# A Climate-Smart Fisheries Toolkit for the Caribbean: Part 1 - Results of a Regional Ecological and Economic Assessment of Climate Change Impacts of Caribbean Fisheries

# Una Caja de Herramientas para la Pesca Climáticamente Inteligente en el Caribe: Parte 1 – Resultados de Una Evaluación Regional de los Impactos Ecológicos y Económicos del Cambio Climático en Recursos Pesqueros del Caribe

# Boîte À Outils pour Soutenir Les Pêcheries Face au Changement Climatique aux Caraïbes: Partie 1 – Résultats d'une Évaluation des Impacts Écologiques et Économiques Regionales lies aux Changements Climatiques sur les Pêcheries des Caraïbes

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## EXTENDED ABSTRACT

### Introduction

Marine biodiversity, ecosystems, and fisheries provide sustenance and livelihoods critical to human well-being in island and coastal communities globally and in the Caribbean region. In the Caribbean, the fisheries sector is economically, socially and culturally important. As such, there is an urgent need to improve understanding of climate change risks and potential impacts to the sector, as well as options to enhance climate resilience. The Inter-American Development Bank has invested in supporting the region's climate resilience, through grant funding for the Caribbean Regional Track of the Pilot Programme for Climate Resilience (PPCR). The "*Fishery-Related Ecological and Socio-Economic Assessments of the Impacts of Climate Change and Variability and Development of an Associated Monitoring System"* project ("the project") delivers on the PPCR regional track. Executed by the Mona Office for Research and Innovation (MORI) at the University of West Indies at Mona, Jamaica, and with the Caribbean Regional Fisheries Mechanism (CRFM) as the co-implementer, the project aims to improve availability and use of information for "climate-smart" planning and management in the fisheries and aquaculture sector in the Caribbean. Research activities and stakeholder engagement are centered on the following six climate-sensitive countries (referred to as "pilot countries"): The Commonwealth of Dominica, Grenada, Haiti, Jamaica, Saint Lucia, and Saint Vincent and the Grenadines (SVG). The project began in January 2018 and is scheduled to conclude in January 2020.

This paper centres on main outputs of the project's Work Package 1, which focused on ecological and socio-economic assessment of climate change impacts on the fisheries resources and sector in the six case study countries. This paper provides key conclusions from the assessment of:

i) Climate risks and ecological impacts for Caribbean marine fish stocks, and
ii) The economic consequences of ecosystem shifts and of increased tropical cyclone activity on fish landings.

It contains the combined results of original ecological and economic modelling done on regional and national levels. Quantitative studies on the impacts of climate change on fishery species in the Caribbean and on the social and economic implications for the fisheries sector are scant (Oxenford and Monnereau 2018). The recent completion of detailed impact assessments for Caribbean fisheries under this PPCR project now provides a stronger foundation for a more systematic and informed approach to climate change adaptation planning in the sector. Assessment results informed development of climate-smart monitoring and management recommendations, which are the subject of a companion paper in this volume.

### Methods

The research team assessed the ecological and socio-economic impacts of climate change on Caribbean fisheries to the 2050s using multiple modelling methods. To assess the ecological climate risks for Caribbean marine fish stocks and fisheries, a first step was to assemble three linked datasets:

i) A list 110 of the region's key marine species, agreed to together with stakeholders, this assessment should focus on,

ii) Occurrence data for species identified in (1), as well as life history (e.g., age at maturity) and ecological data (e.g., depth) associated with these species, and

iii) Variables that globally define the marine environment obtained from a number of separate model outputs.

These data were inputs into three distinct analytical approaches: indicator-based fuzzy logic models to estimate species-specific climate vulnerability and risk indices (Jones and Cheung 2017); species distribution modelling (four environmental niche models were used) to estimate habitat suitability indices and spatial measures of species loss/gain; and, a spatially-explicit dynamic population model to estimate species abundance and maximum catch potential (Cheung et al. 2008). Projected changes in ocean conditions (e.g., sea surface and bottom temperature, acidity, net primary production) derived from four different Earth system models, three providing outputs of lower resolution and one of higher resolution. Projections of ocean conditions corresponded to two Representative Concentration Pathways, which represent two contrasting alternative scenarios of global greenhouse (GHG) mitigation: one consistent with limiting the increase of global mean temperature to 2°C (RCP2.6) and the other in line with business-as-usual emissions (RCP8.5).

To estimate the economic consequences to national fisheries sectors of climate change impacts on landings, a first step was to assemble two sets of data for each of the six pilot countries: a first set comprising economic (e.g., gross domestic product, seafood consumption / production), trade (imports / exports of seafood), landings (weight and value of seafood for seven species groupings) and population data for a baseline period; and a second set comprising historical tropical cyclone data from 1950 to 2014 (location, category, closes point of approach, whether it made landfall) and sea surface temperature data. These data were inputs into two distinct analytical approaches, generating results to 2050s for a series of indicators: domestic fish prices, annual income (supplier and household), fish consumption and fishery production (tonnage and landed value).

