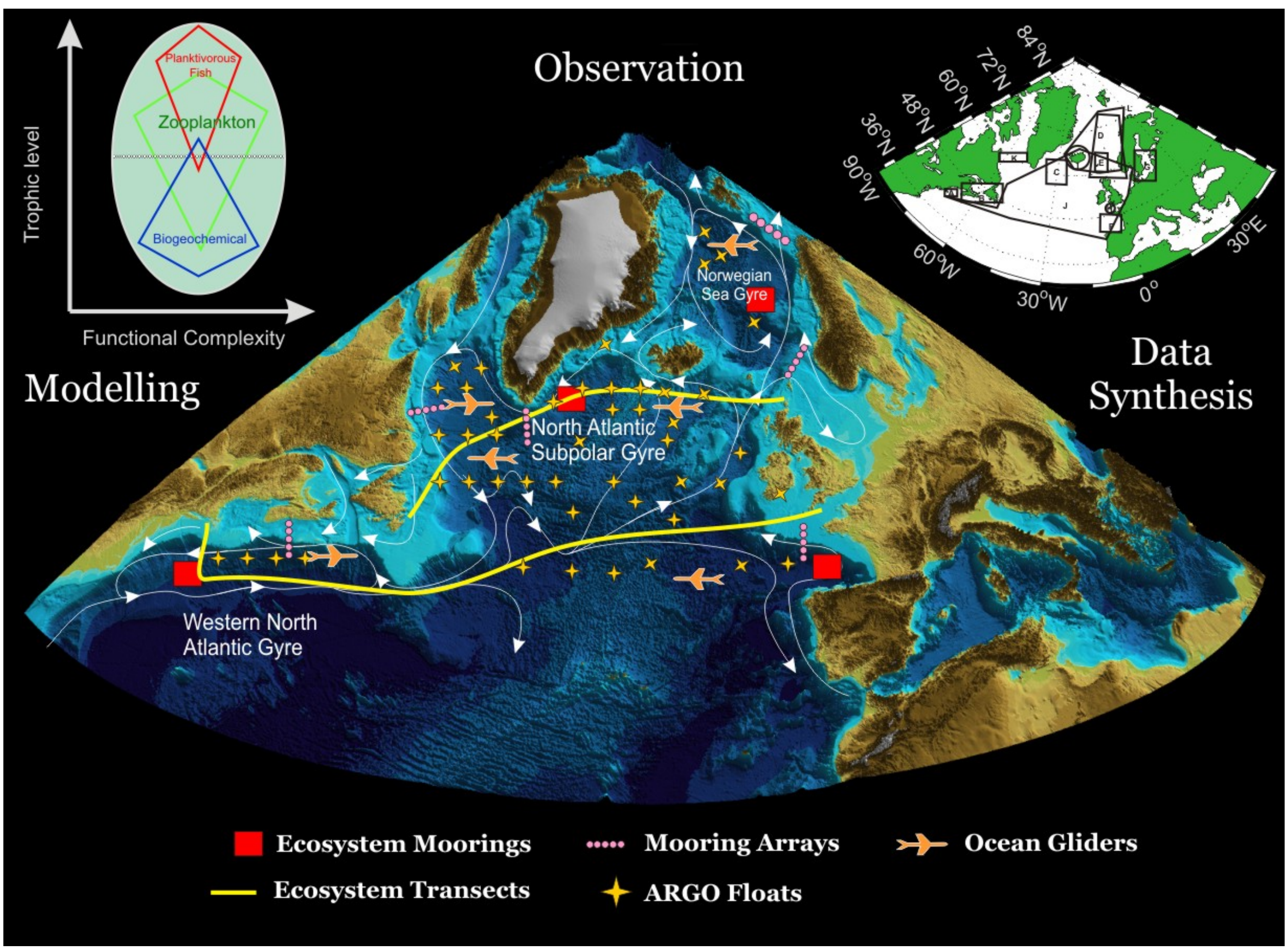
BASIN:Basin-scale Analysis, Synthesis, and Integration

North Atlantic Implementation Plan



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1. INTRODUCTION

The North Atlantic Ocean and the adjoining shelf–seas are critical for the ecological, economic, and societal health of the Americas and Europe. Its deep ocean and shelf seas support major fisheries. The basin where the Atlantic Meridional Overturning Circulation (AMOC) unfolds is a focal area for the effects of climate change, and it plays a key role in the global carbon cycle. The more northern regions are dominated by three major ocean gyres that are interconnected by basin–scale major currents, have similar water properties, and have species complexes that extend across the entire basin from the western to the eastern shores. Populations and trophic dynamics in shelf seas and ocean basins are influenced by cross-shelf exchanges of water masses and biota, cross–gyre currents, common basin–scale atmospheric forcing, and climate change. But there is a significant lack of information and understandings at a mechanistic level about spatial and temporal variations in iron, nitrogen, phosphate and silicate limitations, biogeochemical processes determining bio-carbon fluxes between plankton and fish communities and export associated with community structure and behavior, impacts of removing a certain species on both lower and higher trophic populations, and impacts of climate change on biogeochemical processes, ecosystems and biodiversity in shelf seas and ocean gyres. There is an urgent need to better understand the basin–scale processes and potential changes due to climate change within the North Atlantic, and coupled processes how basin–scale processes affect ecosystems in shelf seas and slopes.

BASIN is a joint European Union (EU)–North American research initiative to elucidate the mechanisms underlying observed physical, biogeochemical, and biological changes in the North Atlantic Ocean and to quantify and predict consequences of climate and environmental variability and change. The ultimate goals are 1) develop an understanding of the links between climate, physical–biogeochemical processes and the marine ecosystems of the North Atlantic and shelf seas and the services these ecosystems provide including exploited marine resources, and 2) use this understanding to develop ecosystem based management strategies that will anticipate the effects of climate change on the carbon fluxes and living resources of the region. Thus the overarching aim of the BASIN initiative is to understand and predict the impact of climate change on biogeochemical processes, carbon fluxes in ecosystems, and key species of plankton and fish, in the North Atlantic basin and surrounding shelves, in order to improve ocean management and conservation. To further our understanding, BASIN seeks to:

- Understand and simulate the biogeochemical processes determining productivity and carbon fluxes between trophic levels, and the population structure and dynamics of broadly distributed, and trophically and biogeochemically important plankton and fish species in the North Atlantic Ocean;
- Resolve the impacts of climate variability on marine ecosystems and the feedbacks to the climate system;
- Develop understanding and models that will advance ocean management.

This document presents the BASIN implementation strategy, which builds upon the BASIN Science Plan (Wiebe et al, 2009). The intent is to provide a more detailed blue print of BASIN Program scientific activities and their sequence.

2. JUSTIFICATION AND BACKGROUND

It is now clear that changes in natural patterns or “modes” of the atmosphere and ocean, such as the El Niño/ Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO), orchestrate large variations in weather and climate over much of the globe on interannual and longer time scales (Joyce, 2001; Visbeck et al., 2001; Trenberth et al., 2002: Kerr, 2005). The spatial pattern of the response to anthropogenic forcing may project principally onto such modes of natural climate variability (*e.g.*, Corti et al. 1999). The interaction of climatic forcing, ocean circulation and changes in greenhouse-gas concentrations influence the dynamics of the thermohaline circulation of the North Atlantic, a factor that has being identified as a key influence on global climate (e.g., Broecker, 1997; Clark *et al.*, 2002, Sutton and Hodsen, 2005) and ecosystem dynamics. For example, changes in the physical environment in the North Atlantic Basin have been linked to changes in vertical stability of water column, mixing processes and winter–spring primary production and carbon export (Siegel et al., 2002; Backhaus et al., 2003; Behrenfeld, 2010), and fluctuations in the population dynamics of key species and exploited fish stocks in the basin itself as well as associated shelves (e.g., Reid et al., 2001; Greene et al., 2003; Beaugrand et al., 2003, 2005; Richardson and Schoeman, 2004; Pedchenko, 2005). Changes in population dynamics have been shown to be influenced by climatically-driven changes in circulation patterns and physiological rates as well as in the timing of the spring bloom (e.g., Reid et al., 2001). These studies clearly identify the importance of the North Atlantic basin for global change research and earth system science as well the implications of changes in the structure and function of its ecosystems and their services.

Developing appropriate environmental policy in the face of global change is one of the greatest challenges facing public authorities and all sectors of society. Anthropogenic greenhouse gases have been implicated in the current rapid climate change that has affected circulation, air–sea interaction, biogeochemical processes and ecosystem. Landings of the capture fisheries have now peaked at approximately 100 million metric tons and according to the FAO (FAO, 2007) nearly 25% of these fisheries are considered to be overexploited. Nonetheless, these fisheries continue to be of substantial economic and societal importance, particularly to countries around the North Atlantic. Trade in fisheries commodities, in the European Community amounts to 3.2 billion USD, and in Canada and the United States (US) the landed value of catches is 2 and 4 billion USD respectively. Presently, a number of these exploited fish stocks indigenous to North Atlantic basin and shelf waters are at historically low levels and in danger of collapse as a result of the combined effects of unsustainable exploitation patterns and climate change.

The need for an ecosystem approach to the management of renewable marine resources has been recognized by a number of nations including Canada, the US, and members of EU countries. Exploiting marine resources face socio-economic and environmental challenges with ongoing crises in fisheries and fisheries management, and clear signals of global change. Until recently, there has been a tendency to treat issues such as fisheries management, climate change, biodiversity, and habitat separately. However, ecosystem-based management seeks to develop a holistic and integrated approach. The development of these management strategies has been identified as a major research priority for the EU (IPTS-JRC 2000 Mega-challenge 2 – Anonymous, 2000), Canada (Fisheries and Oceans Canada, 2007 [http://www.dfo-mpo.gc.ca/sds-sdd/2007-2009/goalc-butc-eng.htm]), and the US (Burgess et al., 2005). Meeting these challenges will require improved, scientific approaches to conservation of natural resources, coastal zone management, fish stock assessment, management, and regulation, and maintenance of ecosystem health and sequestering of green house gases. In turn these approaches need to be based on genuine and sound understanding of the dynamics of ocean ecosystems and their response to human activities and natural climatic variation.

3. WHY IS A BASIN-SCALE STUDY NEEDED?

The challenge of BASIN is to develop the predictive capability necessary to understand the space and time variation of (i) biogeochemical processes determining productivity and carbon fluxes, (ii) broadly distributed and dominant members of the North Atlantic plankton and fish communities, and (iii) feedbacks between and within these components and climate. Analyses at ocean-basin scales through synthesis of observations and modeling and targeted process studies will lead to a necessary and fundamentally new understanding of ecosystem dynamics and allow prediction of responses to climatic variability.

Connectivity in the North Atlantic is determined by the large-scale gyres that span the basin.

Stratification across the Atlantic and AMOC in subpolar regions influences both the local circulation and the larger-scale gyre dynamics. The time-scale for recirculation within these gyres is decadal. Exchanges between the open ocean and shelves are determined by mixing processes at the shelf break. In order to understand marine ecosystem structure and function in the North Atlantic, the influences of the gyres in the horizontal and the vertical must be determined. Atmosphere-ocean coupling, such as through the North Atlantic Oscillation (NAO; Hurrell et al. 1997; Marshall et al., 2001), also plays a critical and varying role across the basin and strongly influences marine ecosystem characteristics.

Basin-scale forcing impacts biogeography and ecosystem structure and function both locally and across the entire region. A large number of regions within the North Atlantic basin are warming apparently in response to climate change and climate variability; bloom timing and nutrient ratios are changing in response to changes in stratification and mixing; new species are moving into the subpolar regions as a result of geographical shifts in their distribution and ecosystem structure trophic interaction and ecosystem function are shifting.

There are a number of key species, community structures, and biodiversity patterns that are distributed across the whole BASIN region (e.g., Brander and Mohn, 2004; Heath et al., 1999, 2008; Beaugrand et al. 2007; Helaoueet and Beaugrand. 2007). Changes in their distribution and the species composition or trophic interactions resulting from shifts in the geographic range of ecosystem components will result in alterations of ecosystem resilience and productivity. Recent large-scale shifts have been observed in portions of the species ranges (Beaugrand et al., 2005; Bonnet et al., 2005, 2007; Lindley and Daykin, 2005; Head and Sameoto, 2007; Valdes et al., 2007; Nye et al. 2009). Because of the complexity of systems, the observed changes represent the interaction of many biological and physical processes, the balance of which will differ among regions. In any one region, many factors fluctuate over different time scales, from interannual to long term changes, making it difficult to determine the relative impact of any single process on regional dynamics. Climate-induced changes in advection and stratification affect basin-scale circulation and transport and vertical processes important to ecosystem and population dynamics. Hence, discriminating between local and remote forcing requires studying key species and key functional groups, such as small pelagic schooling fish, whose abundance and biomass are important to ecosystem dynamics across the whole ocean basin. The basin-scale approach provides a stronger basis, e.g., through comparative studies, to understand the susceptibility of these systems to the appearance of alien and/or biogeographically shifted species. Movement of species into previously unoccupied regions depends on the physical suitability of the habitat for invasion, and is modulated by the presence of predators and prey as well as the level of ecological stress experienced by the existing key species. Thus, the observed shifts in species' biogeographic boundaries are an emergent property of interactions between physiological rates and limits, life history, and climate variability. Furthermore, community changes in the eastern and western Atlantic are likely to occur on different time and space scales because of the differences in the underlying physical processes that drive each region (Pershing et al., 2005; Kane, 2007). By comparing and identifying the response of species to changes in the physical environment (driven by climate change) and regional lower trophic level productivity (biogeochemistry) across many regions, it becomes possible to evaluate the potential impact of changes in species interactions that result from the appearance of alien taxa.

