

# Fisheries Management Science Programme Department for International Development

Effects of climate change on the sustainability of capture and enhancement fisheries important to the poor: analysis of the vulnerability and adaptability of fisherfolk living in poverty.

Summary Report (Project No. R4778J)

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Edward H. Allison<sup>1\*</sup>, W. Neil Adger<sup>2</sup>, Marie-Caroline Badjeck<sup>1</sup>,  
Katrina Brown<sup>1,2</sup>, Declan Conway<sup>1</sup>, Nick K. Dulvy<sup>3</sup>, Ashley Halls<sup>4</sup>,  
Allison Perry<sup>5</sup> & John D. Reynolds<sup>5</sup>



\*Corresponding Author

<sup>1</sup>School of Development Studies/Overseas Development Group  
University of East Anglia  
Norwich, NR4 7TJ, U.K.  
Tel 00-44-1603-593724 Email: [e.allison@uea.ac.uk](mailto:e.allison@uea.ac.uk)

<sup>2</sup>Centre for Social and Economic Research on the Global Environment (CSERGE)  
School of Environmental Sciences/Tyndall Centre for Climate Change  
University of East Anglia  
Norwich NR4 7TJ, U.K.

<sup>3</sup>Centre for Fisheries and Aquatic Sciences (CEFAS),  
Lowestoft Laboratory  
Pakefield Road  
Lowestoft  
Suffolk NR33 0HT, U.K.

<sup>4</sup>Marine Resources Assessment Group Ltd (MRAG)  
47 Prince's Gate  
London SW7 2QA, U.K.

<sup>5</sup>School of Biological Sciences  
University of East Anglia,  
Norwich NR4 7TJ, UK

## **1.1 Importance and vulnerability of small-scale fisheries**

The majority of the world's 200 million full and part-time fisherfolk (fishers, fish processors, traders and ancillary workers) and their dependents live in areas vulnerable to human-induced climate change, or depend for a major part of their livelihood on resources whose distribution and productivity are known to be influenced by climate variation. However, relationships between the biophysical impacts of climate change and the livelihood vulnerability of poor fishing communities have seldom been investigated. Information has been lacking on the areas and people that are likely to be most vulnerable to climate-induced changes in the fisheries. This information is required for the effective prioritisation of development interventions to reduce vulnerability to the impacts of adverse climate change on fisherfolk living in poverty.

The fisheries sector makes important contributions to local development in coastal, lakeshore, floodplain and riparian areas, through employment and multiplier effects. Maintaining or enhancing the benefits of fisheries in the context of a changing climate regime is an important development challenge.

## **1.2 Project purpose**

The purpose of the project was to explore the potential impact of climate change on the sustainability of capture and enhancement fisheries important to poor people with a view to informing the development of a research agenda in this field. The project has provided a synthesis of current thinking on the relations between climate change, vulnerability and adaptation of poor fisherfolk and has provided the outline for a research agenda to enable fisheries agencies and other stakeholders to respond to the challenges posed by rapid climate change.

## **1.3 Poverty and small-scale fisheries**

Recent analysis of poverty in small-scale fisheries, guided by the sustainable livelihoods analytical framework, has identified vulnerability to external shocks and trends, rather than asset or income poverty, as a particular threat to the sustainability of fishing-based livelihoods. These external shocks and trends include climate change, variation and extreme events. High levels of vulnerability potentially undermine the important contributions made by fisheries to poverty alleviation and nutritional security at local, regional and sometimes national levels

## **1.4 The threat of climate change**

It is widely accepted that at least part of the earth's 0.6°C warming during the last 100 years is due to emissions of greenhouse gases caused by human activities. During this century, the world is expected to continue warming, by between 1.4 and 5.8°C. Other predicted impacts by 2100 are a rise in average global sea level of between 0.1 and 0.9 m and changes in weather patterns, including an increased frequency and severity of extreme events such as hurricanes, floods and droughts

Regional patterns of precipitation, storm intensity and sea level rise are much more difficult to predict than global trends and patterns are different between different Global Circulation Models. Mean sea level rise will lead to extreme levels being reached more frequently and changes in storm surge heights may result from increases in strong winds and low pressure events.

The oceanic circulation system is also likely to be strongly influenced by warming, with likelihood of increased frequency of El Niño Southern Oscillation (ENSO) events

affecting current-dependent upwelling fisheries, including the major industrial fisheries for small-pelagic fish, with consequences for global fish supplies.

