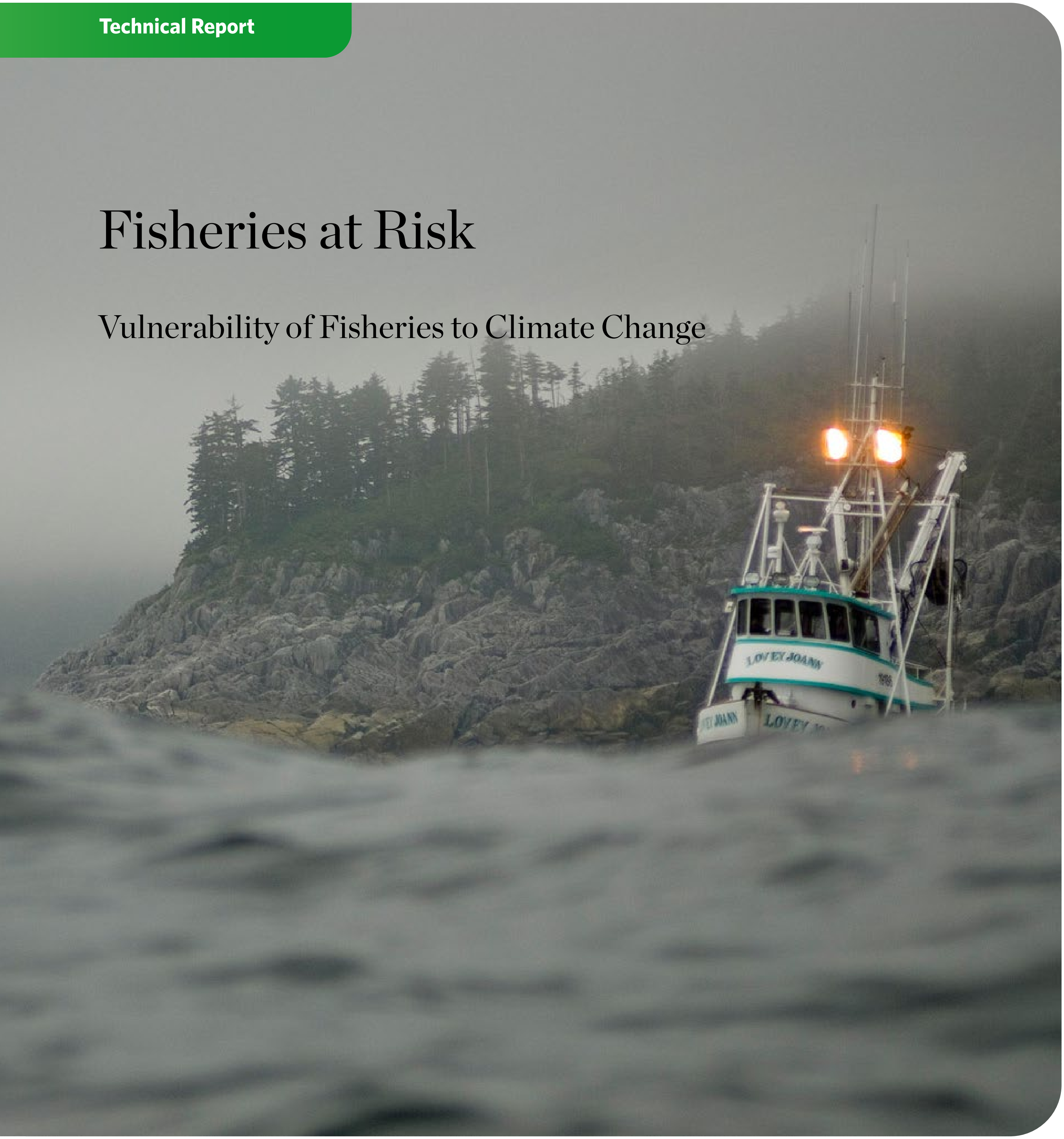
Technical Report

Fisheries at Risk

Vulnerability of Fisheries to Climate Change



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Fisheries at Risk: Vulnerability of Fisheries to Climate Change

Authors:
East Carolina University: Nadine Heck
University of California, Santa Cruz: Nadine Heck, Borja Reguero, Michael W. Beck
The Nature Conservancy: Kerstin Pfliegner
Bündnis Entwicklung Hilft: Peter Mucke, Lotte Kirch
Food and Agriculture Organization of the United Nations: Vera Agostini

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Acronyms List

CHRR	Center for Hazards and Risk Research
CoRTAD	Coral Reef Temperature Anomaly Database
EEZ	Exclusive Economic Zone
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agricultural Organization of the United Nations, Statistical Databases
IPCC	Intergovernmental Panel on Climate Change
OECD	Organization for Economic Co-operation and Development
OHI	Ocean Health Index
RCP	Representative Concentration Pathways
SIDS	Small Island Developing States
SST	Sea Surface Temperature
UNEP / GRID	United Nations Environment Programme Global Resource Information Database
WDPA	World Database on Protected Areas
WTTO	World Travel and Tourism Council


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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 and fishers face growing challenges from coastal hazards and climate change. Many coastal countries and communities need support to build resilience and adapt to these changes. This study examines the impacts of climate change on fish and fishers and informs strategies to support adaptation and risk reduction for fishing communities. It refines previous global fisheries risk assessments by:

(i) focusing on overall risk (not just vulnerability) and (ii) separately examining multiple aspects of coastal hazards (e.g., waves, storms) and climate change (warming, acidification) that differentially affect fish and fishing communities. We show that these differences in exposure of fish and fishers to climate change affect the strategies to reduce these risks. We provide an assessment of near-term and future risk based on expected changes in sea surface temperature, ocean acidification, and sea level rise.

Key Findings and Recommendations:

+ The Fisheries@Risk Index identifies national risks to fish, fishers and fisheries by combining data on exposure to climate change and coastal hazards and vulnerability from social, economic and governance indicators. Countries most at risk include many equatorial small island states (e.g., Kiribati) as well as island nations in northern latitudes (e.g., Greenland) where climate impacts on fisheries are changing rapidly.

+ Findings indicate different exposure profiles for effects on fishers and fish species. The effects of warming and acidification have greater impact on fish catch for countries at higher latitudes. This puts countries such as Greenland and Iceland at particular risk. On the other hand, growing climate-related coastal hazards such as flooding, cyclones and inclement wave conditions for harbours have greater impact on fishers in more equatorial countries where these impacts are more likely to adversely affect fishing communities. This puts countries such as Nauru, St. Kitts and Nevis, and Myanmar at particular risk.

+ This variation in exposure affects strategies for reducing risk to fish and fishing communities. For example, to reduce risk to fishers and fishing communities we should use more risk transfer (e.g., insurance) and hazard risk reduction strategies in tropical countries. More cyclone disaster preparedness, recovery and hazard mitigation funding are needed for fishing communities particularly in tropical countries of the Global South. At present, very little disaster funding supports the recovery and resilience building of these communities.

+ To reduce risks to fish and catch, countries need to focus more on long-term adaptation strategies and policy changes that address shifting fish stocks (e.g., in countries at higher latitudes where temperature and acidification are changing fastest). Coastal nations that are facing more climate-related shifts in fish stocks require better policies to limit overfishing as stocks decline from climate change and policies which encourage diversification of stocks that are fished. Additional funds could be used to further promote more diversified fishing in terms of species and gear. Otherwise, fishers will have to increase their capacity to “follow the fish”, which can be difficult for small-scale fisheries that are most at risk.

+ Micro- and parametric insurance mechanisms could help reduce risk to both impacts on people and fish species. These insurance mechanisms can help prevent fishers from spiraling into poverty with the loss of their boats and gear. At the same time, these mechanisms could also help reduce fishing pressure and enhance recovery of collapsing stocks. Climate adaptation funding and strategies should also be better focused on fishing communities to improve the long-term resilience of these communities and to help ratchet towards more sustainable fishing practices.

1. Introduction

Marine fisheries are vital for coastal nations, and for their coastal communities in particular as fisheries generate employment and income. Moreover, fish are an important source of protein, essential fatty acids and micronutrients (Johnson and Welch 2009, Hall et al. 2013, McClanahan et al. 2015, Hughes et al. 2012). Global marine capture fisheries supply about 80 million tons of protein for direct human consumption per year (Da Silva 2016, FAO 2017a). 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 2017a, Teh and Sumaila 2013).

Yet, marine fisheries are subject to multiple anthropogenic threats that reduce the economic performance of fisheries, including overfishing, habitat loss, pollution, and climate change (Noone et al. 2013, Pitcher and Cheung 2013). Climate change in particular poses a key threat to marine fisheries and to fishing communities. Climate change is already altering chemical and physical conditions of the ocean (Pörtner et al. 2014, Cheung et al. 2010, Allison et al. 2009) for example by changing sea surface temperature and increasing ocean acidification, which are likely to affect catch potential of coastal fisheries in the future due to changes in productivity, food webs, and distribution of fish species (Edwards and Richardson 2004, Barange and Perry 2009, Cheung et al. 2010). These ecological shifts are expected to indirectly affect fishers and fishing communities through altered fishing revenues, higher operation costs, higher insurance costs, and reduced food security (Sumaila et al. 2011, Badjeck et al. 2010, Adger et al. 2009, Ding et al. 2017). Sea level rise and extreme weather events leading to loss of coastal infrastructure and fish habitats such as intertidal wetlands and reefs, which puts additional stress on fisheries and fishing communities (IPCC 2014). The increasing frequency and intensity of extreme climate events affect fish habitats, productivity, and distribution, as well as fishing operations and coastal infrastructure in fishing communities, and also increases the risk fishers face at sea (Knutson et al. 2010, Islam et al. 2014, Cochrane et al. 2009, Allison et al. 2009).

The vulnerability of fisheries to the effects of coastal hazards and climate change needs to be understood to enable fisheries and fishing dependent communities to adapt to long-term changes in environmental conditions (e.g., sea surface temperature, sea level, ocean acidification), seasonal events (e.g., El Nino), and sever weather events (e.g., cyclones). Building on early work by Allison et al. (2009), recent global studies on climate change and fisheries assessed the vulnerability of fishery dependent countries to singular climate change indicators (e.g., present and projected changes in sea surface temperature (Blasiak et al. 2017). Another study by Ding et al. (2017) explored vulnerability of coastal nations to multiple climate change impacts including sea surface temperature, ocean acidification, and sea level rise. Yet, none of these studies included climate related effects on fisheries due to cyclones, which can have direct effects on fishers and thus fisheries in coastal nations (Allison et al. 2005, Islam et al. 2014). Considering these impacts is critical for reducing overall risk to fisheries to both long-term and short-term impacts.

This study therefore refines previous efforts and provides a risk assessment that accounts for both climate related effects on fisheries due to long-term changes in coastal ecosystems and effects of extreme climate events (e.g., cyclones) that are likely to increase in duration and frequency in the future.

In addition, we calculate both exposure of fish to change in marine ecosystems (sea surface temperature, ocean acidification), and direct exposure of fishers to climate-related effects (cyclones, 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 to people and impacts on ecosystems. Another novelty of this study is the inclusion of fishery specific adaptive capacity indicators. Previous studies primarily focused on general adaptive capacity indicators (e.g., GDP, adult literacy, life expectancy) even though it is not clear what role these indicators play for the specific adaptive capacity of fisheries and whether fishers can access these resources (Blasiak et al. 2017). Our study expands on this concept and includes multiple fishery specific indicators to detect the capacity of the fishery sector more specifically to adapt to climate change (e.g., marine livelihood alternatives, gear diversity). This assessment will help to identify region specific strategies for reducing risk to fisheries in coastal nations.

To do this, we use a risk-based framework that is now widely used by both the climate and disaster risk management communities (IPCC 2014). This framework allows for the integration of coastal hazards and climate change.

The report first provides a global assessment of risk to fisheries. In addition, we include a more detailed assessment of a regional study by examining risk to fisheries in the Caribbean. Fisheries in the Caribbean are vital for the well-being of millions of people. The sector is important for food security, its contribution to national GDPs, and provides employment and income for hundreds of thousands of fishers and associated business (Burke and Maidens 2004). At the same time, there is growing concern about accelerated degradation and loss of resources in the region including economic losses in coral reef fisheries, due to anthropogenic threats and present and future climate hazards (Dye et al. 2017). Understanding the nature of risks to fisheries in this region is critical for developing region specific strategies that help reduce risk to fisheries and fishery dependent communities across the Caribbean.

In difference to prior global risk indices such as the WorldRiskIndex (Bündnis Entwicklung Hilft) and the Coasts@Risk (Beck 2014), the Fisheries@Risk Index focuses specifically on fisheries to capture the risks that fisheries-dependent nations face for their social and economic well-being. Fisheries here are recognized as a social-ecological system that contain both fish resources and the people using these.

The main outcomes of the study are the following:

+ 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 consequences of climate change to fish and fishing communities?

Findings of this study provide critical information to national, regional and global 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

2.1 Climate Risk Framework

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. In this study, we use the risk framework proposed in the IPCC Fifth Assessment Report to investigate climate-related risk of fisheries on a global scale (Fig. 1). This updated IPCC framework follows a more risk-based approach and thus can create greater consistency in our understanding of and approaches for addressing adaptation and risk reduction across climate and disaster risk management (UNISDR 2011, 2015, IPCC 2014). Applying a risk-based framework 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 (Mathis et al. 2015, IPCC 2014). The IPCC framework calculates risk as a combination of hazard, exposure, and vulnerability (IPCC 2014).

This risk-based framework also aligns with our work on the WorldRiskIndex and allows us to much more easily integrate across these approaches. For this report, hazard and exposure are combined into one variable following the WorldRiskIndex. Overall risk is calculated based on exposure and vulnerability.

