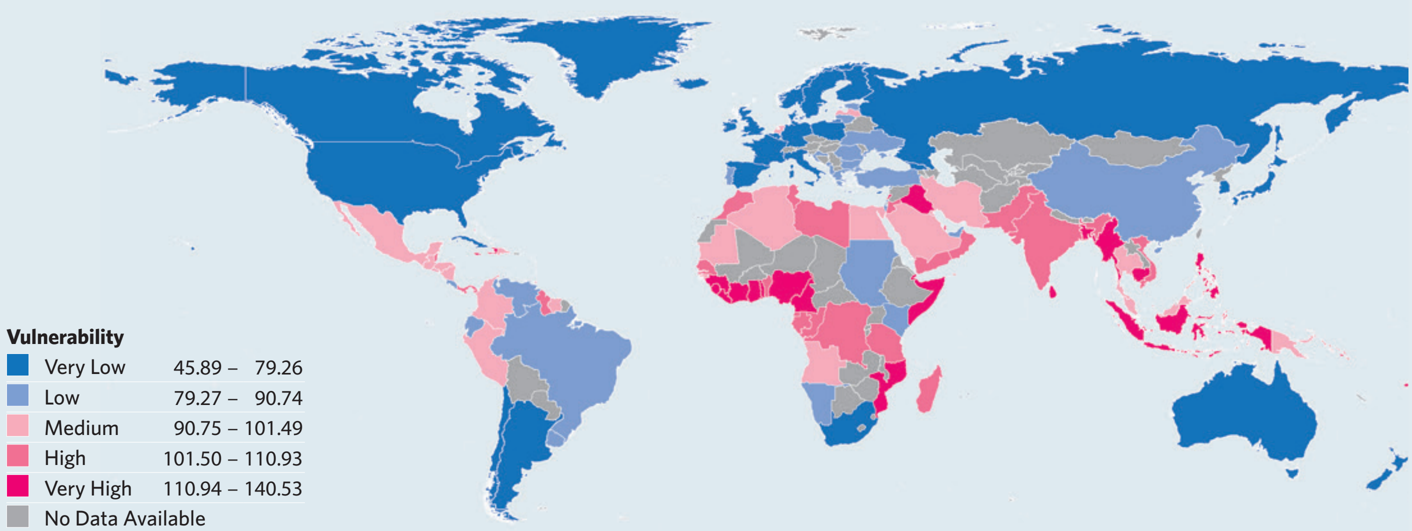

Figure 6: Vulnerability of coastal nations to climate related impacts on fisheries

3.2 Assessment of Mid-Term Climate Risk

In addition to calculating the present climate risk, we use existing predictions of changes in climate variables by mid-century to make predictions about countries that may face the greatest future change in exposure. Expected future exposure of fish species was calculated based on predicted changes in sea surface temperature and ocean acidification multiplied with current landings per capita. Expected change in exposure to fishers was based on predicted changes in sea level rise, cyclones, and wave action multiplied with the current number of fishers per capita. A comparison of the present and future exposure across regions reveals that Europe is the only region where risk is expected to decrease in the future due to a decrease in hazards. Further analysis also reveals that exposure is expected to decrease in OECD countries. Least developed states and SIDS are expected to experience increases in exposure.