The North Atlantic system is a key ocean basin globally for the sequestration of carbon (Behrenfeld and Falkowski 1997).

Recognizing this importance raises issues such as: (i) how the biological pump (primary and export production) will be affected by climate change processes in the North Atlantic, (ii) how do modifications of the biological pump impact the climate (carbon cycle), and (iii) how could modifications of top down control, as driven by climate change and fisheries, change the biological pump (Körtzinger et al., 2008)? A basin-scale budget of the biological pump and submeso–meso–scale biogeochemical processes in the North Atlantic in relation to plankton community and ecosystem structuring should be a long-term goal of studies such as BASIN. Particular emphasis should be placed on the marginal shelves around the basin, as these areas are still poorly constrained and account for a large portion of carbon export towards the deep ocean, and submeso–meso–scale biogeochemical processes associated with upwelling and downwelling within meso–scale eddies and fronts where enhanced primary production and export occurs (Thomas et al., 2004). The impact of the shelf/deep ocean exchanges on the water mass characteristics will also considered at the basin scale (http://www.loicz.org/) in collaboration with the GEOTRACES (http://www.ldeo.columbia.edu/res/pi/geotraces/) and OCB (http://www.us-ocb.org/) programs, among others. To make reliable predictions about carbon flux and sequestration, a basin-scale approach is required to capture the range of hydrodynamic regimes, water masses, and ecosystem types that characterize the North Atlantic biogeochemical environment.

The ecosystem approach to management of widely distributed fish and other key species requires a basin-scale approach.

Climate variability and change have different effects on population dynamics (growth, migration and distribution, mortality, and recruitment) of pan-Atlantic species inhabiting both shelf and high seas areas. This is caused by direct effects of the climate driven ocean physics on the individuals, indirect bottom-up effects through changes in lower trophic level production, and changes in migration and distribution that results in changing overlap between prey and predators in the different systems. Effects are seen on interannual, decadal, and multi-decadal time-scales, and it is anticipated that changes on longer time scales are associated not only with changes in fish stocks, but also with more basic changes in the functioning of the ecosystems. Implementation of a basin-wide approach will enable the integration and comparison of present knowledge and data on climate, environment, and ecosystems throughout the North Atlantic. It will also enable us to understand the processes needed to quantify and predict the complex variability of the different species and their interactions.

In addition to climate, fisheries are the other major driving force on marine ecosystems. Intensive fishing on key species affects not only the exploited fish communities, but also impacts lower trophic levels, i.e., through cascading effects down the trophic pyramid, effects of by-catch, and habitat modification by trawling. Today's fisheries management advice is mostly based on single stock assessment with little consideration of trophic interactions and climate effects. Since the climate prediction scenarios for the next century extend the limits of our experience, it is important that we base our ecosystem predictions as much as possible on basic process understanding.

4. PROGRAM SCIENTIFIC THEMES AND GOALS

Three main thematic questions are identified for examination during BASIN:

Theme 1. How will **climate variability and change** influence the seasonal cycle of primary productivity, trophic interactions, and fluxes of carbon to the benthos and the deep ocean?

- What aspects of the physical system are changing with climate variability and change (for example changes in temperature, stratification, transport, acidification)?
- How will the biogeochemical processes and ecosystem's responses to these changes differ across the basin and among the shelf seas?
- How are the populations of phytoplankton, zooplankton, benthos, and higher trophic levels influenced by large-scale ocean circulation and what is the influence of changes in atmospheric and oceanic climate on their population dynamics and diversity?
- What are the feedbacks from changes in ecosystem structure and dynamics on climate signals?

Theme 2. How do **behavior and life history strategies** of target organisms, including vertical and horizontal migration, contribute to observed population dynamics, community structure, and biogeography?

- How are life history strategies affected by climate variability?
- How will life history strategy influence the response of key species and populations to anthropogenic climate change?
- How are species distributions and migration patterns affected?

Theme 3. How does the **removal of exploited species** influence marine ecosystems and sequestration of carbon?

- Under what conditions can harvesting result in substantial restructuring of shelf or basin ecosystems, i.e., alternate stable states?
- Do such changes extend to primary productivity and nutrient cycling?

- How is resilience of the ecosystem affected?
- What is the potential impact on the sequestration of carbon?

5. BASIN DELIVERABLES

Ultimately the principal deliverable of BASIN will be the development of a holistic and integrated ecosystem approach to management of North Atlantic and shelf sea marine ecosystems and their services. BASIN will advance the predictive understanding of the mechanisms by which climate change, nutrient dynamics, biodiversity, and habitat dynamics and exploitation interact to influence the dynamics of the associated ecosystems. Thereby, BASIN will provide improved scientific ecosystem-based approaches to conservation of natural resources (e.g., fish stocks), the regulation and maintenance of ecosystem health (e.g., biodiversity), and sequestering of green house gases. Specific deliverables and products toward this end that are anticipated during the first phase of the BASIN program are:

1) Enhanced basin-scale coupled climate/ocean/ecosystem modeling systems linking basin- and shelf-scale processes and identification of the climate forcing processes that have the greatest influence on ocean and ecosystem variability.
2) Hindcasts of the state and variability of North Atlantic ecosystems for the past 50 years or more and the construction of future scenarios based on the predicted evolution of climate (e.g., IPCC scenarios) as well as the ecosystems themselves.
3) Provision of all model results to the community for further analysis and comparisons.
4) Estimates of the current state, variability, and vulnerability of North Atlantic and associated shelf ecosystems and their services (e.g., fisheries and carbon sequestration) in response to climate change and exploitation patterns.
5) An assessment of the ecosystem and key species spatial connectivity throughout the North Atlantic and associated shelf seas.
6) An assessment of the top-down effects of upper trophic levels and effect of their exploitation on ecosystem structure and carbon cycling.
7) Identification of the key ecosystem and biogeochemical components and processes that modify population dynamics and their feedbacks to marine ecosystems and climate.
8) Estimates of local (shelf) versus remote (deep ocean) natural and anthropogenic impacts on ecosystem dynamics and exploited resources.
9) Improved assessment and management tools for exploited resources such as fish stocks based on basin-scale forcing.

NORTH AMERICAN IMPLEMENTATION OF BASIN

North American BASIN is an international scientific endeavor involving scientists from all countries bordering the North Atlantic Ocean for developing collaborative research projects. The European Union already has a funded program entitled EURO-BASIN, which is designed to advance our understanding on the variability, potential impacts, and feedbacks of global change and anthropogenic forcing on the structure, function and dynamics of the North Atlantic and associated shelf sea ecosystems as well as the key species influencing carbon sequestering and ecosystem. This program is described in Appendix 1. In the U.S., there are a number of funded and planned programs that contribute to the larger goals of BASIN (see Appendix 2). The Canadians also have a number of ongoing observational programs that contribute to BASIN (see Appendix 3). Our goal here is to layout a general implementation plan for North American BASIN, which complements the EURO-BASIN program. This North Atlantic implementation describes a framework for integrating ongoing activities with planned and future activities in the North Atlantic. Taken together these North American and European activities will achieve the objectives of the BASIN program.

The North American BASIN program will conduct modeling, field studies and data integration–analysis focusing on distributions, connectivity and processes at three scales:

- Basin scale
- Shelf–basin scale
- Submeso–meso-scale

The focus is on the more northern regions of the North Atlantic. The research activities will be coordinated or directly collaborated with comparable EU BASIN projects. The program elements and their implementation activities are described in the following sections.

6.1 Basin–scale connectivity: Currents, nutrients, populations and climate

The major currents in the North Atlantic Ocean and along shelf slopes form basin–scale gyres, Western North Atlantic Gyre, North Atlantic Subpolar Gyre and Norwegian Sea Gyre. These gyres are a critical part of the global thermohaline circulation driven by surface heat and freshwater, and are sensitive to climate change. The climatic signals such as increases of freshwater input in arctic region and North Atlantic warming are carried southward and northward by these major ocean currents; the AMOC in subpolar regions influences both the local circulation and the larger–scale gyre dynamics; and atmosphere–ocean coupling, such as through the North Atlantic Oscillation (NAO), also plays a critical and varying role across the basin and strongly influences biogeochemical processes and population structures (Hurrell et al., 1997; Marshall et al., 2001; Greene and Pershing 2003; Townsend et al., 2010).

The surface and thermohaline circulation crossing different regions and gyres determine basin–scale distributions and connectivity from heat, salt, nutrients to genetics of marine organisms while gyre isolation and local adaptation are sufficient to result in differences of biodiversity, genetic and community structures and life history characteristics among populations of some key species. Under the recent warming in the North Atlantic, zooplankton and fish abundances and distributions have varied in response to environment change (Beaugrand et al., 2002; Greene and Pershing, 2007; Drinkwater, 2009). The genetic connectivity or isolation of a certain species may imply the capability to adapt environment variations caused by climate change (Bucklin et al., 1997, 2000; Provan et al., 2009).

These climatic signals are superimposed with seasonal variations and local physical forcing. Results from the Joint Global Ocean Flux Study (JGOFS)–North Atlantic Bloom Experiment (NABE) suggested that the lateral transport of iron–rich shelf waters is an iron source for surface waters in the basin (Martin et al., 1993). Recent results from the 2003 Climate Variability and Predictability (CLIVAR)–CO_2 Repeat Hydrography A16N transect revealed that the iron from winter dust enriches the surface water in the North Atlantic subpolar gyre (Measures et al., 2008). The availability of light and nutrients and onset of stratification lead to spring blooms, and subduction of surface waters and phytoplankton at fronts leads to significant carbon export (Buesseler et al., 1992). Studies indicated that the nitrogen fixation is controlled by iron supply rather than phosphorus availability in the gyre (Moore et al., 2009). The consumption of both trace metals and macronutrients by blooms leads to either iron or nitrogen limitation, and co–limitation. In late spring or summer, the iron concentration in the upper mixed layer is less than 0.1 nM limiting primary production (Measures et al., 2008; Moore et al., 2009). The variations of nutrient limitations lead to the spatial and temporal variations of plankton communities, carbon export and fluxes through trophic levels from multiple spatial and temporal scales.

To understand the connectivity and isolation of populations and to delineate impacts of climate change in the North Atlantic and seasonal and interannual variability requires:

- Systematic long–term investigations of basin–scale distributions and statistical correlations between currents, hydrography, nutrients, plankton–fish community structures and biodiversity, and population differences
- Resolving gradients of currents, nutrients and populations crossing fronts and gyres, and dispersion processes of zooplankton–fish populations
- Regional differences in physical and biogeochemical processes determining primary production, biomass fluxes through trophic levels, and biodiversity, and their seasonal and climate variations
- Resolving evolution of blooms and seasonal, interannual, and climate variability
- Innovative methods to estimate vital rates of biogeochemical processes and plankton–fish population processes applicable to process and predictive models
- Necessary measurements for initial and boundary conditions of process or predictive models, data assimilation to improve model predictions, and observation-model result comparison to validate model results

6.2 Shelf–basin connectivity: Water masses, nutrients, biomass, populations, and climate

The large marine ecosystem in the northwest Atlantic shelf region consisting of Newfoundland Shelf, Scotian Shelf, New England Shelf, and adjacent shelf basins and banks is characterized by its productivity higher than 300 g C m^{-2} yr^{-1} (Falkowski, 1991, Sherman et al., 1996). Carbon remineralization in the water column and surficial sediments was 33–67 g C m^{-2} yr^{-1} and 99–200 g C m^{-2} yr^{-1} equivalent to 12–23% and 33–67% of daily primary production on shelf and Slope Water areas, respectively (Kemp, 1994). Most biomass is recycled in the water column into higher trophic levels. Especially in the slope region, grazing and respiration of vertical migrating zooplankton and midwater fish contribute significantly to offshelf transport of bio–carbon, and vertical export to deep waters.

Major basin–scale currents also interact with shelf–waters in slope areas and affect regional hydrography, nutrient dynamics and population structures. Changes of the physical environment in the North Atlantic basins have been linked to fluctuations in biodiversities and the population dynamics of key species and exploited fish stocks in the basins as well as associated shelves (Reid et al., 2001; Greene et al., 2003; Beaugrand et al., 2003, 2005; Richardson and Schoeman, 2004; Pedchenko, 2005). Specific changes in plankton community structures and population dynamics have been shown to be influenced by climatically driven changes in circulation patterns, biogeochemical processes and physiological rates as well as in the timing of the spring bloom (Greene and Pershing, 2007; Reid et al., 2001; Townsend et al., 2010). Decades of hydrographic measurements in the northwest Atlantic shelves have suggested two key drivers of ecosystem structure, notably that:

- An increase in arctic freshwater outflow due to global warming has led to the freshening of shelf waters and an increase in coastal currents on shelves which are probably the primary causes for the recent changes in nutrient regime, phytoplankton bloom timing and magnitude, and transport of arctic cold-water zooplankton species into the Scotian Shelf, Gulf of Maine, and Georges Bank (Greene and Pershing, 2007; Head and Pepin 2010; Townsend et al., 2010).
- The Labrador Subarctic Slope Water (LSSW) can extend from its usual position south of the Grand Banks area to the Mid-Atlantic Bight after a high negative phase of the North Atlantic Oscillation (NAO) which is hypothesized to explain some changes observed after negative NAO in the local ecosystems on the Scotian Shelf, Gulf of Maine, and New England Shelf (MERCINA, 2001, 2003; Greene et al., 2003; Frantantoni and Pickart, 2007).

