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Preface

Introduction to the BASIN Special Issue: State of art, past present a view to the future

Introduction

Marine ecosystems are complex networks of organisms interacting either directly or indirectly while under the influence of the physical and chemical properties of the medium they inhabit. The interplay between these biological agents and their abiotic environment results in complex non-linear responses to individual and multiple stressors, influenced by feedbacks between these organisms and their environment. These ecosystems provide key services that benefit humanity such as food provisioning via the transfer of energy to exploited fish populations or climate regulation via the sinking, subsequent mineralization and ultimately storage of carbon in the ocean interior.

These key characteristics or emergent features of marine ecosystems are subject to rapid change (e.g. regime shifts; Alheit et al., 2005; Scheffer et al., 2009), with outcomes that are largely unpredictable in a deterministic sense.

The North Atlantic Ocean is host to a number of such systems which are collectively being influenced by the unique physical and chemical features of this ocean basin, such as the Atlantic Meridional Overturning Circulation (AMOC), the basin's ventilation with the Arctic Ocean, the dynamics of heat transport via the Gulf Stream and the formation of deep water at high latitudes. These features drive the solubility and biological pumps and support the production and environments that results in large exploited fish stocks. Our knowledge of its functioning as a coupled system, and in particular how it will respond to change, is still limited despite the scientific effort exerted over more than 100 years. This is due in part to the difficulty of providing synoptic overviews of a vast area, and to the fact that most fieldwork provides only snapshots of the complex physical, chemical and biological processes and their interactions. These constraints have in the past limited the development of a mechanistic understanding of the basin as a whole, and thus of the services it provides.

An overarching property of North Atlantic ecosystems, in both shelf seas and the open ocean, is that a common atmospheric forcing influences them. However, our mechanistic understanding of how this forcing affects the biochemical, biological and ecological processes of the system, and how these will be affected by climate change, is in its infancy. There is a pressing requirement to better understand the role of basin scale processes within the North Atlantic, as well as to how to downscale from the basin scale to the local scales, where most of the economically important processes take place.

The purpose of this Special Issue is to assess the current status of knowledge on the functioning of North Atlantic marine ecosystems and the services these systems provide, based on preliminary research conducted by the European FP7 Integrated Project EURO-BASIN. The research within EURO-BASIN as well as recent work outside the project, is then used to suggest priority areas for future research to progress in our understanding of the links between biogeochemical fluxes and ecosystem services in the North Atlantic.

History of the North Atlantic BASIN initiative

The starting point for EURO-BASIN were discussions at the Eur-Ocean conference in Hamburg (Germany) in 2000 focusing on perspectives for European and North American research cooperation in the North Atlantic. This conference resulted in a memorandum of understanding signed between the USA National Science Foundation (NSF) and the European Commission (EC), agreeing to support collaborative research in the North Atlantic. However, it was not until 2005 when funds from the USA NSF and the European network of excellence EURO-OCEANS allowed for European, USA and Canadian scientists to meet in Reykjavik, Iceland (Wiebe et al., 2009), to start the process leading to the development of an International North Atlantic Basin scale Science Plan. Subsequently, support for the BASIN community to hold three meetings in 2007–2008 was obtained from the US NSF and a EU 6th Framework Specific Support Action (SSA) BASIN. These meetings, which built upon the issues identified in Reykjavik, were held in Hamburg (Germany), Chapel Hill (USA), and Amsterdam (the Netherlands). The outcome of these meetings was the International BASIN Science Plan, published as a GLOBEC report (Wiebe et al., 2009). Alas, while the science needs were collectively agreed upon, the difficulty of funding coordinating research (both in time and in concept) from both sides of the Atlantic was not easily resolved. Moving ahead, the European Commission issued a call for proposals, which targeted some of the issues outlined in the International BASIN Science Plan. Specifically, the call was focused scientifically "on the need to improve the understanding of the variability, potential impacts, and feedbacks of global change and anthropogenic forcing on the structure, function and dynamics of the ecosystems of the North Atlantic Ocean and associated shelf seas and on their capacity to provide services". The successful project needed to provide new data, analyses and the models necessary to:

(1) Understand and simulate the population structure and dynamics of broadly distributed, and biogeochemically and trophically important plankton and fish species, to resolve the impacts of climate variability on marine ecosystems and the feedbacks to the earth system.

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(2) Develop understanding and strategies that would contribute to improving and advancing ocean management (ecosystem approach).

In response to this call, the successful EURO-BASIN consortium was formed (European Basin Scale Analysis and Synthesis), using as its starting point the BASIN International Science plan. While a similar funding mechanism was not forthcoming from the North American side, North American scientists were able to take advantage of opportunities to participate in EURO-BASIN cruise programs, meetings and to publish joint articles (e.g., this Special Issue).

Objectives and goals of EURO-BASIN

The overarching objectives of EURO-BASIN are encapsulated in the call described above. In order to achieve these objectives, and using the BASIN international science plan as a guideline, the program was geared to:

(1) Resolve the influence of climate variability and change, for example changes in temperature, stratification, transport and acidification, on the seasonal cycle of primary productivity, trophic interactions, and fluxes of carbon from the pelagic to the deep ocean.
(2) Identify how life history strategies and vital rates and limits of key ecosystem and biogeochemical players contribute to the observed population dynamics, community structure, and biogeography.
(3) Assess how the removal of exploited species influences marine ecosystems and the fluxes of carbon?
(4) Improve the science basis for ecosystem based management targets outlined in the European Community's Common Fisheries Policy (CFP), the Marine Strategy Framework Directive (MSFD), the European Strategy for Marine and Maritime Research and the Integrated Maritime Policy for the European Union.