In this report, the term hazard refers to climate-related impacts. Exposure is defined as the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC 2014). In this report, exposure refers to the presence of fishers and fish resources that are of economic value. Vulnerability is defined as the predisposition of people, communities, and / or nations to be adversely affected by hazards; it consists of sensitivity and adaptive capacity (IPCC 2014). In this report, vulnerability refers to social, economic and environmental factors that make fisheries of a nation vulnerable to the effects of climate change. It includes the ability of people to adapt to impacts on fisheries by climate change. It is composed of sensitivity

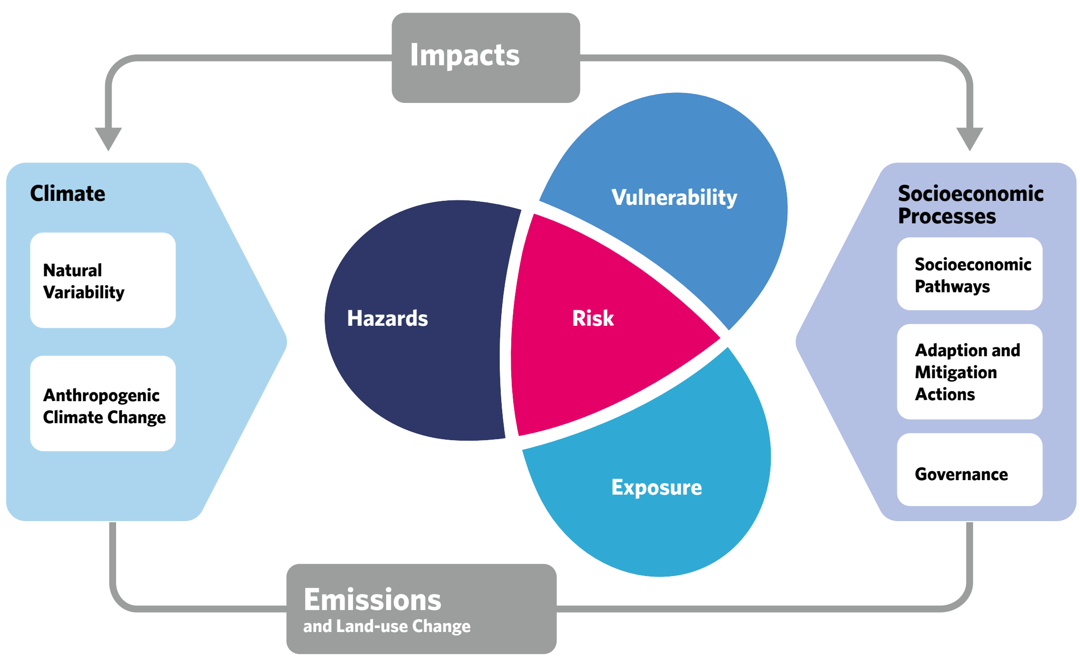
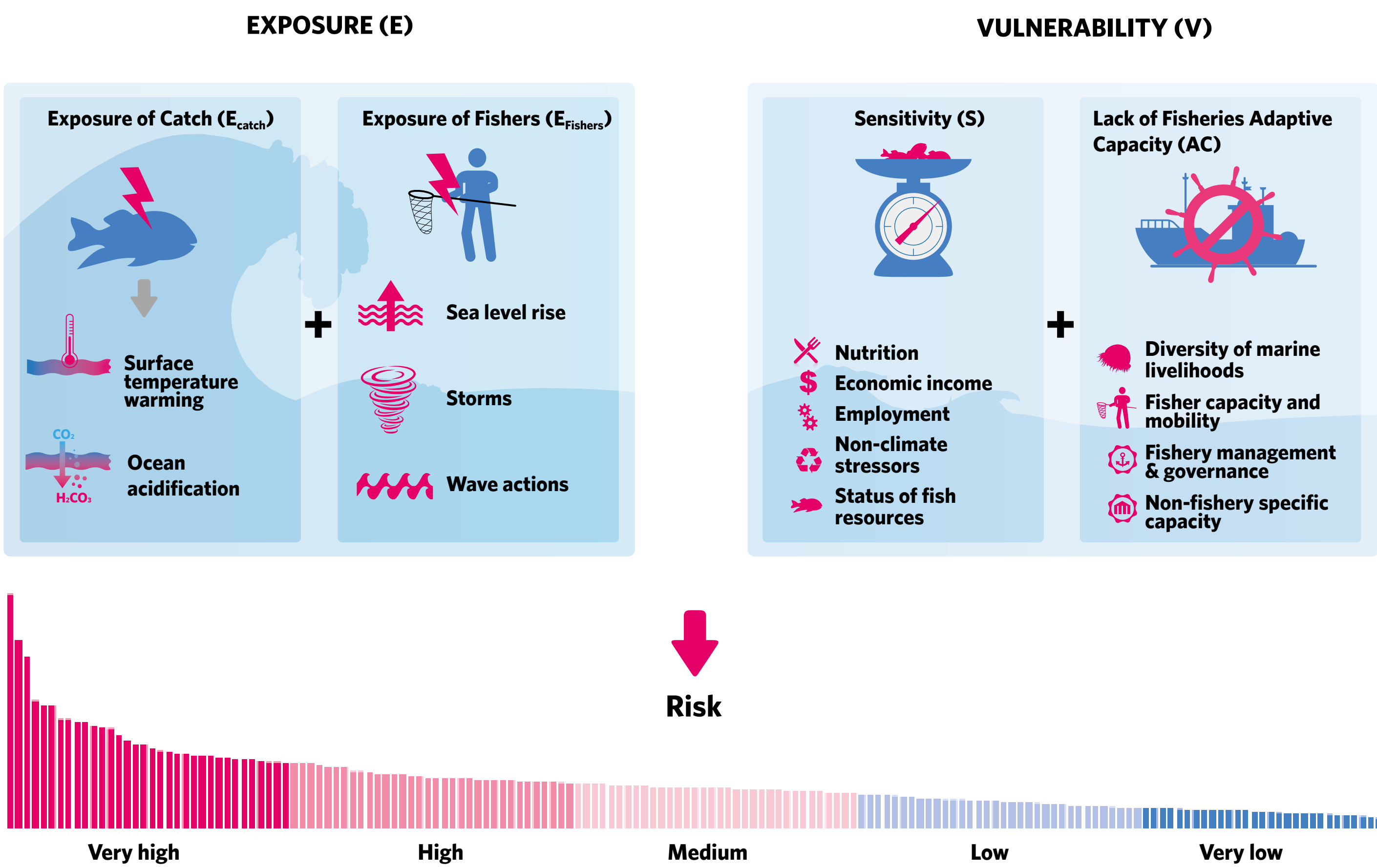


Figure 1: Risk Framework (IPCC 2014)

and lack of fisheries adaptive capacity. Sensitivity refers to the sensitivity of fishery dependent nations and fish species to climate change impacts. Thus, sensitivity is calculated based on a nations' degree of dependence on fisheries for food security, employment, and economic reasons, as well as anthropogenic stressors that render fish resources more susceptible to climate change impacts. The assessment is based on the assumption that social systems are more likely to be sensitive to climate change if they are highly dependent on a climate vulnerable natural resource, such as fisheries (Cinner et al. 2013). Fisheries adaptive capacity refers to the capacity of a country and the fisheries in that country to take actions to counter negative climate change related effects and implement preventive measures. We include adaptive capacity components that are related to the adaptive capacity of people (e.g., fleet size, gear diversity, GDP) and adaptive capacity of the fish resources (e.g., marine protected areas).

2.2 Indicators

The study combines a range of available environmental, social, and economic global data sets to calculate risk based on the indicators (Fig. 2). The challenge was to identify suitable indicators that best capture risk to fisheries across exposure, sensitivity, and adaptive capacity. Building from earlier work on risk of nations to natural hazards, (e.g. WorldRiskIndex and Coast@Risk reports), this study includes several new, fishery specific indicators to examine risk to fisheries, which



The F@R Index is calculated by combining the four components: hazards (H), exposure (E), sensitivity (S), and lack of adaptive capacity (1 - AC). Vulnerability was calculated as the sum of sensitivity and lack of adaptive capacity. Overall risk was calculated as: R= H x E x V; with V = S + (1 - AC). Indicators in subcategories were normalized on a scale from 0-1. The mean of sub-indicators was calculated for each indicators and each indicator was normalized on a scale form 0-1. Overall exposure, sensitivity and adaptive capacity was calculated as the mean of all indicators in the respective category and were translated into a qualitative classification of "very high – high – medium – low – very low.

Figure 2: Fisheries@Risk Index calculation

sharpens our ability to assess industry specific strategies that help reduce risk in coastal areas. Indicators for assessing fisheries adaptive capacity have been developed based on recent work on coastal nations' vulnerability to climate change (Ding et al. 2017, Blasiak et al. 2017, Hughes et al. 2012), resilience of the fisheries sector (Ojea et al. 2017) and adaptive capacity of coastal fishing communities to respond to climate change (Cinner et al. 2018).

All indicators are normalized on a scale from 0-1 using the following conversion: (x-xmin) / (xmax-xmin). First, we normalized all sub-indicators on a scale from 0-1. Indicators that were not normally distributed including numbers of fishers and catch were log transformed before normalization. Next, we calculated exposure, sensitivity and adaptive capacity as the arithmetic mean of all normalized sub-indicators and indicators in the respective categories. All three major indicators, exposure, sensitivity, adaptive capacity were not normalized. We combined sensitivity and adaptive capacity to calculate vulnerability and multiplied the score with the exposure.

2.2.1 Exposure indicators

Exposure was calculated as the mean of exposed catch, based on reported landings in tonnes, and exposed number ... of fishers (Fig. 3). Both indicators were divided by the total population (World Bank 2017e) to obtain per capita values.

(i) Exposure of fish catch
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.

Reported landings were obtained from FAO FishStatJ and averaged over the last three available years (2014-2016) to account for interannual variability in fisheries catch volume.

Changes in *sea surface temperature, ocean acidification* were based on the Ocean Health index 2016 (Halpern et al. 2016). The index measures changes in sea surface temperature as the number of positive temperature anomalies that exceed the natural range of variation for a given area. Ocean acidification was measured as the difference in global distribution changes in the aragonite saturation state between pre-industrial (approx. 1870) and modern times (2000-2009).

Projected changes in sea surface temperature are based on RCP 4.5 (2016-2050) (Blasiak et al. 2017). Projected changes were assessed by calculating the average SST over the selected timeframe 2016-2050, and then subtracting the average SST from the reference climatology (1900±1950).

Projected ocean acidification for the year 2050 was obtained from the Reefs at Risk revisited (World Resource Institute 2012). The data reflects locations of estimated aragonite saturation state under a CO2 stabilization level of 500 ppm. For missing values, we use the data for the neighboring Exclusive Economic Zone (EEZ) if available with the assumption that neighboring EEZ's have similar ocean acidification values.

(ii) Exposure of fishers
Exposure of fishers was calculated based on hazards that directly affect fishers (sea level rise, cyclones, wave actions). We first calculate the product of the normalized values for cyclone frequency, wave action, and sea level rise with

Exposure		
50 %		**Exposure of catch**
	50 %	Surface temperature warming * catch per capita value
	50 %	Ocean acidification * catch per capita value
50 %		**Exposure of fishers**
	33.3 %	Sea level rise * fishers per capita
	33.3 %	Storm frequency * fishers per capita
	33.3 %	Wave action * fishers per capita

Figure 3: Exposure indicators and calculation

the number of fishers per capita and then took the mean of those three values to calculate overall exposure of fishers.

The latest number of fishers was derived from FAO statistics and FAO fishery country profiles (FAO 2017b, a).

Cyclone frequency was calculated based on the Global Cyclone Hazard Frequency and Distribution (CHRR 2005). The dataset is a 2.5-minute grid based on more than 1,600 cyclone tracks for the period 1 January 1980 through 31 December 2000 for the Atlantic, Pacific, and Indian Oceans that were assembled and modelled at UNEP/GRID-Geneva PreView. In each EEZ, we calculated a buffer of 10 km to define the coastal zone ('coastal buffer'). The cyclones frequency was calculated for each coastal buffer, as the mean decile. The EEZ is a marine area extending from the seaward boundaries of the states (3 to 12 nautical miles, in most cases) to 200 nautical miles (370 km) off the coast. Within this area, nations claim and exercise sovereign rights and exclusive fishery management authority over all fish and all continental shelf fishery resources (United Nations 1997).

Wave action is used as a proxy of impaired navigability conditions for fishing and access to landing zones by calculating the percentage of time where conditions exceed certain thresholds (Fig. 4). We focus on swell waves as they are fast moving and extend far deeper than wind waves (Reguero et al. 2015). Swell waves have substantial energy and thus can affect navigation and thereby fishing activity and access to landing facilities depending on other parameters such as direction and currents.

To calculate the 'navigation index' for fishing boats, the time series of significant wave height were obtained from the Global Ocean Waves (GOW) database (Reguero et al. 2012, Reguero et al. 2013), which estimates wave characteristics at points approx. every 20 km globally for all the points in each EEZ. For each time series, we calculated the duration of events where the significant wave height (Hs) exceeded the thresholds of 2, 3 and 4 m, between the years 1948 and 2008 (see Fig. 4). For each EEZ, we then calculated the mean percentage of the time (from years 1948 to 2008) that conditions exceeded each threshold (calculated for each time series and averaged inside each EEZ). For the EEZs that are smaller than the GOW spatial resolution (i.e., EEZ with no wave time series inside), we used the closest point in the dataset (with a maximum distance limit of 3 degrees).

Sea level rise was based on the Ocean Health Index (OHI) (Halpern et al. 2016). This indicator

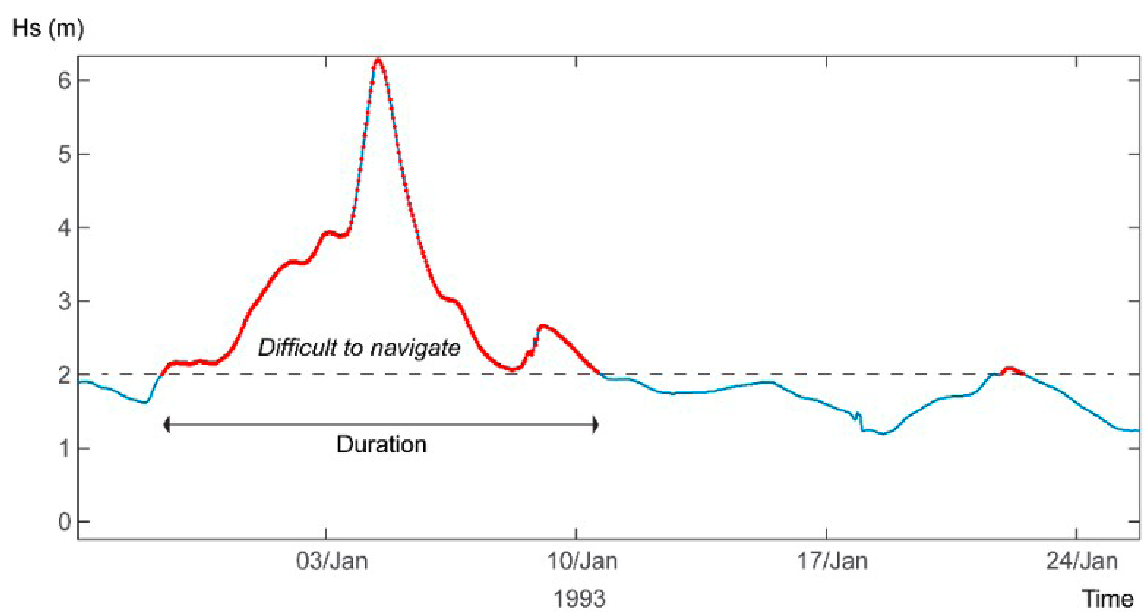


Figure 4: Sketch of duration of cyclone conditions

measures sea level rise as the positive sea level rise value over the study period (October 1992 through December 2012).