Although resource-dependent communities in the developing world have adapted to climate variability throughout history, through maintaining occupational and geographical mobility, projected climate change poses multiple risks to fishery-dependent communities because of the increased frequency of extreme weather events, the potential for large-scale phase shifts, and from risks that lie outside the realm of present day experience. It is also no longer always possible for fisherfolk to fall back on historical adaptive strategies due to increasing coastal and riparian populations, reduced fish catch rates and institutional barriers preventing or reducing the ease of geographical and occupational mobility.

The multiple stresses associated with coastal urbanization, changes in the frequency and intensity of coastal storms and hurricanes, and the impacts of climate change on sensitive coastal ecosystems such as coral reefs and mangroves make this a key issue of concern for vulnerability and security of resource-dependent communities.

In the important inland lake and floodplain fisheries, dynamics of fisheries are driven primarily by climate variations and both the ecosystems and the livelihoods of fisherfolk living near these waterbodies are highly adapted to extensive fluctuations. These systems are therefore particularly climate-change sensitive.

### **1.5 Pathways of impact of climate change on fisheries**

Climate change will impact on fisheries through a diversity of direct and indirect pathways whose importance will vary depending on the type of ecosystem and fishery. Inland fisheries, particularly important for small-scale fishers in developing countries and an integral part of many rural livelihood systems, will be severely impacted by changing water levels and flooding events, while coastal marine fisheries dependent on sensitive ecosystems such as coral reefs will be impacted by rising water temperature that affects ecosystem functions.

Some of the pathways identified in this study are impacts of:

- sea temperature change on aquatic ecology: shifting range of fish species, change in ocean currents affecting upwelling zone fisheries, coral bleaching affecting reef fisheries, disruption to fish reproductive patterns and migratory routes
- precipitation and evapotranspiration change on hydrology of inland waters: river flows and flood timing and extent change, affecting fish reproduction, growth and mortality, as well as other elements of wetland-based livelihoods (agriculture, pastoralism, forestry etc).
- Increased frequency of extreme events: more frequent loss of fishing days due to bad weather, increasing loss of nets, traps and longlines, damage to boats and shore facilities, increased loss of life among fishermen, increase damage to coastal communities – houses, farmland etc.

### **1.6 Defining and measuring vulnerability to climate change**

Vulnerability is the extent to which climate change may damage or harm a system; it depends not only on a system's sensitivity, but also its ability to adapt to new climatic conditions (IPCC, 2001). In the social realm vulnerability can be defined as the exposure of groups or individuals to stress as a result of climate variability and

change. It complements notions of physical vulnerability to the impacts of natural hazards that concentrate on the physical dimensions of risk. Vulnerability is therefore made up of a number of components including exposure and sensitivity to hazard and the capacity to adapt:

$$\text{Vulnerability} = f(\text{exposure, sensitivity, adaptive capacity})$$

Adaptive capacity has diverse elements encompassing the capacity to modify exposure to risks associated with climate change, absorb and recover from losses stemming from climate impacts, and exploit new opportunities that arise in the process of adaptation.

### **1.7 Global analysis of vulnerability of the fisheries sector to projected climate change**

This project set out to use the 2001 Intergovernmental Panel on Climate Change (IPCC) scenarios for global temperature rise to 2050 to assess the vulnerability of fisherfolk to projected climate change on a global level, with the objectives of highlighting the extent of the possible impacts and to identify 'hotspots' – regions and countries where the impacts of climate change would be expected to be severe.

The analysis was conducted at country-level using IPCC climate change scenarios, parameterised with data from the Hadley Centre model, re-scaled to national political boundaries. Vulnerability was assessed as a function of risk exposure, sensitivity and adaptive capacity. Risk exposure was assessed in terms of projected mean temperature change, sensitivity was based on the relative importance of fisheries in terms of production, employment, export revenues and proportional contribution to GNP and agricultural GNP, as well as contribution to dietary protein. Adaptive capacity was assumed to be related to human development indices (HDIs) and economic performance data – countries with higher HDIs and higher per capita GDP are assumed to have higher adaptive capacity. Because poverty data are not widely available for fisherfolk, it was necessary to use national-level averages and assume the distribution of poverty was similar to the average national distribution.

A global database of risk exposure and different elements of sensitivity and adaptive capacity was assembled and analysed to compute vulnerability. Maps showing the global distribution of some of the key variables were developed.