The project funded a consortium of 24 institutions from 9 European countries to conduct coordinated research for the period 2010–2014. This volume summarizes some of the preliminary results of the programme to date as well as the state of the art in the different research areas.

The EURO-BASIN Special Issue

One of the goals of EURO-BASIN was to understand the role of ecosystem restructuring on the efficiency of the biological carbon pump (BCP). As a first step, developing reliable estimates of the magnitude of the North Atlantic biological carbon pump are necessary. To this end Sanders et al. (2014) provided a synthesis of the estimates of strength of BCP in the North Atlantic. They found BCP export to be in the order of $\sim$ 0.55–1.94 GT C yr^{-1}. Furthermore, they highlight that the magnitude of global annual carbon export (11 Gt C yr^{-1}) is more than three times larger than the annual accumulation of CO_2 in the atmosphere due to anthropogenic processes (3.2 Gt C yr^{-1}) and five times larger than the annual net flux of CO_2 into the ocean (2.2 Gt C yr^{-1}) (IPCC, 2007). Small changes in primary production and/or its fate can significantly affect the magnitude of the BCP, and through this, ocean-atmosphere CO_2 partitioning (Rost et al., 2008). Here, Giering et al. (2014) confirmed that zooplankton play a critical role in the BCP, by repackaging organic carbon produced via photosynthesis into faecal pellets thereby the sinking speed of organic material from the surface layer (Turner, 2002). However, in contrast other coprophagic copepod species consume and break up sinking particles, respiring part of this material at different layers of the water column and decreasing flux rates. In a number of papers in this issue the importance of the role of zooplankton is a recurrent theme, including the consequences of shifts in *Calanus* biogeography (Wassmann, 1998) and the role of vertical migration (Bianchi et al., 2013). In contrast to *Calanus,* small copepod species do not perform extensive dial vertical migrations, their grazing impact on the phytoplankton community can still exceed that of *Calanus* spp. (Morales et al., 1991) thus they can maintain significant amounts of carbon nearer the surface (Kiørboe, 2000; Koski et al., 2005). Sanders et al. (2014) highlight this issue stating that the fraction of primary production exported is strongly dependent on the match or mismatch of primary producers and consumers and on the capacity of the pelagic microbial community to remineralise particulate organic matter (Wassmann, 1998). For example, in extreme cases as much as 70% of primary production has been observed to leave the euphotic zone through the sinking of individual cells and particles (Lignell et al., 1993). Typically, however, only 10–30% of material produced via primary production is expected to sink below 100 m (Wassmann et al., 2003; Thomalla et al., 2008; Buesseler and Boyd, 2009), with ultimately only $\sim$1% of surface primary production is thought to be sequestered in the deep ocean (Ducklow et al., 2001; Poulton et al., 2010). Clearly from these findings a restructuring of the lower trophic levels as a result of changes in ecosystem functioning and species dominance, has the potential to influence the efficiency of the North Atlantic biological carbon pump and as a result global climate.

In order to summarize and extend our understanding of the zooplankton community in the North Atlantic Melle et al. (2014), provide a new pan-Atlantic compilation and analysis of data on *C. finmarchicus*, a key copepod species in this system. Their article summarizes and extends the state of the art with respect to abundance, demography, dormancy, egg production and mortality in relation to basin-scale patterns of temperature, phytoplankton biomass, circulation and other environmental characteristics. A number of features emerge from this analysis. These include the role of the contrasting regimes in the eastern and western Atlantic for the populations of this key ecosystem player. For example, diapause duration, timing of recruitment relative to the spring bloom as well as individual size, survival and mortality all differ between the eastern and western Atlantic systems. Melle et al. (2014) highlights that new understanding of habitat suitability, life history strategy and physical–biological coupling of *C. finmarchicus* requires further study in order to adequately re-parameterize life history processes of this species. They note that the Continuous Plankton Recorder (CPR) data in the basin does not include the species population centers in the Norwegian Sea or the Labrador Sea, where the highest population densities are located, and that locations not closely connected to these deep basins had lower population densities. This information suggests that our present understanding of the processes governing the dynamics of this species needs further examination. Finally, Melle et al. (2014) highlight questions about the generality of parameterization of growth, reproduction and diapause timing across the North Atlantic, which are particularly critical for modeling studies.

Mitra et al. (2014) further extended our understanding of the physiology of zooplankton for modeling their vital rates. These authors conducted a comprehensive review of our understanding of zooplankton communities from experimental (laboratory and field) as well as modeling perspectives, in order to update zooplankton parameter estimates. They provide an extensive tabulated summary of the current status of knowledge for the ecophysiological vital rates of the different zooplankton groups, from protists to fish larvae. From their review it is clear that experimental investigations typically concentrate on very few groups of zooplankton, of which the female copepod is the exemplar (Cripps