Predicted cyclone frequency and wave actions were calculated by multiplying the current value of cyclone frequency and wave action with the expected percent increase / decrease in these parameters in six major ocean basins including the North Atlantic, North West Pacific, North East Pacific, Northern Indian Ocean, Southern Indian Ocean, and South West Pacific based on a study by Murakami et al. (2011).

Projected sea level rise is obtained from the projections in IPCC Fifth Assessment Report (Church et al. 2013, Slangen et al. 2014, IPCC 2014). In each EEZ, we calculated all the grid points from the Fifth Assessment Report projections for the RCP 4.5 and 8.5. A Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC for its Fifth Assessment Report in 2014. We then calculated the average value of the mean sea level rise by the end of the century (and the standard deviation of all values in the EEZ). For the EEZs that are smaller than the SLR spatial resolution (i.e. EEZ with no SLR points inside), we used the closest point in the dataset (with a maximum distance limit of 3 degrees).

2.2.2 Vulnerability indicators

Vulnerability consists of the sum of sensitivity and adaptive capacity indicators.

(i) Sensitivity

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 (Fig. 5).

Dependency on fisheries for food security was calculated following Hughes et al. (2012) as . Fish protein and total animal protein consumption data between 2009 and 2011 were obtained from FAO food balance sheets. For each indicator, an average value in the most recent three years was used to account for inter-annual variability (2011-2013) (FAO 2017c).

Employment dependency was measured as people working in marine fisheries as a percentage of total economic active population. The latest number of fishers were based on FAO statistics and FAO fishery country profiles (FAO 2017b, a). Total economically active population was obtained from the World Bank (World Bank 2017c). The data provided by the World Bank is based on data from the International Labour Organization ILOSTAT and World Bank population data.

Economic dependency was calculated based on the economic value of marine fish landings as a percentage of GDP. Economic values of marine fish landings were provided by the Sea Around Us project (Pauly and Zeller 2015b). GDP values were derived from the World Bank (World Bank 2017a). Where World Bank data were missing, we accessed the latest national statistics for countries.

Sensitivity		
25 %		**Nutrition**
		Percentage of animal protein from fish
25 %		**Economic income**
		Percent of active economic population engaged in fisheries
25 %		**Employment**
		Contribution of fisheries to GDP
25 %		**Non-climate stressors (EEZ)**
	50 %	Pollution (chemicail, nutrient, plastic)
	50 %	Habitat destruction (Bottom trawling, poison and dynamite fishing)

Figure 5: Sensitivity indicators and calculation

We also included non-climate stressors on fish resources as part of the sensitivity analysis including pollution and fishing practices that can affect fishery habitats. These stressors may affect the health of fish resources and subsequently render fisheries less resilient to climate impacts. Pollution was assessed based on plastic, nutrient, and chemical pollution in the EEZ using the latest Ocean Health Index (OHI) data (Halpern et al. 2016). Chemical pollution is calculated in the OHI using modelled data for land-based organic pollution (pesticide data), land-based inorganic pollution (using impermeable surfaces as a proxy), and ocean pollution (shipping and ports). These global data are provided at ~1km resolution with raster values scaled from 0-1. To obtain the final stressor value, the sum of the three raster layers was calculated. Nutrient pollution was calculated using modelled plumes of land-based nitrogen pollution that provide intensity of pollution at ~1km resolution. Plastic pollution was modelled using data on the global distribution of floating marine plastics at 0.2 degree resolution (Erikson et al. 2014). Specifically, weight of floating plastics (g/km2) across four different size classes were aggregated to represent total weight of plastic debris per km2. Fishing practices that can affect benthic habitats included in this study are bottom trawling, poison and dynamite fishing. Data on dynamite and poison fishing was based on the OHI (Halpern et al. 2017). Trawl catch data was derived from the Sea Around Us research initiative (2012-2014) (Pauly and Zeller 2015a). Trawl density was calculated by dividing trawl catch data with trawlable habitat extent calculated as part of the OHI (Halpern et al. 2017).

(ii) Fisheries Adaptive Capacity

Adaptive capacity was measured based on 4 indicators (Fig. 6).

Marine livelihood alternatives to fishing was measured based on marine jobs in alternative sectors including aquaculture and marine tourism. These alternative income options are critical for reducing economic instability from climate impacts on fisheries (Badjeck et al. 2010, Sumaila et al. 2011). Number of jobs in aquaculture was obtained from FAO fishery country profiles and the FAOSTAT annual report (FAO 2017a, b).

Fisheries Adaptive Capacity			
25 %	**Diversity of marine livelihoods**		
		50 %	Percent of active economic population engaged in coastal tourism
		50 %	Percent of active economic population engaged in mariculture
25 %	**Fisher capacity and mobility**		
		33.3 %	Fleet size per capita
		33.3 %	Gear diversity
		33.3 %	Proportion of industrial fishery of total fishery
25 %	**Fishery management and governance**		
		16.6 %	Percent unreported landings of total landings
		16.6 %	Percentage of EEZ protected in MPAs
		16.6 %	Use of science in decision-making
		16.6 %	Policy process transparent and participatory
		16.6 %	Capacity to implement and enforce regulations
		16.6 %	Participation in RFMOs
25 %	**Non-fishery specific capacity**		
		33.3 %	GDP per capita
		33.3 %	World Governance index
		33.3 %	Adult Literacy

Figure 6: Fisheries adaptive capacity indicators and calculation

Total tourism employment for each country was derived from the World Travel and Tourism Council (https://www.wttc.org/datagateway/). To estimate alternative income opportunities in the coastal tourism sector, we adjusted national tourism data by the proportion of a country's population that lives within a 25-mile inland coastal zone. Number of jobs in both sectors was divided by total economically active population.

Fishers' capacity and mobility was assessed based on three sub-indicators including fleet size, gear diversity, and proportion of industrial to small scale fisheries. We assume that fisheries in countries with a larger fleet, higher gear diversity, and a large industrial fishery have a higher capacity to respond to changes in target species (Kalikoski et al. 2010, Islam et al. 2014). Data on fleet size was based on FAO fishery country profiles and the FAOSTAT annual report (FAO 2017b, a). Gear diversity was calculated based on data provided by Sea Around Us. Data on industrial and total landings (2012-2014) was obtained from the Sea Around Us website (Pauly and Zeller 2015b).

Fishery management and governance was calculated based on six sub-indicators: unreported landings, marine protection, use of science in decision-making, transparency of policy process, capacity to implement fishery regulations, and participation in Regional Fishery Management Organizations (RFMOs). Countries with higher quality fisheries management are likely to be able to adapt their management systems to change in resource productivity (Mora et al. 2009). High percentages of unreported landings introduce uncertainty about impacts on fishery resources and subsequently the health of fish stocks (Pitcher et al. 2002). Marine protection was included based on the percentage of the EEZ that is protected by marine protected areas (MPAs). While MPAs are a broader marine management mechanism, we included this indicator since conserving marine biodiversity, community structure, and habitats can support fish population resilience and recovery to external stressors (Levin and Lubchenco 2008, Worm et al. 2006). Data was derived from the World Database on Protected Areas 2016 (IUCN and UNEP-WCMC 2016). Data on unreported and reported landings was derived from the Sea Around Us website (Pauly and Zeller 2015b) and averaged for 2012-2014. Data on fishery management was based on Mora et al. (2009). We assess fishery governance based on the participation of countries in RFMOs. RFMOs are international organizations formed by countries with fishing interests in a specific geographic area. The organizations are open to countries located in the region as well as countries with interests in the fisheries concerned. While some RFMOs have a purely advisory role, most have management powers including the ability to set limits for catch and fishing effort, to implement technical measures, and to control obligations (European Union 2017). We include RFMOs as a part of adaptive capacity for coastal nations as governance of fisheries at multiple spatial scales creates flexibility for adapting fishery management to change at an ecosystem scale (Fidelman et al. 2013, Grafton 2010). Some fish species are highly migratory and require management approaches beyond single EEZs. Participation in RFMOs was calculated based on information provided by the Sea Around Us project (Pauly and Zeller 2015b) and websites for individual RFMOs.

Generic adaptive capacity was assessed using three indicators that apply to the adaptive capacity of any sector: GDP per capita, World Governance Indicators, and adult literacy. GDP per capita was selected based on the assumption that countries with high levels of economic capacity have the resources and institutions necessary to undertake adaptation actions. GDP per capita values were derived from the World Bank and averaged over 2011-2017 (World Bank 2017b). For missing data in the World Bank database, we accessed the latest available national statistics.

The World Governance Indicators, developed by the World Bank, were used as a metric for overall governance (World Bank 2017f). The index measures are used here to identify the degree to which a country's institutional and policy frameworks support or hinder adaptation to climate change and to indicate the ability of a country to effectively implement policies and programs that will lead to successful adaptation.

Adult literacy was included as an indicator as it is likely to shape the capacity to access and act on information that helps in climate adaptation.

The indicator assumes that populations in countries with high adult literacy are better equipped to respond to climate change due to their ability to access, synthesize, and incorporate relevant knowledge into decision making (Hughes et al. 2012). Literacy was measured as percentage of population based on data from the World Bank and IndexMundi for countries where World Bank data was not available (World Bank 2017d, IndexMundi 2017).

2.3 Calculation of the Fisheries@Risk Index

The Fisheries@Risk Index is calculated by combining the two components exposure (E) and vulnerability (V). Exposure is a combination of hazards multiplied by the number of fishers and amount of catch. Vulnerability is calculated as the sum of sensitivity and lack of adaptive capacity (Table 1).

For better comprehension and cartographic transformation, all individual indices were classified using the quantile method within the ArcGIS 10 software. Five classes were selected, and each class contains the same number of cases (e.g. countries), which are translated into a qualitative classification of "very high – high – medium – low – very low." For better comparison with previous indices (e.g. WorldRiskIndex), index values were multiplied by 100. Final scores thus range from 0-100.

Risk Components	Calculations
Exposure	$E = (E_{catch} + E_{fishers}) / 2$
Exposure of catch	E_{catch} = ((SST * catch per capita value) + (OA * catch per capita value)) / 2
Exposure of fishers	$E_{fishers}$ = ((SLR * fishers per capita) + (Storm frequency * fishers per capita) + (wave action * fishers per capita)) / 3
Vulnerability	V = S + (1 - AC)
Risk	R = E * (S + (1 - AC))

Table 1: Risk calculations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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. The results of the Fisheries@Risk Index describe the current and potential future risk of fisheries at a national level. The index is meant to characterize underlying factors that shape risk to climate hazards in coastal nations, and to highlight areas that are most vulnerable and need to reduce their sensitivity and / or increase their adaptive capacity. Based on data availability, 143 Exclusive Economic Zones (EEZ) of coastal countries are included in the analysis. Oversea territories which have separated EEZ are included as individual entities and are treated the same as coastal nations for the purpose of this study. EEZ that had missing data for more than 30 percent of indicators in each major category (hazard, exposure, sensitivity and adaptive capacity) were not included in the analysis (see Appendix 4). The aggregated results are mapped to facilitate a general understanding and comparison between

