

## IMPLEMENTING THE GALWAY STATEMENT ATLANTIC OCEAN RESEARCH ALLIANCE

### EU-Canada-US Ecosystem Approach to Ocean Health and Stressors Working Group

### Inventory of Major Canadian, European, and US research activities/projects on ecosystem approach to ocean health and stressors with regard to the North Atlantic



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## Summary

This inventory of research projects focuses on the AORA working group area of Ecosystem Approach to Ocean Health and Stressors. It provides a background to the research area and then an inventory of research projects and initiatives in the North Atlantic. It is the deliverable 4.1 in the AORAC-SA project which supports AORA.

It considers the broad subject of ecosystem approach to ocean health and stressors through eight knowledge themes:

- 1: Methods for developing indicators and targets for biodiversity
- 2: Techniques for assessment that account for differences in scale and resolution of monitoring and management
- 3: Management tools to support the ecosystem approach
- 4: Ecosystem structure and functioning
- 5: Carrying capacity, ecosystem tipping points, and ocean stressors
- 6: Cumulative effects
- 7: Analysis of social and economic consequences of management actions
- 8: Maintaining the legitimacy and credibility of science for evidence based policy

A total of 44 project were examined. The inventory will show that numerous projects focus on “technique for assessment” and “management tools” topics. This reflects the emerging need to take into account governance, policy, economic as well as social and natural science challenges to balance sensibly, goods and services of the ecosystem with pressures and impacts. However research into interactive and cumulative effects of multiple stressors as well as carrying capacity and ecosystem tipping points are largely absent from the 44 projects reviewed.

## Background

### AORAC-SA Transatlantic Working Group on ecosystem approach to ocean health and stressors

The Ecosystem approach (EA or Ecosystem-based management, EBM), is an approach that goes beyond examining single issues, species, or ecosystem functions in isolation. Instead it recognizes ecological systems for what they are: a rich mix of elements that interact with each other in important ways (UNEP, 2011)EA offers a set of principles by which to manage human activities that impact and extract services from the marine ecosystem.

EA integrated approach to management which considers a cross sectoral issues to managing the priority stressors to the system. A key principle is that EA management is based on evidence and understanding of ecological and social systems. EA is requires a knowledge or evidence based process.

By building management from a foundation of the best available knowledge, EA process considers the most appropriate scale for a considered prioritization of management actions and activities.

At the Atlantic Ocean scale and in order to increase coherence and coordination of ocean research cooperation, the Galway Statement establishes a formal Atlantic Ocean Research Cooperation between Canada, the European Union, its Member States, the United States of America that builds on existing initiatives and programmes.

**The Atlantic Ocean Research Alliance (AORA)**<sup>1</sup> is responsible for implementing the Galway Statement. This Statement establishes a formal Atlantic Ocean Research Cooperation between the European Union, its Member States, the United States of America and Canada and partner countries that builds on existing initiatives and programmes to increase coherence and coordination of ocean research cooperation. The following six priority research areas adopted by the Atlantic Ocean Research Alliance were identified in the Galway Statement:

- Marine ecosystem-approach
- Observing systems
- Marine biotechnology

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<sup>1</sup> <http://www.atlanticresource.org/aora/>



*The Atlantic Ocean Research Alliance Coordination & Support Action has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 652677.*

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- Aquaculture
- Ocean literacy - engaging with society
- Seabed and benthic habitat mapping

In each theme, specific issues are identified, and for some working groups have been established.

**The AORAC-SA, a Coordination and Support Action project of the AORA**, will establish complementarities between EU-US-CA activities that will lead to greater integration of research actors and activities, and tackle scientific and industrial challenges in strategically important areas of ocean observation in the North Atlantic and adjacent Seas and Oceans.

The Coordination and Support Action project addresses the specific challenge, scope, and expected impacts by providing a fit-for-purpose mechanism to build dialogue, share knowledge, and facilitate a better mutual understanding between the different North Atlantic scientific communities, cultures, and societies in order to tackle major societal challenges, underpin policies, and stimulate innovation. This mechanism will further support and accelerate the implementation of EU marine policies, including the Blue Growth Strategy.

Furthermore AORAC-SA project brings together a unique partnership of European Marine Research Programming and Funding Organisations (RFOs) and Research Performing Organisations (RPOs) whose active engagement, participation and input is critical to the success of future trans-Atlantic Ocean Research Cooperation. These include the International Council for the Exploration of the Seas (ICES), The Joint Programming Initiative Healthy and Productive Seas and Oceans, the Intergovernmental Oceanographic Commission (IOC) and the World Ocean Council (WOC). In addition to these high-level groups, the project includes leading European Research Institutes who will be responsible for the delivery of expert assessments and mapping of European research capabilities, including industry needs and research gaps, in identified priority areas, and who will ultimately be the main research actors in trans-Atlantic research cooperation.

Building on the proposed structure and partnership, this partnership will contribute significantly towards the achievement of the identified and expected impacts:

- Support the implementation of the Galway Statement on an Atlantic Ocean Research Alliance.
- Improve the international cooperation framework of marine research programmes thus creating the basis for the development of future large-scale joint international marine research programmes.
- Establish a long-term knowledge sharing platform for easy access to available information and data holding significant commercial potential relevant to the EU Blue Growth Agenda.

## Summary of the first AORAC-SA workshop

The first workshop on the Ecosystem Approach to Ocean Health and Stressors was held from 20-22 January 2016 in the EEA Headquarters, Copenhagen, Denmark<sup>2</sup>.

The three-day workshop addressed questions that are currently challenging the implementation of the ecosystem approach to management as it moves from single to multisector. The workshop created an opportunity for researchers, policy developers, managers, and stakeholders to review concepts and address scientific, institutional, legal, and socio-economic challenges related to operationalizing the ecosystem approach. It also allowed for exchange of experiences, discussion of encountered constraints, and the identification of approaches and strategies to make this approach operational.

The following case studies were presented during the workshop:

- The ecosystem approach in South America: where are we and where are we going?
- Protection of the Canary Current Large Marine Ecosystem in North West Africa.
- Ecosystem-Based Management: A US Perspective.
- Celtic Seas Partnership: demonstrating effective stakeholder engagement as part of the ecosystem approach.

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<sup>2</sup> Read the workshop report:

[www.ices.dk/sites/pub/Publication%20Reports/Project%20reports/2016/AORACSA\\_WP4\\_FAO\\_ICES\\_Ecosystem\\_Approach.pdf](http://www.ices.dk/sites/pub/Publication%20Reports/Project%20reports/2016/AORACSA_WP4_FAO_ICES_Ecosystem_Approach.pdf)

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- A pluralistic approach to EBM implementation in the Caribbean.
- Canada LOMA- Large Ocean Management Areas.
- An uncharted voyage: Ten years of integrated ecosystem-based management in the Barents Sea.
- Making EAM operational in Canadian fisheries management.
- EBM in Australia: National, Regional and Local Approaches.
- The NAFO Roadmap for an Ecosystem Approach to Fisheries.
- Application of Marine Planning to Support Protection of Living Marine Resources in Northeast USA Waters.
- A scientist's perspective of implementation of the EU marine strategy framework directive.
- Applying the ecosystem approach in the North-East Atlantic – initial steps and the challenges of reality.

Each case studies presentation were summarized in the workshop report and all presentations are available on ICES website<sup>3</sup>.

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<sup>3</sup> <http://ices.dk/explore-us/projects/Pages/Making-the-ecosystem-approach-operational.aspx>

## American and Canadian organizations involved with Ecosystem Approach research

### *DFO, CANADA*

Fisheries and Oceans Canada<sup>4</sup> (DFO) is the department within the government of Canada that is responsible for developing and implementing policies and programs in support of Canada's economic, ecological, and scientific interests in oceans and inland waters. In 2005, a decision-making body “the Science Management Board (SMB)” was created to support the Government of Canada's priorities, DFO's strategic objectives, and the needs of its client management sectors through strategic direction and leadership to Science. The SMB has confirmed that the highest priority for DFO Science is providing scientific support for ecosystem-based management.

In keeping with international advancements in integrated aquatic management, Fisheries and Oceans Canada is moving towards an ecosystem approach to management<sup>5</sup>. The Science Framework for the Future<sup>6</sup> outlines the Department's approach to aquatic science with an ecosystem framework.

The Strategic Program for Ecosystem-Based Research and Advice (SPERA) supports the Department's objectives for science required for an ecosystem approach to management with research projects and scientific tool development which support national priorities for managing ecosystems.

### **Types of Research Funded by SPERA**

The Strategic Program for Ecosystem-based Research and Advice (SPERA) funds projects by DFO researchers which:

- Assess the ecosystem impacts of human activities;
- Assess and report on ecosystems and
- Develop tools to implement the ecosystem approach to management.

### **List of Maritime projects funded available on the website<sup>7</sup>:**

- Exploration of approaches to assess cumulative impacts of activities in the coastal zone within an Ecosystem Approach to Management Framework (EAM)
- Ecosystem indicators for ecosystem monitoring at different scales
- Identification of benthic ecologically and Biologically Significant Areas (EBSAs) on the Scotian Shelf
- Evaluating ecosystem services and functions in coastal habitats for use in habitat restoration
- Biodiversity measures for use in the Ecosystem Approach to Oceans management
- Evaluation of geospatial tools for delineating concentrations of deep-sea corals and sponges

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<sup>4</sup> <http://www.dfo-mpo.gc.ca/science/ecosystem-eng.htm>

<sup>5</sup> A New Ecosystem Science Framework in Support of Integrated Management <http://www.dfo-mpo.gc.ca/science/publications/ecosystem/index-eng.htm>

<sup>6</sup> Science at Fisheries and Oceans Canada: A Framework for the Future <http://www.dfo-mpo.gc.ca/science/publications/framework-cadre/index-eng.htm>

<sup>7</sup> <http://www.dfo-mpo.gc.ca/science/rp-pr/spera-psrafe/index-eng.asp?group=title>

#### NOAA, USA

Ecosystem-based management requires a strong scientific basis. At NOAA numerous programs and projects<sup>8</sup> provide the research and scientific understanding to ensure that management programs have the information and tools they need to implement EBM.