The unprecedented increase in arctic freshwater outflow from increased precipitation, river discharge, and glacial as well as sea–ice melting, and changes in dominant ecosystem drivers have led us into uncharted territory on physical processes, nutrient dynamics, biogeochemical processes, food web structures and biodiversities in the Northwest Atlantic Shelves, basins, and Slope Water.

The New England Shelf and Gulf of Maine became fresher two years after a negative NAO phase when the cooler fresher LSSW advected southwestward along the shelf slopes replacing warmer and saltier Atlantic Temperate Slope Water (ATSW) (MERCINA, 2001; Greene et al., 2003; Head and Sameoto, 2007; Townsend et al., 2010). In 1996, the NAO value based on the North Annual Mode from EOF analysis dropped to one of the lowest levels (–3.78) in the last 40 years (Fig. 2) (Townsend et al., 2010; http://www.cgd.ucar.edu/cas/jhurrell/indices.html). The water in the Gulf of Maine became fresher, the LSSW advanced into the Slope Water area south of the Mid-Atlantic Bight, and the abundance of *Calanus finmarchicus* dropped one order of magnitude in 1998 (Greene et al., 2003). The NAO index (–4.62) in 2010 exceeded the 1996 value. If the two–year lag cycle holds, a major climatic ecosystem event in the New England Shelf and Gulf of Maine may occur, beginning in late 2011 and extending into 2012–2013. This affords an opportunity to examine outstanding questions concerning how zooplankton and micronekton community structures (e.g., *Calanus*, euphausiids, mesopelagic fishes, shrimp and squid) associated with the shelf and slope regions will be affected by the replacement of the warmer ATSW with the cooler LSSW.

Recent changes observed in the Gulf of Maine in nutrient regime, phytoplankton blooms, and plankton community structure have been hypothesized to relate to a weakening of deep–water intrusion in the Northeast Channel and increased shelf water intrusion due to arctic freshwater outflow. These hypotheses have not been tested nor have these coupled physical–biological processes been studied. There is an urgent need to understand these physical and biological processes, and potential impacts of the major negative NAO–related LSSW southwestward intrusion predicted in late 2011 and 2012 into the Slope Water area south of Scotian and New England shelves on regional ecosystems and biodiversities.

On the slope, the interaction between Gulf Stream warm-core rings, Slope Water, and shelf waters is of critical meso-scale physical processes enhancing primary production and shelf–basin exchange (Ryan et al., 2001). Studies indicate that Scotian and Georges Bank shelf waters can be entrained off the shelf and bank along 100 m isobaths and entrained atop of the warm-core ring water through the secondary circulation enhancing primary production at a scale over 100 km along the shelf-break. Typically, the New England Shelf Slope Water is occupied by ATSW that flows northeastward with direct influence of the Gulf Stream Water, which is warm and salty. After a major negative NAO year, the replacement of the ATSW by the cold and fresh LSSW will expectedly affect the shelf and shelf basin hydrography and meso-scale physical processes, and in turn, nutrient dynamics, productivity, plankton–fish population structures and biodiversities. Such kinds of climate and local process coupling have not been studied.

Crossing the North Atlantic, the sea surface temperatures in the Northeast Atlantic seas and shelves have been increasing 1–2°C in last several decades associated with the increases in warm Slope Water intrusions (Hughes et al., 2010). Such large scale and long term changes have led the shifts in ecosystem dynamics such as plankton community compositions and sizes, and distributions of fish populations (Drinkwater, 2009; Mornán et al., 2010). To understand and delineate seasonal and interannual variability and climate change, long–term monitoring programs have been established in basins and on shelf slopes (Drinkwater 2009; Loeng and Drinkwater, 2007; Zhou et al., 2009; Gaardsted et al., 2010). A series of meso-scale–resolving field studies over the basin scale have been conducted, for example, the polarward warm slope water from Portugal to Norway in negative NAO years and increase in meso-scale eddy activities in the Bay of Biscay (Garcia-Soto et al., 2002), impacts of climate change on fish communities in Bay of Biscay and adjacent seas (Poulard and Blanchard, 2005), the fast increase in temperature, shifting of the ecosystem and invasion of warm water species in the North Sea (Dulvy et al., 2008), intrusions of slope waters and biota onto shelves and offshelf transport of shelf biota (Zhu et al., 2009), convergence of overwintering *Calanus finmarchicus* along shelf slopes (Gaardsted et al., 2010), and along–slope and on–shelf transports of *C. finmarchicus* and fish larvae (Fossheim et al., 2005; Pedersen et al., 2010).

These bottom–up processes are combined with top–down effects associated with fisheries. Fisheries have affected local and regional marine ecosystems in the North Atlantic, for example, the collapses or significant reduction of the northern cod stock off Newfoundland in the 1990s and the Norwegian Coastal Cod (Drinkwater, 2002; Hutchings and Reynolds, 2004; Frank et al., 2005; ICES, 2005; Worm et al., 2006; Myers et al., 2007). As the top–down, removal of top predators has produced significant cascading effects on marine ecosystems and unpredictable oscillations (Frank et al., 2005; Myers et al., 2007), biodiversity loss has led to an increase in resource collapses and a decrease in recovery potential (Worm et al., 2006). Both fisheries and climate change contribute to the oscillations and collapse of marine resources.

The coastal shelf, banks, and ledges shallower than 100 m are the primary locations for the Northwest Atlantic fisheries. Planktivorous fish, e.g. herring, mackerel, sand lance, are key prey for higher trophic level fish and mammals in these areas while these planktivores feed on mesozooplankton and micronekton. Zooplankton community structure showed significant changes with the southwestward intrusion of the LSSW and shelf water freshening (Miller et al., 1991; Head et al., 1999; Greene et al., 2003; Greene and Pershing 2007; Head and Pepin, 2007). It has been long recognized that zooplankton populations of the Northwest Atlantic shelves are significantly affected by advection of upstream zooplankton populations in the coastal currents on the Scotian Shelf and in the deep intruding Slope Water (Miller, et al., 1998*;* MERCINA, 2004; Ji et al., 2008; Pershing et al., 2010). A similar phenomenon has also been found in the Norwegian Sea and its adjacent shelves where the northward transport of *C. finmarchicus* plays a key role in the ecosystem dynamics of the Barents and northern Norwegian Sea (Planque and Batten, 2000; Heath et al., 2000, 2004, 2008; Slagstad and Tande, 2007; Zhu et al., 2009).

Euphausiids are a key component in the Northwest Atlantic ecosystems (Parsons and Lalli, 1988; Cochrane et al., 1994, 2000). *Thysanoessa inermis* and *Thysanoessa raschii* are found in coastal regions while *Meganyctiphanes norvegica, Euphausia krohnii, Nematoscelis megalops,* and *Thysanoessa longicaudata* are found in the deep basins and off shelf regions. Large populations of *M. norvegica* are found in the Gulf of St. Lawrence, deep basins on the Scotian Shelf, and in the Gulf of Maine where they feed on dense aggregations of *C. finmarchicus* (Lewis and Sameoto, 1988a, b, c, 1989; Sameoto and Herman, 1990). *Thysanoessa* species preferentially feed on phytoplankton in spring and change to omnivorous feeding in other seasons (Bamstedt and Karlson, 1998). Euphausiids start reproduction during spring blooms and reach a biomass maximum in fall (Astthorsson, 1990; Dalpadado and Skjoldal, 1996). Thus, transport of both *C. finmarchicus* and euphausiids by coastal, shelf-break, and Slope Water currents is an important source or sink for their populations and abundances on Northwest Atlantic Shelf and shelf seas, and are subjected to the impact of climate change.

The impacts of climate change, fisheries, and other human activities on ecosystems in local shelf–Slope Water regions are determined by interactions of basin–scale circulation and atmospheric forcing with regional physical, biogeochemical, and population dynamics processes. Identification of common and unique processes and features between the northeastern and northwestern Atlantic shelf regions and understanding of how climate change and fisheries affects local ecosystems require studies of physical, biogeochemical, and population-community processes in each region. The North American BASIN will connect basin and regional scale processes to coastal ecosystems by addressing the following questions:

- For the Northwest Atlantic shelf, basins, and Slope Water, what is the importance of local (e.g., local production and mortality, riverine/coastal processes, heat flux, pH, fisheries) versus remote forcing (e.g., St. Lawrence River discharge and upstream transport from the Labrador Sea and boundary forcing by the Gulf Stream) in controlling the abundance and productivity of key taxa, and the biodiversity and stability of ecosystems in shelf seas? Key taxa might include lipid-rich copepods, euphausiids, and planktivorous fish (e.g. herring, mackerel, sand lance, and capelin).
- What is the exchange of carbon/nutrients/plankton/fish both onto and off the continental shelf, and along-shelf? What are the impacts of this exchange on population and ecosystem dynamics?
- Are the responses to large scale processes different in the eastern and western regions of the North Atlantic, as well as northern and southern regions within each?

To answer these questions and to respond to the BASIN deliverables, the following research needs have been identified that need to be determined:

- NW Atlantic circulation patterns and their responses to climate change.
- Life histories and vital rates of key taxa for which little is known (e.g., euphausiids, gelatinous zooplankton), as well as their responses to climate change (e.g., thermal

response of vital rates).

- Ecosystem consequences to substantial reductions in abundances of key species or substantial shifts in species/community/functional group compositions and biodiversity under climate change.
- Energetic demands, diet changes, and behavior responses of resident fish species and higher trophic levels under regime or climate change.
- Prey-predator interaction, mortality, and biomass transfer efficiencies, assessing top-down regulation of key species, functional groups, community structure, and biodiversity.
- Diel and seasonal horizontal and vertical distributions of life stages and migration behavior of key taxa.
- Shelf-slope exchange processes associated with topographic features and roles of shelf-sea basin populations in maintaining population abundances, trophic interaction, biodiversity, and carbon transport, and supporting coastal fisheries (e.g. Wilkinson Basin).
- New approaches integrating molecular identification, isotopic ratios, size relationship, and traditional taxonomic analysis for biodiversity, trophic interactions at community levels, and their spatiotemporal variability.
- Impacts of fine-scale stratification and timing of stratification to primary production, larvae dispersion, biomass export to benthic communities, and shelf–basin exchange, and their changes in response to climate change.

6.3 Submeso–meso-scale processes: Upwelling, nutrients, plankton–nekton communities

Studies in last 20 years have revealed that the enhancements of nutrient supplies occur at submeso–meso-scales by upwelling within meso-scale eddies, jets, and meanders, and produce high primary production, carbon export, and aggregations of marine organisms at all trophic levels. Different physical mechanisms for upwelling at the submeso-scale within meso-scale eddies have been found associated with secondary circulation, uplifting of thermocline as internal wave propagation, and wind–eddy interaction (Pollard and Regier, 1992; Rudnick, 1996; McGillicuddy et al., 1998; Shearman et al., 1999; Martin and Richards; 2001; Dorland and Zhou, 2008). Primary production is enhanced from nutrient additions supplied by upwelling and stratification induced by different layered water masses and can be significantly higher than that of large–scale hydrographic and nutrient fields. In response to enhanced primary production, zooplankton and fish aggregate at submeso–mesos-scales (Huntley et al., 1995; McGillicuddy et al., 1998; Zhou, 1998; Zhou et al., 2001).

Understanding of coupled submeso–meso-scale physical and biogeochemical processes is challenged by multiple time scales of meso-scale eddy evolution, nutrient injection and biological removal of new nutrients, and evolution of plankton–fish communities. In addition, the seasonal differences in dominant physical and biogeochemical processes associated with thermal stratification, wind fields, mixing, and behavior–life histories of high trophic organisms also need to be taken into account. For example, recent studies have revealed enhanced primary production, convection, and subduction of biomass in winter into deep waters though the scale and vertical structure of a convection cell and mechanisms not previously understood (Backhaus et al., 2003; Behrenfeld, 2010).

The Lagrangian nature of plankton community evolution presents another challenge in understanding nutrient recycling and the time scales of plankton species response to nutrients and available biomass that determine carbon fluxes through trophic levels. Lagrangian technologies to follow a chosen water mass have been developed, for example, using Rhodamine or FS6 as tracers. These technologies have been challenged by vertical and horizontal velocity shears and secondary circulation at fronts, and the migration behavior of zooplankton and fish, which redistributes bio–carbon horizontal and vertically (Steinberg et al, 2008). It has been estimated that mesozooplankton respiration alone can contribute 13.4±4.2 Gt C yr^{-1} in the global ocean, which is approximately 17–32% of total primary production (Hernandez-Leon and Ikeda, 2005). Respiration rates of and carbon fluxes into zooplankton–fish communities in meso-scale eddies and meanders can significantly exceed these global means.

These submeso–meso-scale processes are affected by climate change. The increase in arctic freshwater outflow has reduced the surface salinity in the North Atlantic Sub-polar Gyre, and there is significant correlation between the sea surface temperature and NAO (Metzl et al., 2010; Reverdin, 2010). These climatic processes affect the vertical stability of water column and horizontal transport of freshwater, which affect submeso–meso-scale upwelling and mixing processes and in turn winter–spring primary production and carbon export (Siegel et al., 2002; Backhaus et al., 2003; Behrenfeld, 2010).