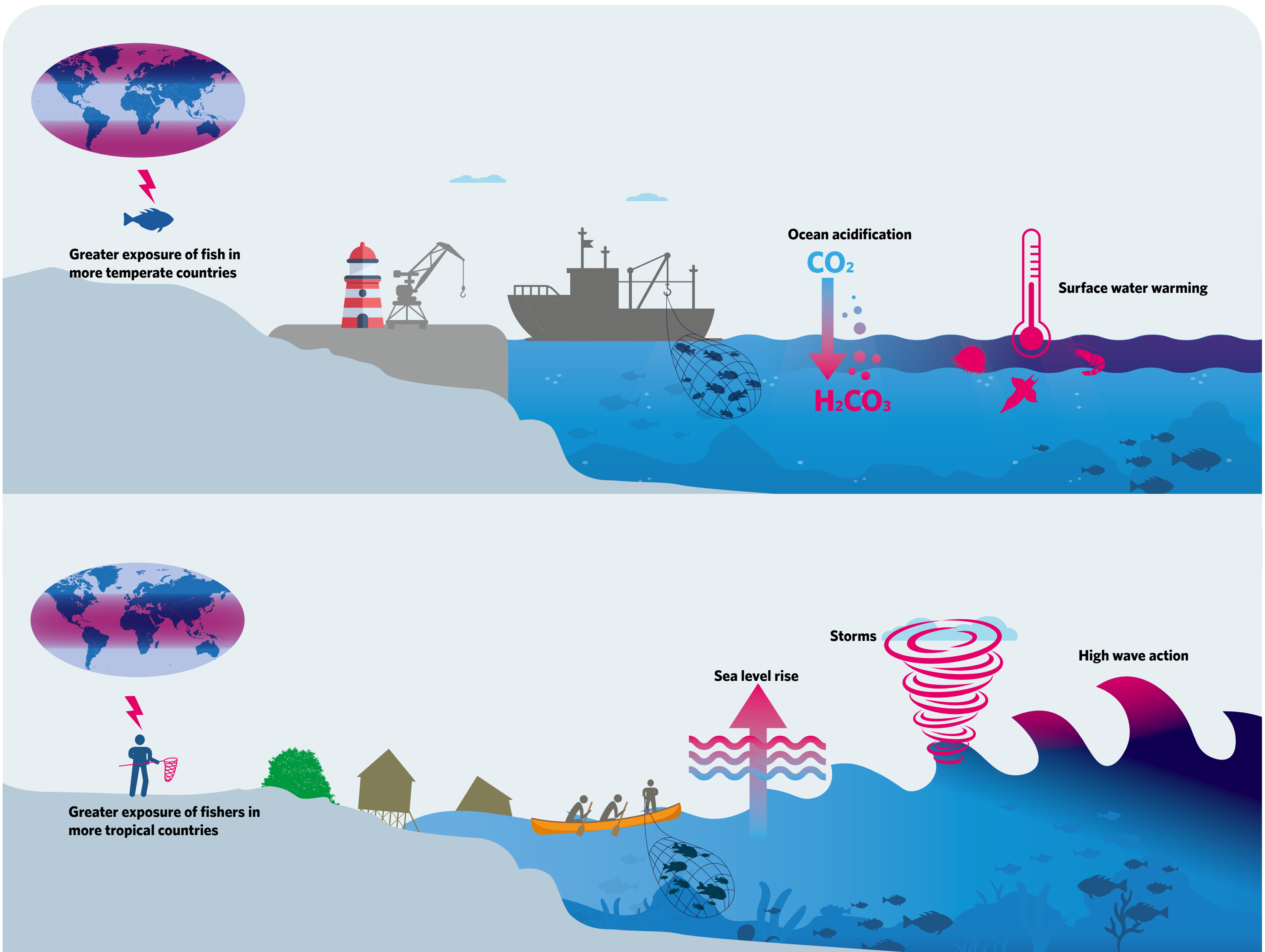

Figure 7: Differences in exposure across geographic regions

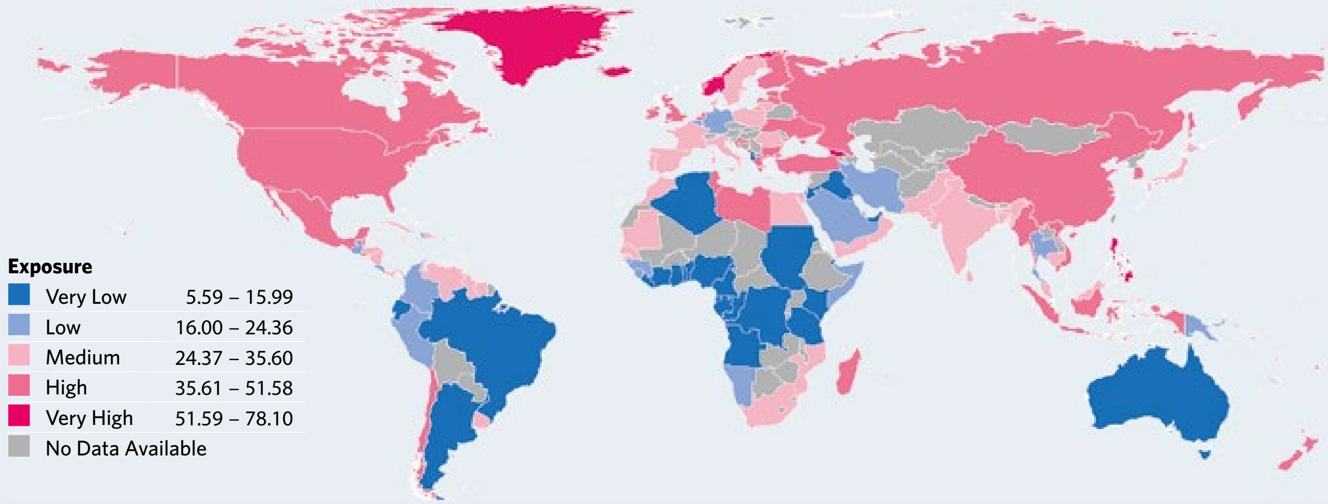

Figure 8: Current exposure of fisheries to climate-related impacts

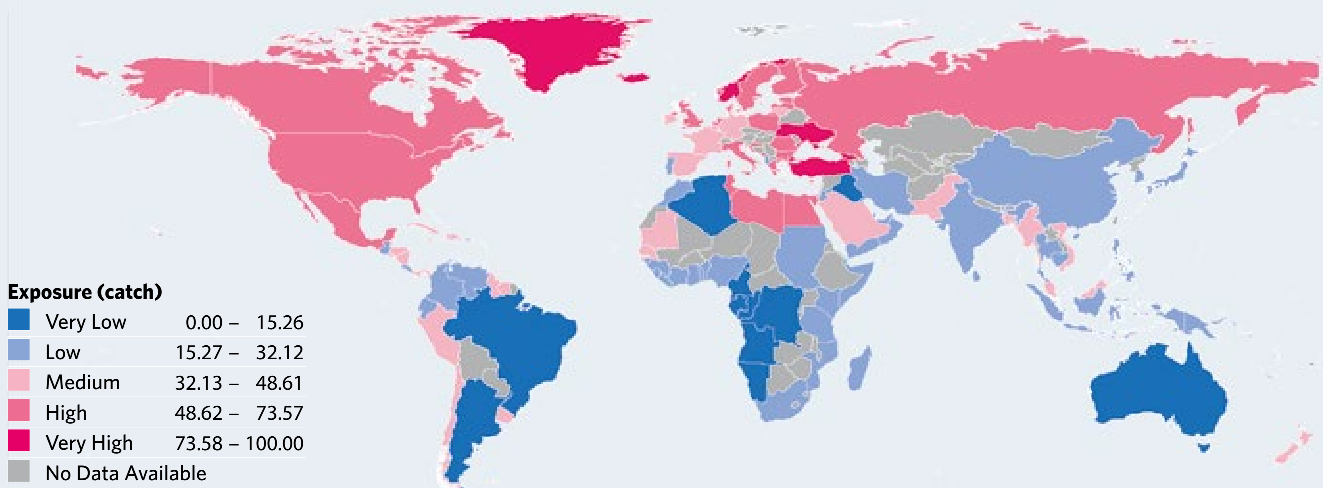

Figure 9: Exposure of catch to sea surface temperature change and ocean acidification

countries and regions. We also examine changes in key indicators. The individual components will be presented first, followed by the overall Fisheries@ Risk Index.

3.1.1 Exposure

Figure 8 shows the current exposure of coastal nations to climate-related impacts on their fisheries. Hot spots of high exposure can be seen in Southeast Asia and Northern Europe. Table 3 provides an overview of the 10 most exposed countries.

Overall there is an interesting mix of both high and low latitude as well as nations of the Global North and Global South in the list of countries where exposure contributes greatly to fisheries risk. Some of the most exposed nations are islands states in higher latitudes including Iceland and Greenland, as well as Small Island Developing States (SIDS) in tropical areas such as Nauru, Vanuatu, Kiribati, and Samoa.

However, when we break out the different components of exposure, we see better the underlying reasons for these differences. Figure 9 shows that

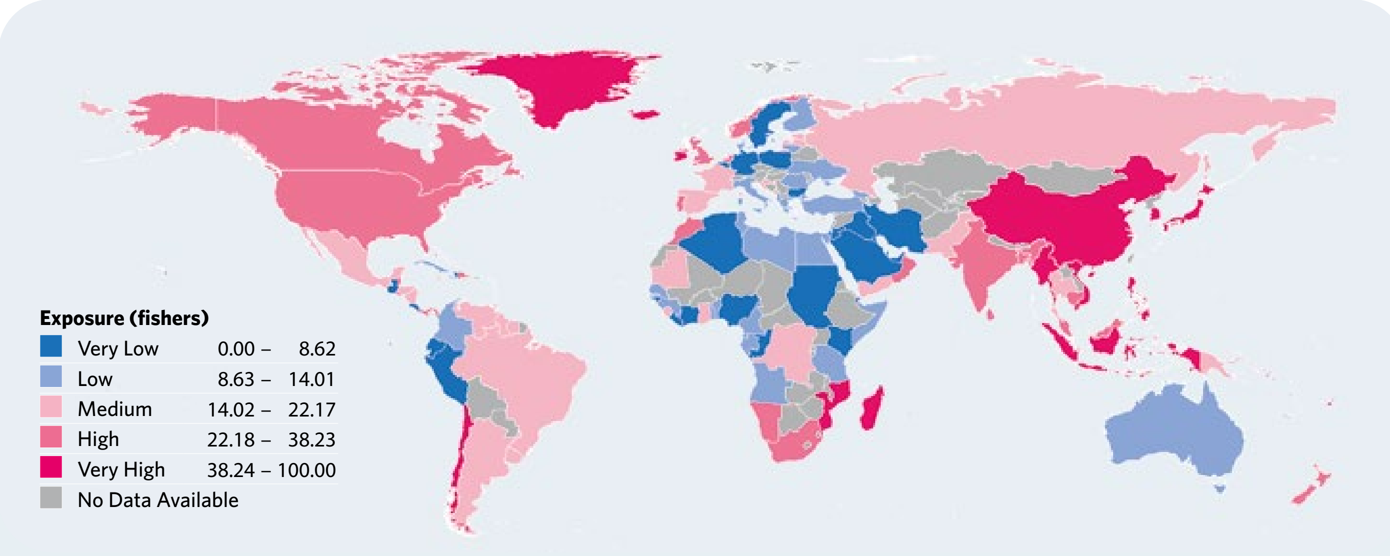

Figure 10: Exposure of fishers to sea level rise, cyclones, and high wave action

Note: Number of fishers are calculated as per capita values for better comparison across countries

	Exposure catch				Exposure fishers					
	SST		OA		Sea level rise		Cyclones		Wave action	
Rank	Country	Value	Country	Value	Country	Value	Country	Value	Country	Value
1	Norway	68.68	Greenland	78.24	Micronesia	81.20	Vanuatu	71.85	Greenland	51.90
2	Iceland	66.30	Georgia	65.17	Nauru	58.17	Sint Maarten	64.20	Iceland	50.28
3	Croatia	65.75	Canada	60.48	El Salvador	53.28	Philippines	60.20	Chile	49.14
4	Turkey	64.97	Russia	54.44	Solomon Islands	51.51	Micronesia	57.77	Ireland	35.71
5	Greece	64.93	Iceland	54.06	Philippines	51.13	British VI	56.66	Norway	28.69
6	Georgia	64.43	Ukraine	52.68	Vanuatu	50.39	Seychelles	55.64	Mauritius	23.32
7	Bulgaria	63.60	Norway	47.00	Tonga	44.29	St. Kitts and Nevis	54.14	New Zealand	22.34
8	Libya	60.83	Turkey	41.31	Timor Leste	43.56	Mauritius	52.48	Portugal	22.26
9	Montenegro	59.97	Estonia	38.85	Indonesia	41.51	Turks and Caicos	51.31	Namibia	20.24
10	Turks and Caicos	57.08	Finland	35.14	Fiji	39.09	Bahamas	49.96	Oman	19.27

Table 2: Top 10 Countries with the highest exposure of catch to warming and acidification and of fishers to cyclones, SLR, and wave action

Rank	Country	Exposure value
1	Greenland	78.10
2	Iceland	77.41
3	Micronesia	68.43
4	Norway	62.88
5	British VI	59.41
6	Philippines	58.46
7	Mauritius	58.30
8	Turks and Caicos	58.10
9	Vanuatu	57.18
10	Sint Maarten	55.67

Table 3: Top 10 Countries with the highest exposure

the climate-related impacts on fish due to changes in sea surface temperature and ocean acidification will likely most 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. 10 and Table 2).

3.1.2 Sensitivity

Figure 11 displays the sensitivity of coastal nations to climate impacts. Regions of high sensitivity are particularly prevalent in West and South-East Africa and Southeast Asia (Table 4).

Many of these countries rely primarily on small-scale fisheries that are often considered to be less adaptable to climate change than industrial fisheries.

There are some differences in the underlying reasons for the sensitivity of countries to climate change effects. Coastal nations in Africa (e.g., Sierra Leone, Togo, Nigeria) are particularly sensitive due to a high dependency on fisheries for food security, as fisheries contribute a high amount of animal protein in these countries (Table 5). The indicators suggest that non-climate stressors (e.g., pollution) may have important effect on sensitivity in a number of African countries (Table 5).

Nutrient, chemical, and plastic pollution, however, is most apparent in Europe (e.g., Germany, Belgium, Poland, Israel, Lebanon). Nearly all small island states, including islands in the Pacific (e.g., Kiribati, Solomon Islands, Micronesia, Vanuatu, Samoa) and the Caribbean (e.g., St. Vincent and the Grenadines), have high sensitivity due to a high dependency on fisheries for economic income and employment. Multiple countries in Southeast Asia (e.g., Philippines, Indonesia, Sri Lanka) are highly sensitive due to fishing practices that can affect benthic fishery habitats (Table 6).

Rank	Country	Sensitivity Value
1	British VI	70.47
2	Sint Maarten	62.35
3	Sierra Leone	58.10
4	Solomon Islands	57.16
5	Nigeria	55.52
6	Sri Lanka	55.20
7	Togo	54.53
8	Indonesia	51.30
9	Cameroon	51.16
10	Sao Tome and Principe	51.15

Table 4: Top 10 Countries with highest sensitivity

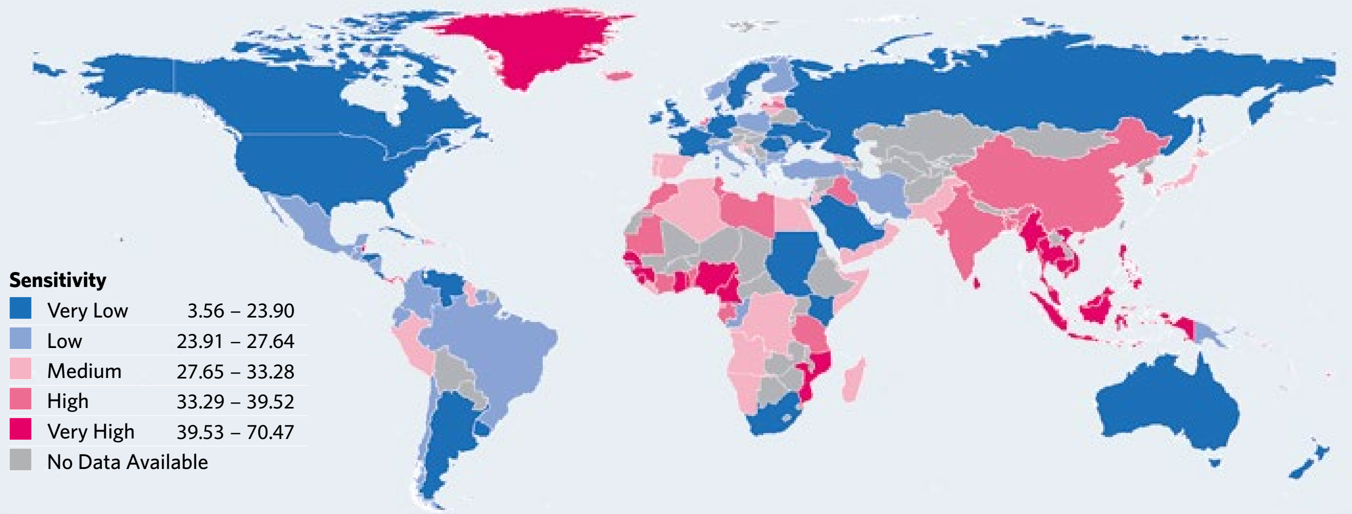

Figure 11: Sensitivity of coastal nations to climate-related impacts on fisheries

	Food dependency		Economic dependency value		Employment dependency		Non-climate stressors	
Rank	**Country**	**Value**	**Country**	**Value**	**Country**	**Value**	**Country**	**Value**
1	Sierra Leone	100.00	Kiribati	100.00	Samoa	100.00	Nigeria	100.00
2	Togo	97.68	Greenland	65.13	Vanuatu	89.95	Bulgaria	95.31
3	Mozambique	97.38	Micronesia	50.73	Myanmar	89.30	Bahamas	77.46
4	Solomon Islands	85.76	Belize	24.50	Panama	87.16	Qatar	72.63
5	Nigeria	85.65	Iceland	20.45	St. Vincent and the Grenadines	86.94	Iraq	72.17
6	Sri Lanka	79.02	Maldives	19.22	Turks and Caicos	83.46	Dominican Rep.	69.22
7	Sao Tome and Principe	78.06	St. Vincent and the Grenadines	18.81	Cambodia	83.30	Finland	68.97
8	Ivory coast	70.70	Solomon Islands	13.74	Sao Tome and Principe	82.61	Djibouti	59.88
9	Gambia	70.35	Vanuatu	13.41	Maldives	82.50	Belgium	59.83
10	Ghana	64.13	Senegal	12.22	Cape Verde	81.73	Vietnam	58.43

Table 5: Top 10 Countries across sensitivity indicators; Note: higher score indicates higher sensitivity

	Chemical and Nutrient pollution		Plastic pollution		Fishing practices that affect habitats	
Rank	**Country**	**Value**	**Country**	**Value**	**Country**	**Value**
1	Iraq	100.00	Cameroon	100.00	Nigeria	100.00
2	Jordan	74.82	Israel	99.47	Tanzania	92.44
3	Belgium	48.61	Libya	91.15	Philippines	90.02
4	Germany	43.19	Egypt	90.31	Vietnam	87.95
5	Poland	42.54	Sudan	85.64	Malaysia	86.55
6	Lithuania	39.66	Tunisia	83.88	Indonesia	85.80
7	Netherlands	38.72	Lebanon	83.46	Timor Leste	80.20
8	Albania	37.00	South Cyprus	82.96	Thailand	79.67
9	Sint Maarten	36.69	Thailand	82.72	Cambodia	75.34
10	Denmark	36.11	Myanmar	81.83	Solomon Islands	75.15

Table 6: Top 10 Countries for pollution and fishing practices that can impact fishery habitats

3.1.3 Lack of Fisheries Adaptive Capacity

According to the index, Africa is a hot spot region that severely lacks the adaptive capacity to respond to climate-related impacts on its fisheries, followed by several countries in Southeast Asia, and parts of the Caribbean (Fig. 12 and Table 7).