Global climate change scenarios from IPCC suggest that the Asian landmass, the Amazon basin and the Western Sahara are the regions most at risk from climate change (highest predicted temperature change). The level and distribution of projected change varies according to different scenarios for economic growth.

The largest number of poor fisherfolk are likely to be found in South and South East Asia, where the majority (over 80%) of the world's fisherfolk are to be found. Although fisherfolk are fewer in Africa, the low per capita GDP of most African countries means that it is likely there are significant numbers of fisherfolk living in poverty. In Latin America, Colombia, Guyana, Bolivia and Honduras are the poor countries with significant employment in the fisheries sector.

Many of the most nutritionally dependent countries are small island states. The populous major fishing nations of Ghana, Indonesia and Bangladesh are also represented.

Combining economic dependency indices (production and trade), nutritional index and number of fisherfolk living in poverty leads to a composite index of sensitivity of the fisheries sector to climate change. The most sensitive countries are, in Asia; China, Indonesia, India and Vietnam; in Africa, Mauritania; and in Latin America, Peru. Iceland is the most sensitive country in the developed world

Combining risk exposure, sensitivity and adaptive capacity gives a composite index of vulnerability. The analysis shows that it is African countries whose fishery sectors and fishing people are most vulnerable to climate change (see table overleaf) and that it is those semi-arid countries with significant coastal or inland fisheries that will be most vulnerable. Among the non-African countries, only the Russian Federation and Peru appear in the top fifteen most vulnerable. Which IPCC scenario is chosen makes relatively little difference to the results. Poor countries with important fisheries such as Angola and Mauritania top both lists.

*Countries with the highest projected indices of vulnerability of fisheries to climate change under two different IPCC future climate change scenarios*

Rapid Development, High Emissions Scenario (IPCC A1F1)		Local Development, Lower Emissions Scenario (IPCC B2)	
Angola	81.97	Mauritania	83.10
Mauritania	81.18	Angola	82.15
Niger	79.24	Zimbabwe	79.32
Congo, Dem Rep	78.82	Niger	78.95
Mali	78.01	Congo, Dem Rep	76.03
Sierra Leone	77.09	Mali	75.92
Burkina Faso	76.01	Mozambique	75.13
Burundi	74.96	Russian Federation	74.33
Mozambique	74.86	Sierra Leone	73.61
Zimbabwe	74.55	Senegal	73.31
Senegal	73.70	Botswana	72.96
Guinea-Bissau	72.97	Zambia	71.78
Côte d'Ivoire	71.18	Burundi	71.68
Sudan	70.68	Burkina Faso	71.57
Russian Federation	70.57	Peru	70.98

The indices have their limitations. Principal among these are the reliance on air temperature change as a risk-exposure variable. In aquatic systems, precipitation and sea/water temperature change would be more appropriate, but these variables are less available on a global scale.

Despite its shortcomings, the analysis has provided a testable methodology for vulnerability assessment and has produced results that may surprise and stimulate new analysis.

## **1.8 Case studies of sensitive areas/ecosystems**

Because the pathways linking climate change to vulnerability of fisherfolk are so diverse, the global analysis was supplemented by a series of specific area or ecosystem based case studies to illustrate the type of issues that might be confronted by attempts to support vulnerability reduction programmes targeted at fisherfolk. No unified 'method' was imposed for these studies and they represent a snapshot of current research efforts in the field.

### **1.8.1 Coral Reefs**

Thermal bleaching along with fisheries exploitation, pollution and disease are the greatest threats to coral reefs. Coral reefs are a major source of ecosystem goods and services, particularly for small island developing states. Tens of millions of people in over 100 countries are likely to depend on coral reefs for part of their livelihood or for part of their protein intake.

The aim of this case study analysis was to analyse the link between the per capita fish consumption of fisherfolk and the potential supply and demand of reef resources at national scales, taking projected population growth and projected climate change into account.

The relative effect of projected human population growth and loss of coral reef area on per capita fish consumption are compared from 2000 – 2015. Projected human population growth is predicted to reduce per capita fish consumption by 0.88% year<sup>-1</sup> and the loss of coral reef area due to climate-change induced bleaching is predicted to reduce per capita fish consumption by 0.1-0.3% year<sup>-1</sup>. The highest rate of reduction in per capita fish consumption is based on a loss of coral reef area of 1% year<sup>-1</sup>.