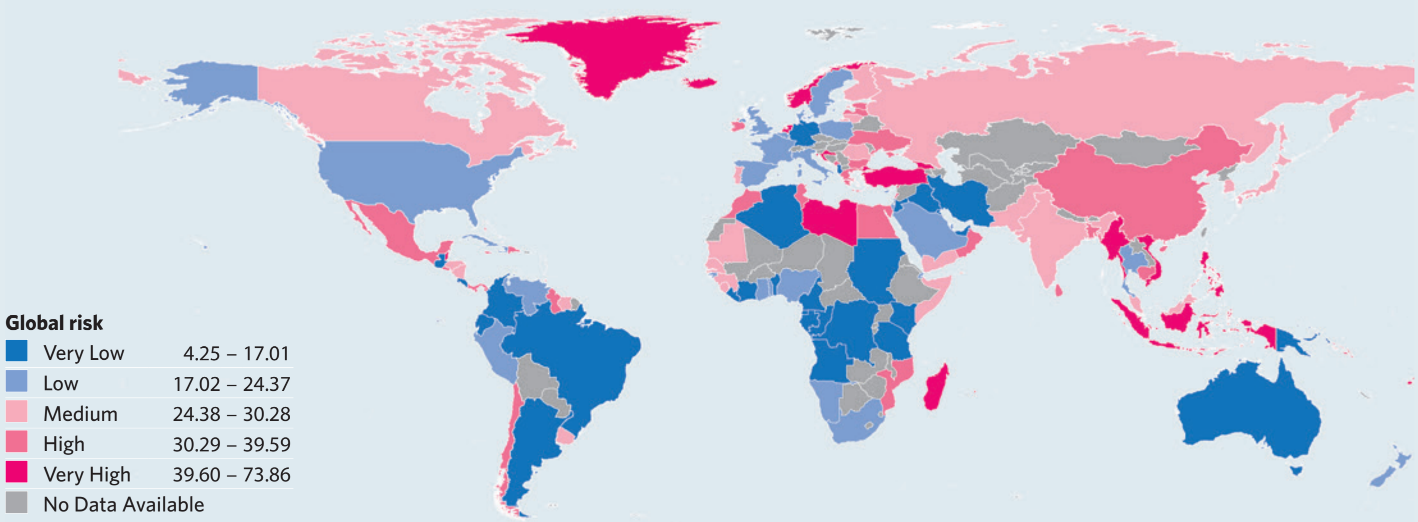

Figure 7: Risk to coastal nations due to climate effects on fisheries

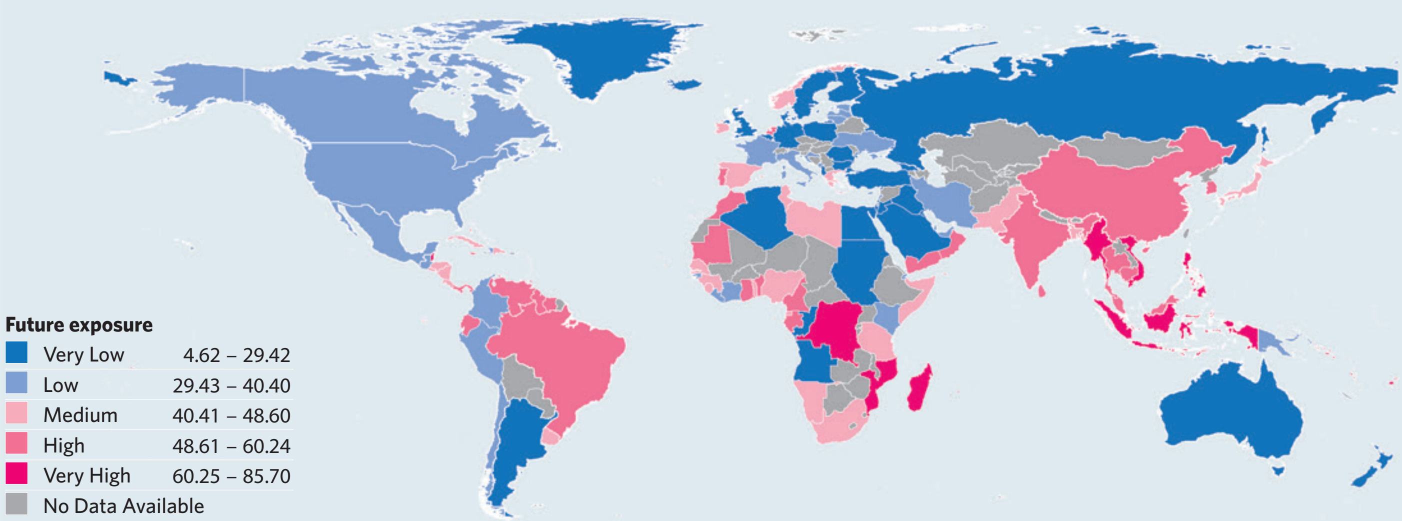

Figure 8: Future exposure of fisheries

Case study

Fishing communities adapting to climate change in Liberia

According to the Fisheries@Risk Index, Liberia ranks among the most vulnerable countries to climate impacts on fisheries. The high vulnerability towards extreme weather events is also confirmed by the WorldRiskIndex (rank 10 of 180 countries, Bündnis Entwicklung Hilft / IFHV 2019). The small-scale coastal subsector is particularly important in providing nutrition and employment for approximately 33,000 full-time fishers and processors located along the Atlantic coast of Liberia. Many small-scale fishers use simple fishing techniques based on hook and line fishing with paddled boats that are typically passed on from one generation to the next. These fishers face competition from big industrial vessels that plunder hundreds of tons of fish in Liberia's Exclusive Economic Zone (EEZ).