The analysis of the top 10 countries with the highest lack of fisheries adaptive capacity for the different dimensions (Table 8) reveals differences in the types of adaptive capacity that is lacking. A lack of alternative marine livelihoods was prevalent in a number of African countries (e.g., Congo, Sudan, Equatorial Guinea) and parts of the Middle East (e.g., Jordan, Iran, Yemen) indicating that these countries might not offer a high number of alternative livelihood options for fishers.

The mobility and technical capacity of fishers to respond to changes in marine ecosystems is low in parts of the Caribbean (e.g., Haiti, Jamaica), which are also among the countries that have challenges in effective fishery management and governance. Coastal nations that lack general national adaptive capacity in terms of adult literacy, GDP per capita, and general governance are primarily African ones (Table 8).

Rank	Country	Lack of adaptive capacity value
1	Iraq	91.62
2	Djibouti	89.94
3	Haiti	89.87
4	Somalia	87.95
5	Nigeria	85.01
6	Myanmar	83.52
7	Liberia	82.79
8	Lebanon	82.39
9	Cameroon	81.04
10	Comoros	79.26

Table 7: Top 10 Countries with greatest lack of fisheries adaptive capacity

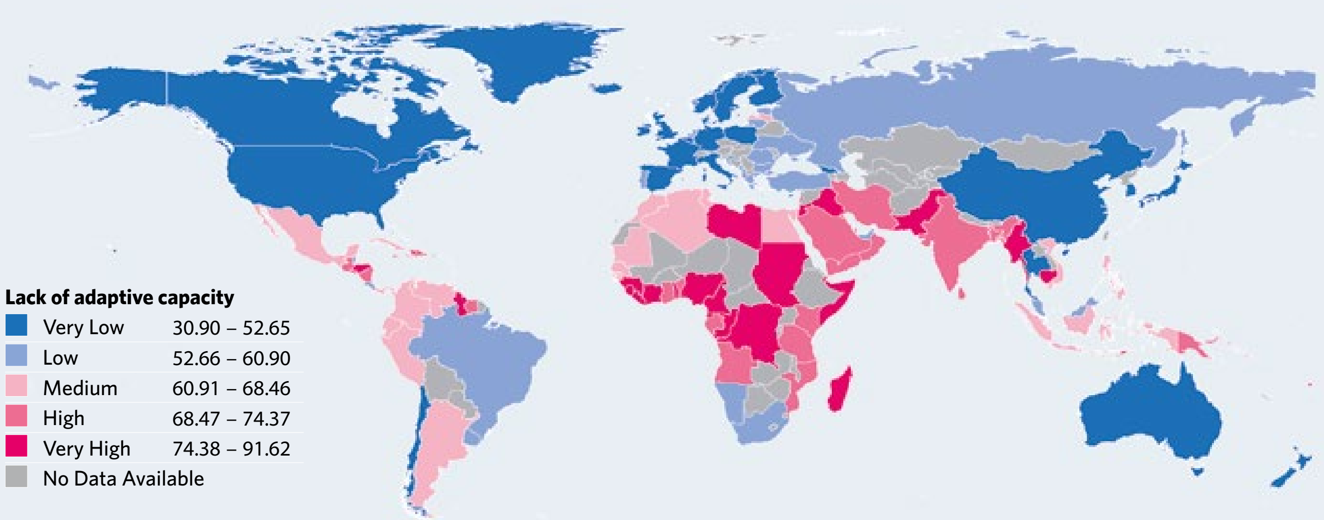

Figure 12: Lack of fisheries adaptive capacity to respond to climate impacts

	Alternative marine livelihoods		Fishers' capacity and mobility		Fishery management		Non-fishery capacity	
Rank	**Country**	**Value**	**Country**	**Value**	**Country**	**Value**	**Country**	**Value**
1	Saba and St. Eustaius	100.00	Saba and St. Eustaius	100.00	Djibouti	100.00	Curacao	100.00
2	Congo	99.99	Liberia	100.00	Myanmar	98.89	Somalia	96.83
3	Equatorial Guinea	99.99	Lebanon	100.00	Haiti	87.34	Guinea	89.17
4	Iraq	99.97	Djibouti	99.22	Guyana	84.99	Sierra Leone	87.21
5	Sudan	99.96	Jordan	98.89	Iraq	82.95	Iraq	86.11
6	Russia	99.96	Haiti	98.13	Sri Lanka	82.50	Guinea-Bissau	84.21
7	Congo, R. of	99.94	Iraq	97.46	Lebanon	82.03	Benin	83.79
8	Romania	99.92	Qatar	96.81	Solomon Islands	81.71	Gambia	82.52
9	Brazil	99.91	Guinea-Bissau	96.42	Kenya	81.47	Liberia	80.31
10	Iran	99.91	Togo	94.96	Somalia	79.43	Ivory coast	79.91

Table 8: Top 10 Countries with highest lack of fisheries adaptive capacity across the five main adaptive capacity indicators

3.1.4 Vulnerability

Vulnerability combines Sensitivity and Adaptive Capacity. Figure 13 shows that coastal countries in West and South-East Africa (e.g., Cameroon, Sierra Leone, Togo, Mozambique) and parts of Southeast Asia (e.g., Myanmar, Cambodia) are particularly vulnerable to climate impacts to their fisheries.

Table 9 provides an overview of the 10 most vulnerable coastal nations. Maximum potential value for vulnerability is 200 based on the combination of sensitivity (max. value=100) and adaptive capacity (max. value = 100).

Rank	Country	Vulnerability Value
1	Nigeria	140.53
2	Sierra Leone	136.05
3	Cameroon	133.55
4	Togo	132.97
5	Solomon Islands	130.94
6	Sint Maarten	128.86
7	Iraq	128.17
8	Sri Lanka	127.78
9	Cambodia	126.04
10	Myanmar	124.97

Table 9: Top 10 Countries with highest vulnerability

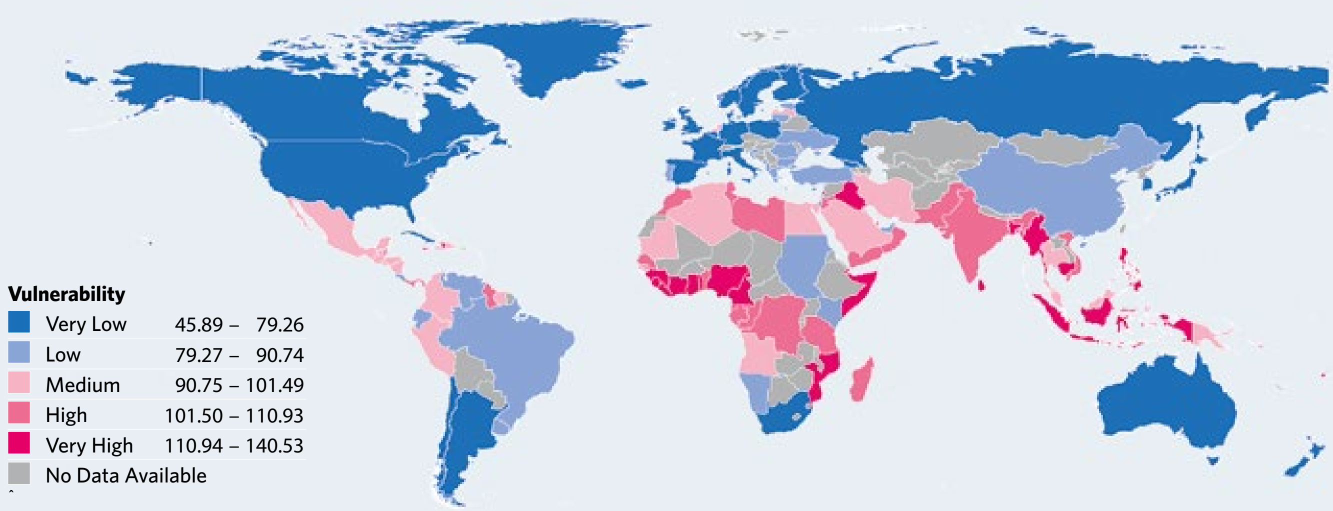

Figure 13: Vulnerability of coastal nations to climate-related impacts on fisheries

3.1.5 Risk

The results show that seven out of the 10 nations most at risk are SIDS in the Pacific and Caribbean including countries such as Micronesia, Sint Maarten and the British Virgin Islands. But among the 10 countries with the highest risk there are two countries in higher latitudes (Greenland and Iceland) revealing the widespread nature of climate impacts to fisheries. Other coastal countries with very high or high risk to climate-related impacts on their fisheries are found in Asia and parts of Africa (Fig. 14 and Table 10). Some of the countries on the west coast of Africa that scored high in terms of vulnerability are not among the nations with the highest risk. This finding is to some extent a result of a lower exposure to climate hazards and a medium exposure to climate change such as sea surface temperature change, ocean acidification, and sea level rise in these countries.

Rank	Country	Risk Value
1	Micronesia	73.86
2	Sint Maarten	71.73
3	British VI	65.93
4	Philippines	64.91
5	Solomon Islands	64.33
6	Turks and Caicos	63.96
7	Vanuatu	59.56
8	Iceland	59.13
9	Greenland	57.74
10	Tonga	52.15

Table 10: Top 10 Countries with highest current risk

	Country group	Risk	Exposure	Sensitivity	Lack of Adaptive Capacity
Geographic location	North America	37,30	5,80	5,10	25,60
	Oceania	45,60	24,40	16,90	40,90
	Africa	54,00	2,50	1,70	37,00
	Europe	23,70	5,20	6,40	25,70
	South America	37,00	1,80	1,60	22,60
	Asia	43,50	3,60	2,40	31,10
Development status	OECD	1,80	3,20	24,50	29,00
	LDC	3,80	2,10	37,70	74,90
	SIDS	13,80	10,20	36,30	60,70

Table 11: Comparison of risk components among country groups (mean values)

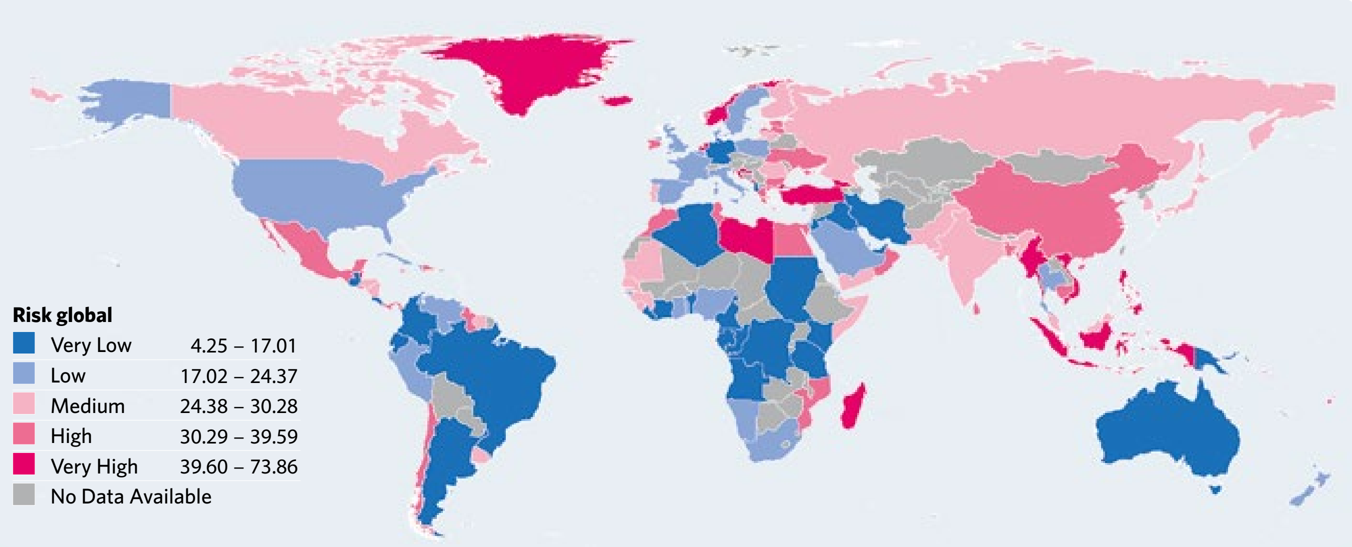

Figure 14: The Fisheries@Risk Index, which indicates overall risk of coastal nations due to climate effects on fisheries

3.2 Assessment of Mid-Term Climate Risk

As noted in methods, we focus above mainly on present climate risk. In addition, we use existing prediction 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. Findings reveal that SIDS are expected to experience the highest increase in exposure (Fig. 15 and Table 12). The increase in exposure for a number of these islands include both an increase in exposure of fish and fishers. This trend will require substantial efforts to reduce vulnerability in these nations to account for an increase in exposure.