Understanding coupled multi–scale physical and biogeochemical processes from nutrient injection, community structure evolution, and seasonal variations is essential for developing carbon flux and ecosystem models to understand potential impacts of climate change and anthropogenic influences such as removing certain fish species and increase atmospheric CO_2. A series of process studies on the following topics must be conducted to develop this knowledge:

- Upwelling and nutrient injection into euphotic zone within a meso-scale physical–biogeochemical field, and enhancement of primary production.
- Nutrient recycling processes associated with microbial processes, nutrient limitations, evolution of a plankton community structure, and longevity of a plankton bloom.
- Carbon fluxes between trophic levels and processes that control the biological pump.
- Vertical redistribution and export of carbon through zooplankton and midwater fish grazing, respiration, and diel vertical migration.
- Seasonal variations of submeso–meso-scale processes and key events in an annual cycle.
- New sensor and platform development resolving long–term submeso–meso-scale carbon budget and community structures.
- New approaches integrating molecular identification, isotopic ratios, size relationships, and traditional taxonomic analysis for trophic interactions at community levels
- New mathematical approaches integrating in situ physical and biogeochemical measurements for estimating upwelling and nutrient injection.
- New models simulating biomass recycling and fluxes within a microbial-plankton-fish community based on observable variables and rates.
- Parameterization of submeso–meso-scale rates, processes, and models for basin–scale process and predictive models.

7. NORTH AMERICAN BASIN RESEARCH ACTIVITIES

BASIN research will involve a combination of modeling, data synthesis, regional and basin scale surveys and time series, and process studies including laboratory and field measurements of vital rates and biogeochemical processes (Table 1).

7.1 Modeling

Modeling activities will provide analytical tools for submeso–meso-scale physical and biogeochemical fields, synthesis tools for coupled physical–biogeochemical–population processes, hindcasting–forecasting tools for ecosystem state and variability, and management tools for socioeconomics and policy making. The objectives of the modeling component are:

- Enhancing data assimilation nested submeso-scale–meso-scale models integrated with field observations for assisting data analysis and integration.
- Developing process–oriented models for interpreting data from field process studies, and vital rate estimates.
- Developing innovative models based on taxa, functional groups, or size spectra for addressing mortality, prey–predator relationships, and carbon fluxes between trophic levels.
- Enhancing basin–scale coupled climate/ocean/ecosystem modeling systems linking basin– and shelf–scale processes and field observations.
- Making hindcasts of the state and variability of North Atlantic ecosystems for the past 50 years and verifying model results.
- Identifying the climate forcing processes that have the greatest influence on ocean and ecosystem variability.
- Assessing ecosystem and key species spatial connectivity throughout the North Atlantic and associated shelf seas.
- Assessing top-down effects of upper trophic levels and effect of their exploitation on ecosystem structure and carbon cycling.
- Estimating local (shelf) versus remote (deep ocean) natural and anthropogenic impacts on ecosystem dynamics and exploited resources.
- Improving assessment and management tools for exploited resources such as fish stocks based on basin-scale forcing, and potential impacts of climate change on ocean warming, acidification, carbon flux, and ecosystem functioning.
- Embracing the ensemble approach and providing model outputs in a unified format that can be used and compared by the scientific community.

The first deliverable (from Section 5) involves all the modeling activities, from model development, skill assessment, hindcast–forecast, eventually to the implementation of integrated basin-scale modeling and observing systems. The model development will encourage both refining existing models and developing new innovative physical, biogeochemical, and ecosystem models to couple the regional and basin scale physical models, nested feature–

following data assimilation submeso–meso-scale hydrodynamic models, biogeochemical process models, and biological models based on individuals, functional groups, communities, and size spectra. It is necessary to verify model results by observed data and processes so that modeling experiments (performed as Observing System Simulation Experiments - OSSEs) can be conducted for analyzing field observing systems, identifying data gaps, guiding field experimental designs and ultimately improving model results. These modeling activities are essential for the hindcast/forecast of the ecosystem state and variability (deliverable 2 and 4), for assessing population connectivity across the basin (deliverable 5), and for understanding regional to basin-scale ecosystem and biogeochemistry processes (deliverable 6 and 7). The model results should be accessible for the community through a distributed database structure for further analysis and comparisons (deliverable 3), and for assisting the interpretation of physical, biogeochemical, and ecosystem processes. Assessment and management tools for exploited resources will be developed for management and policy making (deliverable 8 and 9).

7.2 Synthesis

Retrospective data analysis/synthesis should begin in parallel with the modeling effort to identify extant knowledge and provide data for verify model results. There are significant datasets available to address climatic impacts on regional and North Atlantic ecosystems such as:

- Canadian Atlantic Zone Offshore Monitoring Programme (AZOMP) and Atlantic Zone Monitoring Programme (AZMP) hydrographic, nutrients, and plankton–fish datasets since 1994 and 1998, respectively.
- CLIVAR and GEOTRACES hydrographic, nutrient, and trace element datasets along transects in the North Atlantic.
- JGOFS and GLOBEC hydrographic, nutrients, plankton–fish, and carbon export datasets.
- NOAA's MARMAP, EcoMon, and trawl survey data sets
- SAHFOS CPR data sets.

For developing better physical, biogeochemical and ecosystem models, time series observations and process studies will clearly need for providing better understanding of processes, better process rates for models, and better parameterizing subgrid processes. The limitations of physical–biogeochemical–ecosystem models and knowledge gaps in biogeochemical–ecosystem processes and individual–population behavior have been long recognized. An integrative approach will be strongly encouraged.

Table 1. Timelines and deliverables

Activities	2012	2013	2014	2015	2016	Deliverables
7.1. Modeling						
Coupling basin–regional models	X	X	X	X	X	1, 4, 8
Submeso–meso-scale modeling	X	X	X	X	X	3,4,5, 7
Hindcasting & skill assessment		X	X	X	X	1, 2, 3, 4
Observing system simulation	X	X	X			1, 2, 9
Developing biogeochemical, species population & trophic level models	X	X	X			1, 6, 7, 8, 9
Coupling physical, biogeochemical and biological models	X	X	X	X		1, 2, 3, 5, 6

Activities	2012	2013	2014	2015	2016	Deliverables
Data assimilation implementation		X	X	X	X	1, 2
Forecasting & skill assessment		X	X	X	X	1, 4, 9
Basin-scale modeling & observing system implementation			X	X	X	1, 9
Twilight zone models of biological processes, and flux attenuation	X	X	X	X	X	3,4,5, 7
Model result inter-comparison					X	1, 9
7.2. Synthesis						
Retrospective data synthesis.	X	X				2, 3, 5
Analyzing observed and modeled variability & assessing predictability		X	X	X	X	1, 2, 4, 9
Transferring scientific results to management & outreach.		X	X	X	X	8, 9
Remote-sensing applications	X	X	X	X	X	4, 5, 9
7.3. Field studies						
7.3.1) Lab-shipboard-mesocosm study						
Biogeochemical processes	X	X	X	X	X	1, 7
Vital rates	X	X	X	X	X	1, 7
Impacts of acidification, salinity, and temperature	X	X	X	X	X	5, 7
Behavior	X	X	X	X	X	5, 6,7
Trophic interaction	X	X	X	X	X	5, 6, 7
7.3.2) Process field studies						
EU BASIN process study	X	X	X	X		4, 5, 7
Submeso-meso-scale physical-biogeochemical-biological processes	X	X	X	X		5, 7, 8
Frontal and shelf slope exchange of nutrients, populations & carbon	X	X	X	X		5, 7, 8
Evolution of species distributions & community structures	X	X	X	X		5, 7
Carbon transfers & export	X	X	X	X		4, 5, 7
Food web & ecosystem dynamics	X	X	X	X		4, 5, 6, 7
7.3.3) Shelf–Sea Studies						
Canadian AZMP project	X	X	X	X	X	4, 5, 6, 7
EU shelf sea studies	X	X	X	X		4, 5, 6, 7
Impacts of negative NAO events on NE US shelf sea ecosystems & biodiversity	X	X	X			4, 5, 6, 7, 8
Impacts of climate change on NE US shelf sea productivity, diversity & ecosystems	X	X	X	X	X	4, 5, 6, 7, 8
Fisheries surveys & ecosystem	X	X	X	X	X	4, 5, 6, 7, 8

Activities	2012	2013	2014	2015	2016	Deliverables
monitoring						
Bottom-up and top down controls on shelf sea ecosystem	X	X	X	X	X	4, 5, 6, 7, 8
7.3.4) Transatlantic transects						
EU BASIN transatlantic study		X	X	X		4, 5, 6, 7, 8
Canadian AZOMP	X	X	X	X	X	4, 5, 6, 7, 8
US AMOC project	X	X	X	X	X	7
Ships of opportunity (e.g. CPR)	X	X	X	X	X	4, 5, 8
Seasonal and spatial variations of nutrient & ecosystem dynamics	X	X	X	X	X	4, 7, 8
Distributions & dispersion of populations and connectivity	X	X	X	X	X	4, 5, 6, 7, 8
7.3.5) Time Series						
Fixed stations: Environmental & ecosystem state variables	X	X	X	X	X	4, 5, 7, 8
Moorings: Environmental & ecosystem state variables	X	X	X	X	X	4, 5, 7, 8
Lagrangian platforms–floats and drifters: Environmental & ecosystem state variables	X	X	X	X	X	4, 7, 8
Autonomous vehicles–AUVs, gliders & profilers: Environmental & ecosystem state variables	X	X	X	X	X	4, 7, 8
Remote sensing: Satellite, in situ, and shore-based sensors	X	X	X	X	X	4, 7, 8
7.4. Technology Development						
Acoustics/optics for small platforms	X	X	X			4, 5, 7
Imaging systems	X	X	X			4, 5, 7
Genetic and genomic approaches	X	X	X			4, 5, 7
Field sensor and platform tests		X	X	X		4
Sensor and method inter-comparison	X	X				4
7.5. Management applications						
General management framework	X	X				3, 8, 9
Spatial planning and management	X	X	X	X	X	3, 8, 9
Integrating ecosystem and biodiversity variables and indices into management models	X	X	X	X	X	3, 8, 9
7.6. E-Science						
BASIN Virtual Observatory (BVO)			X	X	X	4, 5, 6, 7, 8, 9
Formation of BVO alliance	X	X	X			4, 5, 6, 7, 8, 9
Informatics tools and services			X	X	X	4, 5, 6, 7, 8, 9

7.3 Field studies

The field studies of North Atlantic BASIN include providing necessary time series and spatial distributions of physical and ecosystem state variables and especially their variations associated with seasonal and interannual variability and impacts of climate change and human activities, resolving unknown key processes and vital rates, and developing new sensors, approaches, and process models for observations and process rate estimates. The objectives of field studies are:

- Generating datasets resolving spatial and temporal patters and connectivity of hydrography, currents, nutrients, biomass, key species, population genetics, community structures, and biodiversity within water column and benthos necessary for delineating multiple scale physical, biogeochemical, population, and ecosystem processes.
- Improving both quality and quantity of datasets to construct initial and boundary conditions for models, to compare with model results for validation, and to be used in data–assimilation models for improving model results.
- Estimating *in situ* vital rates of individuals, populations, and especially prey–predation relationships at levels of key species, functional groups, sizes, or communities.
- Resolving key meso–basin–scale physical processes and rates responsible for cross–shelf slope and cross–gyre exchange, mixing and dispersion of water masses, nutrients, biomasses, and populations.
- Resolving submeso–meso–scale physical and biogeochemical processes and rates within meso-scale eddies and frontal zone for better understandings of spatio-temporal coupling and decoupling between upwelling of nutrients, primary production, biomass fluxes between trophic levels, and carbon export.
- Providing the baseline and variations of key species, community structures, ecosystem states, and biodiversity in response to climate change and events such as increased arctic freshwater outflow, ocean warming and negative NAO events, and identifying the climate forcing processes that have the greatest influence on ocean and ecosystem variability.
- Testing new innovative platform-sensors, *in situ* and laboratory experiments, and field approaches for improving measurements of key variables, processes, and rate estimates, better understandings of physical–biogeochemical–ecosystem processes, and refining empirical and mechanistic models.
- Developing innovative approaches integrating sensors such as CTD, ADCP, trace metal clean rosette, optical sensors for phytoplankton and zooplankton, acoustic sensors for mesozooplankton and midwater fish, and traditional net systems, and combining field surveys, experiments, and models for resolving coupled physical–biogeochemical–ecosystem processes and rates.

The North Atlantic BASIN field studies will be integrated with the cruises already funded by Canadian North Atlantic Zone Monitoring Program (AZMP), the NOAA EcoMon program,and those funded and proposed by EU BASIN Program. Coordination with other programs will also be sought (e.g., OOI, AMOC). The planned NA BASIN cruises are listed in Table 2 (but not limited to) for determining impacts of the 2010 lowest negative NAO event (-4.62) in last 40 years on key population abundances, community structures and biodiversities, obtaining baseline nutrients and key population and community structures and their potential variations necessary for initiating model setups and executions, understanding key biogeochemical, population and ecosystem processes for improving models, syntheses, and fieldwork, and testing new sensors and platforms.

Table 2. Planned US and European cruises.