An increase in extreme weather events as a result of climate change reduces the opportunities for fishers to leave the coast in small boats for fishing. Overharvesting of mangroves for wood for fish drying and landfilling for housing construction in swamps with the increasing temperatures contribute to the destruction of such coastal ecosystems serving as habitats and spawning grounds for fish, mussels and crabs. This puts further pressure on coastal fish resources, by reducing fish stocks and increasing the competition among small-scale fishers.

Welthungerhilfe - one of the members of Bündnis Entwicklung Hilft - started working with fishery communities in southeast Liberia in 2017 as part of a broader project on adaptation to climate change. Through local NGOs, Welthungerhilfe worked together with a cooperative of local fisher families to raise awareness on the dynamics of climate change and develop appropriate adaptation strategies based on available resources and skills. The project supports fishing families to expand their capacities and diversify their income to strengthen resilience to climate change impacts. For example, they were trained in the maintenance and operation of motorized vessels as well as processing methods that enhance longer storage capacity to sustain fish market supplies for a greater duration. The project also supports the local construction of affordable and accessible solar dryers by using local materials such as plastic and excess wood available in the environment to reduce pressures on mangrove deforestation. An increasing number of motorized boats, under the management of the cooperative, allows fishers to leave the coast despite rougher weather conditions and reach further away fishing sites. Using the fishing boats for marine transport over short distances during poor or low catch periods was also presented as an alternative means of creating additional income opportunities.

Through these combined measures, the targeted fishing families managed to progressively raise their incomes and to enhance preventive measures against climate change impacts. Fishers can now save and borrow through the local Village Savings and Loan Associations (VSLAs) for other small investment opportunities, which help to meet basic social service needs. The additional income from small-scale investments makes it possible to maintain running costs on fishing boats or equipment. All of this contributes to the socio-economic well-being of the fisher families and strengthens their resilience in the long-term.

4. Discussion and Recommendations

This study provides critical insights on the combined risk of coastal hazards and long-term climate change that fishery dependent countries are facing now and in the future. The findings show that fisheries in most countries are at risk to climate hazards and long-term climate change. An increase in the frequency, and/or intensity of extreme weather events could have direct impacts on fishing operations, and the physical infrastructure of coastal communities as cyclones can destroy or severely damage assets such as boats, landing sites, post-harvesting facilities and roads. These coastal hazards, combined with the long-term impacts of climate change on productivity and species distributions (Cheung et al. 2010), present a risk for fisheries in many coastal nations. The resulting declines in catch rates in addition to the loss of critical infrastructure and access to markets will affect both local livelihoods and the economy of coastal countries (Sumaila et al. 2011), particularly in nations which are highly dependent on fisheries for food security, economic contribution to GDP, and employment.

Risk is highest in SIDS

This study shows that risk is not evenly distributed geographically. Most countries in Europe and South America, for example, are displaying relatively low levels of risk. Oceania and Africa, on the other hand, contain a number of countries that have a high risk of climate change impacts on their fisheries. SIDS in particular face high exposure and vulnerability and are most at risk to combined impacts of coastal hazards and long-term climate change. These islands thus will require more efforts and economic resources for reducing their vulnerability, as compared to other countries.

Vulnerability is multi-faceted

The results of this study further highlight where and how adaptation measures could be tailored to reduce vulnerability and risk. Promoting more effective fishery management via improved fishery regulations, enforcement, and insurance mechanisms that foster sustainable fishing practices might allow fish stocks and coastal ecosystems to recover (e.g. in Philippines, Indonesia, Sri Lanka), thus reducing sensitivity. A number of countries, on the other hand, are primarily sensitive due to pollution of coastal ecosystems (e.g., in Germany, Belgium, Poland, Israel, Lebanon) and would rather require more emphasis on pollution reduction strategies to reduce the sensitivity of their fish resources.

