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Quantitative pathways for Northeast Atlantic fisheries based on climate, ecological–economic and governance modelling scenarios

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ABSTRACT

Here we present quantitative projections of potential futures for ecosystems in the North Atlantic basin generated from coupling a climate change-driven biophysical model (representing ecosystem and fish populations under climate change) and a scenario-driven ecological–economic model (representing fleets and industries under economic globalization). Four contrasting scenarios (Baseline, Fortress, Global Commons, Free Trade) were defined from the perspective of alternative regional management and governance of the oceanic basin, providing pathways for the future of ecosystems in the Northeast Atlantic basin by 2040. Results indicate that in the time frame considered: (1) the effects of governance and trade decisions are more significant in determining outcomes than the effects of climate change alone, (2) climate change is likely to result in a poleward latitudinal shift of species ranges and thus resources, with implications for exploitation patterns, (3) the level of fisheries regulation is the most important factor in determining the long term evolution of the fisheries system, (4) coupling climate change and governance impacts demonstrates the complex interaction between different components of this social–ecological system, (5) an important driver of change for the future of the North Atlantic and the European fishing fleets appears to be the interplay between wild fisheries and aquaculture development, and finally (6) scenarios demonstrate that the viability and profit of fisheries industries is highly volatile. This study highlights the need to explore basin-scale policy that combines medium to long-term environmental and socio-economic considerations, and the importance of defining alternative sustainable pathways.

1. Introduction

The North Atlantic is a dynamic ocean basin, characterized by large inter-annual to decadal variations in physical, chemical and biological properties (Sundby and Drinkwater, 2007), which have profound implications for European and North American weather (Peings and Magnusdottir, 2014). It is rapidly changing in response to global environmental change, a result of disproportionately accumulating anthropogenic heat and carbon compared to the global ocean (Sabine et al., 2004; IPCC, 2014). In recent years Arctic Sea ice loss has freshened the northern North Atlantic region while the southern part of the region has become comparatively more saline (Pierce et al., 2012). Changes in ocean properties have led to reorganizations and biogeographical shifts in the marine pelagic (Beaugrand et al., 2002) and benthic communities (Genner et al., 2004). Climate change impacts are expected to accelerate in coming decades, especially near the Arctic, where physical and chemical properties, including pH, are likely to change at disproportionate rates compared to the global ocean (Bates et al., 2012).

Projecting future states for North Atlantic fisheries need also to consider the past and future patterns of change in human activity. The North Atlantic went through an intense period of fisheries development from the 1940s to the 1970s, an era of significant resource overexploitation that extended to the turn of the 21th century (Christensen et al., 2003). Recently, a new period has been dominated by rebuilding of stocks, following more sustainable exploitation policies (Fernandes and Cook, 2013). The role of humans as modulators or enhancers of change has been previously noted (Leichenko and O'Brien, 2008), and this includes recognition of the globalized economies which frame resource exploitation

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investments (Berkes et al., 2006). In the last few decades, there has been a growing trend towards trade liberalization and the emergence of a global market becomes evident for marine commodities (Asche, 2006; Mullon et al., 2009; Merino et al., 2010). Understanding the fisheries system to be able to project future states requires an integrated approach of the drivers and processes of change in the physical, ecological and socio-economic systems (Sumaila et al., 2011).

Previous analyses have demonstrated the potential role of resource management adaptations to moderate or exacerbate the impacts of global environmental climate change (Merino et al., 2012). In this paper we assess the integrated effects of climate change and economic globalization on the social–ecological North Atlantic fisheries system (Taylor et al., 2007). The concurrent assessment of the impact of these drivers is important because their interactions can amplify or reduce these impacts (O'Brien and Leichenko, 2000; Leichenko and O'Brien, 2008) at certain observation scales (local, national, global), influencing the emergence of winners and losers (Barange et al., 2014).

Understanding the challenges posed by multiple interacting social, economic and ecological drivers can be addressed using deliberative approaches (Dryzek and Stevenson, 2011), characterized by communication and discussion initiatives across a wide range of stakeholders, from decision makers to the wider public. Deliberative approaches require specific tools and processes to ensure the effective communication of key issues and concerns between participants with diverse backgrounds. In the case of North Atlantic fisheries participants should include national governments, relevant inter-governmental organizations, environmental non-governmental organizations, scientific organizations, and representatives of civil society. The building of scenarios that describe or visualize possible alternative futures (Börjeson et al., 2006; Bishop et al., 2007) is one of the most efficient ways to facilitate deliberation. These approaches, however, need appropriate quantitative tools capable of capturing the main complexities of the system, from climate to trade.