Year	Season	Country	Ship	Area	Science	Length (days)	PI Status
2011	bimonthly	US	Delaware II Henry Bigelow	Northeast U.S shelf	Hydrography, plankton fish	4 18 day 2 60 day	NOAA NEFSC funded
	Spring Summer Fall	Canada	Hudson	Labrador Scotian Shelves	Shelf/slope waters Nutrients plankton–fish		DFO Funded
	Summer	US	Oceanus	NW Atlantic	Ocean acidification pteropod study	26	Lawson Funded
2012	bimonthly	US	Delaware II Henry Bigelow	Northeast U.S shelf	Hydrography, plankton fish	4 18 day 2 60 day	NOAA NEFSC funded
	Spring Summer Fall	Canada	Hudson	Labrador Scotian Shelves	Shelf/slope waters Nutrients plankton–fish		
	Spring	Denmark	Dana	W. Greenland	Multi-disciplines	30	30
	Spring	Germany	Meteor	NE Atlantic	Convection–plankton	45	45
	Spring / Summer	US	Global	Iceland shelf	Off shelf transport / iron limitation study	40	BASIN Planned
	Spring Summer Fall	US	Regional	NE Shelf GOM	Slope water Exchange Nutrient–fish	3 20–day cruises	BASIN Planned
	Spring	US	Knorr	NW Subtropical	Submeso-scale physics and biogeochemistry	34	Buesseler submitted
	Fall	US	Regional	Gulf of Maine	Ocean acidification stratification study	12	Runge Funded
	Summer	US	Global	Labrador Sea	Meso-scale processes	25	BASIN Planned
2013	bimonthly	US	Delaware II Henry Bigelow	Northeast U.S shelf	Hydrography, plankton fish	4 18 day 2 60 day	NOAA NEFSC funded
	Spring Summer Fall	Canada	Hudson	Labrador Scotian Shelves	Hydrography–nutrients–plankton–fish		
	Spring	UK	Unknown	Station PAP	NA Bloom	30	30

					Experiments		
	Spring	Iceland	Saemun-dsson	Iceland shelf	Connectivity, gradients	10	10
	Monthly	Norway	GO Sars	No. shelf	Plankton seasonality	2	
	Spring	Norway	GO Sars	Transatlantic	Connectivity, gradients	45	45
	Summer	German	Meteor	Transatlantic	Connectivity, gradients	45	45
	Spring	US	Global	NA Subpolar	Submeso-scale Nutrients, blooms, fluxes upwelling	40	BASIN Planned
	Spring Summer Fall	US	Regional	NE Shelf GOM	Regional Exchange processes / shelf stratification studies	3 12–day cruises	BASIN Planned
	Fall	US	Global	Transatlantic	Connectivity, gradients	40	BASIN Planned
	Spring/summer	US	Global	Iceland Basin	NACycle	25	BASIN Planned
	Spring/summer	US	Ocean	Iceland Basin	Meso-scale processes	25	BASIN Planned
	Summer	US	Knorr	NW Subtropical	Submeso-scale physics and biogeochemistry	34	Buesseler submitted
2014	bimonthly	US	Delaware II Henry Bigelow	Northeast U.S shelf	Hydrography, plankton fish	4 18 day 2 60 day	NOAA NEFSC funded
	Spring Summer Fall	Canada	Hudson	Labrador Scotian Shelves	Hydrography–nutrients–plankton–fish		
	Spring	Iceland	Saemundsson	NA fronts	Zooplankton–fish		
	Monthly	Norway	GO Sars	Norwegian shelf	Seasonality of zooplankton	2	
	Spring Summer Fall	US	Regional	NE Shelf GOM	Slope water Exchange Nutrient–fish	3 20–day cruises	BASIN Planned
	Spring Summer Fall	US	Regional	NE Shelf GOM	Regional Exchange processes / shelf stratification studies	3 12–day cruises	BASIN Planned
	Spring	US	Global	Iceland Basin	NACycle	25	BASIN Planned
	Spring	US	Ocean	Iceland Basin	Meso-scale processes	25	BASIN Planned

7.4 Technology development

A critical aspect for the success of BASIN is transition of new technology through further development, so that the new sampling capacity needed for the program can be attained soon after the program begins. These new technologies include sampling on small platforms and moorings using acoustics, optical imaging systems, and nutrient sensors. In addition, operational underway instruments need further development. New approaches to trophic studies are also required and will be supported include molecular and isotopic techniques. These new technology developments are viewed as high priority.

7.5 Management applications

BASIN, as a science program, has the opportunity to inform a number of critical management issues: overfishing, protected species, spatial management, and ocean acidification. Overfishing remains a primary concern in marine management. There is a growing appreciation that the population dynamics of fishery species are controlled by more than just fishing (Hillborn and Walters, 2004). Environmental effects and species interactions change the productive capacity of target populations and thus benchmarks used in making management decisions are continually changing. To improve the sustainability of exploited marine resources, the factors and processes responsible for changing population productivity must be understood, incorporated into scientific assessments, and communicated to managers.

Most nations bordering the North Atlantic have legislation designed to protect and rebuild marine mammal and sea turtle populations. In some cases, these protections have lead to increases in protected species, which has created conflicts with fisheries (Trzcinski et al., 2006). In other cases, populations remain low and are in danger of extinction; understanding the effect of natural processes (Greene and Pershing, 2004) and including this understanding in assessments are critical to recovery of these species.

Spatial management is one tool that is being used globally to support fisheries and to protect endangered species. Under the Convention of Biological Diversity, many nations have committed to establish comprehensive, effectively-managed and ecologically representative national and regional systems of Marine Protected Areas (MPAs) by 2012. The objectives of spatial management are multifaceted and the science is species and region specific and there have been notable successes in the North Atlantic. The recovery of the Atlantic sea scallop is in part attributed to the creation of large closed areas on the northeast U.S. shelf (Hart and Rago, 2006). Spatial management can also be used in strategies to further protect marine mammals (Vanderlann and Taggart, 2009). There also remain a number of complex science issues including defining priority areas for protection, understanding the movement of animals among protected and non-protected areas, understanding the roles of protected areas in supporting habitat and ecosystem services, and including protected areas in spatially-explicit descriptions of population dynamics.

Climate change is a major issue for marine resource management that impacts exploited species, protected species and protected areas. The exploitation of some species may become unsustainable under climate change. The status of marine mammal populations may change and protected areas may no longer meet their objectives owing to changes in species distribution and underlying ecosystem function. One critical component of climate change is ocean acidification, which is caused by increasing concentrations of CO2 in seawater. Acidification may interfere with the ability of organisms to form calcium carbonate structures and may affect seawater chemistry with indirect effects of marine animals. Although the potential impacts are large and numerous, the resiliency of marine populations and ecosystems to acidification is largely unknown. Information on climate change and ocean acidification in the North Atlantic is needed to ensure management goals and objectives are met in the long-term.

The BASIN approach to informing management will be two-fold. First, BASIN results will be incorporated into targeted assessments. The assessments will be identified through a process that includes identifying important management needs and the likelihood that BASIN could contribute to these needs. Second, BASIN results will be used in the context of supporting future assessment and management activities. These emerging issues will also be identified through a formal process. In both cases, BASIN seeks to support scientists to bridge the gap between research and assessment with the goal of improving the advice provided to managers. ICES already hosts several working groups that work between research and assessments and participation of these groups in BASIN will be encouraged (e.g., WGOOFE, http://www.ices.dk/workinggroups/ViewWorkingGroup.aspx?ID=322).

The various marine management processes in the North Atlantic will be identified and mapped in a common framework. This will provide the BASIN program and BASIN scientists with a clear view of how the science needs to be transferred to management. These management processes include: Fishery Management Councils of the U.S., Regional Directors in Canada, European Commission, International Council for the Exploration of the Sea, the North Atlantic Fisheries Organization, the International Whaling Commission, national protected species legislation, and the Convention on Biological Diversity. Once the management processes are mapped, priority research needs will be obtained from each organization. These needs will then be considered in the context of BASIN's goals and science questions; specifically, will BASIN be able to provide concrete products to improve specific assessments or management processes. Based on this review, specific management activities will be targeted by the BASIN program. Support will be sought for a bridging activity between the BASIN program and the specific scientists involved in the management process. These activities will be pursued during the first phase of BASIN and then a formal review process will be undertaken at the end of Phase I.

In addition to targeted current management activities, BASIN will also contribute to emerging management issues. Emerging issues will be identified through a formal process and then the ability of BASIN to contribute to these issues will be assessed. Several important and BASIN-relevant issues will be identified and scientists will be encouraged to work to bridge BASIN research and the emerging management issues. These activities will also be reviewed at the end of Phase I.

An important component of the application of BASIN science to management is the perspective from management to BASIN. In addition to incorporating BASIN science into assessments and management, the scientists identified above will also work with BASIN researchers to make sure that the information necessary for management is generated by BASIN. This two-way communication is important to ensure that BASIN research and applications to management continued to be matched during the program.

7.6 E–Science

The successful efforts undertaken in other programs (e.g JGOFS, GLOBEC, GEOTRACES, etc.) and support from organizations (e.g. ICES and NSF) have led to the development of modern e–science and informatics data infrastructures for organizing and conducting science. BASIN will carry out working group level activities to support BASIN science and technology development.

E–science working activities will be organized around the principle that progress in basin-scale investigations requires new forms of scholarly publishing, and the structure needed to bring researchers into contact with data sets, models, and each other, across disciplines and national boundaries and perform the diverse analyses and modeling required to gain new insights and achieve the BASIN science goals. Due to the heterogeneity of vocabularies, and the complexity and diversity of data structures and formats, an informatics approach is needed that focuses on defining and answering science questions (use cases) to drive the required semantic and syntactic technical developments. As such, partnerships between scientists, their teams, data managers, and informatics practitioners need to be created. Key elements for the BASIN e–science effort include:

- An International BASIN Observatory Alliance (IBOA) that
  - integrates regional data repositories and other virtual observatories,
  - provides access to computing resources,
  - provides regional data management and preservation.
- Objectives:
  - Developing and implementing a suite of interoperability standards.
  - Developing data visualization and data sampling tools for scientists and managers.
  - Developing statistical tools and models for statistical analysis and prediction.
  - Developing data mining tools for identifying critical features and processes.

A formed and functioning International BASIN Observatory Alliance (IBOA) will be needed at the onset of the program. There is a need for a suite of interoperability standards and implementations for assessing program activities. A BASIN Virtual Observatory (BVO) needs to be created that integrates regional data repositories and VOs, provides access to computing resources, and provides regional data management and preservation.

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APPENDIX 1. EUROPEAN BASIN ACTIVITIES

1.1. Project summary

EURO-BASIN is designed to advance our understanding on the variability, potential impacts, and feedbacks of global change and anthropogenic forcing on the structure, function and dynamics of the North Atlantic and associated shelf sea ecosystems as well as the key species influencing carbon sequestering and ecosystem functioning. The ultimate goal of the programme is to further our capacity to manage these systems in a sustainable manner following the ecosystem approach. Given the scope and the international significance, EURO-BASIN is part of a multidisciplinary international effort linked with similar activities in the US and Canada. EURO-BASIN focuses on a number of key groups characterizing food web types, e.g. diatoms versus microbial loop players; key species copepods of the genus *Calanus*; pelagic fish, herring (*Clupea harengus*), mackerel (*Scomber scombrus*), blue whiting *(Micromesistius poutassou*) which represent some of the largest fish stocks on the planet; piscivorous pelagic bluefin tuna (*Thunnus thynnus*) and albacore (*Thunnus alalunga*) all of which serve to structure the ecosystem and thereby influence the flux of carbon from the euphotic zone via the biological carbon pump. In order to establish relationships between these key players, the project identifies and accesses relevant international databases and develops methods to integrate long term observations. These data will be used to perform retrospective analyses on ecosystem and key species/group dynamics, which will be augmented by new data from laboratory experiments, mesocosm studies and field programmes. These activities serve to advance modelling and predictive capacities based on an ensemble approach where modelling approaches such as size spectrum; mass balance; coupled NPZD; fisheries “end to end” models as well as ecosystem indicators are combined to develop understanding of the past, present and future dynamics of North Atlantic and shelf sea ecosystems and their living marine resources.

1.2. General objectives

The North Atlantic Ocean and its contiguous shelf seas are crucial for the ecological, economic, and societal health of both Europe and North America. For example the Atlantic Meridional Overturning Circulation (AMOC) is a focal point for the effects of climate change, and it plays a key role in the global carbon cycle. In addition both the deep ocean and shelf seas support major fisheries. An overarching property of the ecosystems of the shelf seas and the deep ocean is that they are influenced at the basin scale by a common atmospheric forcing. However there is a significant lack of information at a mechanistic level about how the forcing impacts marine populations and how impending climate changes may alter the ecology and biogeochemical cycling of the basin. Consequently there is pressing requirement to better understand the basin scale processes within the North Atlantic, to be able to predict likely future ecosystem states due to climate change, and to be able to integrate from the basin scale to the local scales the economically important basin shelf systems.