The programs below represent a few of the many scientific and research programs supporting EBM at NOAA:

- Integrated Ecosystem Assessments<sup>9</sup>
- Fisheries Ecosystem Science<sup>10</sup>
- Fisheries and the Environment<sup>11</sup>
- Ocean Exploration and Research<sup>12</sup>
- National Centers for Coastal and Ocean Science<sup>13</sup>
- Large Marine Ecosystems Program<sup>14</sup>
- Ocean Acidification Program<sup>15</sup>
- Ecological Forecasting<sup>16</sup>

With regard to France (Ifremer) and US (NOAA) cooperation, main topics for cooperation in the field of ecosystem Approach with NOAA are:

- Ocean And Human Health, notably on Harmful Algal Bloom (in particular through the current IOC/IPHAB Global Ciguatera Strategy 2015-2019 which acts as a relevant international platform for multilateral cooperation between France, Canada and the USA).
- Exchange of information on Marine microbes
- Deep-sea biodiversity (taxonomy, assessment, sampling etc.)
- Cooperation/information exchange on the topic of "maritime economy" which includes:
  - Integrated assessments in support of policies & integrated bio-economic modelling of fisheries;
  - Economics in support of fishery management;
  - Aquaculture models, Carrying capacity
  - Analysis of fishing boats cruises

#### **A selection of recommended references regarding Ecosystem-based Management (EBM) is listed below:**

##### Applying a more holistic Ecosystem-Based Approach to coastal and marine resource management

- *Introduction to Ecosystem-Based Management, Ecological Principles & Ecosystem Vulnerability*

- *Agency Overviews, Case Study Analyses & Future Actions*

- *Overarching Management Themes & Conclusions*

> Centre for Ocean Solutions. 2012. Incorporating Ecological Principles into California Ocean and Coastal Management: Examples from Practice. Stanford Woods Institute for the Environment, Stanford University, CA

##### The status of marine and coastal ecosystem-based management among the network of U.S. federal programs

*This paper summarizes the status of EBM for federal programs under the agencies of the National Ocean Council that implement or support marine and coastal EBM activities.*

> Dell'Apa, Andrea; Adam Fullerton; Franklin Schwing; & Margaret M. Brady. "The status of marine and coastal ecosystem-based management among the network of U.S. federal programs". Marine Policy 60 (2015) 249-258.

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<sup>8</sup> <http://ecosystems.noaa.gov/>

<sup>9</sup> <http://www.noaa.gov/iea/>

<sup>10</sup> <http://www.st.nmfs.noaa.gov/ecosystems/index>

<sup>11</sup> <http://www.st.nmfs.noaa.gov/fate/>

<sup>12</sup> <http://oceanexplorer.noaa.gov/>

<sup>13</sup> <https://coastalscience.noaa.gov/>

<sup>14</sup> <http://www.st.nmfs.noaa.gov/ecosystems/lme/>

<sup>15</sup> <http://oceanacidification.noaa.gov/>

<sup>16</sup> <http://oceanservice.noaa.gov/ecoforecasting/>

### Integrated Ecosystem Assessments

#### *A Five Step Process for an IEA*

>Levin, P.S., M.J. Fogarty, G.C. Matlock, and M. Ernst. 2008. Integrated ecosystem assessments. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-92, 20 pp.

>Levin P.S., Fogarty M.J., Murawski S.A., Fluharty D. 2009. Integrated ecosystem assessments: Developing the scientific basis for ecosystem-based management of the ocean. PLoS Biol 7(1): e1000014.doi:10.1371/journal.pbio.1000014

### Ecosystem-Based Management Consensus Statement

*Comprehensive ecosystem-based management (EBM) was called for by both U.S. ocean commissions. This statement, signed by over 200 scientists and policy experts, highlights current scientific understanding of marine ecosystems, explains how this knowledge shapes the call for a new management approach, and provides a definition for what the scientific community envisions when it recommends "ecosystem-based management" for the ocean.*

>McLeod, K. L., J. Lubchenco, S. R. Palumbi, and A. A. Rosenberg. 2005. Scientific Consensus Statement on Marine Ecosystem-Based Management. Communication Partnership for Science and the Sea, Corvallis, OR.

<http://compassonline.org/resources>

### The Millennium Ecosystem Assessment (MA)

*The Millennium Ecosystem Assessment (MA) was called for by the United Nations Secretary-General Kofi Annan in 2000. Initiated in 2001, the objective of the MA was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being.*

>Millennium Ecosystem Assessment, 2005. Island Press, Washington, DC.

### International Earth system expert workshop on ocean stresses and impacts - Summary workshop report

*Between 11th and 13th April 2011 world experts on the ocean met at the Margaret Thatcher Conference Centre, Somerville College, University of Oxford. This event was led by the International Programme on the State of the Ocean (IPSO), in partnership with the International Union for Conservation of Nature (IUCN) and the International Geosphere and Biosphere Programme (IGBP), and brought together a select group of world science leaders on ocean stresses and impacts to reflect on these, and propose creative solutions.*

>Rogers, A.D. & Laffoley, D.d'A. 2011. International Earth system expert workshop on ocean stresses and impacts. Summary report. IPSO Oxford, 18 pp.

### Charting the Course for Ocean Science in the United States for the Next Decade – An Ocean Research Priorities Plan and Implementation Strategy.

*The goal of this document is to provide the guidance to build the scientific foundation to improve society's stewardship and use of, and interaction with, the ocean.*

>Charting the Course for Ocean Science in the United States for the Next Decade – An Ocean Research Priorities Plan and Implementation Strategy. NSTC Joint Subcommittee on Ocean Science and Technology. January 26, 2007. <http://www.whitehouse.gov/sites/default/files/microsites/ostp/nstc-orppis.pdf>

### Taking Steps toward Marine and Coastal Ecosystem-Based Management - An Introductory Guide

*The ecosystem approach lays out a series of principles to guide management towards long-term sustainability of marine and coastal ecosystems. With this new guide on Marine and Coastal Ecosystem-Based Management (EBM), UNEP seeks to assist countries and communities to take steps towards making marine and coastal ecosystem-based management operational - from strategic planning to on-site implementation.*

>UNEP. "Taking Steps toward Marine and Coastal Ecosystem-Based Management - An Introductory Guide," by Tundi Agardy, John Davis, Kristin Sherwood and Ole Vestergaard. UNEP Regional Seas Reports and Studies, 189. (June 2011). [http://www.unep.org/pdf/EBM\\_Manual\\_r15\\_Final.pdf](http://www.unep.org/pdf/EBM_Manual_r15_Final.pdf)

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Final Recommendations of the Interagency Ocean Policy Task Force.

*In order to better meet our Nation's stewardship responsibilities for the ocean, our coasts, and the Great Lakes, President Obama established the Interagency Ocean Policy Task Force (Task Force) on June 12, 2009. The President charged the Task Force with developing recommendations to enhance our ability to maintain healthy, resilient, and sustainable ocean, coasts, and Great Lakes resources for the benefit of present and future generations.*

>White House Council on Environmental Quality. Final Recommendations of the Interagency Ocean Policy Task Force. July 19, 2010. [http://www.whitehouse.gov/files/documents/OPTF\\_FinalRecs.pdf](http://www.whitehouse.gov/files/documents/OPTF_FinalRecs.pdf)

## Inventory of major Canadian, European, and US research activities/projects on ecosystem approach to ocean health and stressors with regard to the North Atlantic

### Guidelines

One of the priority research areas identified in the Galway Statement and adopted by the Atlantic Ocean Research Alliance is the Ecosystem Approach to Ocean Health and Stressors. In order to provide the EU-USA-CA Atlantic Ocean Research Alliance with relevant and responsive information on the status of ecosystem approach research to ocean health and stressors, one task was to carry out an inventory of major Canadian, European, and US research activities/projects.

This inventory document is intended to provide an overview of results and outputs of projects focused on the following subjects, relevant for consideration of the ecosystem approach to ocean health and stressors:

- Methods for developing indicators and targets for biodiversity
- Techniques for assessment that account for differences in scale and resolution of monitoring and management
- Management tools for ecosystem approach
- Ecosystem structure and functioning
- Carrying capacity, ecosystem tipping points, and ocean stressors
- Cumulative effects
- Analysis of social and economic consequences of management actions
- Maintaining the legitimacy and credibility of science for evidence based policy

In doing so, the inventory document attempts to answer the following questions:

- What has been studied?
- What are the gaps?
- What is required?

### Sources of information

The inventory of European ecosystem research activities and projects is based on two main databases and partners contributions.

1/The Marine Knowledge Gate 2.0 (EurOcean\_KG) is an innovative online repository of marine research projects and results (Knowledge Outputs). The data base includes records of marine research projects and results with funding from the EU and major national Research Funding and Performing Organisations (RFPOs) from 25 European coastal countries, as well as from Regional and International Agencies. Through EurOcean involvement in the FP7 Coordination and Support Action "STAGES" project (Science and Technology Advancing Governance on Good Environmental Status), EurOcean\_KG has been expanded to include projects from new EU Funding Programmes as well as projects with national and regional funding. The H2020 "Columbus" project aims to maintain and develop the Marine Research Knowledge Gate ensuring it is up to date and fit for purpose.

2/Data were supplemented with data from CORDIS (the Community Research and Development Information Service), the European Commission's primary public repository and portal to disseminate information on all EU-funded research projects and their results in the broadest sense. The website and repository include all public information held by the Commission including project factsheets, publishable reports and deliverables, and comprehensive links to external sources such as open access publications and websites.

3/Contributions received from the AORAC-SA WP4 partners (input requested from marine Institutes in the USA, Canada, and Europe namely England, France, Ireland, Portugal, and Spain).