Here we present a scenario and modelling framework to investigate the impacts of global environmental change and alteration of the trade patterns of fisheries commodities on marine fisheries resources in the North Atlantic basin. We do so by developing a set of scenarios describing plausible changes in bio-physical and socio-economic drivers; the key drivers were projected using a ecological–economic model with multiple commodities based on the principles of network economics (Nagurney, 1993; Mullon, 2013). Compared to other modelling approaches to marine ecosystems under climate change and economic globalization (Parry et al., 2004), network economics allows integrating economic and ecological processes at an intermediate scales, i.e., with several tenths or hundreds of entities. Through the developed scenarios, we explore the possible future of fisheries in the North Atlantic Ocean under different levels of governance and management. In particular, we address the question of whether current trends in fisheries management in the North Atlantic are sufficient to ensure its long-term sustainability under projected future global environmental and economic changes.

The approach we propose is characterized by the integration of biochemical, ecological and economic processes at the scale of an oceanic basin and with a long-term time horizon. This is a deviation from, for example, the Atlantis modelling framework (Fulton et al., 2011a), where the scale is smaller, the time horizon is closer and the integration consists of coupling pre-existing complex and powerful models on the ecological side with, on the economic side, models having a different level of deterministic understanding (Fulton et al., 2011b). Here, we propose building simple models of macroeconomic processes on one side, and ecological processes on the other side, both with a focus on their integration. We also differ from the FAO IMPACT-Model, a global, multimarket, partial equilibrium economic model dedicated to the analysis of agricultural supply chains and that has been recently applied to fish products (World-Bank, 2013). In this case, scale is larger (worldwide), although we share time horizon, the goal of alternative scenarios, and the principle of market equilibrium. The main difference, however, lies in the representation of ecological processes (biological production) and economic processes (profit, investment) that are more detailed in our approach.

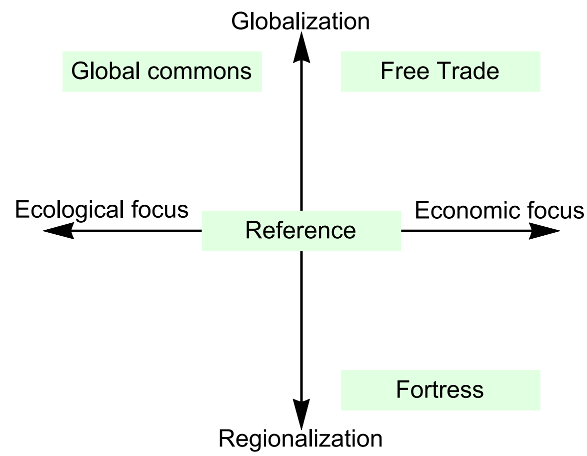

Fig. 1. Contrasted scenarios about the future of the Northeast Atlantic basin: Baseline, Fortress, Free Trade, and Global Commons.

2. Methods (1): scenarios

Twelve scenarios have been defined, coupling four socio-economic scenarios and three climate scenarios selected from IPCC (International Panel for Climate Change) projections.

2.1. Development of ecological–economic scenarios

Four socio-economic scenarios were formulated using a methodology described by Van Notten et al. (2003) and inspired by a comparable attempt on the future of marine ecosystems (Pinnegar et al., 2006). They were defined to occupy different regions in the space created by two axes that capture convergence vs. divergence of policy responses (global vs. regional) and ecological vs. economic focus in these responses (Fig. 1). These scenarios have a simple management narrative defined as follows.

In the *Baseline scenario*, there are no major changes in management of the fisheries and in the organization of trade from present. Total Allowable Catches (TACs) remain at present level of catches, with no restriction of trade between countries that are under the European Union (EU) while import and export taxes with countries outside the EU remain low (as currently defined by the World Trade Organization).

The *Fortress scenario* corresponds to a situation with a disproportional support of the European Union to the fishing and the aquaculture sectors, neglecting concerns over their impact on ecosystems. TACs in all areas are expected to increase, there is no restriction of trade inside EU but import and export taxes to countries outside EU are expected to increase.

The *Free Trade* scenario corresponds to a situation where an economic competition is encouraged over other considerations. TAC is not actively used to limit fishing pressure, there is no restriction of trade inside EU but import and export taxes to countries outside EU are expected to decrease.

The *Global Commons* scenario corresponds to a situation with the development of economic exchanges and a global policy for