Furthermore, the need for an ecosystem approach to management of marine systems and their services has been clearly identified in all jurisdictions surrounding the North Atlantic basin (e.g. EC (IPTS-JRC 2000 Mega-challenge 2; Marine Strategy Framework Directive (Directive 2008/56); Common Fisheries Policy (Council regulation 2371/2002)), Canada (Fisheries and Oceans Canada, 2007) and the US (Burgess et al., 2005). Consequently, the European Strategy for Marine and Maritime Research (COM(2008)534) prioritises the following cross-thematic research challenges: 1) climate change and the oceans, 2) impact of human activities on coastal and marine ecosystems and their management, 3) ecosystem approach to resource management and spatial planning and 4) marine biodiversity and biotechnology. Addressing and meeting these challenges requires improved, scientific ecosystem-based approaches to conservation of natural resources, coastal zone management, fish stock assessment, management, and regulation, and maintenance of ecosystem health and sequestering of green house gases. These in turn need to be soundly based on genuine understanding of the dynamics of ocean ecosystems and their response to man's activities and natural climatic variation. EURO-BASIN is designed to address these goals and is part of a joint EC / North American research initiative 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 underlying goal of EURO-BASIN is the creation of predictive understanding based on furthering the knowledge base on key species and processes which determine ecosystem dynamics and feed back to climate via carbon sequestration. To this end EURO-BASIN will use a range of approaches: exploiting existing data and filling data gaps through targeted laboratory and field studies as well as the application of integrative modelling techniques. The modelling approaches will range from simple to complex coupled ecosystem models (e.g. N,P,Z,D type), mass balance (e.g. ECOPATH & ECOSIM); dynamic higher trophic levels models (e.g. GADGET), fully coupled lower and higher trophic level models including fisheries and size spectrum models as well as integrated assessment approaches. These models will be used to create an ensemble of ecosystem responses and through an extension of the Integrated Ecosystem Assessment approach further our understanding of the impacts of climate variability on marine ecosystems and the feedbacks to the earth system. The furthering of our process understanding and development and application of this ensemble model approach will allow the projection of future states of key species and ecosystems. This will enable us to assess ramifications of climate and fisheries activities on the population structure and dynamics of broadly distributed, biogeochemically and trophically important plankton and fish species, the latter comprising some of the largest and most valuable fish stocks on earth. Based on these enhanced predictive capacities, the programme will develop understanding and strategies that will improve and advance ocean management. This will enable management to address the combined effects of climate change, species interactions and fisheries on major living resources of the region and thereby contribute to the realization of an ecosystem-based approach to the management of the North Atlantic basin. This approach is a major objective outlined in the revision of the CFP (COM(2009)163). As well, the underpinning of the ecosystem approach to marine management, through the implementation of the Marine Strategy Framework Directive (MSFD, Directive 2008/56) and the Maximum Sustainable Yield (MSY) concept (Green Paper; COM (2006) 360) is agreed upon by WSSD (2002). EURO-BASIN is designed to deliver substantial and necessary input to this process for the North Atlantic and its shelf sea ecosystems.

1.3. Scientific and Technical objectives

Scientific Objectives: The overarching objectives of the EURO-BASIN initiative are to:

i) Understand and predict the population structure and dynamics of broadly distributed, biogeochemically and trophically important plankton and fish species of the North Atlantic and shelf seas.

ii) Assess impacts of climate variability on North Atlantic marine ecosystems and their goods and services including feedbacks to the earth system.

iii) Develop understanding and strategies that will contribute to improve and advance management of North Atlantic marine ecosystems following the ecosystem approach.

In order to achieve these objectives the programme will:

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 to the benthos and the deep ocean. Answering questions such as:

- How will the ecosystem's response to these changes differ across the basin and among the shelf seas?
- How are the populations of phytoplankton, zooplankton, and higher trophic levels influenced by large-scale ocean circulation and what is the influence of changes in atmospheric and oceanic climate on their population dynamics?
- What are the feedbacks from changes in ecosystem structure and dynamics on climate?

2) Identify how **life history strategies and vital rates and limits** of key ecosystem and biogeochemical players contribute to observed population dynamics, community structure, and biogeography? Answering questions such as:

- How are life history strategies affected by climate variability?
- How will life history strategy influence the response of key species and populations to anthropogenic forcing and climate change?

3) Assess how the **removal of exploited species** influences marine ecosystems and sequestration of carbon? Answering questions such as:

- Under what conditions can harvesting result in substantial restructuring of shelf or basin ecosystems and initiate regime shifts/alternate stable states?
- Do such changes at higher trophic levels cascade to influence the level of autotrophic biomass?
- What is the potential impact of changes in ecosystem structure; composition and size on the sequestration of carbon?
- How is the resilience of the ecosystem to other drivers such as climate affected?

4) **Improve the science basis for ecosystem based management targets** outlined in the EC Common Fisheries Policy (CFP), the Marine Strategy Framework Directive (MSFD), the European Strategy for Marine and Maritime Research (COM(2008)534) and the Integrated Maritime Policy for the European Union(COM(2007)575). Answering such questions as:

- What are the potential economic impacts of changes in climate and resource exploitation on the North Atlantic carbon cycle?
- What is the future potential distribution and production of key fish stocks based on climate change projections and what are the implications for sustainable fisheries?

- How can the CFP ensure consistency with the MSFD and its implementation and how can it support adaptations to climate change and ensure that fisheries do not undermine the resilience of marine ecosystems?
- How can management objectives regarding ecological, economic and social sustainability be defined in a clear, prioritised manner giving guidance in the short term and ensuring the long-term sustainability and viability of fisheries?
- How can ecosystem and species indicators and targets as well as harvest control rules for be defined to provide proper guidance for implementation in management plans and decision including accountability? How should timeframes be identified for achieving targets?

Technical Objectives: For the purposes of this section technical objectives are considered to be the development of new tools. These are as follows:

DATABASE Integration: EURO-BASIN in collaboration with initiatives in the US and Canada (see letters of support in Appendix 1) will develop protocols and methods to consolidate and integrate long-term observations from EC and international databases for modelling and prediction of the Atlantic Ocean ecosystem and related services. EURO-BASIN will build on best practices and technologies developed by European and international data management initiatives and will engage with DFO in Canada and BCO-DMO and NOAA in the U.S.A. to integrate North Atlantic and shelf seas ecosystem data at the basin-scale.

Development of an Integrative Modelling Framework: EURO-BASIN will in conjunction with advanced process understanding and rate parameterizations create a hierarchy of ecosystem and biogeochemical models having as the core the Nucleus for European Modelling of the Ocean **(**NEMO) as the ocean dynamics component for the EURO-BASIN integrative modelling. NEMO is a state-of-the-art modelling framework for oceanographic research, operational oceanography seasonal forecast and climate studies. It provides a consistent version control code, which can be run at both global and regional scales and both eddy resolving and eddy permitting resolutions. We will use NEMO as the general circulation model, with common forcing to harmonise the physical environment the various ecosystem models are coupled to facilitate the analysis and inter-comparison of different ecosystem models driven by common scenarios. In order to examine ecosystem and biogeochemical dynamics an ensemble of simulations will be performed using a range of simple and more complex ecosystem model, each with a NEMO coupler. This will allow us to build up a multi-model multi-scenario 'super-ensemble'.

1.4. Progress beyond the State of the Art

Research area: State of the Art

The interaction of climatic forcing, ocean circulation and changes in greenhouse gas concentrations influence the dynamics of the thermohaline circulation of the North Atlantic, a factor that has being identified as a key influence on global climate (e.g. Sutton and Hodsen, 2005). Changes in the physical environment of the North Atlantic basin have been linked to fluctuations in the population dynamics of key mid trophic level species and exploited fish stocks in the basin itself as well as on associated shelves (e.g. Beaugrand *et al.*, 2003, 2005). Moreover, these climatic changes have been linked to the timing of the spring bloom (e.g. Reid *et al.*, 2001) thus having the potential to influence the match or mismatch of early life history stages of fish and copepods with their prey (e.g. Cushing, 1990). There are a number of key species distributed across the EURO-BASIN region (e.g. Heath *et al.*, 1999, Helaoueet and Beaugrand, 2007), which have been and will be impacted upon by these changes. For example, large - scale shifts have been observed in portions of the species ranges of key copepod species with impacts on higher trophic levels (e.g. Beaugrand, 2005). Changes in distribution and trophic interactions resulting from these shifts in the geographic range of ecosystem components have the potential to result in alterations of ecosystem resilience and productivity due to loss of critical habitat and changes in food web structure.

Adding further stress to the system, overfishing on higher trophic levels has resulted in fisheries in many parts of world switching to the harvest of lower trophic levels (Pauly *et al.*, 1998). In the North Atlantic this has a structuring effect as manifested by trophic cascades. Trophic cascades are the signature of indirect effects of changes in the abundance of individuals in one trophic level on other trophic levels (Pace *et al.* 1999). Trophic cascades can occur when the abundance of a top predator is decreased, releasing the trophic level below from predation. The released trophic level reacts by an increase in abundance, which imposes an increased predation pressure on the next lower trophic level, etc. In the case of marine systems, the outside perturbation often stems from fishing, but may also be influenced by changes in productivity caused by changes in the environment. Trophic cascades had not been thought to occur in marine systems (Steele, 1998), but recently trophic cascades have been demonstrated in several large marine systems: the Black Sea (Daskalov *et al.*, 2007), the Baltic Sea (Casini *et al*., 2008; Möllmann *et al.,* 2008) and parts of the Northwest Atlantic Frank *et al.,* 2005, 2006; Myers *et al.,* 2007). These trophic cascades have been observed to cover up to four trophic levels and reach all the way down to primary production. Despite the evidence for trophic cascades in some systems, trophic cascades appear to be absent in other systems, even though they are heavily perturbed by fishing—in particular, the North Sea (Reid *et al.,* 2000). The presence or absence of trophic cascades can be attributed to high temperature (which leads to faster growth rates and therefore less sensitivity to fishing) or to a higher diversity that stabilizes the system (Frank *et al*., 2007). Frank *et al*., 2007 stated that cold and species-poor areas such as the North Atlantic might readily succumb to structuring by top-down control and recover slowly (if ever) whereas, warmer areas with more species might oscillate between top-down and bottom-up control, depending on exploitation rates and, possibly, changing temperature regimes.

Critically for feedbacks to climate, the characteristics of trophic webs largely determines the fate of biogenic carbon, in particular its export below the euphotic zone, either by the sinking of particles or by the diel vertical movements of the organisms (Wilson *et al*., 2008). This is of fundamental importance for the climate system as the biological CO_2 pump in the ocean is one of the major sinks of atmospheric CO_2. These feedback processes, linking bottom up and top down processes, cannot be understood and described without an effective understanding of the links between lower and higher trophic levels, as well as with the biogeochemical cycles. Thus, to develop scenarios of the future, it is important to understand and capture the interactions between climate, ecosystem dynamics and fisheries production.

One of the major issues in marine science is understanding and providing predictive advice regarding how food webs are controlled or regulated by their environment and human activities. The ability to predict the emergent properties (e.g. carbon sequestration, biodiversity and production of exploited resources such as fish stocks) of the complex adaptive interactions within the food webs (St. John *et al*., 2010) has important implications for the management of marine resources, both for harvesting these resources and protection of species. The characteristics of food webs and their constituent species are ultimately the result of interactions between species with physical forcing, ocean biogeochemistry and system characteristics (e.g. Lehodey *et al.*, 2006). However, deterministic predictions of species or ecosystem responses have proven difficult (e.g. Myers, 1998). Short-term predictions of system characteristics based on the application of intermediate complexity models are however plausible (e.g. Hannah *et al.*, 2010; Allen and Fulton, 2010). These approaches are able to capture prominent system features however resolving the magnitude of the response is elusive. In part this is the result of the dynamic nature of the interactions within food web (e.g. Levin, 1998; Link, 2002; St John *et al*., 2010). In essence there is no "ecological steady state" upon which long term deterministic predictions can be based "physics and chemistry set the boundaries while biology finds the loopholes" (St. John *et al.,* 2010). Due to the complexity of interactions, ecosystem and key species dynamics need to be explored via controlled experiments, through the extensive use and extension of mathematical models and their iteration and comparative ecosystem analyses (Murawski *et al*., 2010).

Mathematical models follow a number of approaches to examine the dynamics of ecosystems and species. The limiting nutrient approach, based on Redfield stoichiometry or a modification is the core of most coupled hydrodynamic ecosystem models which are used to assess bottom up controls on ecosystems and biogeochemistry (e.g. Allen *et al*., 2001). Simple NPZD schemes (incorporating one nutrient term, one primary producer, one consumer (zooplankton), and one detritus) employed since the late eighties (e.g. Fasham *et al*., 1990) may often capture bulk properties and the essential dynamics of events such as the North Atlantic bloom. This description can be elaborated somewhat (3N2P2Z2D models, for instance, Aumont *et al*., 2003) and may begin to capture certain key feedbacks in much of the world ocean. However, in order to describe the multidimensional behaviour of ecosystems and their interaction with many interlinked biogeochemical cycles, the degree of elaboration may have to increase substantially (Hood *et al*., 2006).

Size spectrum approaches, based upon the distribution of biomass by size have been used to develop relationships between biomass spectrum slope, community assimilation efficiency and trophic structure (i.e. Basedow *et al.,* 2009). Relationships with biomass spectra have been found to be consistent with observed water types, current systems, and trophic players, even in closely associated locations such as shelf and off-shelf waters (Zhou *et al*., 2009). The mass balance approach, is based upon the flow of biomass between compartments, popular examples are ECOSIM an ECOPATH (e.g. Pauly *et al.,* 2000). This class of model solves a set of linear equations representing the steady state annual flux of biomass taxa in a feeding network, predicated on some assumptions or data on consumption/biomass or production/biomass ratios. ECOPATH uses sets of diet data, mainly for upper trophic levels, to compute mass-balanced fluxes of biomass between components of a food web. Finally, species interaction models, primarily the domain of fisheries scientists, include models such as the MSVPA and GADGET (Begley and Howell, 2004). The MSVPA, as an example calculates the fishing mortality at age, recruitment, stock size, suitability coefficients and predation mortality based on catch-at-age data, predator ration and predator diet information. The MSVPA allows the estimation of vital population rates and is used in the management of fishing resources. Recently spatially explicit fish life cycle models linked to hydrodynamic models (e.g. Huse, 2005) have been developed.