Theme 1: Methods for developing indicators and targets for biodiversity

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>INCOFISH</b>	Integrating Multiple Demands on Coastal Zones with Emphasis on Aquatic Ecosystems and Fisheries	-Simple Indicators for Sustainable Resource Use -Indicators of fisheries mismanagement	Large marine ecosystems	UE FP6 2005-2008	none	- <i>Publications:</i> <a href="http://www.incofish.org/Results/Publications.php">www.incofish.org/Results/Publications.php</a> - <i>Results:</i> <a href="http://www.incofish.org/">www.incofish.org/</a> & <a href="http://cordis.europa.eu/project/rcn/79797_en.html">cordis.europa.eu/project/rcn/79797_en.html</a>
<b>IndiSeas</b>	Indicators for the seas	-Indicators to evaluate the effects of fishing on the health status of marine ecosystems	Large marine ecosystems	IOC/UNESCO & Eur-Oceans 2005-2013	yes	- <i>Publications:</i> <a href="http://www.indiseas.org/more-information#publications">www.indiseas.org/more-information#publications</a> - <i>Results:</i> <a href="http://www.indiseas.org/comparative-approach">www.indiseas.org/comparative-approach</a>
<b>MEECE</b>	Marine Ecosystem Evolution in a Changing Environment	-Fisheries, climate change, European seas -Indicators to help quantify the impact of fishing -Comparative analysis of ecosystem indicators	Global, MFSD	UE FP7 2008-2013	yes	- <i>Publications:</i> <a href="http://www.meece.eu/documents/MEECE_papers.pdf">www.meece.eu/documents/MEECE_papers.pdf</a> - <i>Results:</i> <a href="http://www.meece.eu/Deliv.html">www.meece.eu/Deliv.html</a> & <a href="http://cordis.europa.eu/project/rcn/89307_en.html">cordis.europa.eu/project/rcn/89307_en.html</a>
<b>EURO-BASIN</b>	European Union Basin-scale Analysis, Synthesis, and Integration	-Good Environmental Status indicators and reference points regarding pelagic species and climate change -Zooplankton, climate indicators	North Atlantic and Arctic	UE FP7 2010-2014	yes	- <i>Publications:</i> <a href="http://www.euro-basin.eu/">http://www.euro-basin.eu/</a> - <i>Results:</i> <a href="http://www.euro-basin.eu/">http://www.euro-basin.eu/</a> & <a href="http://cordis.europa.eu/project/rcn/97329_en.html">cordis.europa.eu/project/rcn/97329_en.html</a>
<b>GREENSEAS</b>	Development of global plankton data base and model system for eco-climate early warning	-Innovative indicators to monitor the structure and functioning of marine ecosystems and their effects on global biogeochemical cycling and fisheries	Atlantic, Arctic and Southern Oceans	UE FP7 2011-2015	none	- <i>Results:</i> <a href="http://www.greenseas.eu/deliverables">www.greenseas.eu/deliverables</a> & <a href="http://cordis.europa.eu/project/rcn/97177_en.html">cordis.europa.eu/project/rcn/97177_en.html</a>
<b>DEVOTES</b>	Development of innovative tools for understanding marine biodiversity and assessing good environmental status	-New and updated indicators and methods for setting reference and target values -Keystone Species Catalogue and review, as indicators in monitoring programmes	Europe, MSFD	UE FP7 2012-2016	yes	- <i>Publications:</i> <a href="http://www.devotes-project.eu/publications/">www.devotes-project.eu/publications/</a> - <i>Results:</i> <a href="http://www.devotes-project.eu/deliverables-and-milestones/">www.devotes-project.eu/deliverables-and-milestones/</a> & <a href="http://cordis.europa.eu/project/rcn/105613_en.html">cordis.europa.eu/project/rcn/105613_en.html</a>

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>Myfish</b>	Maximising yield of fisheries while balancing ecosystem, economic, and social concerns	-Europe, Fisheries, maximum sustainable yield (MSY), GES -Definitions of MSY variants	Europe, CFP, MSFD	UE FP7 2012-2016	yes	- <i>Publications:</i> <a href="http://www.myfishproject.eu/media-centre-2/myfish-publications">www.myfishproject.eu/media-centre-2/myfish-publications</a> - <i>Results:</i> <a href="http://www.myfishproject.eu/myfish-regional-studies/myfish-decision-support-tables">www.myfishproject.eu/myfish-regional-studies/myfish-decision-support-tables</a> & <a href="http://cordis.europa.eu/project/rcn/101745_en.html">cordis.europa.eu/project/rcn/101745_en.html</a>

### Indicators for fisheries

IndiSeas was a scientific program which evaluated the effects of fishing on the health status of marine ecosystems. A panel of indicators is provided to reflect the ecological and biodiversity status of marine ecosystems, and the effects of fishing on ecosystem functions and properties, to characterize marine ecosystems states and trends and to provide a human dimension as part of fisheries indicators. Scientific experts from each ecosystem represented have calculated the necessary indicators and provided background information and overview of the status of their ecosystem. Indicator series currently extend to 2010, but the database may be updated on a regular basis. IndiSeas has developed a “generic dashboard” to present the ecosystem indicators describing the state of ecosystems and the trends within them, and to provide a multivariate view of the ecosystem using it as a comparative tool.

MEECE project scientists collaborated at an international level to help define a range of indicators to help quantify the impact of fishing and provide support for fisheries management. With an emphasis on the European Marine Strategy and under the auspices of the IndiSeas project, scientists worked collectively to perform comparative analysis of ecosystem indicators for many of the world's marine ecosystems. This comparative framework allows for the selection of a robust suite of indicators that are meaningful and measurable over diverse and contrasting conditions (e.g. environmental change).

Myfish project aims at developing maximum sustainable yield (MSY) indicators and to provide suggestions for alternative MSY solutions that can ensure high levels of fishery yield while respecting ecological, economic, and social sustainability in accordance with both the precautionary approach, an ecosystem approach to fisheries, and the MSY approach. The ecosystem components addressed give special attention to descriptors and indicators that will be used to determine Good Environmental Status. Through providing definitions of MSY variants, MYFISH developed an ecological-economic model of the Baltic Sea, simulating stock dynamics of interacting populations to define multi-species maximum sustainable yield (MMSY) and providing a guide for policy makers to select operational targets and adopt appropriate management instruments. Evaluations of the effect of these variants on ecosystems, economic, and social aspects are conducted. The social and ecological desirability of the MSY criteria is considered and an operational framework for implementation is provided. The MYFISH work has identified and adapted the indicators and models required to produce decision support advice.

### Good Environmental Status indicators within the Marine Strategy Framework Directive

Focused on the Northeast Atlantic pelagic ecosystems, EURO-BASIN developed a list of intermediate level ecological, economic, and social management objectives and then carried out evidence-based selection of corresponding Good Environmental Status indicators and reference points. EURO-BASIN concluded that future projections of ocean productivity, based on habitat species distribution, are needed for a detailed assessment of ocean health and benefits and for achieving or maintaining the good environmental status of the North Atlantic. The predictability of how oceanographic conditions affect the pelagic species so far remains underutilized in fisheries management and for understanding and predicting dynamics of fish populations and marine ecosystem dynamics in the North Atlantic.

Regarding the Arctic marine ecosystem, EURO-BASIN characterized population genetic structures of keystone species, important for biogeochemical and trophic functioning using novel molecular approaches, as well as to determine their evolutionary responses to climate change. EURO-BASIN focused on the distribution of the Calanoid copepods species (zooplankton), *C. glacialis* (corresponding to Arctic water masses) and *C. finmarchicus* (to Atlantic water masses), frequently used as climate indicators.

GREENSEAS developed new indicators of change in planktonic ecosystems and defined a set of indicators which can be used to describe changes in the state of marine ecosystems. Satellite data have been combined with other observing systems in a novel approach to help define a suite of ecological indicators to support ecosystem management. GREENSEAS project used two case studies to demonstrate how different types of ocean observations can be used in the development and implementation of plankton indicators, and how they are relevant to marine policy.

DEVOTES project documented the results of the refinement of 13 indicators and new development of 16 indicators for the Marine Strategy Framework Directive (MSFD) targeting mainly descriptors D1 (Biodiversity), D2 (Non-indigenous species), D3 (fishing), D4 (Marine food webs), D5 (eutrophication), and D6 (Seafloor integrity). In total, 29 indicators have been evaluated. 16 of the indicators documented in the deliverable 3.3 report are newly developed, while 13 indicators have been refined. A method to use quantitative criteria for the derivation of target values and reference levels is presented and discussed along with policy implications in the context of sustainability.

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DEVOTES project discussed the possibility of using keystone species as indicators in monitoring programmes and suggested that keystone indicators can provide relevant information for the future consequences of environmental changes in the entire ecosystem. The DEVOTES Catalogue of Keystone species and associated report is a review of potential keystone species in European marine habitats. The catalogue has 844 individual entries, which includes 210 distinct species and 19 groups classified by major habitat in the EU Regional Seas and the Norwegian Sea. The scientific community is aware that important difficulties remain in the definition of keystone species.

Theme 2: Techniques for assessment that account for differences in scale and resolution of monitoring and management

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>ECOKNOWS</b>	Effective use of ecosystem and biological knowledge in fisheries	-Fisheries stock assessment, MSY, fisheries reference points	North Atlantic and Europe	UE FP7 2010-2014	yes	- <i>Publications &amp; Results</i> : <a href="http://cordis.europa.eu/project/rcn/95519_en.html">cordis.europa.eu/project/rcn/95519_en.html</a>
<b>BLUEAGE</b>	Validated age and growth analysis of Atlantic Bluefin tuna ( <i>Thunnus thynnus</i> )	-Fisheries stock assessment, age determination	Atlantic	UE FP7 2011-2012	yes	- <i>Publications</i> : <a href="http://www.iccat.int/Documents/CVSP/CV068_2012/no_1/CV068010254.pdf">www.iccat.int/Documents/CVSP/CV068_2012/no_1/CV068010254.pdf</a>
<b>COEXIST</b>	Interaction in coastal waters: A roadmap to sustainable integration of aquaculture and fisheries	-Assessment of interactions between fisheries and aquaculture and other uses of the coastal zone	Europe	UE FP7 2010-2013	yes	- <i>Publications</i> : <a href="http://www.coexistproject.eu/coexist-results/publications">www.coexistproject.eu/coexist-results/publications</a> - <i>Results</i> : <a href="http://www.coexistproject.eu/coexist-results/tool">www.coexistproject.eu/coexist-results/tool</a> & <a href="http://cordis.europa.eu/project/rcn/94252_en.html">cordis.europa.eu/project/rcn/94252_en.html</a>
<b>MEECE</b>	Marine Ecosystem Evolution in a Changing Environment	-Links between human activities and GES descriptors, MSFD, expert judgement assessment -Tool for climate change impacts assessment	Global, MSFD	UE FP7 2008-2013	yes	- <i>Publications</i> : <a href="http://www.meece.eu/documents/MEECE_papers.pdf">www.meece.eu/documents/MEECE_papers.pdf</a> - <i>Results</i> : <a href="http://www.meece.eu/Deliv.html">www.meece.eu/Deliv.html</a> & <a href="http://cordis.europa.eu/project/rcn/89307_en.html">cordis.europa.eu/project/rcn/89307_en.html</a>
<b>MESMA</b>	Monitoring and Evaluation of Spatially Managed Areas	-The relative value of seabed biotopes: goods and services, sensitivity issues, management and protection tools at European or international level	Europe	EU - FP7 2009-2013	none	- <i>Publications</i> : <a href="http://cordis.europa.eu/project/rcn/92591_en.html">cordis.europa.eu/project/rcn/92591_en.html</a> - <i>Results</i> : <a href="http://www.mesmacentralexchange.eu">www.mesmacentralexchange.eu</a>
<b>OPEC</b>	OPERational ECology: Ecosystem forecast products to enhance marine GMES applications	-Assessment of current operational ecosystem monitoring systems	Europe	UE FP7 2012-2014	none	- <i>Publications</i> : <a href="http://cordis.europa.eu/project/rcn/100881_en.html">cordis.europa.eu/project/rcn/100881_en.html</a> - <i>Results</i> : <a href="http://marine-opec.eu/default.html">marine-opec.eu/default.html</a>
<b>KNOWSEAS</b>	Knowledge-based Sustainable Management for Europe's Seas	-Assessment of the costs and benefits of fishing, transport, energy aquaculture, water quality and recreation -Method for mapping of governance	Europe, MSFD	UE FP7 2009-2013	yes	- <i>Publications</i> : <a href="http://www.knowseas.com/links-and-data/project-publications">www.knowseas.com/links-and-data/project-publications</a> - <i>Results</i> : <a href="http://www.knowseas.com/links-and-data">www.knowseas.com/links-and-data</a> & <a href="http://cordis.europa.eu/project/rcn/92053_en.html">cordis.europa.eu/project/rcn/92053_en.html</a>
<b>ODEMM</b>	Options for Delivering Ecosystem-Based Marine Management	-Pressure assessment methodology -Ecological risk assessment -Rapid assessment of the current state of the Good Environmental Status	Europe, MSFD	UE FP7 2010-2013	yes	- <i>Results</i> : <a href="http://odemmm.com/content/resources">odemmm.com/content/resources</a> & <a href="http://cordis.europa.eu/result/rcn/55984_en.html">cordis.europa.eu/result/rcn/55984_en.html</a>