Figure 16 shows that the greatest increase in exposure (near-term vs mid-term) is expected to occur in parts of Central America (e.g., Ecuador and Brazil), as well as parts of Africa (e.g., Mozambique, Madagascar) and Southeast Asia (e.g.,

	Future exposure		Change in Exposure to fish		Change in exposure to fishers	
Rank	Country	Value	Country	Value	Country	Value
1	Seychelles	85.70	Vanuatu	60.05	Congo	65.47
2	St. Kitts and Nevis	85.09	Gabon	54.49	Gabon	46.27
3	Sint Maarten	85.04	Comoros	53.72	Ecuador	44.53
4	British VI	81.70	Congo	52.87	Benin	41.81
5	Micronesia	81.24	Sao Tome and Principe	52.87	Angola	41.16
6	Mauritius	80.71	Micronesia	52.21	Peru	41.00
7	Vanuatu	79.46	Kiribati	51.96	Maldives	37.15
8	Turks and Caicos	78.32	Mozambique	51.68	Brazil	36.54
9	Kiribati	76.06	Brazil	50.15	Sao Tome and Principe	35.31
10	Nauru	74.86	Equatorial Guinea	49.24	Bahamas	34.29

Table 12: Highest future exposure and change in exposure between near and mid-term future

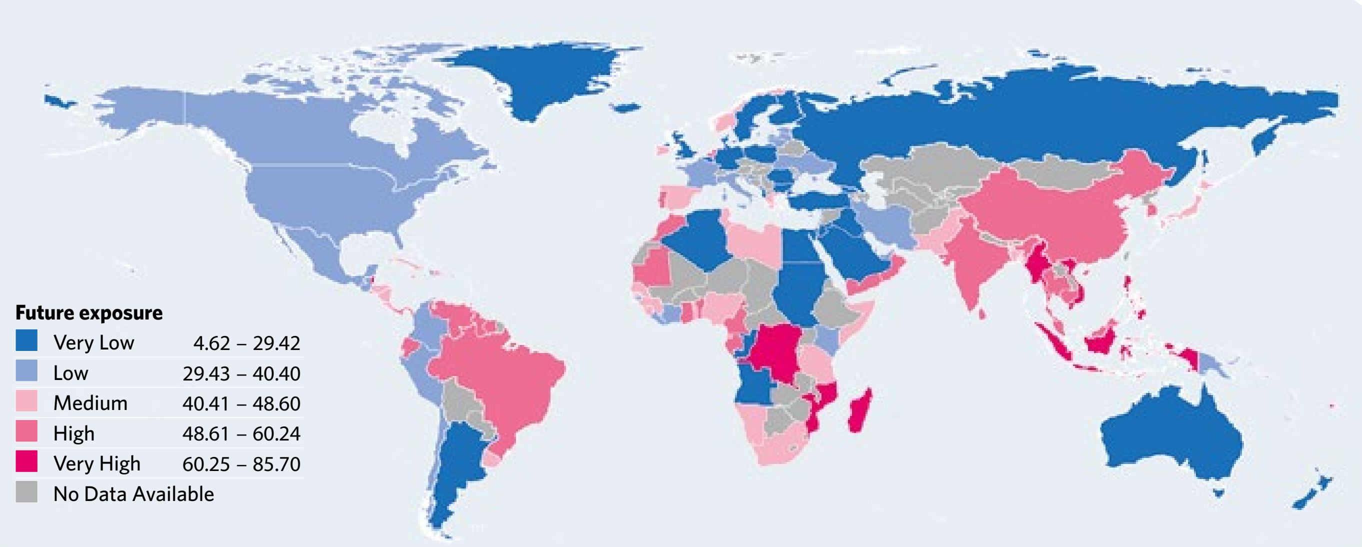

Figure 15: Future exposure of fisheries

Malaysia, Indonesia and Bangladesh). Table 12 further reveals that most of the top 10 countries that are subject to a high exposure to climate-related impacts on fisheries and the highest increase in exposure are SIDS such as Seychelles, St. Kitts and Nevis, Kiribati, and Nauru.

Figure 17 reveals that Europe is the only region where risk is expected to decrease in the future due to a decrease in hazards. Oceania and North America, including the Caribbean, on the other hand are expected to experience a high increase in risk to climate-related effects on fisheries. Further analysis also reveals that exposure is expected to decrease in OECD countries whereas Least Developed Countries and SIDS are expected to experience an increase in exposure. If these countries don't invest more efforts to reduce their vulnerability, they will be at higher risk in the future to climate-related impacts on their fisheries.

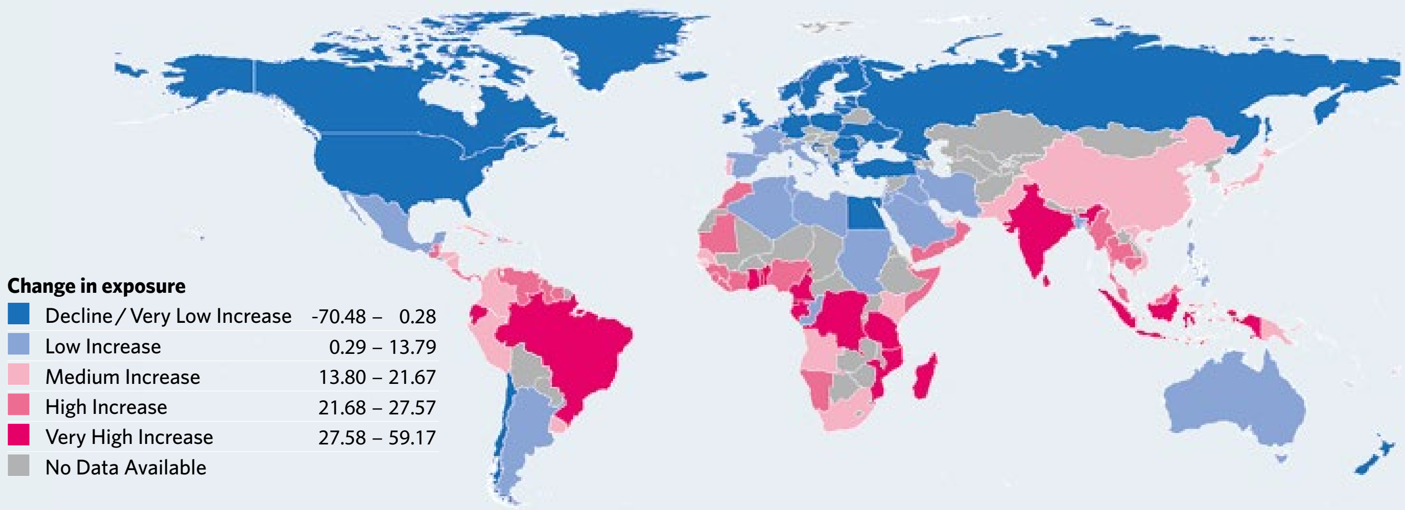

Figure 16: Change in climate exposure based on difference in climate exposure in the near-term and the mid-term

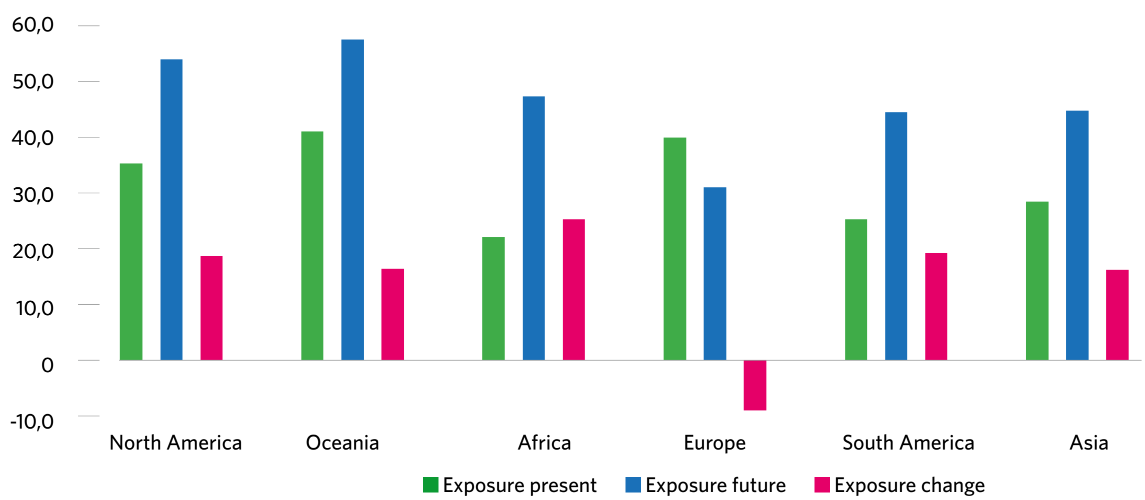

Figure 17: Comparison of present and future exposure across regions

3.3 Regional Assessment: Caribbean

We also conducted a more in-depth assessment of risk to fisheries in the Caribbean, which is among the regions that are most at risk. Countries with the highest exposure and highest overall risk are primarily Caribbean island nations such as St. Kitts and Nevis and Antigua and Barbuda as well as Panama and Belize (Fig. 18).

There were some differences in drivers of vulnerability among Caribbean countries (Table 13). A number of countries including the British Virgin Islands, Sint Maarten, and Turks and Caicos display high sensitivity. In contrast Haiti, Jamaica, and Honduras are primarily vulnerable due to a lack of fisheries adaptive capacity. Understanding

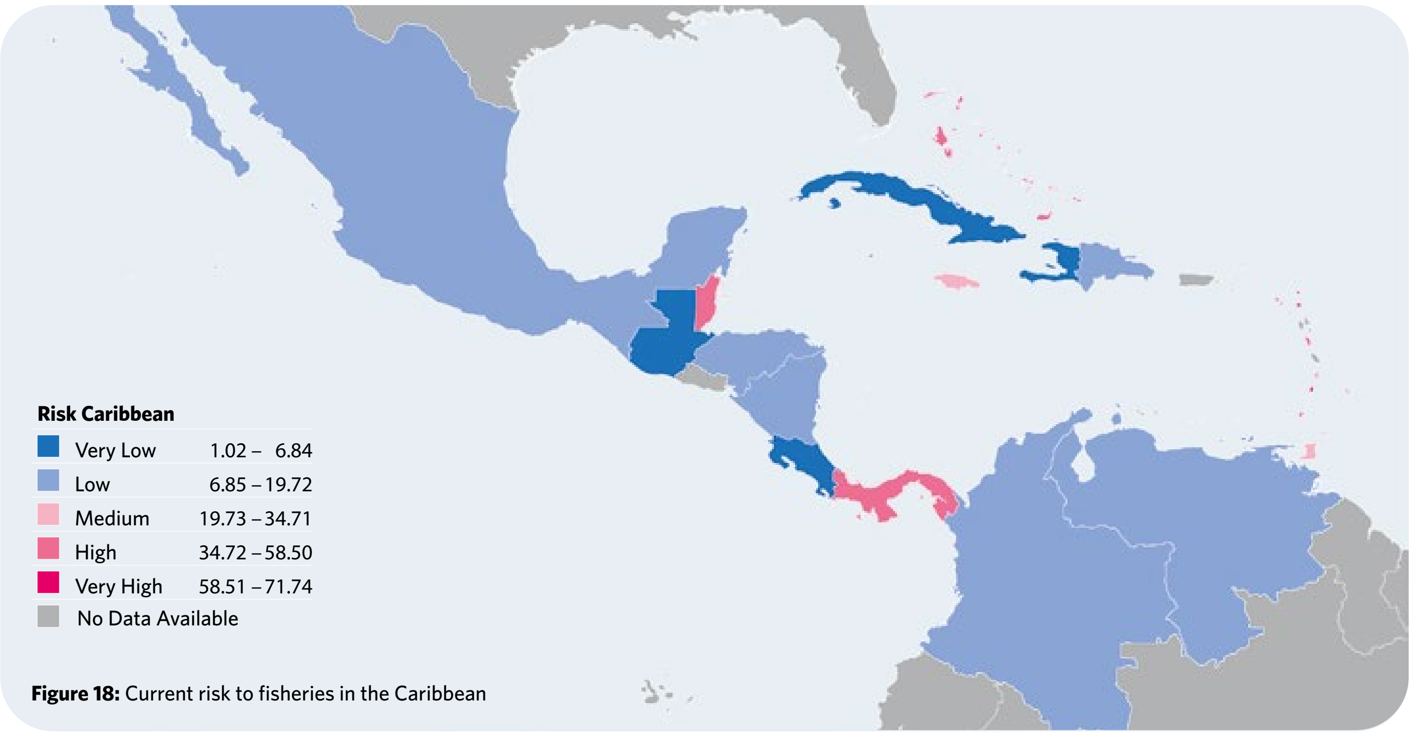

Figure 18: Current risk to fisheries in the Caribbean

	Exposure		Future exposure		Vulnerability		Risk	
Rank	**Country**	**Value**	**Country**	**Value**	**Country**	**Value**	**Country**	**Value**
1	St. Kitts and Nevis	80.07	St. Kitts and Nevis	75.61	Haiti	131.72	St. Kitts and Nevis	71.74
2	Antigua and Barbuda	74.95	British VI	71.53	Saba and St. Eustaius	116.51	British VI	71.47
3	British VI	69.47	Bahamas	71.37	Belize	114.37	Antigua and Barbuda	70.62
4	St. Vincent and the Grenadines	68.39	Turks and Caicos	69.06	Jamaica	113.47	Turks and Caicos	63.38
5	Turks and Caicos	57.45	Anguilla	56.69	Turks and Caicos	110.32	St. Vincent and the Grenadines	60.41
6	Sint Maarten	57.38	Sint Maarten	54.65	British VI	102.88	Belize	58.50
7	Anguilla	51.46	Antigua and Barbuda	49.33	Dominican Republic	102.35	Sint Maarten	55.99
8	Belize	51.15	St. Vincent and the Grenadines	48.13	Guatemala	99.99	Bahamas	45.81
9	Bahamas	50.16	Dominica	37.29	Grenada	99.56	Grenada	43.54
10	Dominica	44.45	Jamaica	33.49	Panama	98.79	Dominica	39.81

Table 13: Comparison of top 10 Caribbean countries across risk dimensions

the underlying reasons for a countries' vulnerability is important for developing salient strategies that will reduce vulnerability to climate change.

The assessment of changes in exposure to fisheries in the region reveals that a number of island nations (e.g., Bahamas, Turks and Caicos, Jamaica, British Virgin Islands, Anguilla, Cuba) as well as multiple countries on the mainland (e.g., Guatemala, Honduras) are likely to see an increase in exposure (Fig. 19). Bahamas, Jamaica, Turks and Caicos in particular are expected to see an increase in exposure, and thus risk, if these countries do not take actions to reduce their vulnerability.