Reducing the dependency on fisheries for food, employment, and income could be more difficult as fishing is a way of life for many fishers. Countries that are primarily sensitive due to their dependency on the fishery sector (e.g. Kiribati, Solomon Islands, Micronesia, Vanuatu, Samoa, Saint Vincent & the Grenadines) thus should focus more on increasing fisheries adaptive capacity than reducing sensitivity. Our study shows that individual countries lack different types of adaptive capacity. For example, in parts of the Caribbean, the mobility and technical capacity of fishers to respond to changes in marine ecosystems is particularly limited. Identifying the distinct capacity issues that reduce the ability of a coastal nation and its fishing communities to respond to coastal hazards and adapt to climate driven long-term changes is imperative to designing strategies that reduce vulnerability. Adaptation planning is also likely to be more effective if it builds on existing capacities.

Methodological approaches to identify fisheries specific risks to coastal nations

The study demonstrates how risk and vulnerability of fisheries can be assessed using a set of fishery specific indicators. Such analyses can be used to identify trends and possible opportunities for adaptation in the face of climate change. The approach outlined here could be adapted and expanded in the future to conduct vulnerability analyses for specific climate change impacts in greater detail and at different spatial scales, including local and regional studies. However, it is important to acknowledge that climate change is a multifaceted threat which comprises multiple interacting impacts on fisheries (Daw et al. 2009). Given the uncertainties around the processes driving vulnerability, any risk analysis of climate change impacts on fisheries should account for these uncertainties when being used to develop adaptation policies.

New approaches are needed to help reduce risks to fish and fishers

Fishers face two kinds of particularly grave risk from (i) storms and (ii) steep declines or even collapse of fish stocks from overfishing and other anthropogenic impacts. Insurance can be used to reduce and transfer risk and support ecosystem-based adaptation (Beck et al. 2019, Reguero et al. 2020). Presently insurance is used in a number of cases to help reduce risks of storm damage to the boats and gear of small-scale fishers. In the future, insurance tools could be developed that could be used to transfer risk from the loss of fisheries and even help promote better fisheries management to reduce these risks. The Caribbean Oceans and Aquaculture Sustainability Facility (COAST) initiative aims to help to reduce the risk that climate change poses to food security and nutrition and to mitigate climate change impacts on the fisheries sector and to sustainable food production overall. COAST's first insurance product primarily reduces storm risk but has also been used to promote better fisheries management by ensuring that fishers are registered nationally to access the insurance (Beck et al. 2019).

Future capture fish stock insurance could be based on indicators that measure the status and health of stocks, and set premiums based on the likelihood of the collapse of the fisheries. Fisheries insurance schemes that target vessels and fishing practices may indirectly help to protect the health of fish stocks by encouraging fishing practices that are potentially less destructive and improve compliance with enforcement regulations by favouring certain types of gear, species, and fishing practices (Mumford et al. 2009).

4.1 Gaps and Constraints

There are important considerations for any type of index as the calculations depend heavily on the selection of indicators, availability of data, as well as differences in time and spatial scales of data sets. Some fishery specific variables (e.g., fish catch and stock status) are known to be less reliable for some tropical countries given limitations in fisheries data collection. Future modelling efforts could improve the calculation by predicting responses of individual fish species to sea surface temperature change and ocean acidification, and by modelling impacts of coastal hazards on fishers and fishing communities in locations where subnational data on landings and fishery activities are available. Additionally, our future risk calculation only accounts for changes in hazards. Potential changes in exposure due to changes in catch and fishers as well as changes in vulnerability indicators were not available and have therefore not been included in the analysis of future risk.

4.2 Implications and Recommendations

Efforts to reduce risk of fisheries to climate change need to consider the underlying reasons for risk and be tailored to the specific needs of countries. By analyzing the spatial variation of risk to fisheries, findings in studies such as this one can help tailor risk reduction efforts and inform policy, practice, and financing of the fishery sector. As summarized in Figure 2, **countries in higher latitudes** that are likely to experience climate-induced shifts in species distribution due to slow changing climate variables (e.g., sea surface temperature change and ocean acidification) **need efforts for switching target species, gear types, or access to a variety of fishing grounds,** including more distant ones (Sumaila et al. 2011). **Tropical coastal nations** that are subject to more immediate climate-related hazards and short-term impacts on fishing efforts and income **would benefit from disaster preparedness and relief** after extreme weather events. The explicit separation of climate exposure to those that affect fish and those that affect fishers informs our recommendations.