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>GREENSEAS</b>	Development of global plankton data base and model system for eco-climate early warning	-Models for future assessments of climate change	Atlantic, Arctic and Southern Oceans	UE FP7 2011-2014	yes	- <i>Publications:</i> <a href="http://cordis.europa.eu/project/rcn/97177_en.html">cordis.europa.eu/project/rcn/97177_en.html</a> - <i>Results:</i> <a href="http://www.greenseas.eu/deliverables">www.greenseas.eu/deliverables</a>
<b>VECTORS</b>	Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors	-Ecosystem service assessments: Impacts of change on ecosystem services and their values -Economic impact assessment -Risk assessments leading to best practice in Fisheries management -Risk assessments leading to best practice in resource exploitation – renewable energy	Europe	UE FP7 2011-2015	none	- <i>Publications:</i> <a href="http://www.marine-vectors.eu/Publications">www.marine-vectors.eu/Publications</a> - <i>Results:</i> <a href="http://www.marine-vectors.eu/">www.marine-vectors.eu/</a> & <a href="http://cordis.europa.eu/project/rcn/97826_en.html">cordis.europa.eu/project/rcn/97826_en.html</a>
<b>DEVOTES</b>	Development of innovative tools for understanding marine biodiversity and assessing good environmental status	From indicators to assessment: -Catalogue of the Monitoring Networks -DEVOTool software: 577 indicators of marine biodiversity -Catalogue of models and their derived indicators -Sea-specific matrices of pressure-impact links -Seafloor integrity and biodiversity assessment -Pressure assessment gaps -Benthic ecosystem services assessment -Risk Assessment and Risk Management tool	Europe, MSFD	UE FP7 2012-2016	none	- <i>Publications:</i> <a href="http://www.devotes-project.eu/publications/">www.devotes-project.eu/publications/</a> - <i>Results:</i> <a href="http://www.devotes-project.eu/deliverables-and-milestones/">www.devotes-project.eu/deliverables-and-milestones/</a> & <a href="http://cordis.europa.eu/project/rcn/105613_en.html">cordis.europa.eu/project/rcn/105613_en.html</a>
<b>BENTHIS</b>	Benthic ecosystem fisheries Impact Study	-Assessment of the impact of bottom trawling	Europe	UE FP7 2012-2017	none	- <i>Publications and results:</i> <a href="http://cordis.europa.eu/project/rcn/105132_en.html">cordis.europa.eu/project/rcn/105132_en.html</a> & <a href="http://www.benthis.eu/en/benthis/Results.htm">www.benthis.eu/en/benthis/Results.htm</a>
<b>NEXOS</b>	Next generation, Cost-effective, Compact, Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management	-Sensor systems for more precise monitoring and modelling of the marine environment	Global, GOOS, MSFD, CFP	UE FP7 2013-2017	Canada/S pain	- <i>Publications:</i> <a href="http://www.nexosproject.eu/dissemination/publications">www.nexosproject.eu/dissemination/publications</a> - <i>Results:</i> <a href="http://www.nexosproject.eu/">www.nexosproject.eu/</a> & <a href="http://cordis.europa.eu/project/rcn/111405_en.html">cordis.europa.eu/project/rcn/111405_en.html</a>

### **From indicators to assessment**

DEVOTES developed the DEVOTool software which facilitates navigation of a database of existing indicators of marine biodiversity (577 indicators that report on diverse aspects related to the biota and their habitat features, but also to activities and pressures), within European Regional Seas. These scientific indicators are potential tools that can be used to assess the environmental status of European seas. DEVOTES also built a catalogue of models and their derived indicators to assess which models were able to demonstrate the linkages between indicators and ecosystem structure and function and the impact of pressures on ecosystem state through indicators. DEVOTES identified 44 ecological models being implemented in Europe, with a high prevalence of those that focus on links between hydrodynamics and biogeochemistry, followed by end-to-end, species distribution/habitat suitability, bio-optical (remote sensing) and multispecies models. Approximately 200 indicators could be derived from these models.

### **Pressure-impact links**

- **Matrices of Pressure-impact links**

The DEVOTES Report on sea-specific matrices of pressure-impact links describes the development and application of simple models to assess the consequence of anthropogenic marine pressures through the application of a Scale Intensity Consequence Assessment approach. The holistic modelling approach considers a total of 84 activities, 22 pressures, 23 habitats, and 11 Biodiversity components. The subdivision into individual activities of each key activity sector, contributing most to the overall levels of pressure, enables users to identify management options specific to particular activities. The linked matrices that underpin the model are based on the generalised response of ecosystems to given stressors. The DEVOTES model has been successfully trialled on a series of 5 case studies.

- **Seafloor integrity and biodiversity assessment**

The applicability of a process-driven benthic sedimentary habitat model, analysed through DEVOTES project, is considered as being highly useful for seafloor integrity and biodiversity assessment for sedimentary habitats, to be used in the implementation of the MSFD. The approach is used to project, onto a map, the major environmental factors influencing soft-bottom macrobenthic community structure and the life-history traits of species. Combination of water depth, mean grain size, a wave-induced sediment resuspension index and annual bottom maximum temperature, are found to be the most significant factors explaining the variability in the structure of benthic communities in the study area. Moreover, benthic community structure anomalies due to human pressures could be detected also, within the model produced.

- **Impact of bottom trawling assessment**

BENTHIS develops generic quantitative tools that can be applied to a wide range of seafloor ecosystems and fishing gear. They assess the impact of bottom trawling on the seafloor and the economic consequences that will be applied in regional case studies. Researchers also develop indicators for the impact of bottom fishing on the benthic ecosystem that are consistent with the EU's Marine Strategy Framework Directive (MSFD). A framework for assessing the impact of fisheries on benthic ecosystems has already been developed. This included a summary of the key characteristics of the fishing gear, which is used to analyse impact on the benthic ecosystem. BENTHIS results will be used to create a European-wide map of trawling activity. This will enable researchers to identify which combinations of fishing gear have the greatest impact on benthic ecosystems. In addition, the effect of innovation in fishing technology and management practices on fisheries will be measured and the results discussed with stakeholders.

- **Climate change assessment**

The MEECE Model Atlas provides climate and ecosystem response scenarios, from plankton to fish, in a readily accessible form for marine policy and management.

The information presented in the model comes from ecosystem models. The Model Library provides all necessary documentation, technical guides and metadata so that any competent programmer unfamiliar with model, can perform integrated end-to-end numerical experiments necessary to assess how ecosystems are impacted by global change via drivers such as acidification, pollution, overfishing, and invasive species. The MEECE model Atlas covers the main European regional seas and provides simulations and projections for how ecosystems will respond to different scenarios of environmental change.

These scenarios include the Intergovernmental Panel on Climate Change (IPCC) climate projections for near future (up to 2040) and the far future (up to 2100) alongside human development. The library currently proposes modelling tools that can be applied in European Seas to address questions on 7 of the 11 GES descriptors for the regional sea of interest.

The GREENSEAS analytical plankton database is a collaborative, knowledge exchange product designed to bring together historical plankton data and associated environmental data to improve current biogeochemical models and projections used for future assessments of climate change. By collating 20 years of data it is possible to assess the state of the marine planktonic ecosystem by providing benchmarks of its current state for the future assessment of impacts of climate. The GREENSEAS project has also developed multiple simulation models of plankton ecology to monitor and assess environmental pressures and risks, including tensions and conflicts related to the depletion of natural resources and environmental services which may arise due to rapid environmental changes and/or natural and man-made hazards. Modelling included water colour measurements, nitrogen uptake, and geographical distribution of the plankton in the Atlantic and Southern Oceans.

### **Pressure assessment gaps**

With respect to the gaps addressed to pressures, DEVOTES has noted that the majority of ecological models for assessing environmental status require further work to show how sensitive and specific to pressures they are. Underwater noise, marine litter and contamination by microbial pathogens are poorly addressed by existing models and those that have been reported to produce indicators that are sensitive to these pressures require further development.

Further developments related to the setting of targets and to evaluate uncertainty associated with model results would produce more robust assessments and forecasts and therefore more reliable indicators.

European geographical coverage is also very heterogeneous with several identified marine areas with enormous potential for improvement.

Also certain habitats (e.g., ice-associated habitats or continental shelf sublittoral mud) and biodiversity components (e.g., microbes) are underrepresented in the modelling approaches presently in the DEVOTES catalogue. Current gaps should, therefore, be evaluated on a regional scale basis.

In addition, regional model runs identified the need to improve the existing models with regards to species diversity (e.g., adding certain species or refining subgroups), spatial resolution for selected species and for better description of the direct effect of anthropogenic pressures on ecosystems. Model response towards the impact of certain pressures still requires further testing. Relevance of certain pressures differs across regional marine areas.

### **Benthic ecosystem services assessment**

DEVOTES's researches have provided a first assessment of the benthic ecosystem services at Atlantic European scale, with the provision of ecosystem services maps and their general spatial distribution patterns. In total, 62 habitats have been analysed in relation to 12 ecosystem services over 1.7 million km<sup>2</sup>. The research has produced some tables to assess ecosystem services for each habitat and seabed feature type in relation to the distance to the coast and with depth. The results obtained in this investigation highlight the need for diverse, healthy and extensive benthic habitat areas to support the provision of important and valuable ecosystem services (i.e., food provisioning, disturbance prevention, nutrient cycling, etc.).

### **Cost and benefit / good and services**

An aggregate assessment of the costs and benefits in Europe's regional seas has been completed by KNOWSEAS focusing on fishing, transport, energy aquaculture, water quality, and recreation. A series of guidance notes has also been produced on the theory and application of values to case studies. An updated version of the DPSIR, renamed the DPSWR, that elucidates the cost benefit trade-offs of environmental decision making has been published.