The economic impacts of climate-induced ecosystem shifts and related changes in fishery production (landings) were assessed using a market supply-demand model developed for each of the six case study countries (see Dey et al. 2016 for the analytical framework that inspired our work). It is based on theoretical concepts of traditional welfare economics, which seeks to explore how the allocation of resources affects well-being of producers and consumers in an economic system. The impacts of climate change were integrated into the modelling framework as a supply shock. Maximum catch potential derived from the ecological modelling work were converted into percentage reductions in landings by main species groups by GHG emissions scenarios and time period. To assess the economic consequences of more intense tropical cyclones for fisheries, we followed methods outlined in Nordhaus (2010) and Acevedo (2016). This analysis simulates the incremental economic impact of a 'what if' scenario: all else being equal (historical catches, prices, adaptation, etc.), what if the same sample of storms reoccurred but with higher intensities anticipated with warming sea-surface temperatures?

**Results & Discusson**

Regardless of global model and emissions scenario use, climate and ocean conditions in the Caribbean Sea in the 2050s are expected to be warmer, more acidic, with higher salinity, less oxygen and lower primary production, as compared to baseline levels. Overall, multiple lines of evidence suggest large risk and impacts of climate change on Caribbean fish stocks and fisheries by the 2050s. Exposure and vulnerability to climate hazards (warming, deoxygenation, acidification and decline in net primary production) is expected to be high to very high across all modelled species under both strong global mitigation and business-as-usual emission scenarios. Pelagic species (oceanic and reef) consistently had the highest risk and projected impacts (e.g., *Thunnus thynnus, Istiophorus albicans*), given their exposure to the larger projected changes in ocean conditions at the sea surface, relative to changes in sea bottom. Some demersal species (e.g., *Holothuria (Halodeima) mexicana* and *Holothuria floridana*) have a limited geographic range, exacerbating their sensitivity to climate impacts. In response to changing ocean conditions, marine species are projected to shift their distributions by tens to hundreds of kilometers resulting in local species gains and losses that significantly reduce species richness and change community composition. Climate change is also projected to result in a substantial decrease in maximum fisheries catch potential. Even in scenarios of strong global mitigation, maximum catch potential could drop between 10 and 30% by 2050s relative to baseline values (1970-2000). Table 1 below includes selected results for indicators of climate vulnerability, net change in habitat suitability and maximum catch potential by country.

Projected declines in maximum catch potential – or lower catches –in turn, have significant market impacts, including higher fish prices, lower domestic demand, and reduced incomes. Under business-as-usual emissions, domestic fish prices are projected to increase between 5 to 10% by 2050s relative to projected prices under the reference case. As a result of price changes, domestic fish consumption is projected to decrease by about 5% by 2050s, relative to the reference case. Seafood is an important source of animal protein in the Caribbean, comprising about 10% of animal protein consumed (Vannucinni et al. 2018). Therefore, price changes have implications for regional food security. Overall, the project market shifts are expected to result in decreased economic well-being (decreased income) due to too little production and consumption of seafood (see Table 2 below for selected results). The tropical cyclone analysis highlights a large pre-existing “adaptation deficit” in the sector, since incremental economic impacts due to climate change appear small relative to current loss and damages registered. For example, by the 2050s under RCP 8.5, projected

**Table 1.** Indicators of climate change impact on marine species and associated fisheries in the Caribbean Sea, broken down by country.

| Indicator | Jamaica | | | Haiti | | | Dominica | | | St. Lucia | | | St. Vincent and the Grenadines | | | Grenada | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Median Climate Vulnerability Index for Fished Species / 100 | 57.5 (across 78 species) | | | 56.5 (across 82 species) | | | 56.4 (across 42 species) | | | 57 (across 72 species) | | | 55.5 (across 60 species) | | | 55.0 (across 66 species) | | |
| | **RCP** | **2030-39** | **2050-59** | **RCP** | **2030-39** | **2050-59** | **RCP** | **2030-39** | **2050-59** | **RCP** | **2030-39** | **2050-59** | **RCP** | **2030-39** | **2050-59** | **RCP** | **2030-39** | **2050-59** |
| Δ In The Sum Of Species' Habitat Suitability Index (HSI) (relative to current HSI) | 8.5 | - 18% | - 29% | 8.5 | - 25% | - 29% | 8.5 | - 21% | - 49% | 8.5 | - 26% | - 39% | 8.5 | - 32% | - 47% | 8.5 | - 32% | - 47% |
| | **RCP** | **2030-39** | **2050-59** | **RCP** | **2030-39** | **2050-59** | **RCP** | **2030-39** | **2050-59** | **RCP** | **2030-39** | **2050-59** | **RCP** | **2030-39** | **2050-59** | **RCP** | **2030-39** | **2050-59** |
| | 2.6 | - 5-15% | - 10-30% | 2.6 | - 5-15% | - 10-30% | 2.6 | - 5-15% | - 15-30% | 2.6 | - 5-15% | - 10-30% | 2.6 | - 5-15% | - 10-30% | 2.6 | - 5-15% | - 10-30% |
| Δ In Maximum Catch Potential (relative to 1970-2000) | 8.5 | - 10-30% | - 20-60% | 8.5 | - 10-30% | - 20-60% | 8.5 | - 10-30% | - 30-60% | 8.5 | - 10-30% | - 20-60% | 8.5 | - 10-30% | - 20-60% | 8.5 | - 10-30% | - 20-60% |
| Key Geographic Areas of Change within National EEZs | Offshore areas to the northwest were projected to have both particularly high species gains (>50%) and extinctions (40-50%), while Pedro Bank may see relatively lower impacts in terms of shifting species composition and local extinctions. Catches are projected to decline in all areas around the island, particularly along the north coast and Pedro Bank. | | | Offshore areas in the Gulf de la Gonâveare expected to see the greatest species gains (40-60%) and, to a lesser extent, extinctions (30-50%), while the north coast of Haiti will also see a high proportion of species extinctions with few gains. Catches are projected to decline in all areas around the island. | | | Offshore areas closer to the west side of the island are expected to see modest species losses (10-20%), while offshore areas to the southwest are expected to see the greatest species gains (30-40%). Maximum catch potential will remain concentrated in eastern offshore waters, but overall catches are projected to decline to some degree in all areas around the island. | | | Offshore areas to the south and west are projected to have large species losses (up to 50-60%), while limited species gains (30-40%) will be concentrated in limited offshore areas east of the island. Catches are projected to decline in all areas around the island, but especially to the southwest. | | | Offshore areas to the east are expected to see modest species gains (20-30%)while species losses (up to 50-60%) will be seen in all offshore areas surrounding the islands, but will be less pronounced throughout the Grenadine Bank. Catches are projected to decline in all areas around the islands. | | | Offshore areas to the east and south are expected to see modest species gains (20-40%) while species losses (up to 50-60%) will be seen in all offshore areas surrounding the islands, but will be less pronounced throughout the Grenadine Bank and in southernmost areas of the EEZ. Catches are projected to decline in all areas around the islands. | | |