### **1.8.2 African Lakes**

The African Great Lakes region harbour important fisheries that contribute to employment, food security, government tax revenues, domestic markets and exports. The production systems of these lakes are known to be climate-sensitive.

For the extensive shallow lake-wetland complexes such as Lakes Chad, Kyoga and Chilwa, analyses of links between rainfall variation, lake levels and fish catches indicate that predicted reductions in rainfall in some regions are likely to result in significant reduction of lake and wetland area, with resulting large reductions in fish production and supply, particularly in the case of wetlands in arid and semi-arid areas. With the resilience of these production systems partly dependent on the existence of dry season refugia for fish, increasing duration of the dry seasons and increased number of drought years, forecast in some regional climate models, is likely to result in reduced resilience of these lakes and increased pressure on dry-season refugia.

In the large rift valley lakes with significant fisheries for small pelagic species, climate-associated changes in their productivity has apparently led to reduced fish production.

Livelihoods around these lakes combine farming and fishing, and with both negatively affected by rainfall reduction, if regional climate forecasts are accurate, it seems likely that rural livelihoods in lakeshore regions will become more precarious

and less viable over time. Migration from lake to lake, and from lakeshore regions to cities and other areas of economic opportunity is already common in the region. These migrations are likely to increase as rainfall variability increases.

### **1.8.3 River basins and floodplains - Bangladesh**

The biology and ecology of fish in large rivers are strongly linked to the hydrological regime in the main channel and the regular flooding of their adjacent floodplains. The absolute and relative abundance and biomass of species of fish inhabiting large rivers are predicted to change in response to both natural intra-annual variations in flooding regimes as well as long-term climatic shifts.

Using an age-structured population dynamics model we explored how hydrological conditions within a theoretical floodplain river system may affect the dynamics and exploitable biomass of fish of the type that dominate catches in Bangladesh and also in the Tonle Sap and Lower Mekong rivers, which have common characteristics including rapid growth, small maximum size and sexual maturation by the end of their first year. Model simulations suggest that exploitable biomass is predicted to increase with increasing hydrological stability. Conversely, diminished and less stable flooding conditions would be expected to reduce exploitable biomass.

The implications of these simulation results were explored by combining their insights with knowledge of the fisheries sector in Bangladesh, where both the fisheries and agricultural sectors of the economy rely heavily upon the seasonal rainfall and floodplain inundation for their production. The results are ambiguous and depend on how other sectors – flood control and irrigation, for example - react to climate-induced change.

Any reductions in fisheries production will require fishers to further diversify their activities and flexibly exploit resources as they become available. Their vulnerability to change will largely be a function of their capacity to adapt. Their ability to adapt is, however, largely constrained by their paucity of financial and human capital. Their typically poor health and inadequate health care systems makes them further vulnerable to extreme events and outbreaks of disease.

## **1.9 Dissemination of results and recommendations**

The project was essentially a scoping study and literature review, although significant analysis of available data has taken place. The work will feed into a synthesis of contributions of FMSP, ASP and RNRS projects to understanding vulnerability of fisherfolk and others living at the land-water interface, to enable agencies involved in fisheries management and development to respond in ways that help to build adaptive capacity. This dissemination-focused project has begun, and involves some of the project team that contributed to this report.

The results of the analysis and scoping study will also be submitted for publication in the peer-reviewed scientific and development literatures.

## **1.10 Recommendations for future research**

The analysis in this report provides a basis for targeting future interventions to support adaptation to future climate change among poor fisherfolk and in fishing-dependent regions but there remain several key knowledge-gaps that constrain our ability to advise on appropriate means to implement such interventions. These

knowledge gaps are briefly summarised here. They could form the basis for a future research agenda in this field.

### ***1.10.1 Improving global and regional vulnerability assessments***

This project has developed a methodology for preliminary analysis of vulnerability of poor fisherfolk to climate change, using available national-level data to produce the first global assessment of this issue. There are a number of possible improvements that can be suggested to develop vulnerability assessments that can be defended with greater confidence. At regional level, we have outlined a number of case-studies that illustrate how climate change, physical habitat change could be related to ecological and livelihood responses and coping ability or resilience. Suggestions to improve parameterisation of these assessments, as well as alternative or complementary assessment methods, are given below.

#### Researchable constraints:

Lack of appropriate methodology and limited availability of appropriate data for vulnerability assessment to identify priority areas for action.