### **Risk Assessment and Risk Management tool**

The DPSIR framework and its derivatives is predominantly used as a Risk Assessment and Risk Management tool. The Bow-Tie application is introduced as a marine risk assessment and risk management tool and the conceptual framework is redefined to incorporate mechanisms of pressure effect into a new model structure that supports the application of risk management approaches. DEVOTES developed a DPSIR-BowTie (DPSIR-BT) linked approach in which the main risks and hazards creating pressures, and thus the Main Event of concern can be addressed. It is of note that ICES (2014) has

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recommended that the BowTie framework is used to address cumulative and in-combination pressures and their consequences.

**Risk assessments leading to best practice: Fisheries management**

VECTORS has assessed the efficacy of marine planning in minimising risk in the context of a case study on risk assessment of fishery management in a Marine Protected Area of the Western Mediterranean. VECTORS has developed Bow Tie analysis as a tool to determine how risks of over-exploitation of the biological resource can be prevented and if not prevented, how they can be mitigated.

**Risk assessments leading to best practice: Resource exploitation – renewable energy**

VECTORS has assessed the efficacy of marine planning in minimising risk in the context of offshore wind farm developments in the North Sea. The Bow Tie method was used to assess risk in the case study of offshore wind power on the Dogger Bank as an example of an area primed for large scale wind farm development in the near future.

### Theme 3: Management tools to support the ecosystem approach

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>BECAUSE</b>	Critical interactions between species and their implications for a precautionary fisheries management in a variable environment – a modelling approach	-Description of food web structures and the derivation of precautionary reference points for ecosystem oriented fisheries management	Europe	EU - FP6 2004-2007	none	-Results: <a href="http://cordis.europa.eu/project/rcn/73839_en.html">cordis.europa.eu/project/rcn/73839_en.html</a> & <a href="http://cordis.europa.eu/docs/publications/1247/124722981-6_en.pdf">cordis.europa.eu/docs/publications/1247/124722981-6_en.pdf</a>
<b>INCOFISH</b>	Integrating Multiple Demands on Coastal Zones with Emphasis on Aquatic Ecosystems and Fisheries	-Standardised electronic maps of predicted distributions for all coastal zone species -Multispecies models -Tool for best placement of MPAs -Decision-making framework and communication tool for integrated coastal zone management -Analytical tool for fisheries management to diagnose drawbacks in existing management systems -Tool to evaluate the performance of any specific marine area in the world in terms of quality of its ecotourism management system	Large marine ecosystems	UE FP6 2005-2008	none	-Publications: <a href="http://www.incofish.org/Results/Publications.php">www.incofish.org/Results/Publications.php</a> -Results: <a href="http://www.incofish.org/">www.incofish.org/</a> & <a href="http://cordis.europa.eu/project/rcn/79797_en.html">cordis.europa.eu/project/rcn/79797_en.html</a>
<b>CoralFISH</b>	Assessment of the interaction between corals, fish and fisheries, in order to develop monitoring and predictive modelling tools for ecosystem based management in the deep waters of Europe and beyond	Decision support tools for policymakers and planners engaged in spatial planning in offshore and High Seas areas	Europe and beyond	EU - FP7 2008-2013	none	-Publications: <a href="http://eu-fp7-coralfish.net/publications1.php">http://eu-fp7-coralfish.net/publications1.php</a> -Results: <a href="http://eu-fp7-coralfish.net/habitat_suitability_modelling_WP6.php">http://eu-fp7-coralfish.net/habitat_suitability_modelling_WP6.php</a> & <a href="http://cordis.europa.eu/project/rcn/89331_en.html">cordis.europa.eu/project/rcn/89331_en.html</a>
<b>NEREIDA &amp; NOVA NEREIDA</b>	NAFO PotEntial VulneRable Marine Ecosystems-Impacts of Deep-seA Fisheries	Tool in the process of selecting protected areas in order to identify and protect vulnerable marine ecosystems (cold water corals, large sponges...) in the NAFO Regulatory Area	NAFO waters	National 2009-2010	Canada/Spain	-Publications and results: <a href="http://www.nafo.int/science/nereida.html">www.nafo.int/science/nereida.html</a> & <a href="http://www.ices.dk/sites/pub/CM%20Documents/CM-2014/Theme%20Session%20B%20contributions/B2214.pdf">www.ices.dk/sites/pub/CM%20Documents/CM-2014/Theme%20Session%20B%20contributions/B2214.pdf</a>
<b>PISCES</b>	Partnerships Involving Stakeholders in the Celtic sea Eco-System	Guide on implementation of the ecosystem approach in the Celtic Sea	Celtic sea	LIFE+ 2009-2012	none	-Results: <a href="http://www.kg.eurocean.org/proj.jsp?load=100152">www.kg.eurocean.org/proj.jsp?load=100152</a> & <a href="http://www.projectpisces.eu/">www.projectpisces.eu/</a>

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>MESMA</b>	Monitoring and Evaluation of Spatially Managed Areas	-Framework for monitoring and evaluation of spatially managed areas and the construction of a governance analysis framework -Decision support tools for the monitoring and evaluation of spatially managed areas -The MESMA governance analysis framework: a systematic and structured approach to analysing governance issues in marine spatial planning -The relevant policy objectives and parameters linked to the success or failure of the different spatially managed areas (SMA) regimes	Europe	EU - FP7 2009-2013	none	- <i>Publications:</i> <a href="http://cordis.europa.eu/project/rcn/92591_en.html">cordis.europa.eu/project/rcn/92591_en.html</a> - <i>Results:</i> <a href="http://www.mesmacentralexchange.eu">www.mesmacentralexchange.eu</a>
<b>KNOWSEAS</b>	Knowledge-based Sustainable Management for Europe's Seas	-Guidelines to understand conflict of interests and gather consensus -Guidelines about how to adapt to change and deal with a complex system through an adaptive management -Guidelines to design and set policy and management	Europe, MSFD	EU - FP7 2009-2013	yes	- <i>Publications:</i> <a href="http://www.knowseas.com/links-and-data/project-publications">http://www.knowseas.com/links-and-data/project-publications</a> - <i>Results:</i> <a href="http://www.msfd.eu/knowseas/what.html">www.msfd.eu/knowseas/what.html</a>
<b>ODEMM</b>	Options for Delivering Ecosystem-Based Marine Management	-Integrated Management Strategy Evaluation tool -Nested Governance Structures and Alternative Governance Models: tools to elaborate different scenarios for changing governance structures and legislation to facilitate a gradual transition from the current fragmented management approach towards fully integrated ecosystem management	Europe, MSFD	EU - FP7 2010-2013	none	- <i>Publications:</i> <a href="http://cordis.europa.eu/result/rcn/55984_en.html">cordis.europa.eu/result/rcn/55984_en.html</a> - <i>Results:</i> <a href="http://odemmm.com/sites/odemmm.com/files/ODEMM%20Report_0.pdf">odemmm.com/sites/odemmm.com/files/ODEMM%20Report_0.pdf</a> & <a href="http://odemmm.com/content/resources">odemmm.com/content/resources</a>
<b>COEXIST</b>	Interaction in coastal waters: A roadmap to sustainable integration of aquaculture and fisheries	-Management tools in coastal waters: roadmap to better integration, sustainability, and synergies among different activities in the coastal zone	Europe	EU - FP7 2010-2013	none	- <i>Publications and results:</i> <a href="http://cordis.europa.eu/project/rcn/94252_en.html">http://cordis.europa.eu/project/rcn/94252_en.html</a> & <a href="http://www.coexistproject.eu/index.php">http://www.coexistproject.eu/index.php</a>
<b>FORCE</b>	Future of Reefs in a Changing Environment (FORCE): An ecosystem approach to managing Caribbean coral reefs in the face of climate change	-Handbook that aims to provide reef managers with tools, information, and recommendations on management of coral reef ecosystems -WebGIS & Reef Health Simulator	Europe and the Caribbean	EU - FP7 2010-2014	none	- <i>Publications:</i> <a href="http://www.force-project.eu/node/237">www.force-project.eu/node/237</a> - <i>Results:</i> <a href="http://www.force-project.eu/">www.force-project.eu/</a> & <a href="http://cordis.europa.eu/project/rcn/93849_en.html">cordis.europa.eu/project/rcn/93849_en.html</a>

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>iMarine</b>	Data e-Infrastructure Initiative for Fisheries Management and Conservation of Marine Living Resources	-e-infrastructure to support the Ecosystem Approach to fisheries management and conservation of marine living resources	Global	EU - FP7 2011-2014	none	-Results: <a href="http://www.i-marine.eu/Pages/Home.aspx">www.i-marine.eu/Pages/Home.aspx</a> & <a href="http://cordis.europa.eu/project/rcn/99770_en.html">cordis.europa.eu/project/rcn/99770_en.html</a>
<b>Multiprojects (see results)</b> <b>The Atlas of habitats and resources and of their interactions for spatial management of marine protected areas)</b>	Development and comparisons of techniques for the characterization of habitats occupied by priority species (rare and endangered species, species having an important role within the ecosystem, the species with economic interests, etc.) and sites of conservation interest (marine protected areas)	<p>1/ Within the context of research initiative in the Lower St. Lawrence Estuary.</p> <p>&amp; Within two projects of the Canadian Aquatic Climate Change Adaptation Services Program (<b>ACCASP</b>)</p> <p>&amp; Within the Canadian Strategic Program for Ecosystem-Based Research and Advice (SPERA) :</p> <p>-Collaboration to develop a generic approach to describe the spatial distribution of a limited number of species</p> <p>-Seabed classification and description of some associated marine organisms</p> <p>-To establish a reference condition before human activities impacts</p> <p>-To evaluate the success of monitoring plans (case study: the American Bank, as an area of interest for establishment as a marine protected area)</p> <p>2/ Within the <b>CHARM project</b>: innovative approach to spatial ecosystem modelling</p> <p>3/ Within the <b>PANACHE project</b>, Protected Area Network Across the Channel Ecosystem, 2012-2015:</p> <p>-To develop underwater imaging equipment</p> <p>NB: Those bilateral projects finally converged into one main overarching initiative which is <b>the International Research Network called "Responses of populations and communities exploited by fisheries and aquaculture and of their habitats to global change" GDR-I RECHAGLO</b></p>	Different ecosystems of European waters (English Channel, Bay of Biscay) and Canadians (Estuary and Gulf of St. Lawrence).	2009-2015  National funding & the Interreg IV A France (Channel) - England 2007-2013  European Program me	Bilateral cooperation between France and Canada	<p>ACCASP: <a href="http://www.dfo-mpo.gc.ca/science/oceanography-oceanographie/accasp/index-eng.html">www.dfo-mpo.gc.ca/science/oceanography-oceanographie/accasp/index-eng.html</a></p> <p>SPERA : <a href="http://www.dfo-mpo.gc.ca/science/rp-pr/sperapsrafe/index-eng.asp">www.dfo-mpo.gc.ca/science/rp-pr/sperapsrafe/index-eng.asp</a></p> <p>PANACHE Project : <a href="http://www.panache.eu.com/home_panache">www.panache.eu.com/home_panache</a></p> <p>CHARM Project : <a href="http://webgate.ec.europa.eu/maritimeforum/en/node/2199">webgate.ec.europa.eu/maritimeforum/en/node/2199</a></p> <p>- <a href="http://archimer.ifremer.fr/doc/00138/24972/">archimer.ifremer.fr/doc/00138/24972/</a></p> <p>- <a href="http://ices.dk/sites/pub/CM%20Documents/CM-2010/Q/Q1210.pdf">ices.dk/sites/pub/CM%20Documents/CM-2010/Q/Q1210.pdf</a></p>