Each of these approaches has strengths as well as weaknesses (e.g. St. John *et al*., 2010) one of the most important weaknesses is their inability to capture the complex and adaptive nature of interactions within the food web (e.g. Levin, 1998). Attempts to circumvent this problem require increasing model complexity by adding more compartments or processes. A fundamental problem is to find the appropriate level of complexity that will enable ecosystem models to have most skill predicting biogeochemical fluxes (Fulton *et al*., 2003). We must bear in mind that level of complexity also depends on how well we can parameterise interactions; the quest for greater detail has to be tempered by our ignorance of the ecology of the organisms in question (e.g. Allen and Fulton, 2010). Critically as outlined by Murawski *et al*., (2010) and St. John *et al*., (2010) all of the approaches outlined above require the advancement of process knowledge and model parameterizations in particular necessitating controlled experiments. These experiments need to assess an organism's vital rates (e.g. growth, reproduction, mortality) and physiological limits (e.g. Pörtner and Farell, 2008) as well as their ability to modify these rates, which are critical for reproductive success. Furthermore, field observations are necessary in order to identify the habitats utilized by key species (e.g. Beaugrand *et al*., 2003). Their identification in conjunction with information on the effects of abiotic constraints on vital rates allows the future projection of habits using hydrodynamic modelling tools thus giving clues as to the future structure and function of marine ecosystems.

To provide a holistic impression of past ecosystem changes the aggregated approach of Integrated Ecosystem Assessments (IEAs) is being increasingly employed. IEAs are essentially multivariate statistical analyses (e.g. Principal Component Analyses, Canonical Correlation Analyses) of large data sets integrating knowledge on spatial and temporal trends of all important ecosystem components and driving forces. Examples exist for the northwest Atlantic ecosystems of Georges Bank US (Link *et al*., 2002) and the Scotian Shelf (Choi *et al*., 2005) as well as the North Sea and Baltic Seas (Möllmann *et al*., 2009; Kenny *et al*., 2009; Lindegren *et al*., in press). IEAs provide i) a possibility to visualize ecosystem changes using the "traffic light approach" used in fisheries management, ii) aggregated indicators of ecosystem change which can be used to investigate structural ecosystem changes such as "regime shifts", "trophic cascades" and "oscillating controls" (Frank *et al*., 2005; Hunt *et al*., 2002; Litzow and Ciannelli, 2007), iii) to identify the major drivers of change (Möllmann *et al*,. 2009), and iv) to derive indications on the functional relationships between the most important ecosystem players as well as biotic and abiotic drivers.

Research themes: State of the Art

EURO-BASIN represents the first major multidisciplinary programme focused on creating predictive understanding of key species and the emergent ecosystem and biogeochemical features of the North Atlantic basin in order to further the abilities to understand predict and contribute to the development and implementations of the ecosystem approach to resource management. In order to keep the programme tractable EURO-BASIN is focused on pelagic processes and species with broad distributions utilizing the North Atlantic pelagic open ocean and regional seas (Figure 1). Activities are focused on key species or groups (as defined by their relevance for ecosystem functioning, biogeochemistry and resource exploitation) occurring or interacting with the euphotic zone. The areas with specific sampling activities to identify and quantify interactions, vital rates and habitats for the advancement of ecosystem modelling activities are shown in the cover page. Modelling activities to advance predictive capacities are focused on the North Atlantic basin proper as well as the European regional seas (i.e. Iceland; Greenland; Norwegian Sea; Barents Sea; North Sea and the western European continental shelf.

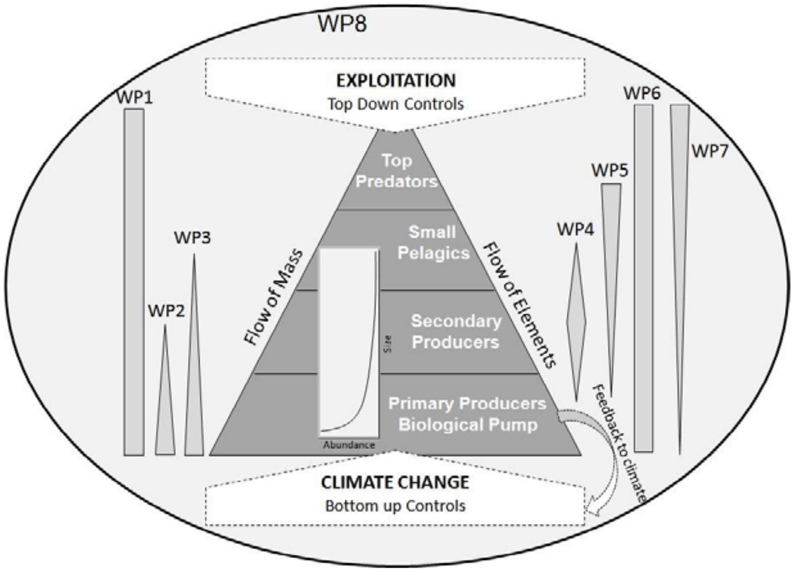


Figure 1 EURO-BASIN metrics of modelling and assessing ecosystem characteristics, the stressors influencing the trophic cascade from prmary producers to top predators as well as the domain and distribution of effort in the various WPs in EURO-BASIN.

Ecosystems represent complex networks of interacting species (e.g. Link et al., 2002), some of which perform critical structuring functions in the system (e.g. keystone species). Furthermore some groups typify specific oceanographic regimes (i.e. diatoms; microbial loop). In order to keep the programme tractable, EURO-BASIN focuses on a number of key groups characterizing food web types e.g. diatoms versus the microbial loop players; key species copepods of the genus *Calanus* co-exist in the North Atlantic which have been linked to the dynamics of higher trophic levels; the small pelagic fish, herring (*Clupea harengus*), mackerel (*Scomber scombrus*) and blue whiting *(Micromesistius poutassou*) which are the most abundant in the system, having the ability to structure lower trophic levels; piscivorous pelagic fish bluefin tuna (*Thunnus thynnus*) and albacore (*Thunnus alalunga*) which inhabit the whole North Atlantic basin, and carry out large transatlantic migrations. Uniquely, EURO-BASIN will establish and quantify the links between these trophic levels and assess the implications of changes in the players on the flux of carbon.

In order to link ecosytems and key species to carbon flux EURO-BASIN follows a trophic cascade framework, quantifying the flow of mass and elements between key species and groups and a size spectrum approach both of which are used to assess the emergent properties of ecosystems, create metrics for the prediction of future states and contribute to the assessment and implementation of an ecosystem approach for the management of exploited resources. Figure 1 illustrates the various metrics of modelling and assessing ecosystem characteristics, the stressors influencing the trophic cascade from primary producers to top predators as well as the domain and distribution of effort in the various WPs in EURO-BASIN. As depicted in Figure 2 is composed of a number of research themes and technical activities. The state of the art with respect to these areas and advances in the state of the art are as follows:

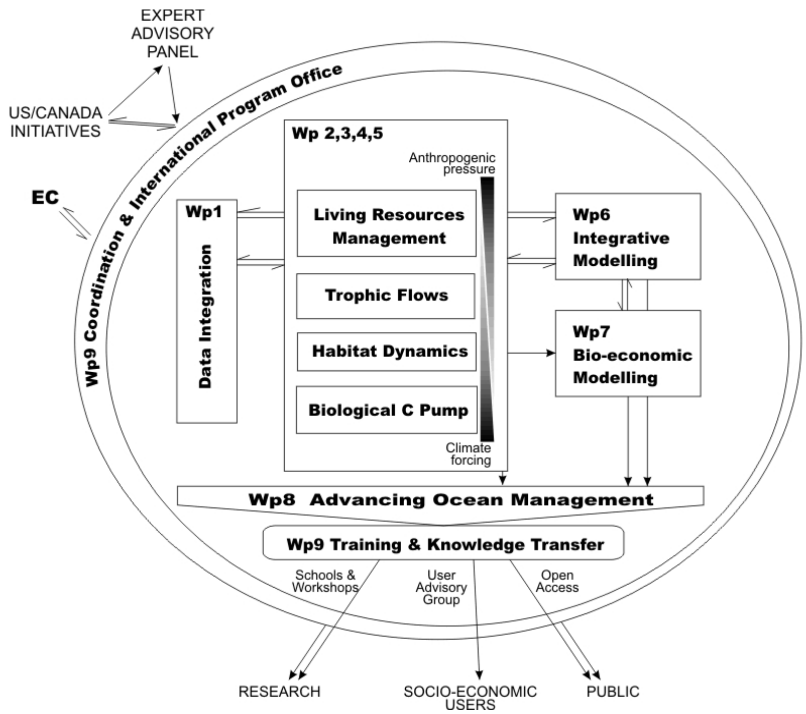


Figure 2. The structure and interactions of EURO-BASIN. For more details on strategies for International collaborations see B3.1.3

1.5. S/T Methodology and Associated Work Plan

The project follows a logical structure and timelines shown in Charts 1 and 2; the first WP serves as a source of data for retrospective analyses performed in subsequent WPs. The next four WPs proceed from biogeochemistry to upper trophic levels, each perform retrospective analyses, acquire new data to further process understanding, developing process indicators for use in WP7&8, advanced process model parameterization for transfer and implementation in WP6 integrative modelling. The modelling tools in WP6 are then used to perform simulations, which are subsequently utilized in WP7 for bio economic modelling. The final scientific WP8, focuses on furthering Ocean Management. WP9 serves to coordinate activities both within the programme as well as liaison with International partners.

WP1. The primary objective is to develop methods to consolidate and assess datasets as well as to integrate long-term observations from European and international databases and use these methods to assemble historical data, new field observations and experimental results into comprehensive datasets.

WP2. Activities involve the performance of field and mesocosm studies examining how environmental conditions including plankton community structure (size and composition) and grazing drive aggregate formation, stability and sinking rate. These will be combined with literature data to generate new particle flux algorithms, which will be tested in 1Dmodels of plankton ecology and particle flux within the WP and then transferred to WP6 for advancement of the modelling tools.

WP3. This WP resolves the oceanographic habitats utilized by key biogeochemical and ecosystem species characterizing community size structure and habitat characteristics. This is achieved by the performance of retrospective analyses and field studies using dedicated cruise programmes provided by National agencies as well as ships of opportunity programmes.

WP4. The overall objective of this WP is to quantify, the key processes controlling the flow of carbon and energy within the plankton in the North Atlantic ecosystems. Information obtained via field and laboratory studies will be used to develop advanced parameterizations for use in WP6 and develop ecosystem and key species indicators for use in WP8.

WP5. Activities determine the role of key fish stocks on ecosystem structure and the determination of how carrying capacity and trophic controls may change with changing climate and impact on the production and role of economically and trophically important key fish stocks. The WP provides advanced model parameterizations for modelling activities in WP6 as well as simulations on the impact of fishing on ecosystems and key species by fully coupled hydrodynamic, lower and higher trophic level regional models to be used in WP7 for bioeconomic modelling and in WP8 for testing various fisheries management options under climate change.

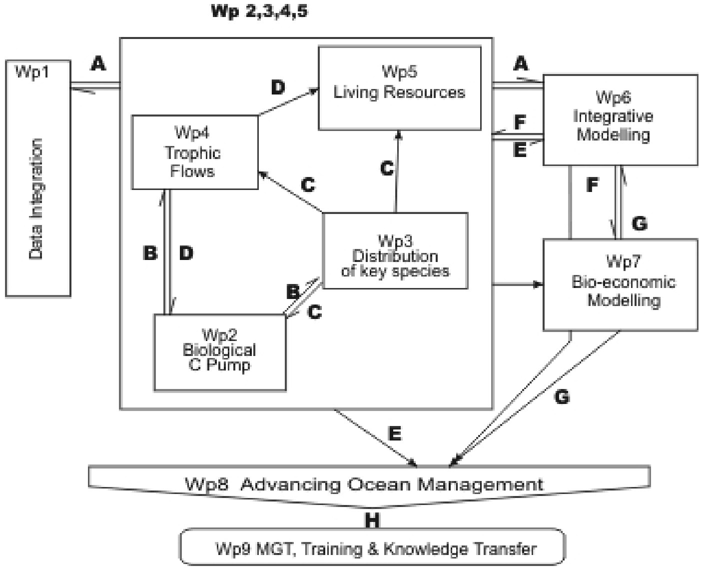
WP6. This WP advances existing modelling tools based on process understanding obtained in WP1-5 and provides model output and indices for use in WP7 & 8. It employs a basin-scale modelling approach, simulating the response of marine ecosystems by considering four classes of experiments using coupled physical-biogeochemical-MTL models: re-analysis forced simulations, climate-scenario forced simulations, top down control perturbation experiments and a fully coupled end to end ecosystem model. The WP receives validation data and new parameterizations from earlier WP and provides simulation outputs to WP7 and 8.

WP7. The overall objective of WP6 is to “assess the impacts of Global Environmental Change (GEC), including climate change, fisheries management and market developments, on the productivity, dynamics and services of basin-wide fish commodities. The WP takes advantage of data, information and advanced process and regional models and size spectra information developed in WP1-5 and implemented in WP6.

WP8. This WP, based on information from the preceding WPs, develops understanding and approaches that will improve and advance ocean management by strengthening the ecosystem approach to resource management. The WP applies size spectrum, mass balance and ecosystem models and integrated assessment approaches to test and develop predictive capacities. Activities also assess the present recommended approaches for the implementation of an ecosystem approach to the management of marine resources (e.g. setting indicators of good ecological status within the MSFD and target indicators in harvest control rules of fisheries plans under the CFP) for their robustness against climate change allowing an assessment of the applicability of existing EC management measures and directives. Finally, the WP assesses the economic impact of climate change and resource exploitation on the North Atlantic carbon cycle.

WP9. The actions performed by WP9 serve to coordinate and manage activities within EUR-BASIN, as well as interact with international partners and reporting to the EC.

Chart 1. EURO-BASIN PERT Chart. Letters indicate the links between WPs as defined:



WP1 provides historical data rescue and products for retrospective analysis in WP2-WP5 and modelling WP6; in return WP1 archives all observational data and modelling output.