+ **Invest in fishery disaster preparedness and hazard mitigation:** It is well known that pre-hazard actions and investments are particularly cost effective for risk reduction. Unfortunately, these actions are difficult to fund.

+ **Climate adaptation funding** should be better used to reduce current and future risks to fishing communities. For many of the most vulnerable nations, the best opportunities to support risk reduction likely come from adaptation funds. Unfortunately, the fishing sector and communities are often forgotten in adaptation funding and strategies. These sectors need to be better represented in national adaptation plans and in, for example, proposals to the Green Climate Fund.

+ **Direct disaster recovery funding to improve resilience and adaptation of fishers:** Sensible investments could help fishers recover and even to improve fish stocks and fisheries by directing resources to the most vulnerable sectors of fishing communities, for example, women fishers (Thomas et al. 2019). Back to work programs could be directed at fishers and could target recovery and restoration of critical nursery habitats for fished species. Recovery funding could be used to support many of the common and sensible recommendations such as diversification of fisheries, improvements in gear to be less destructive, opportunities for alternative livelihoods, and income diversification. This funding could be a critical tool to decrease sensitivity and to improve the adaptive capacity of fisheries, including fish and fishers.

+ **Provide insurance for fishers:** There is and has been a growing role for insurance in reducing risks of coastal hazards to fishers, including micro-insurance schemes for small scale fishers. Most of these tools aim to replace critical losses such as boats or motors, which is essential and can avoid a spiral into poverty or more destructive fishing practices. (Micro) insurance or other schemes such as loans should be made easier to access for fishers. To do so means additional support for premium payment will often be needed. This support could then help to incentivize better practices and adaptation along the lines of the strategies identified in the Disaster Recovery section above.

+ **Provide insurance for fish:** Insurance mechanisms could also be developed that help fish and fishers to recover by transferring and reducing risks associated with the collapse of fisheries. These mechanisms could increase adaptive capacity by providing income to fishers when fishing efforts should be reduced to allow fish stocks to recover. These mechanisms could also include incentives to manage fisheries better, for example, by creating fisher registries and reducing premium costs for fisheries which are less likely to collapse.

+ **Reduce non-climate stressors:** These stressors could be reduced by using area-based tools and policies that minimize impacts on critical fishery habitat (e.g., bottom trawling), implementing appropriate fishery closures, ensuring the enforcement of designated regulations, and reducing pollution sources. Better regulations and terrestrial protections could help reduce impacts of agricultural and urban run-off on important fishing areas. In addition, reducing plastic pollution will be critical.

+ **Adapt fishery policy to better account for climate-related changes** in distribution and productivity of fish stocks, which is particularly critical for nations at higher latitudes. Economic funds could be used to promote more diversified fishing, which is a strategy to respond to climate-related spatial range shifts in fishery species. Otherwise, fishers will have to increase their means to "follow the fish", which can be difficult for small-scale fisheries that are most at risk. Improving catch diversity might also require changes in shoreside markets and infrastructure to accommodate a larger variety of caught species. Another important factor would be management strategies, including catch shares and access regulations that enable a higher catch diversity in national and local fishery fleets.

+ **Diversify fisheries and/or livelihoods** to replace or supplement fishery livelihood opportunities; provide opportunities to enhance skillsets of fishers. Fishery communities should be strengthened by using efficient and sustainable methods for commercial and subsistence use of the catch. A primary focus should be on income-generating measures for households and small-scale producers.

+ **Encourage collaboration between local users, managers, and the scientific community:** Increasing interactions among scientists, managers, and the fishing community will be critical to fuse local knowledge and adaptation strategies with science-driven data and models. The integration of multiple information sources can help to identify adaptation strategies that are embedded in the local context and help to address local adaptation needs for reducing vulnerability. As part of this effort, the use of co-monitoring and community-based data collection programs would foster communication and data acquisition among scientist, fishers and citizen science groups (Barange et al. 2018).

+ **The activities of internationally operating trawlers should be limited** - legally and practically - in order to retain local fisheries. This is particularly critical in areas where fish and fishing communities are most at risk to coastal hazards and climate change. Marine and coastal areas, especially spawning grounds, should be protected at a minimum to an extent which ensures fish stocks can be maintained and/or recover from overfishing.

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This Summary Report, and its accompanying Technical Report, may be found at:
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