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>VECTORS</b>	Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors	-New approaches to model changes in the distribution and productivity of fish and other living marine resources -Tool to support marine management decisions, policies and governance as well as future research and investment -Decision support systems regarding ballast water discharges, aquatic species invasions -Recommendations for regional adaptive management strategies addressing EU policies	Europe	EU - FP7 2011- 2015	none	- <i>Publications:</i> <a href="http://www.marine-vectors.eu/Publications">www.marine-vectors.eu/Publications</a> - <i>Results:</i> <a href="http://www.marine-vectors.eu/">http://www.marine-vectors.eu/</a>
<b>COMFISH</b>	Strengthening the impact of fisheries related research through dissemination, communication, and technology transfer	-Fisheries regional challenges and possible solutions in line with the ecosystem approach	Europe, CFP	EU - FP7 2012- 2015	none	Results: <a href="http://www.eusem.com/main/ComFish/Cfdeliverables">www.eusem.com/main/ComFish/Cfdeliverables</a> & <a href="http://cordis.europa.eu/project/rcn/101668_en.html">http://cordis.europa.eu/project/rcn/101668_en.html</a>
<b>DEVOTES</b>	Development of innovative tools for understanding marine biodiversity and assessing good environmental status	-Climate change and Marine Strategy Framework Directive (MSFD) implementation relationship analysis	Europe, MSFD	EU - FP7 2012- 2016	yes	- <i>Results:</i> <a href="http://www.sciencedirect.com/science/article/pii/S0025326X15001472">www.sciencedirect.com/science/article/pii/S0025326X15001472</a>
<b>CSP</b>	Celtic Seas Partnership (CSP) - stakeholder driven integrated management of the Celtic Seas Marine Region	-Collaborative and innovative approaches to managing marine environment	Celtic seas	LIFE+ 2013- 2016	none	- <i>Results:</i> <a href="http://celticseaspartnership.eu/library/">celticseaspartnership.eu/library/</a> & <a href="http://www.kg.eurocean.org/proj.jsp?load=100084">www.kg.eurocean.org/proj.jsp?load=100084</a>
<b>GADCAP</b>	Implementation of a multispecies model GADGET to the ecosystem of Flemish Cap and incorporation to the fisheries stock assessment of NAFO; a case study	-Multispecies model for practical advice in fisheries management	NAFO area	EU - FP7 2014- 2016	none	- <i>Publication:</i> <a href="http://www.ices.dk/sites/pub/ASCEExtendedAbstracts/Shared%20Documents/A%20-%20Advancement%20of%20stock%20assessment%20methods%E2%80%8B%20for%20sustainable%20fisheries%E2%80%8B%E2%80%8B/A0415.pdf">www.ices.dk/sites/pub/ASCEExtendedAbstracts/Shared%20Documents/A%20-%20Advancement%20of%20stock%20assessment%20methods%E2%80%8B%20for%20sustainable%20fisheries%E2%80%8B%E2%80%8B/A0415.pdf</a>
<b>SPONGES</b>	Deep-sea Sponge Grounds Ecosystems of the North Atlantic: an integrated approach towards their preservation and sustainable exploitation	-Guidelines for the preservation and sustainable exploitation of vulnerable sponge ecosystems -Decision support tools for management -An adaptive ecosystem-based management plan	North Atlantic	H2020 2016- 2020	yes	<a href="http://cordis.europa.eu/project/rcn/200161_en.html">cordis.europa.eu/project/rcn/200161_en.html</a>

### **Fisheries, aquaculture, and marine living resources**

iMarine is an initiative aimed at supporting the implementation of the Ecosystem Approach to fisheries management and the conservation of living marine resources. To achieve its objectives, iMarine provides a data e-infrastructure that facilitates open access and sharing of a multitude of data, collaborative analysis, processing and mining processing, as well as publication and diffusion of newly generated knowledge.

Most of the worldwide marine fish resources are fully exploited or overexploited. There is a general consensus to change fisheries management toward a multispecies approach that considers species interactions and don't overestimate stock-biomass per recruit, as it occurs with the current monospecific approach. The GADGET multispecies model has been considered by the Food and Agriculture Organization (FAO) with the greatest potential for practical advice in fisheries management. The Working Group for the Ecosystem Approach to Fisheries Management (WGEAFM) leads an innovative framework in the NAFO area. GADCAP dealt with the creation of a GADGET multispecies model in the Flemish Cap, including cod, redfish and shrimp, considering the most relevant biological information, predator-prey consumption, and fleet characteristics. With the resulting multispecies model, several projections of population state were conducted for all modelled species by introducing variations in recruitment, species interactions, and fishing mortality. Different scenarios were considered in the context of NAFO management strategies. Based in the innovative approach conducted by the WGEAFM, GADCAP represented an extraordinary opportunity to go further on in the development of the multispecies and ecosystem management approaches not just for the NAFO area, but also for other European fishing grounds.

### **Vulnerable ecosystems**

In Europe, the main vulnerable marine ecosystems found in offshore waters are cold-water coral and sponge habitats. CoralFISH set out to provide the science, tools and methods necessary to support ecosystem based management of deep-sea resources through the study of the interaction between one of these vulnerable marine ecosystem examples - cold-water corals, and the fish and fisheries found in their vicinity. CoralFISH has developed decision support tools for policymakers and planners engaged in spatial planning in offshore and High Seas areas to address marine protected area network connectivity and the development of models to predict coral habitat distribution at global, regional, and local levels in areas where data are lacking. To assist policy makers with the application of an ecosystem approach to fisheries management, CoralFISH undertook the development of web-enabled Geographic Information System tools. These tools demonstrate the technical feasibility of using web-services to produce predicted habitat maps outputs using different thresholds (i.e. likelihood of occurrence). These layers can then be queried against the fishing footprint to assess the risk of impact in coral habitats. Appropriate fisheries management measures can then be applied to manage this risk and ensure minimal interaction between fisheries and vulnerable marine ecosystems.

The objective of SponGES is to develop an integrated ecosystem-based approach to preserve and sustainably use vulnerable sponge ecosystems of the North Atlantic. The approach will address the scope and challenges of EC's Blue Growth Call by strengthening the knowledge base, improving innovation, predicting changes, and providing decision support tools for management and sustainable use of marine resources. SponGES will fill knowledge gaps on vulnerable sponge ecosystems and provide guidelines for their preservation and sustainable exploitation. North Atlantic deep-sea sponge grounds will be mapped and characterized, and a geographical information system on sponge grounds will be developed to determine drivers of past and present distribution. Diversity, biogeographic and connectivity patterns will be investigated through a genomic approach. Function of sponge ecosystems and the goods and services they provide, e.g. in habitat provision, benthic-pelagic coupling and biogeochemical cycling will be identified and quantified. It will improve predictive capacities by quantifying threats related to fishing, climate change, and local disturbances. SponGES outputs will form the basis for modelling and predicting future ecosystem dynamics under environmental changes. The ultimate goal is to develop an adaptive ecosystem-based management plan that enables conservation and good governance of these marine resources on regional and international levels.

### **Partnerships**

PISCES (Partnerships Involving Stakeholders in the Celtic Sea Ecosystem) has brought together stakeholders from the Celtic Sea to develop this practical guide on implementing the ecosystem approach in the context of the European Union Marine Strategy Framework Directive. The guide aims to de-mystify terminology and makes practical recommendations for stakeholders and governments. It explores what is needed to implement the ecosystem approach in the context of

the MSFD, following statutory commitments and good practice. Recommendations are relevant to other marine policy areas and contexts.

The Celtic Seas Partnership will build on the success of the PISCES project. The Celtic Seas Partnership is a pioneering four year project that brings together sea-users, scientists and governments to help achieve healthy and sustainable seas. The new project will focus on the Marine Strategy Framework Directive. It operates on a greater scale than PISCES as it covers the Celtic Seas and not just the Celtic Sea. The Celtic Seas includes the Celtic Sea but also expands to cover a much bigger geographical area.

FORCE provided coral reef managers with a toolbox of sustainable management practices that minimise the loss of coral reef health and biodiversity. The project has produced a handbook that aims to provide reef managers with tools, information, and recommendations on management of coral reef ecosystems. The handbook sections range from ecological history and biogeography, resilience as well as climate change issues to fisheries, governance, and the monitoring of coral reef ecosystems. FORCE has also produced four case studies on reef dependency and change. Then the webGIS & Reef Health Simulator, online Geographic Information System, enables to display coral reef related data and interact with maps on Caribbean coral reefs. The unique reef health simulator is an interactive, scenario-building, simulation tool which can be used to estimate changes in reef resilience under different environmental regimes and management policies.

### **Governance, policies, management**

The project Monitoring and Evaluation of Spatially Managed Areas developed an integrated management tool box for SMAs. The MESMA Framework represents the outcome of an iterative process, provides guidance on the selection, mapping and assessment of ecosystem components and human pressures, the evaluation of management effectiveness and potential adaptations to management, in order to monitor and evaluate spatially managed marine areas (SMAs) in a systematic way. The suggested stepwise process is based on existing concepts of adaptive management and considers a number of practical examples. The developed conceptual tools were tested for their applicability in nine case studies, distributed over the European marine regions, and reflecting the complexity of the marine spatial planning process in Europe. To support the implementation of an ecosystem based marine spatial management approach, the framework considers interactions between ecosystem components, management sectors, institutions and key actors, as well as the cumulative impacts of human activities. MESMA collected and described over 70 tools such as models, databases and decision support tools that are relevant for the monitoring and evaluation of spatially managed areas.