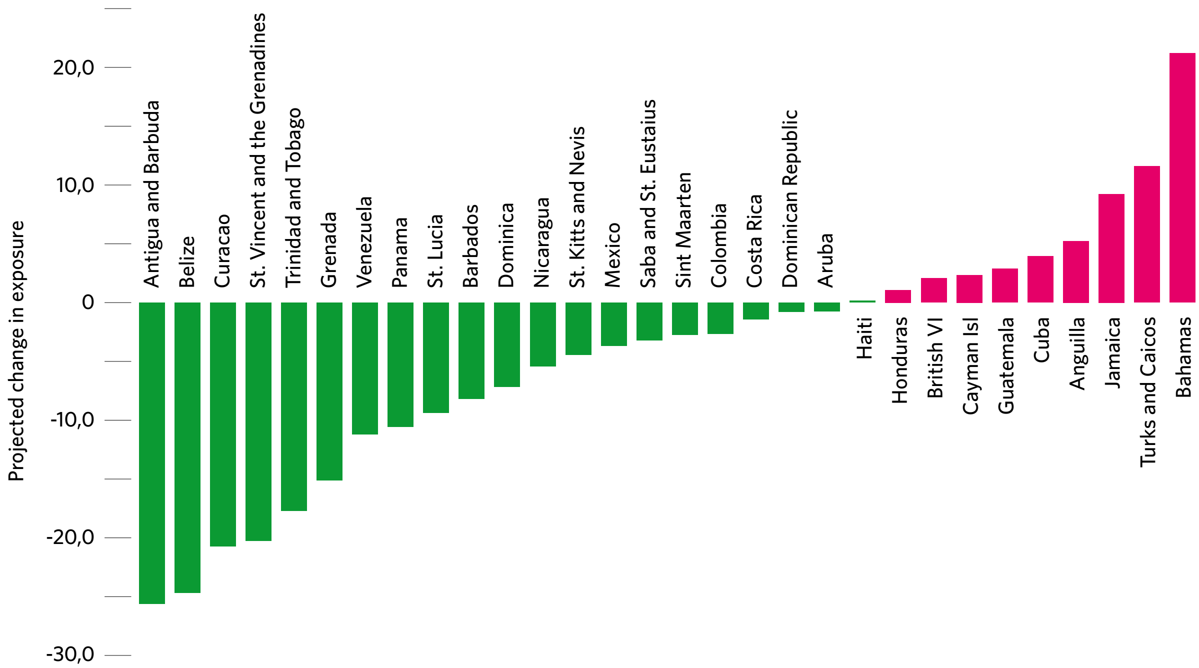

Figure 19: Projected change in exposure


CHEVROLET

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. Liberia's fishery adaptive capacity is especially low (rank 7). The high vulnerability towards extreme weather events is also confirmed by the WorldRiskIndex (rank 10 of 180 countries, Bündnis Entwicklung Hilft / IFHV 2019). The fisheries sector contributes about 12 percent of Liberia's agricultural gross domestic product (GDP) and 3 percent of the overall GDP. The small-scale coastal subsector is particularly important in providing nutrition and employment for the population in coastal areas. Small-scale fisheries provide livelihoods for approximately 33,000 full-time fishers and processors located along the Atlantic coast of Liberia. Many small-scale fishers do not have a formal education. They use simple fishing techniques based on hook and line fishing with paddled boats that are typically passed on from one generation to the next. Their fishing activities are seasonally limited and particularly low between June and September. They also 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, such as tropical storms, heavy rainfall and rough wave action 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. Climate change impacts add to existing stresses in the fishery sector in Liberia and threaten the socio-economic well-being of fishing communities.

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 36 fishing families belonging to a cooperative to expand their capacities and diversify their income to strengthen resilience to climate change impacts. Fishing families received assistance in structuring and governance of the cooperative and participated in various skill trainings relevant for fisheries. For example, they were trained in the maintenance and operation of motorized vessels as well as processing methods that enhance longer storage capacity in order 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, in order to reduce pressures on mangrove deforestation. A fish processing facility is currently under construction with basic equipment being provided by the project funds for the cooperative. 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. Additionally, fishers have also been taught to read the weather better and have received safety equipment to give them more security at sea. 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 have been able to progressively raise their incomes as well as 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 including health care, education, shelter and food. Most of the loans obtained through the VSLAs go towards financing other small-scale businesses such as soap making or pastry bakeries. The additional income from small-scale investments makes it possible to maintain running costs on fishing boats or equipment. Members are also buying shares within the cooperative, which increases the spirit of ownership and provides a sense of common purpose. 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 analysis shows that multiple countries, particularly in Africa and among SIDS, are highly dependent on fisheries for food security, economic contribution to GDP, and employment. At the same time, 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 overall economy of coastal countries (Sumaila et al. 2011).

Risk is highest in SIDS

This study shows that risk is not evenly distributed geographically. Oceania and Africa, for example, contain a number of countries that have high risk to climate change impacts on their fisheries. Most countries in Europe and South America, on the other hand, are displaying relatively low levels of risk. In addition, we find that countries of the Global North, such as OECD countries, are less at risk than countries of the Global South. 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 might 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. Vulnerability is a composite of sensitivity and lack of fisheries adaptive capacity. Strategies to reduce vulnerability thus need to be tailored to country specific sensitivity and adaptive capacity issues. An indicator-based approach such as the one we highlight here can help to formulate these strategies. For example, our study highlights countries where specific aspects of fisheries adaptive capacity are relatively low and where different types of sensitivity are relatively high.

Fishing practices that can affect the health of benthic habitats, for example, increase the sensitivity of marine ecosystems and fishery habitats in a number of coastal nations. Coral reefs, for example, are particularly subject to anthropogenic impacts due to destructive fishing practices such as cyanide and poison fishing (Riegl et al. 2009). 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, thus reducing sensitivity. A number of countries on the other hand are primarily sensitive due to pollution of coastal ecosystems. These areas require more emphasis on pollution reduction strategies to reduce the sensitivity of economically important 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 thus should focus more on increasing fisheries adaptive capacity than reducing sensitivity. Our study shows that individual countries lack different types of adaptive capacity. African nations, for example, are scoring the highest in terms of lack of generic adaptive capacity. The mobility and technical capacity of fishers to respond to changes in marine ecosystems is particularly lacking in parts of the Caribbean Islands. 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 that 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 was developed by the Caribbean Catastrophe Risk Insurance Facility, The World Bank, and Caribbean Regional Fisheries Mechanism. It'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. Our analysis also combines the magnitude and frequency of coastal hazards with the volume of catch and number of fishers to calculate exposure. Future modelling efforts could improve the calculation by predicting responses of individual fish species to sea surface temperature change and ocean acidification, and to model impacts of coastal hazards on fishers and fishing communities in locations where subnational data on landings and fishery activities are available. In addition, 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 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. Overall, countries 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). 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 an extreme weather event.

Based on our analysis, we developed multiple recommendations for reducing climate-related risk to fisheries. Some of these recommendations are not that surprising and there have been many sensible calls for their implementation, which are still much needed. We have tended to put some of these common recommendations further below – not because they are any less important – but to also focus on some recommendations that are newer and more specific to this work.

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 in general (e.g., only a small part of national budgets) and particularly so for fisheries. The Liberia example in this report highlights some of the important actions that can be taken to help reduce the vulnerability of fishing communities.

+ **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**. Tens to hundreds of billions of dollars are spent in coastal communities on post-cyclone recovery, but very little of this is directed to support fishing communities and almost none to helping them adapt. 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 (e.g., debris removal from fish habitats) 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 not only recover but also to improve the adaptive capacity of fisheries including fish and fishers.

+ **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 schemes 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 (see example Liberia) should be made easier to access for fishers. To do so means there will often need to be additional support for premium payment. This support could then help to incentivize better practices and adaptation along the lines of the strategies identified in the Disaster Recovery section above.

+ **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. The World Economic Forum (2016), for example, reports that there could be more plastic than fish in the ocean by 2050 and global efforts are needed to ensure that important fish species are healthy and safe for consumption.

+ **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. Besides financial means, 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 ensure fish stocks can be maintained and / or recover from overfishing.

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Appendices

Appendix 1: Indicators descriptions

Indicator	Measurement	Data source	Time frame	Rationale
Exposure				
Sea Surface temperature	Number of positive temperature anomalies that exceed the natural range of variation	Ocean Health Index (CoRTAD)	2016	Altered timing and reduced productivity across marine water systems (Daw et al. 2009, Perry et al. 2005).
Sea Surface temperature anomalies predicted global	RCP 8.5	Blasiak et al. (2017)	2016-2050	
Sea Surface temperature predicted Caribbean	Estimated frequency of severe thermal stress (NOAA Bleaching Alert Level 2) as percentage of the decade in which the grid cell would experience severe thermal stress under an IPCC "business-as-usual" emissions scenario	Reefs at Risk Burke, 2011 #105	2050	
Ocean acidification	Difference in global distribution changes in the aragonite saturation state	Ocean Health Index	1870 and 2000-2009	Potentially reduced production for calciferous marine resources and ecologically related species and declines in yields (Daw et al. 2009).
Ocean acidification predicted	Estimated aragonite saturation state under a CO2 stabilization level of 500 ppm	Reefs at Risk Burke, 2011 #105	2050	
Sea level rise		Ocean Health Index (AVISO)	1993-2015	Sea level rise leads to reduced production and yield due to loss of coastal fish breeding and bursary habitats. In addition, sea level rise increase the potential of disruption and loss of coastal communities and infrastructure (Daw et al. 2009).
Sea level rise predicted	IPCC AR5 projections	CIESIN Columbia University	2100	
Cyclone frequency	Global Cyclone Hazard Frequency and Distribution	CHRR	1980-2000	Cyclones increase the risk associate with fishing at sea and can affect access to the resource by reducing days spent at sea. In addition, cyclones lead to reduced profitability of fisheries due to increased costs of insurance and / or rebuilding and increase the risk of flooding in low lying coastal areas (Daw et al. 2009).
Strom frequency predicted	Downscale CMIP3 multi-model ens. A1B change	Murakami et al. 2013	2075-2099 minus control period	
Wave action	Historical time series	Global Ocean Waves	1948-2008	Wave action is used as a proxy of impaired navigability conditions for fishing and access to landing zones. High wave action increase the risk associate with fishing at sea and reduces access to the resource.
Wave action predicted	Downscale CMIP3 multi-model ens. A1B change	Murakami et al. 2013	2075-2099 minus control period	
Fishers exposed to climate-related impacts	Number of fishers per capita	FAO fisheries country profiles and SOFIA report	2017-2018	Presence of fishers exposed to hazards.
Catch exposed to climate-related impacts	Reported landings per capita	FAO FishStatJ	2014-2016	Presence of economically important species exposed to hazards.

Indicator	Measurement	Data source	Time frame	Rationale
Sensitivity				
Dependency on fish for nutrition	fish protection / total animal protection g / day) / (total animal protein / required protein (36g) per capita)	FAO STAT	2011-2013	Countries that rely on fisheries for food security are more sensitive to impacts on fisheries due to climate hazards and climate change.
Economic dependency	Value of landings per GDP	Sea Around Us World Bank	2012-2014 2017	Countries that rely on fisheries whose GPD depends on fisheries are more sensitive to impacts on fisheries due to climate hazards and climate change.
Employment dependency	Fishers as percentage of active working population	FAO fisheries country profiles and SOFIA report World Bank	2018 2018	Countries where fisheries contribute to employment are more sensitive to impacts on fisheries.
Non-climatic stressors	Nutrient pollution	Ocean Health index	2016	Non-climatic stressors render fisheries systems less resilient to climate impacts.
	Chemical pollution	Ocean Health index	2016	
	Plastic pollution	Ocean Health index		
	Amount of catch caught by trawl / soft bottom habitat	Sea Around Us Ocean Health Index	2012-2014 2016	
	Dynamite fishing	Ocean Health index	2016	
	Cyanide fishing	Ocean Health index	2016	
Fishery Adaptive capacity				
Alternative livelihood opportunities	Coastal tourism: Total employment in tourism sector adjusted by percent of a country's populations living within a 25 miles inland coastal zone	WTTO GPW v4 (SEDAC)	2017 2015	Alternative sources of income for fishers increase social resilience in the face of economic instability from climate impacts on fisheries.
	Employment in mariculture	FAO Aquaculture country profiles	2018	
Fisher capacity and technology	Fleet size	FAO	2017	Technology and capacity to change fishing locations increase social resilience under shifting stocks.
	Gear diversity for reported landings	Sea Around Us	2014	
	Ratio industrial landings to total landings)	Sea Around Us	2012-2014	

Indicator	Measurement	Data source	Time frame	Rationale
Fishery Adaptive capacity (cont.)				
Effective fishery management	Use of sciences in management process	Mora	2009	Successful fisheries management and MPAs have the potential to increase ecosystem resilience. Governance over a fishery at different scales creates a flexible structure for adapting to change at multiple scales.
	Capacity to implement regulations	Mora	2009	Successful fisheries management and MPAs have the potential to increase ecosystem resilience. Governance over a fishery at different scales creates a flexible structure for adapting to change at multiple scales.
	Transparency of process	Mora	2009	Successful fisheries management and MPAs have the potential to increase ecosystem resilience. Governance over a fishery at different scales creates a flexible structure for adapting to change at multiple scales.
	Unreported landings as percent of total landings	Sea Around Us	2012-2014	
	# of RFMOs memberships	Sea Around Us RFMO websites	2017 2017	
	Percentage of EEZ protected in MPAs	WDPA	2016	Conserving biodiversity, community structure, and habitats support fish population resistance and recovery to external stressors.
General adaptive capacity	GDP per capita	World Bank	2017	Economic capacity was defined as the resources a country has at its disposal to assist the fisheries sector in responding to a decline in fisheries.
	World Governance Indicators	World Bank	2017	The World Government Indicators, developed by the World Bank, was used as a metric for overall governance. The index measures the degree to which a country's institutional and policy frameworks support or hinder adaptation to climate change and indicates the ability of a country to effectively take steps toward change and implement policies and programs that will lead to successful adaptation.
	Adult literacy rate (%)	World Bank IndexMundi	2017 2017	A country that is adapting well would be able to acquire, synthesize, and incorporate new knowledge into decision making, including knowledge from resource users. Following previous studies, we assume that countries with higher adult literacy rates have more resources dedicated to education; their populations will be better equipped to respond to changes to food systems, access alternative food sources, and incorporate new knowledge that will improve their adaptive capacity.

