QUEST-FISH: Predicting the impacts and consequences of climate change on global fish production

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Quantifying and Understanding the Earth System

The UK Natural Environment Research Council (NERC) has funded a new 2.5 year research programme entitled "QUEST-Fish: Predicting the impacts and consequences of climate change on global fish production". QUEST-Fish is part of the UK QUEST programme (Quantifying and Understanding the Earth System (http://quest.bris.ac.uk/), and is a contribution to UK GLOBEC and to GLOBEC International Integration and Synthesis.

QUEST-Fish was put together in response to the increasing demand for information on the expected impact of global environmental change on the productivity of marine ecosystems, including fish and other higher trophic organisms (IPCC, 2007). Work conducted largely under the umbrella of GLOBEC has demonstrated that climate variability and change drives abundance fluctuations of fish populations at all scales and latitudes (Lehodey *et al.*, 2006), with particularly clear fluctuation patterns linked to warm and cold climate periods over decadal (Chavez *et al.*, 2003), multi-decadal (Ranvier and Fromentin, 2004) and multi-centennial (Baumgartner *et al.*, 1996) scales. Particularly evident are biological responses to reversals in climate indices, such as Pacific tuna in response to *El Niño*/*La Niña* (Lehodey *et al.*, 2003) or sub-Arctic cod stocks in response to the North Atlantic Oscillation (Ottersen *et al.*, 2004), among others.

Despite this volume of work the quantification of direct climate impacts on the production of fish resources at the global scale, and the risks and vulnerabilities of these impacts, has been hampered by:

a) difficulties of downscaling Global Climate Models to the scales of biological relevance,

b) lack of adequate global ecosystem models capable of capturing biological processes up to fish populations at the right scale and resolution,

c) uncertainties over future global aquatic net primary production (NPP), and the transfer of this production through the food chain and,

d) inadequate methodology to estimate human vulnerabilities to these changes at all scales.

In addition, fish populations are affected by multiple additional stressors related to exploitation practices, thus hampering the development of predictive models.

QUEST-Fish will address some of these challenges by focusing on investigating how climate change would affect the potential production for global fisheries resources in the future, compared to past and present scenarios, in the absence of exploitation. This approach removes uncertainties as to what exploitation regulations will be implemented in coming decades, and focuses on the added impacts that climate change is likely to cause, and on the subsequent additional risks and vulnerabilities to human societies.

QUEST-Fish: Exploring the past and future of fish production. Aquaculture pen at the Palace of the Popes, Avignon, France. Painting by M. Giovanetti, 1343.

The main objective of QUEST-Fish is to elucidate how climate change will affect the potential production for global fisheries resources in the future and to estimate the added vulnerability of these effects on national and regional economies in fishery-dependent areas and on specific elements of the fishery system at different scales.

The geographical unit of QUEST-Fish will be based on the Large Marine Ecosystem (LME) concept. QUEST-Fish will select a number of LME units, based on their contribution to global fish catches and their ecological and societal diversity and will compute potential fish production estimates for these areas, based on ecosystem considerations, for four fixed temporal scenarios: pre-industrial (1800), present (2005), and future (2050 and 2100). In order to estimate impacts and vulnerabilities for human societies of the production scenarios developed, figures for LMEs will be downscaled to national boundaries.

QUEST-Fish has four research modules:

1) **Climate change forcing scenarios and predictive planktonic ecosystem responses:** The aim of this module is to estimate primary (phytoplankton) and secondary (zooplankton) production in key coastal-ocean fisheries around the world under climate change scenarios provided by IPCC-AR4. Physical forcing scenarios will be based on GCOMS, a system for running multiple shelf seas model domains coupled to a global physics-ecosystem model (POLCOMS-ERSEM; Holt *et al.*, 2005), providing coverage of the coastal-ocean ecosystems around the world at a resolution of ~1/10° and including tides, stratification, river runoff, ocean-shelf exchange and upwelling. ERSEM will provide quantitative estimates of plankton production for Plankton Functional Types (PFT) for each system.

2) **Development of fish biomass and production predictions:** The goal of this module is to use plankton production estimates from Module 1 to estimate potential fish production, and to develop climate-forced models of fish biomass and production. Three complementary work streams will contribute to meeting this goal, including the development of new theory and models to allow prediction of fish biomass and production using metabolic scaling theory and dynamic size spectra models. These methods are based on metabolic scaling rules and knowledge of predator-prey interactions and energy transfer in size-based food webs supported by phytoplankton (Jennings and Mackinson, 2003; Jennings, 2005).

3) **Impacts and consequences of global environmental change on the fishmeal-based global food markets:** The main objective of this module is to develop scenarios to investigate the economic consequences of climate-driven changes for the global production of fishmeal. Fishmeal is a global commodity used in the animal feeds and aquaculture market. The majority of the species contributing to the fishmeal market are small pelagic fish with strong dependence to climate variability and change (e.g. Peruvian anchoveta). We will identify realistic scenarios of supply (production) and demand (market) for the fishmeal global markets, examine the impact of these scenarios on small pelagic fish stocks, fisheries and related markets through an integrated global bioeconomic model (Mullon and Freon, 2006) and examine the implications of substituting fishmeal in aquaculture (Kristofersson and Anderson 2006).

4) **Future vulnerability of national economies and global fishmeal and food markets to effects of climate change and other drivers on fisheries:** The main objective of this Module is to develop improved ways of assessing vulnerability of fisheries to future climate change (Allison *et al.*, 2005), in the context of other drivers of change: supply-demand changes, governance scenarios, macro-economic change (e.g. fuel price changes). Specific objectives are to use an Intergovernmental Panel on Climate Change (IPCC)-type risk exposure-sensitivity-adaptive capacity analysis to elucidate the pathways of potential climate impact on fish capture, aquaculture production and trade and consumption. We will develop a simple method of assessing climate change vulnerability and will analyse the vulnerability of fisheries to climate change at global, LMEs and national level.

QUEST-Fish is a partnership between the Plymouth Marine Laboratory (PML), the Universities of Plymouth (UoP), East Anglia (UEA) and Portsmouth (CEMARE), the Proudman Oceanographic Laboratory (POL) and the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), in collaboration with the WorldFish Centre (www.worldfishcenter.org). In order to liaise properly with other international efforts inside and outside GLOBEC, QUEST-Fish will appoint a group of selected international experts that will provide steering and networking with relevant work conducted elsewhere.

As a GLOBEC-affiliated project QUEST-Fish will report developments through this Newsletter. For more information please contact the Principal Investigator, Dr Manuel Barange, or follow links to our website through the GLOBEC International website (http://www.globec.org).

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