A key aspect of ecosystem-based management is the choice of management options that can target the major threats to the different aspects of the ecosystem. The ODEMM Pressure and Ecological Risk Assessments allow the main threats to be identified and indicate the links between components and human activities. The ODEMM integrated Management Strategy Evaluation tool is based on the Ecological Risk Assessment consisting of Driver-Pressure-State combinations and can be used to link types of management options with the categories of the Pressure Assessment, allowing different manageable aspects of human activities to be targeted to address the main threats in the system. Management options can focus on drivers, pressures, ecological components or combinations of these. The ODEMM iMSE tool is a comprehensive framework that aims to provide guidance for the identification and selection of consistently defined management options and allows an evaluation of these options to achieve policy objectives through their reduction of risk.

VECTORS evaluates current forms and mechanisms of marine governance in relation to the vectors of change. Based on its findings, VECTORS provides solutions and tools for relevant stakeholders and policymakers, to be available for use during the lifetime of the project. VECTORS has provided advice for the management of marine resources that are influenced by a variety of manageable (e.g., fishing, energy, shipping) and non-manageable (climate) pressures.

#### Theme 4: Ecosystem structure and functioning

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>MEECE</b>	Marine Ecosystem Evolution in a Changing Environment	-Ecosystem Models including all relevant processes in the system, from physics to chemistry, and plankton to fish	Global, MSFD	EU - FP7 2008-2013	yes	- <i>Publications and results:</i> <a href="http://cordis.europa.eu/project/rcn/89307_en.html">cordis.europa.eu/project/rcn/89307_en.html</a>
<b>CoralFISH</b>	Assessment of the interaction between corals, fish and fisheries, in order to develop monitoring and predictive modelling tools for ecosystem based management in the deep waters of Europe and beyond	-Standard methodologies and tools to produce the first comprehensive catalogue and sea floor maps of European coral habitats -knowledge regarding coral ecosystem functioning including the role of fish	Europe and beyond	EU - FP7 2008-2013	none	- <i>Publications:</i> <a href="http://eu-fp7-coralfish.net/publications1.php">http://eu-fp7-coralfish.net/publications1.php</a> - <i>Results:</i> <a href="http://eu-fp7-coralfish.net/habitat_suitability_modelling_WP6.php">http://eu-fp7-coralfish.net/habitat_suitability_modelling_WP6.php</a> & <a href="http://cordis.europa.eu/project/rcn/89331_en.html">cordis.europa.eu/project/rcn/89331_en.html</a>
<b>EURO-BASIN</b>	European Union Basin-scale Analysis, Synthesis and Integration	-State of the art by producing new observations of particle formation, aggregation, sinking and decomposition in a range of marine ecosystems, focussed on the North Atlantic basin -Oceanographic habitats utilized by key biogeochemical and ecosystem species in the North Atlantic -Key processes controlling the flow of carbon and energy, within and between trophic levels in the North Atlantic and shelf ecosystems -Models to estimate changes in Carbon fluxes in the North Atlantic and consequences regarding Climate Change -Modelling tools to improve understanding of factors influencing the distributions of top predators	North Atlantic and Arctic	EU - FP7 2010-2014	yes	- <i>Publications:</i> <a href="http://www.euro-basin.eu/www.euro-basin.eu">www.euro-basin.eu/www.euro-basin.eu</a> - <i>Results:</i> <a href="http://cordis.europa.eu/project/rcn/97329_en.html">cordis.europa.eu/project/rcn/97329_en.html</a> & <a href="http://www.euro-basin.eu/">www.euro-basin.eu/</a>
<b>CODEMAP</b>	COmplex Deep-sea Environments: Mapping habitat heterogeneity As Proxy for biodiversity	-Methods to quantify deep-sea biodiversity	Global	EU - FP7 - ERC 2011-2017	none	- <i>Publications and results:</i> <a href="http://www.codemap.eu/outputs">www.codemap.eu/outputs</a> & <a href="http://cordis.europa.eu/project/rcn/97797_en.html">cordis.europa.eu/project/rcn/97797_en.html</a>
<b>DEVOTES</b>	Development of innovative tools for understanding marine biodiversity and assessing good environmental status	-Criteria for the practical application of BEF (Biodiversity and Ecosystem Functioning) relationships	Europe, MSFD	EU - FP7 2012-2016	yes	- <i>Publications:</i> <a href="http://www.devotes-project.eu/publications/">www.devotes-project.eu/publications/</a> & - <i>Results:</i> <a href="http://www.devotes-project.eu/deliverables-and-milestones/">www.devotes-project.eu/deliverables-and-milestones/</a> & <a href="http://cordis.europa.eu/project/rcn/105613_en.html">cordis.europa.eu/project/rcn/105613_en.html</a>

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>TESELA</b>	Transporte de sedimentos en la plataforma continental de Andalucía Oriental: Observación multiescalar, modelado y simulación numérica	-Better understanding of sedimentary processes	Andalusia	National 2013-2016	Spain/US A	- <i>Publication:</i> <a href="http://www.ieo.es/proyectos?p_p_id=ieoproyectosmain_WAR_IEOProyectosportlet&amp;p_p_lifecycle=0&amp;p_p_state=normal&amp;p_p_mode=view&amp;p_p_col_id=column-2&amp;p_p_col_pos=1&amp;p_p_col_count=2&amp;ieoproyectosmain_WAR_IEOProyectosportlet_acronimo=TESELA">www.ieo.es/proyectos?p_p_id=ieoproyectosmain_WAR_IEOProyectosportlet&amp;p_p_lifecycle=0&amp;p_p_state=normal&amp;p_p_mode=view&amp;p_p_col_id=column-2&amp;p_p_col_pos=1&amp;p_p_col_count=2&amp;ieoproyectosmain_WAR_IEOProyectosportlet_acronimo=TESELA</a>
<b>ATLAS</b>	A Trans-Atlantic Assessment and deep-water ecosystem-based Spatial management plan for Europe	-Step-change in understanding of sensitive Atlantic ecosystems (sponge, cold-water coral, seamount and mid-ocean ridge ecosystems) connectivity, functioning, and responses to future changes in human use and ocean climate	Atlantic	H2020 2016-2020	yes	<a href="http://cordis.europa.eu/project/rcn/200481_en.html">cordis.europa.eu/project/rcn/200481_en.html</a>

MEECE has developed end-to-end models which aim to represent an entire ecosystem by including all relevant processes in the system, from physics to chemistry, and plankton to fish. To achieve this three types of models have been coupled: hydrodynamic models, lower trophic level (bacteria, phytoplankton, and zooplankton) and higher trophic level (mainly fish species) into a single modelling framework.

The models developed and applied in MEECE provide tools for addressing the complex impact of drivers (Climate change, acidification, eutrophication, invasive species, pollution, fishing, multiple drivers) and ecosystem responses. For each eight drivers, ecosystem models lead to different scopes and limitations. Such numerical models which can simulate and predict changes in the state of marine ecosystem in response to different drivers and management scenarios, and can support the decision-making process.

EURO-BASIN was designed 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 North Atlantic ecosystems are a major player in the global carbon cycle. These ecosystems, the key species responsible for carbon flow, and their habitats, are constantly changing, under the influence of both large-scale fishing and climate change. Their evolving capacity to sequester carbon and provide services to society, should current climate and fishing trends continue, still warrants further investigation. In order to better understand the basin scale processes impacting upon these ecosystems, EUROBASIN develop some models 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 dynamics of basin and shelf ecosystems for the advancement of ecosystem based management strategies.

Some directives (e.g. WFD and Habitats Directive) have focussed on the structure of the ecosystem and its components (such as species richness, abundance, percentage cover) rather than the functioning (such as rate processes, primary production, and population dynamics). Despite this, the maintenance of ecosystem functioning and its relationship with biodiversity is central to a healthy ecosystem and hence to attaining GES especially for the biodiversity descriptors. Therefore, DEVOTES addresses the question of incorporating functioning into status classification and its relationship with biodiversity. DEVOTES identified five important criteria for the practical application of BEF (Biodiversity and Ecosystem Functioning) relationships although the information required does not yet exist for immediate implementation of BEF relationships within operational marine monitoring.

With the ever-increasing pressure on Deep Oceans, there is a rising and urgent need for the quantification of deep-sea biodiversity. As indicator of ecosystem status and functioning, it is a key aspect in fundamental understanding of deep-sea biology. To quantify deep-sea biodiversity, CODEMAP aims to map deep-sea cliffs and overhangs using underwater vehicles, to develop visualisation models, including derivation of 3D habitat heterogeneity measures. In the CODEMAP study, the four main branches of Whittard Canyon, Northeast Atlantic, were mapped using multibeam and sidescan sonars to examine which environmental variables were most useful in predicting regions of higher biodiversity. By using ensemble mapping approaches, the approach developed provides a cost-effective strategy to facilitate the location of rare biological communities of conservation importance and guide further sampling efforts to help ensure that appropriate monitoring can be implemented.

ATLAS creates a dynamic new partnership between multinational industries, SMEs, governments and academia to assess the Atlantic's deep-sea ecosystems and Marine Genetic Resources to create the integrated and adaptive planning products needed for sustainable Blue Growth. ATLAS will gather diverse new information on sensitive Atlantic ecosystems (incl. VMEs and EBSAs) to produce a step-change in our understanding of their connectivity, functioning and responses to future changes in human use and ocean climate. This is possible because ATLAS takes innovative approaches to its work and interweaves its objectives by placing business, policy, and socioeconomic development at the forefront with science. ATLAS not only uses trans-Atlantic oceanographic arrays to understand and predict future change in living marine resources, but enhances their capacity with new sensors to make measurements directly relevant to ecosystem function. The ATLAS team has the track record needed to meet the project's ambitions and has already developed a programme of 25 deep-sea cruises, with more pending final decision. These cruises will study a network of 12 Case Studies spanning the Atlantic including sponge, cold-water coral, seamount and mid-ocean ridge ecosystems.