#### Suggested Research areas:

##### *a. Improving parameterisation of 'risk exposure' to climate change*

- Exploring the effects of including projected changes in precipitation in vulnerability analyses - particularly for inland fisheries.
- Incorporating additional environmental factors into vulnerability assessments - such as storm and flood frequencies (based on historic observations), and sea level rise (on a case study basis, for areas where regional models exist).

##### *b. Improving parameterisation of sensitivity and adaptive capacity*

- Using regional demographic data (e.g. global database on the number of people who live within 100 km of the coast, and the number of those living in poverty) to refine some of the indices of sensitivity and adaptive capacity currently calculated at national level.
- Obtain data on poverty and HDIs specific to fisherfolk. Developing a suitable set of indicators of sensitivity and adaptive capacity for both national and regional-level assessments is a key requirement for any future assessment of vulnerability.
- Incorporate future changes in socioeconomic parameters (e.g. demographic change, projected HDI and poverty data), reflecting the assumptions that underlie the various IPCC scenarios. At present, we have projected climate change (i.e. risk exposure) but have used current values, rather than projected values, for sensitivity and adaptive capacity.

The outputs of these research activities would be improved assessments of vulnerability to provide a better basis for planned interventions to support adaptation strategies.

##### *c. Using 'expert elicitation techniques' to assess global and regional risks of climate change to fisheries and livelihoods.*

Much global scale analysis of exposure risks from climate change relies on modelling techniques that struggle to capture the complexities of social and ecological processes. Often, relevant data on climate variables are missing. An alternative rapid assessment technique to assess global or regional risks involves use of expert elicitation techniques, used in health, climate and other risk fields. A strategic assessment of the relative importance of risks in this area, compared to other stressors on fisheries sectors, could be undertaken to quantify specified risks. Such analyses are increasingly influential in framing future risk strategies that involve deep uncertainties.

*d. Developing methods of vulnerability analysis for fisheries at different scales.*

Development and well-being trends are linked to vulnerability and exposure to climate change impacts can exacerbate vulnerability but the processes that link risk exposure to vulnerability are not well understood across scales. The relationship between climate and environmental drivers with other multiple stressors is also not understood. The benefits of this research would be a more precise targeting of adaptation action and interventions to the most vulnerable fisheries systems.

**1.10.2 Research needs for vulnerable fishery systems**

Some fishery systems (coupled social-ecological systems) are shown to be particularly sensitive to future climate change. Such systems that also support significant fisheries supporting the livelihoods of the poor are: coral reefs and associated habitats (eelgrass beds and mangroves), fisheries in inland waters that are highly dependent on climate-driven variations in hydrology (e.g. shallow lakes, river floodplains), and coastal pelagic zones (including upwelling areas accessible to small-boat fisheries) Low human adaptive capacity (weak economies, low human development indices) appear to make fishery-dependent African countries particularly vulnerable.

Researchable Constraints:

Insufficient understanding of the links between projected climate change, environmental responses, fish stock and aquatic ecosystem responses, livelihood impacts and responses, and the adaptive capacity of institutions, at scales relevant to fisheries management (e.g. coastal zone, reef, large marine ecosystem, river basin, lake catchment)

Research priorities:

Focused studies on risk exposure, livelihood sensitivity and peoples' vulnerability, including:

- a. Research on adaptive fisheries management in identified vulnerability hotspots*
- b. Analysis of vulnerability of the poor dependent on coral reef systems*
- c. Assessing resilience and vulnerability in Inland Fisheries, in the context of water resources management*
- d. Analysis of adaptive capacity to change in climate-sensitive coastal small-scale fisheries in West Africa and S/SE Asian nations with important fishery sectors*

## **1.11 Conclusion**

The outputs of the research proposed above would provide information for management decision-making and development intervention specific to particular types of fishery. These fishery types are those that are particularly important to small-scale fisheries, where the largest numbers of the poor are found. Together with existing work, they would provide a firm basis upon which to integrate climate science with development needs.

Recent analysis of global climate models show that, even if the concentrations of greenhouse gases in the atmosphere had been stabilized in the year 2000, we are already committed to further global warming of about another half degree and an additional 320 % sea level rise caused by thermal expansion by the end of the 21<sup>st</sup> Century. This means that, whatever progress is made over the coming decades in climate change mitigation, it will be necessary to plan and adapt for impacts of unstoppable change. It seems appropriate to give prominence in the response to global climate change to those people whose lives depend so directly on the rising and receding waters that the coming century will bring.