Appendix 2: Fisheries@Risk Index

Rank	EEZ	F@R Index	Exposure	Vulnerability	Sensitivity	Lack of fisheries adaptive capacity
1	Micronesia	73.86	68.43	107.94	51.12	56.82
2	Sint Maarten	71.73	55.67	128.86	62.35	66.52
3	British VI	65.93	59.41	110.97	70.47	40.50
4	Philippines	64.91	58.46	111.04	47.88	63.16
5	Solomon Islands	64.33	49.13	130.94	57.16	73.78
6	Turks and Caicos	63.96	58.10	110.09	51.13	58.96
7	Vanuatu	59.56	57.18	104.16	43.77	60.39
8	Iceland	59.13	77.41	76.38	34.25	42.13
9	Greenland	57.74	78.10	73.93	43.03	30.90
10	Tonga	52.15	52.56	99.20	33.28	65.92
11	Mauritius	51.98	58.30	89.17	25.64	63.54
12	Fiji	51.65	46.17	111.88	37.61	74.27
13	Kiribati	51.27	47.82	107.20	47.63	59.57
14	Vietnam	49.58	45.99	107.79	42.32	65.46
15	St. Kitts and Nevis	48.94	51.58	94.88	26.66	68.21
16	Madagascar	47.22	44.04	107.23	30.49	76.73
17	Samoa	46.97	44.66	105.18	33.31	71.87
18	Myanmar	46.67	37.35	124.97	43.93	81.04
19	Libya	45.56	41.20	110.58	36.13	74.45
20	Belize	44.15	43.42	101.67	42.13	59.53
21	Indonesia	43.64	37.02	117.89	51.30	66.59
22	Georgia	43.21	54.53	79.23	29.68	49.55
23	Norway	41.24	62.88	65.59	25.97	39.62
24	Turkey	40.70	47.08	86.46	27.45	59.01
25	Dominica	40.60	40.43	100.42	39.52	60.90
26	Croatia	40.19	47.02	85.49	30.04	55.45
27	Netherlands	39.95	42.28	94.50	37.29	57.21
28	Seychelles	39.72	49.66	79.99	16.83	63.16
29	St. Vincent and the Grenadines	39.67	36.61	108.36	39.28	69.08
30	Mozambique	39.59	31.75	124.70	50.78	73.92
31	Bangladesh	38.37	34.49	111.26	36.89	74.37
32	Ukraine	37.79	46.75	80.84	23.65	57.19
33	Tunisia	37.75	36.60	103.12	36.32	66.81
34	Greece	37.10	43.08	86.13	26.54	59.59
35	Latvia	36.47	37.18	98.10	36.33	61.77
36	Estonia	35.94	41.54	86.51	29.14	57.38
37	Bahamas	35.82	38.00	94.25	38.89	55.36
38	Chile	35.51	45.71	77.67	25.30	52.37
39	Comoros	35.43	29.95	118.30	40.37	77.93
40	Cambodia	35.34	28.04	126.04	47.16	78.88
41	Sri Lanka	35.08	27.45	127.78	55.20	72.59
42	China	35.03	39.75	88.13	37.84	50.30
43	El Salvador	34.96	36.77	95.08	26.40	68.68
44	Montenegro	34.09	41.99	81.19	25.96	55.22
45	Mexico	33.76	36.72	91.95	24.67	67.27
46	Lebanon	33.07	27.79	119.00	36.21	82.79
47	Gambia	32.42	26.09	124.26	48.03	76.23
48	Morocco	32.03	30.27	105.79	37.33	68.46
49	Panama	32.03	31.10	102.99	36.76	66.23
50	Bulgaria	32.00	36.68	87.24	26.98	60.27
51	Ireland	31.96	45.85	69.71	20.52	49.19
52	Oman	31.91	30.87	103.37	32.30	71.07

Rank	EEZ	F@R Index	Exposure	Vulnerability	Sensitivity	Lack of fisheries adaptive capacity
53	Egypt	31.46	32.11	97.97	30.87	67.10
54	Guyana	30.83	28.27	109.08	31.22	77.86
55	Jamaica	30.79	26.77	115.00	37.39	77.61
56	Timor Leste	30.45	26.42	115.23	39.10	76.13
57	Dominican Republic	30.38	30.55	99.47	27.96	71.51
58	Cape Verde	30.28	34.14	88.69	38.29	50.40
59	South Korea	30.26	40.19	75.30	34.43	40.87
60	Grenada	29.17	32.61	89.46	20.22	69.24
61	India	29.12	28.18	103.35	33.50	69.86
62	Senegal	28.94	26.08	110.93	48.38	62.55
63	Pakistan	28.74	26.79	107.29	30.54	76.75
64	Nauru	28.66	41.00	69.91	3.56	66.35
65	Sierra Leone	28.32	20.82	136.05	58.10	77.94
66	Trinidad and Tobago	28.24	30.95	91.25	28.16	63.09
67	Honduras	28.09	28.72	97.79	23.31	74.48
68	Malaysia	28.06	28.16	99.65	43.74	55.91
69	Romania	27.92	34.51	80.91	21.67	59.24
70	St. Lucia	27.83	29.13	95.54	32.64	62.90
71	Russia	27.72	40.33	68.74	15.64	53.10
72	Saba and St. Eustaius	27.65	25.70	107.59	44.21	63.37
73	Lithuania	26.81	30.66	87.45	29.68	57.77
74	Mauritania	26.78	26.47	101.17	33.42	67.75
75	Curacao	26.68	25.96	102.77	31.41	71.35
76	Somalia	26.28	22.49	116.83	28.88	87.95
77	Nicaragua	26.25	27.13	96.73	27.41	69.32
78	Barbados	26.24	30.30	86.59	29.53	57.06
79	Portugal	26.05	31.90	81.67	27.97	53.70
80	Maldives	25.79	28.42	90.74	40.60	50.14
81	Yemen	25.67	25.07	102.38	30.52	71.86
82	Uruguay	25.57	30.53	83.74	22.90	60.84
83	Guinea	25.51	20.61	123.79	44.53	79.26
84	Canada	25.33	44.92	56.40	13.91	42.48
85	Japan	25.17	34.42	73.14	29.53	43.61
86	Finland	24.99	40.02	62.44	24.33	38.11
87	Suriname	24.96	26.01	95.95	25.44	70.51
88	Italy	24.37	33.33	73.13	27.64	45.49
89	Haiti	24.20	20.69	117.00	27.06	89.94
90	Spain	24.00	30.50	78.68	27.96	50.72
91	South Cyprus	23.54	34.91	67.45	27.13	40.32
92	Cuba	22.93	28.93	79.26	17.29	61.96
93	United Kingdom	22.81	38.22	59.68	16.55	43.12
94	Venezuela	22.68	25.31	89.60	22.98	66.62
95	South Africa	22.51	29.09	77.35	18.61	58.74
96	Thailand	22.18	23.88	92.88	40.23	52.65
97	Sweden	21.85	35.60	61.38	17.44	43.94
98	USA	21.81	41.63	52.39	17.21	35.18
99	Poland	21.45	28.88	74.26	25.10	49.15
100	Sao Tome and Principe	21.22	17.22	123.23	51.15	72.08
101	Denmark	21.18	33.94	62.39	23.90	38.49
102	Togo	21.01	15.80	132.97	54.53	78.44
103	Israel	20.81	24.36	85.43	23.69	61.74
104	New Zealand	20.64	38.61	53.47	15.09	38.38

Rank	EEZ	F@R Index	Exposure	Vulnerability	Sensitivity	Lack of fisheries adaptive capacity
105	Nigeria	20.24	14.40	140.53	55.52	85.01
106	France	20.19	32.85	61.47	22.62	38.85
107	Saudi Arabia	19.98	20.92	95.52	22.57	72.96
108	Namibia	19.33	21.93	88.15	30.53	57.63
109	Ghana	18.90	15.99	118.19	45.76	72.43
110	Bahrain	18.75	17.78	105.47	39.32	66.15
111	Peru	18.36	19.23	95.49	31.18	64.31
112	Belgium	18.35	24.28	75.58	26.00	49.57
113	Qatar	18.31	17.27	106.06	35.03	71.03
114	Djibouti	17.98	15.05	119.49	29.61	89.87
115	Guinea-Bissau	17.72	19.37	91.50	24.64	66.86
116	Benin	17.01	15.40	110.43	36.32	74.12
117	Iran	16.57	16.79	98.72	27.41	71.31
118	Cameroon	16.55	12.40	133.55	51.16	82.39
119	Guatemala	16.43	17.12	95.95	24.70	71.25
120	Colombia	16.34	17.76	91.98	24.70	67.28
121	Papua New Guinea	16.18	16.65	97.19	24.84	72.34
122	Tanzania	16.07	15.18	105.83	34.77	71.06
123	Jordan	15.41	14.45	106.70	30.15	76.55
124	Germany	15.37	23.28	66.04	17.82	48.22
125	Costa Rica	14.93	17.97	83.07	23.33	59.73
126	Liberia	14.68	13.03	112.68	29.16	83.52
127	Kuwait	14.16	14.99	94.48	23.45	71.02
128	Albania	13.58	15.99	84.93	24.66	60.26
129	Brazil	13.51	15.42	87.61	27.53	60.08
130	United Arab Emirates	12.87	15.61	82.47	26.11	56.36
131	Sudan	12.54	14.21	88.20	12.66	75.54
132	Côte d'Ivoire	12.45	11.01	113.08	38.11	74.97
133	Ecuador	12.16	13.80	88.13	25.56	62.57
134	Kenya	11.56	13.04	88.64	18.73	69.92
135	Iraq	11.38	8.88	128.17	36.55	91.62
136	Congo, R. of	10.63	10.00	106.30	27.43	78.87
137	Equatorial Guinea	10.62	10.30	103.05	27.96	75.08
138	Gabon	10.25	9.59	106.90	34.24	72.66
139	Congo	8.04	7.64	105.28	29.26	76.02
140	Argentina	7.35	9.76	75.36	13.23	62.13
141	Angola	7.11	7.01	101.49	32.50	68.98
142	Algeria	5.46	5.59	97.70	33.10	64.60
143	Australia	4.25	9.26	45.89	10.33	35.55

Appendix 3: List of EEZ in alphabetical order

EEZ	Rank	F@R
Albania	128	13.58
Algeria	142	5.46
Angola	141	7.11
Argentina	140	7.35
Australia	143	4.25
Bahamas	37	35.82
Bahrain	110	18.75
Bangladesh	31	38.37
Barbados	78	26.24
Belgium	112	18.35
Belize	20	44.15
Benin	116	17.01
Brazil	129	13.51
British VI	3	65.93
Bulgaria	50	32.00
Cambodia	40	35.34
Cameroon	118	16.55
Canada	84	25.33
Cape Verde	58	30.28
Chile	38	35.51
China	42	35.03
Colombia	120	16.34
Comoros	39	35.43
Congo	139	8.04
Congo, R. of	136	10.63
Costa Rica	125	14.93
Côte d'Ivoire	132	12.45
Croatia	26	40.19
Cuba	92	22.93
Curacao	75	26.68
Denmark	101	21.18
Djibouti	114	17.98
Dominica	25	40.60
Dominican Republic	57	30.38
Ecuador	133	12.16
Egypt	53	31.46
El Salvador	43	34.96
Equatorial Guinea	137	10.62
Estonia	36	35.94
Fiji	12	51.65
Finland	86	24.99
France	106	20.19
Gabon	138	10.25
Gambia	47	32.42
Georgia	22	43.21
Germany	124	15.37
Ghana	109	18.90
Greece	34	37.10

EEZ	Rank	F@R
Greenland	9	57.74
Grenada	60	29.17
Guatemala	119	16.43
Guinea	83	25.51
Guinea-Bissau	115	17.72
Guyana	54	30.83
Haiti	89	24.20
Honduras	67	28.09
Iceland	8	59.13
India	61	29.12
Indonesia	21	43.64
Iran	117	16.57
Iraq	135	11.38
Ireland	51	31.96
Israel	103	20.81
Italy	88	24.37
Jamaica	55	30.79
Japan	85	25.17
Jordan	123	15.41
Kenya	134	11.56
Kiribati	13	51.27
Kuwait	127	14.16
Latvia	35	36.47
Lebanon	46	33.07
Liberia	126	14.68
Libya	19	45.56
Lithuania	73	26.81
Madagascar	16	47.22
Malaysia	68	28.06
Maldives	80	25.79
Mauritania	74	26.78
Mauritius	11	51.98
Mexico	45	33.76
Micronesia	1	73.86
Montenegro	44	34.09
Morocco	48	32.03
Mozambique	30	39.59
Myanmar	18	46.67
Namibia	108	19.33
Nauru	64	28.66
Netherlands	27	39.95
New Zealand	104	20.64
Nicaragua	77	26.25
Nigeria	105	20.24
Norway	23	41.24
Oman	52	31.91
Pakistan	63	28.74
Panama	49	32.03

EEZ	Rank	F@R
Papua New Guinea	121	16.18
Peru	111	18.36
Philippines	4	64.91
Poland	99	21.45
Portugal	79	26.05
Qatar	113	18.31
Romania	69	27.92
Russia	71	27.72
Saba and St. Eustaius	72	27.65
St. Lucia	70	27.83
Samoa	17	46.97
Sao Tome and Principe	100	21.22
Saudi Arabia	107	19.98
Senegal	62	28.94
Seychelles	28	39.72
Sierra Leone	65	28.32
Sint Maarten	2	71.73
Solomon Islands	5	64.33
Somalia	76	26.28
South Africa	95	22.51
South Cyprus	91	23.54
South Korea	59	30.26
Spain	90	24.00
Sri Lanka	41	35.08

EEZ	Rank	F@R
St. Kitts and Nevis	15	48.94
St. Vincent and the Grenadines	29	39.67
Sudan	131	12.54
Suriname	87	24.96
Sweden	97	21.85
Tanzania	122	16.07
Thailand	96	22.18
Timor Leste	56	30.45
Togo	102	21.01
Tonga	10	52.15
Trinidad and Tobago	66	28.24
Tunisia	33	37.75
Turkey	24	40.70
Turks and Caicos	6	63.96
Ukraine	32	37.79
United Arab Emirates	130	12.87
United Kingdom	93	22.81
Uruguay	82	25.57
USA	98	21.81
Vanuatu	7	59.56
Venezuela	94	22.68
Vietnam	14	49.58
Yemen	81	25.67

Appendix 4: Missing Economic Exclusive Zones in alphabetical order

EEZ
American Samoa
Antigua and Barbuda
Azerbaijan
Bermuda
Bonaire
Bosnia and Herzegovina
Brunai
Christmas islands
Cocos Islands
Cook Islands
Crozet Islands
Eritrea
Faroes Islands
French Polynesia
Guadeloupe
Guam
Jan Mayen
La Reunion
Monaco
Montserrat
New Caledonia
Norfolk Islands
North Korea
Pitcairn Islands
Puerto Rico
Saba
St. Eustasius
St. Pierre and Miquelon
St. Barthelemy
Singapore
Slovenia
Svalbard
Syria
Taiwan
Tokelau
Turkmen
Tuvalu
United Arab Emirates
Wallis and Futuna
Western Sahara

This Technical Report, and its accompanying Summary Report, may be found at:
https://entwicklung-hilft.de/download/5215/ and **https://entwicklung-hilft.de/download/5211/**

Contact: europe@tnc.org

The Nature Conservancy, Schiffbauerdamm 8, 10117 Berlin, Germany, **www.nature.org**
University of California Santa Cruz, UCSC Coastal Resilience Lab, 1156 High St, Santa Cruz, CA 95064, United States, **www.coastalresiliencelab.org**
Bündnis Entwicklung Hilft, Schöneberger Ufer 61, 10785 Berlin, Germany, **www.entwicklung-hilft.de**