Table 2. Indicators of economic impact of climate change impact on marine species and associated fisheries in the Caribbean Sea, broken down by country. All monetary values are in US$2010, meaning that 2010 is the base year and all estimates are converted from current (nominal) dollar values to constant (real) dollar values.

| Indicator | Jamaica | | Haiti | | Dominica | | St. Lucia | | St. Vincent and the Grenadines | | Grenada | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Due to Climate-Change Induced Impacts on Fishery Production** | | | | | | | | | | | | |
| | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** |
| Δ in Aggregate Fish Consumption (relative to projected future demand)) | 2.6 | -4.6% | 2.6 | -4.6% | 2.6 | -4.1% | 2.6 | -4.3% | 2.6 | -4.6% | 2.6 | -4.7% |
| | 8.5 | -5.7% | 8.5 | -5.8% | 8.5 | -5.2% | 8.5 | -5.5% | 8.5 | -5.6% | 8.5 | -5.8% |
| | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** |
| Δ in Fish Prices (relative to projected future demand) | 2.6 | 5.6% | 2.6 | 3.8% | 2.6 | 5.6% | 2.6 | 7.1% | 2.6 | 6.8% | 2.6 | 7.7% |
| | 8.5 | 6.9% | 8.5 | 4.8% | 8.5 | 7.2% | 8.5 | 9.1% | 8.5 | 8.2% | 8.5 | 9.5% |
| | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** |
| Net Welfare* Loss (thousand US $ per year in 2010 prices) | 2.6 | -8000 | 2.6 | -3200 | 2.6 | -500 | 2.6 | -1600 | 2.6 | -580 | 2.6 | -600 |
| | 8.5 | -8900 | 8.5 | -3800 | 8.5 | -600 | 8.5 | -2000 | 8.5 | -640 | 8.5 | -760 |
| | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** | **RCP** | **2050s** |
| Reduction in Household Fish Food Consumption due to Climate-Induced Δ in Price and Consumption (per capita per day) | 2.6 | -4.6% | 2.6 | -4.4% | 2.6 | -4% | 2.6 | -4.2% | 2.6 | -4.6% | 2.6 | -4.5% |
| | 8.5 | -5.8% | 8.5 | -5.8% | 8.5 | -5% | 8.5 | -5.6% | 8.5 | -5.6% | 8.5 | -6% |

*Welfare is an economic metric closely linked to the concept of well-being. Specifically, this metric includes losses in both producer and consumer-side impacts on economic well-being incremental losses in tonnage and landed value due to climate change amounts to about 0.5% of historic total losses.

The projected high levels of species turnover, declines in maximum catch potential and pronounced market shifts suggest that fisheries in the region and in these pilot countries in particular are expected to be exposed to large uncertainties around the future abundance of their fisheries resources and health of the sector. The scale and speed of these changes pose substantial challenges for both ecological and human systems to adapt, demanding swift transformations across the fish value chain, as well as more coordinated fish value chain management. These reforms include improvements in the implementation of ecosystem-based and integrated management along a ridge to reef gradient, better management capacity at local levels, private-public partnerships and monitoring climate change impacts and responses (Pittman et al. 2015, Ali et al. 2018). With this project, access to quantitative information on climate change impacts on regional fisheries has increased and can support adaptation planning and targeted measures in the region.

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