A. WP2 will provide retrospective analysis (input from WP1) and generate new observations (see Section 'B2.4 Resources to be committed' for EURO-BASIN dedicated field campaigns) on lower trophic levels ecosystem structure for habitat mapping (input to WP3) and constraining physiological vital rates and improved particle flux modelling (collaboration with WP4 and 6)
B. WP3 will provide retrospective analysis (input from WP1) and develop geographic habitat maps within which vital rates will be better constrained (WP4). WP3 will also provide prey fields for those key habitats to feed into WP5 and for basin-scale modelling in WP6.
C. WP4 will constrain key trophic flows (in collaboration with WP2) within the key habitats identified (WP3). WP4 will provide prey fields vital rates to WP5 and enhanced modelling parameterisation for WP6.
D. WP5 will use prey fields input, in terms of biogeography (WP3) and physiology (WP2 & 4), as well as retrospective analysis (WP2-5) and assess the dynamics of exploitable living resources under climate and anthropogenic pressure. WP2-5 provide ecosystem and key species indicators to WP6,7 & 8;
E. WP6 will simulate changes in ocean carbon storage, habitat evolution and dynamics exploitable resources under impact of climate and anthropogenic pressure, to test the effect of fisheries management strategies on biogeochemical cycling and the biological carbon pump (WP2-5).
F. WP7 will estimate the economic cost of sub-optimal basin-scale North Atlantic fisheries management and develop a bio-economic model of fish commodities linking supply (ecosystem) and demand (exploitation). WP7 feeds input to WP8 and receives simulation output from WP 6 and validation data from WPs 1-5.
G. WP8 Advancing Ocean Management integrates observational and retrospective analysis (WP2-5) and biogeochemical and ecosystem indices (WP6) to assess the basin-scale applicability of EC management measures and directives (e.g. Common Fisheries Policy, Marine Strategy Framework Directive) as well as provide scientific recommendations.

APPENDIX 2. US EXISTING PROGRAMS RELEVANT TO BASIN

In addition to entertaining new proposals, NSF and NOAA have also encouraged investigators with existing BASIN-related projects to participate in the program. There are a number of existing and anticipated efforts supported by NSF, NOAA, NASA, and other agencies in the US that will allow close collaboration with the proposed BASIN program. Table 3 is a list of existing US Projects and Programs relevant to BASIN that represent complementary activities.

Table 3. Existing US Projects and Programs relevant to BASIN

AMOC: Atlantic Meridional Overturning Circulation Program is an interagency program in support of the US National Science and Technology Council's Joint Subcommittee on Ocean Science and Technology (JSOST) to study the Atlantic Meridional Overturning Circulation.
NERACOOS: Northeastern Regional Association of Coastal Ocean Observing Systems (http://www.neracoos.org/) – A NOAA IOOS funded association for ocean observing between New York and Nova Scotia, which includes both U.S. and Canadian scientists.
MARCOOS: Mid-Atlantic Regional Coastal Ocean Observing System Association (http://www.marcoos.org/) – A NOAA IOOS funded association for ocean observing between New York and Virginia.
OOI: Ocean Observatories Initiative (http://www.oceanleadership.org/programs-and-partnerships/ocean-observing/ooi/) – A NSF funded program of science-driven sensor systems to measure the physical, chemical, geological and biological variables in the ocean and seafloor. Specific to BASIN, there are sites on the northeast U.S. continental shelf and in the Irminger Sea.
NOAA/CPO: Climate Program Office –(http://www.oco.noaa.gov/) - Builds, sustains, and coordinates a global climate observing system with a wide variety of assets in the North Atlantic including U.S. contributions to the Global Drifter Program, support for high density XBT lines across the North Atlantic, and pCO2 measurements on NOAA and merchant vessels.
NOAA FATE: Fisheries And The Environment (http://fate.nmfs.noaa.gov/) – Improves single species and ecosystem assessments across the US. There are several projects in the North Atlantic including habitat modeling of fishery species, integrative modeling focused on cod recruitment, and work examining the dynamics of Atlantic herring. A number of other relevant proposals were recently submitted to the 2010 funding call.
BCO-DMO: Biological and Chemical Oceanography Data Management Office (http://www.bco-dmo.org/) – Supports the scientific community through improved accessibility to ocean science data. The BCO-DMO provides continuing curatorship for the US GLOBEC and US JGOFS data repositories as well as several others, which are highly relevant to the BASIN program.
CAMEO: Comparative Analysis of Marine Ecosystem Organization (http://cameo.noaa.gov/) - A partnership between the NOAA and NSF that supports fundamental research to

understand complex dynamics controlling ecosystem structure, productivity, behavior, resilience, and population connectivity, as well as effects of climate variability and anthropogenic pressures on living marine resources and critical habitats. There are currently two funded projects and a funded post-doc that are relevant to the BASIN program as well as several submitted proposals that are under consideration for funding in 2010.
NOAA/NEFSC: The Northeast Fisheries Science Center (http://www.nefsc.noaa.gov/) – Responsible for the assessment, conservation and protection of living marine resources within the northeast United States' Exclusive Economic Zone (water three to 200 mile offshore). There are a number of activities relevant to BASIN including fishery and oceanographic observing programs (trawl survey, EcoMon, SOOP-CPR), data integration and management activities, measurements of vital rates and habitat, trophic and food web modeling, population modeling, and a wide variety of bioecomic modeling and ocean management activities. Most of the programs are ongoing.
US GLOBEC: US Global Ocean Ecosystems Dynamic Program (http://www.usglobec.org/) - a multi-disciplinary research program that examines the potential impact of global climate change on ocean ecosystems. The Georges Bank / NW Atlantic GLOBEC Program was one of three national level programs which was funded during the 1990's. The national program is now in a Pan-synthesis phase with several funded projects working in the North Atlantic that are highly relevant to the BASIN program.
CINAR: Cooperative Institute for the North Atlantic (http://www.whoi.edu/page.do?pid=30715) - Conducts and coordinates cutting-edge research engaging both NOAA and academic scientists to enable informed decisions by NOAA for sustainable and beneficial management of the northwestern Atlantic shelf ecosystem. There are numerous activities underway by CINAR members that are relate to the EU BASIN program
COML: Census of Marine Life (http://www.coml.org/) – An international effort to assess and explain the diversity, distribution, and abundance of life in the oceans. As part of COML, a program was established in the Gulf of Maine; the goal of this regional program is to advance knowledge of both biodiversity and ecological processes over a range of habitats and food-chain levels, from plankton to whales
BATS: Bermuda Atlantic Time-Series Study (http://bats.bios.edu/) – A funded program south of Bermuda that maintains deep-ocean time-series, with a focus on the importance of biological diversity in understanding biological and chemical cycles and in particular the Biological Carbon Pump.

APPENDIX 3 CANADIAN BASIN ACTIVITIES

The Department of Fisheries and Oceans (DFO) has as a major priority for both the Maritimes and Newfoundland regions of DFO to describe and understand coupled ocean and shelf processes in order to assess and predict the impact of climate variability and climate change on marine ecosystems and exploitable resources. This is in agreement with the overarching aim of BASIN and provides a solid basis for cooperation. Under the BASIN umbrella, DFO is pursuing a number of initiatives that could become contributions and the following lists projects under the major components of the BASIN Science Plan (Table 4). These initiatives have varying levels and duration of approved funding, from the proposal stage for some to current multi-year funding for others. Resources invested in each activity are in dollar-equivalent are per year. For example, the Canadian Atlantic Zone Monitoring Program (AZMP; http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html) and Canadian Atlantic Zone Offshore Monitoring Program (AZOMP; http://www.bio.gc.ca/monitoring-monitorage/azomp-pmzao/index- eng.htm) are conducting monitoring relevant to BASIN including transects, fixed stations, and ground fish surveys on North Atlantic Canadian shelves and the offshore monitoring program in the Labrador Sea. Satellite remote sensing studies include ocean color, sea surface temperature, sea surface altimetry and primary production. The Continuous Plankton Recorder (CPR) surveys are coordinated with EU and US colleagues for spatial distributions and relative abundances of key plankton species, community structures and diversities that are relevant to BASIN. In addition, there are "teleost" trips in spring and summer, and a Hudson cruise in the fall. The ecosystem research initiative is designed to enhance surveys in Newfoundland and Labrador Shelves and Labrador Sea system (NL), and to identify and track main pathways for energy flow in the NL system. There are ongoing basin-scale modeling activities on water masses, circulation and plankton–fish populations, and platform-sensor development. Finally, there are opportunities for international collaborators to participate in the cruises, data analyses and data interpretation.

Table 4. Existing Canadian Projects and Programs relevant to BASIN

Modelling
• Climate variability and shelf-ocean coupling: NEMO at global (1 deg), basin (1/4 deg) and shelf (1/12 deg). Simulations from 1950 to present. *Contacts:* Youyu Lu and Dave Brickman; *Resources:* $100K (computer equipment depreciation) + $100K (personnel) (approved to 2010, with possible follow-on)
• Climate change simulations: dynamical downscaling of atmospheric scenarios to the ocean shelf model. Simulations from 1970 to 2070 . *Contacts:* Joel Chasse, Will Perrie; Resources: $100K (computer equipment depreciation) + $100K (personnel), (approved 2008-2011, with possible follow-on)
• Physical-biological modelling: coupling of shelf model with simple NPZ. *Contacts:* Alain Vezina, Diane Lavoie Resources:$25 K (equipment / depreciation) + $40K (personnel) (approved to 2011).
• Ecosystem modelling: Bioenergetic modelling of the coupled pelagic-benthic ecosystem. *Contacts:* Alida Bundy, Mariano Koen-Alonso. *Resources:* $30K (operations) + $100K (personnel) (approved to 2011).

Retrospective/reanalysis
• Assessment of climate change and impacts in the NW Atlantic: analysis and synthesis of existing data supported by CCSI and IGS. *Contacts:* John Loder**.** *Resources:* \$30K (vessels) + \$100K (operations and computer/field equipment depreciation) + \$100K (personnel), confirmed through 2011 only
• Compilation and synthesis of ecosystem data to support assessments of fishng and climate impacts. *Contacts:* Ken Frank, Bill Li. *Resources:* \$15K (operations) + \$100K (personnel) (Ongoing research plus support from DFO programs confirmed to 2010-2011).
Observations
• Labrador Sea Line (AR7W) Monitoring: occupied once a year, with measurements of physical, chemical and biological properties across deep Labrador basin and both the Greenland and Labrador shelves. Long-term near-bottom current-meter mooring on Labrador Slope. Piggy-back opportunity for additional sampling such as eddies and ocean acidification. Extended Halifax Line Monitoring: occupied once a year with measurements of physical, chemical and biological properties across Scotian Slope and Rise. *Contacts:* John Loder, Glen Harrison. *Resources:* \$480K (vessels) + \$120K (operations and equip depreciation) + \$180K (personnel) (ongoing monitoring with variable funding for add-on research)
• Atlantic Zone Monitoring Program (AZMP): combination of shelf time series and sections that run across the shelf to the continental slope where physico-chemical and lower trophic level variables are measured. The program also includes measurements of these same variables during bi-annual multispecies (ecosystem) surveys to link with higher trophic levels. *Contacts:* Pierre Pepin, Glen Harrison; *Resources:* \$2550K (vessels) + \$480K (operations) + \$540K (personnel) (ongoing monitoring with variable funding for add-on research)
• Ocean climate variability from Argo floats: updated time series of key water mass properties such as Labrador sea Water. *Contact:* Igor Yashayaev; *Resources:* \$120K (floats) + \$30K (personnel) (ongoing monitoring with variable funding for interpretation)
• Ocean SST, SSS, SSH, sea-ice and ocean colour:processing and validation of data from SeaWiFS / MERIS, TOPEX/Poseidon and other satellites, production of imagery / data sets for the NW Atlantic, and research on improvements of algorithms for optically complex waters. *Contacts:* Ed Horne, Peter Smith. Resources: \$100K (equipment/depreciation) + \$50K (operations) + \$180K (personnel) (ongoing monitoring) and \$3350K in research and development (confirmed to 2011).
• NW Atlantic slope currents variability: Since 2000, moored current measurements of 1-6 years duration have been made in several deep-water slope regions with petroleum, climate and/or ecosystem interest. These have included Orphan Basin,

Flemish Pass, Laurentian Fan and the Scotian Slope/Rise. Moorings are presently deployed in the Orphan Basin/Knoll, Laurentian Fan and Scotian Rise (as part of UK RAPID) regions, and are expected to be re-deployed in the latter two regions for at least one more year. There is potential for planned analyses for seasonal and interannual variability in subpolar gyre currents and water masses to be a contribution to BASIN. *Contacts:* John Loder and Blair Greenan; *Resources:* $480K (vessels) + $250K (operations and equip depreciation) + $100K (personnel) (funded through 2010-11, with possibility of follow-on).
• Ocean Tracking Network: deployment of gliders along Halifax lines with physical and biological sensors. *Contact:* Peter Smith. *Resources:* $250K (vessel time) + $250K (equipment) + $150K (personel) (funding confirmed to 2012).
• Data management and integration: The data generated by these programs are processed, quality-controlled and entered systematically in DFO-managed databases. With respect to BASIN data integration objectives, DFO is investing and participating in the development of standards that facilitate interoperability and international exchange of data (e.g. IOC/IODE). We are already in touch with the leader of the Data integration WP (Stephane Pesant) and will cooperate with the effort to integrate data sets across the N Atlantic basin. *Contact:* Mary Kennedy; *Resources*: $70K (operations) + $100K (personel).