Theme 5: Carrying capacity, ecosystem tipping points, and ocean stressors

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>COMITE</b>	Plancton microbiano y temperatura en el océano costero	-Effects of future warming on the ecology and biogeochemical role of temperate coastal microbial assemblages	National	2011	Spain/USA	<a href="http://ocean5.uca.es/cytmarphp/public.Proyectos.php?operation=view&amp;pk0=155">ocean5.uca.es/cytmarphp/public.Proyectos.php?operation=view&amp;pk0=155</a>
<b>MEECE</b>	Marine Ecosystem Evolution in a Changing Environment	-The MEECE Model Atlas: simulations and projections for how ecosystems will respond to different scenarios for environmental change covering the main European regional seas	Global, MFSD	EU - FP7 2008-2013	yes	- <i>Publications:</i> <a href="http://cordis.europa.eu/project/rcn/89307_en.html">cordis.europa.eu/project/rcn/89307_en.html</a> - <i>Results:</i> <a href="http://www.meece.eu/">www.meece.eu/</a>
<b>FACT</b>	Forage Fish Interactions	-Estimation of the effect of forage fish exploitation on biodiversity and ecosystem stability	Europe	EU - FP7 2010-2012	none	- <i>Results:</i> <a href="http://cordis.europa.eu/project/rcn/93618_en.html">cordis.europa.eu/project/rcn/93618_en.html</a> & <a href="http://www.facts-project.eu/">www.facts-project.eu/</a>
<b>SOUNDMAR</b>	Sound use for orientation by marine fauna, an ecosystem approach considering anthropogenic noise	-Impact of acoustic pollution on the base levels of marine trophic webs, study of wild scallop larvae -Impact of ship collisions on marine macrofauna, study of Brydes' whales	Global	EU - FP7 2010-2013	yes	- <i>Results:</i> <a href="http://cordis.europa.eu/project/rcn/93092_en.html">cordis.europa.eu/project/rcn/93092_en.html</a>
<b>ODEMM</b>	Options for Delivering Ecosystem-Based Marine Management	-The ODEMM Linkage Framework: tool to understand the pathways through which sector-activities affect ecological components	Europe, MSFD	EU - FP7 2010-2013	none	- <i>Publications:</i> <a href="http://cordis.europa.eu/result/rcn/55984_en.html">cordis.europa.eu/result/rcn/55984_en.html</a> - <i>Results:</i> <a href="http://odemmm.com/sites/odemmm.com/files/ODEMM%20Report_0.pdf">odemmm.com/sites/odemmm.com/files/ODEMM%20Report_0.pdf</a> & <a href="http://odemmm.com/content/resources">odemmm.com/content/resources</a>
<b>EURO-BASIN</b>	European Union Basin-scale Analysis, Synthesis and Integration	-Models to estimate species distribution under future climate change scenarios and impacts of climate change on biodiversity and habitats -Understand and predict the impact of climate change and variability and anthropogenic activity (fisheries) on marine ecosystem structure and function in the North Atlantic Ocean and shelf seas -Models to evaluate the impacts of future climate change in phytoplankton and zooplankton community	North Atlantic and Arctic	EU - FP7 2010-2014	yes	- <i>Publications and results:</i> <a href="http://cordis.europa.eu/project/rcn/97329_en.html">cordis.europa.eu/project/rcn/97329_en.html</a> & <a href="http://www.euro-basin.eu/">www.euro-basin.eu/</a>

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>ARPA</b>	Estudio de la biología y pesquería de atún rojo en el Atlántico Este	-Study of the biology and the Spanish fisheries of red tuna of the Atlantic Ocean - stock assessment	Atlantic Ocean	National 2010-2016	Spain/USA	- <i>Publications:</i> <a href="http://www.ieo.es/area-pesqueras?p_p_id=ieoproyectosmain_WAR_IEOProyectosportlet&amp;p_p_lifecycle=0&amp;p_p_state=normal&amp;p_p_mode=view&amp;p_p_col_id=column-2&amp;p_p_col_pos=2&amp;p_p_col_count=3&amp;_ieoproyectosmain_WAR_IEOProyectosportlet_acronimo=ARPA-4&amp;_ieoproyectosmain_WAR_IEOProyectosportlet_filtroArea=Pesquer%C3%ADas&amp;_ieoproyectosmain_WAR_IEOProyectosportlet_filtroCentros=Todos">www.ieo.es/area-pesqueras?p_p_id=ieoproyectosmain_WAR_IEOProyectosportlet&amp;p_p_lifecycle=0&amp;p_p_state=normal&amp;p_p_mode=view&amp;p_p_col_id=column-2&amp;p_p_col_pos=2&amp;p_p_col_count=3&amp;_ieoproyectosmain_WAR_IEOProyectosportlet_acronimo=ARPA-4&amp;_ieoproyectosmain_WAR_IEOProyectosportlet_filtroArea=Pesquer%C3%ADas&amp;_ieoproyectosmain_WAR_IEOProyectosportlet_filtroCentros=Todos</a>
<b>VECTORS</b>	Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors	-Models to investigate consequences of future climate change and other stressors -Review of regional seas vectors and drivers and review of direct and indirect pressures for change in European Regional Seas: -Ballast water management -Climate change and related impacts -Fisheries -Interactions between multiple users and sectors -Land-based pollution -Maritime transport -Ocean acidification -Tourism -Bioinvasions	Europe	EU - FP7 2011-2015	none	- <i>Publication:</i> <a href="http://www.marine-vectors.eu/Publications">www.marine-vectors.eu/Publications</a> - <i>Results:</i> <a href="http://www.marine-vectors.eu/">www.marine-vectors.eu/</a>
<b>GDR-I RECHAGLO</b>	International Research Network on the "Responses of populations and communities exploited by fisheries and aquaculture and of their habitats to global change	-Study of the effects of global change, mainly climate change and overexploitation, on the biological compartments of inshore and offshore marine ecosystems that sustain economic activity, namely fisheries and aquaculture, and their consequences in terms of exploited living resource management and ecosystem conservation.	Atlantic Ocean	National 2015-2018	France/Canada	<a href="http://wwz.ifremer.fr/institut_eng/The-Institute/Europe-et-International/Zone-Amerique">wwz.ifremer.fr/institut_eng/The-Institute/Europe-et-International/Zone-Amerique</a>

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>A Plan for Improved Research and Management of Ciguatera on a global scale</b>	At the 11th Session of the Intergovernmental Oceanographic Commission's (IOC) Intergovernmental Panel on Harmful Algal Blooms (IPHAB), a Recommendation was adopted to develop "A Plan for Improved Research and Management" of Ciguatera on a global scale. This Recommendation was subsequently adopted by the full IOC Assembly at its 27th Session.	<ol style="list-style-type: none"> <li>1. Develop a coordinated Ciguatera strategy</li> <li>2. Improve organism detection and sampling strategies</li> <li>3. Improve toxin detection</li> <li>4. Improve epidemiological data collection, reporting and assessments</li> </ol>	IOC/IPHAB Global Ciguatera Strategy	2015-2019	IOC Harmful Algal Bloom Programme  IOC-FAO-WHO	<a href="http://hab.ioc-unesco.org/index.php?option=com_content&amp;view=article&amp;id=47:ciguatera&amp;catid=29:activities">hab.ioc-unesco.org/index.php?option=com_content&amp;view=article&amp;id=47:ciguatera&amp;catid=29:activities</a>

## Ocean stressors

The ODEMM project carried out an extensive review of the status, trends, pressures and impacts of the marine regions of Europe and comprehensive reviews of the legal and institutional aspects of the governance situation in Europe.

These compilations of current knowledge allowed the development of a linkage framework that identifies all relevant interactions between key ecosystem components – human activities or sectors, their pressures, ecological components, and ecosystem services, and the relevant policy objectives.

- **Climate change and Ocean acidification**

Microbes are fundamental players in the biogeochemical cycling of carbon in the coastal ocean. For instance, there is growing consensus that bacterial biomass will increase in a warmer ocean likely characterized by lower phytoplankton biomass, a trend that contradicts the predictions of the metabolic theory of ecology. COMITE will address the effects of future warming on the ecology and biogeochemical role of temperate coastal microbial assemblages through three different approaches. The final goal of COMITE environmental and perturbation experiments data analysis is to build a predictive, testable model on the effects of realistic temperature rises on the biogeochemical role of oceanic bacteria.

EURO-BASIN have estimated changes in Carbon fluxes in the North Atlantic based on biochemical models (ERSEM, MEDUSA and PICSES). Model projections indicate that the rate of carbon uptake by ocean will decrease over the 21st century, largely as a result of saturation. They analysed significant changes in the biogeography of the North Atlantic Ocean over the next century.

By coupling habitat models with hydrographic-biogeochemical models, EURO-BASIN have stimulated species distribution under future change scenarios.

EURO-BASIN constructed a bio-economic model including 19 fish stocks, 11 fishing systems, 4 aquaculture systems, 12 fish commodities, 11 geographical areas, 22 political nodes, 23 trade systems, and 67 markets to predict consequences of climate change in the North Atlantic on distributional shifts of key fish stocks (distribution and production in relation with habitat preferences, ecosystem changes and competitive interactions between species) between 2010 and 2040.

A classification has been developed based on environmental indicators relevant to the describing of the distributions of fish habitats and hence by inference fish populations.

EURO-BASIN illustrated changes in the phytoplankton phenology. These changes will impact the distributions of phytoplankton along with its community structure and condition, all of which are indicators for assess pelagic habitat. Consequently the future assessment of GES for pelagic habitats will need to be able take account of such changes if we are to correctly maintain it in the future.

EURO-BASIN also provided new observations of zooplankton aggregation, flux and disintegration were combined with existing data through large scale numerical models. This enabled modelling experiments predicting the likely response of the biological carbon pump and hence ocean CO<sub>2</sub> storage relative to climate change.

EURO-BASIN developed statistical-based habitat models for 14 copepod species in the North Atlantic Ocean, to evaluate the impacts of future climate change in community structure, diversity, distribution, and phenology of zooplankton community. Projections for the end of the century indicated that copepod community is expected to respond substantially to climate change.

Based on these findings EURO-BASIN developed habitat and process models for monitoring and predicting the future changes in key species and food web biogeography due to prominent ecosystem drivers thereby developing indices of the physical characteristics of key species and food web habitats for assessing the past, present and future states of marine ecosystems and their services.

Ecosystem models provide a tool through which EURO-BASIN can also explore the consequences of changes in energy transfer on foodwebs and illustrate the ecosystem response to climate change at different levels of ecosystem function (Net Primary Production regarding Sea Surface Temperature, Secondary Production regarding Net Primary Production and Carbon Export Net regarding Primary Production).

GDR-I RECHAGLO aims to study the effects of global change, mainly climate change and overexploitation, on the biological compartments of inshore and offshore marine ecosystems that sustain economic activity, namely fisheries and aquaculture, and their consequences in terms of exploited living resource management and ecosystem conservation. More precisely, the objectives of the GDR-I RECHAGLO are:

- To explore separate and combined effects of environmental perturbations resulting from global change (e.g. temperature, hydrodynamics, water acidity, oxygen concentration, exploitation mortality) using experimental and modelling approaches;
- To consider these effects at different biological and spatial scales;
- To quantify the relative contribution of the different factors identified to the changes observed within the biological

compartment of ecosystems;

- To develop and propose, on the basis of the previous results, scenarios and projections regarding the dynamics of exploited resources and their ecosystems at various time-horizons
- To propose and evaluate adaptation frameworks and tools that allow integrating global change effects within strategies for the management of exploited living resources and their ecosystems

The three European seas investigated in VECTORS, the Mediterranean Sea, the Baltic Sea and the North Sea, have all undergone continuous warming during the second half of the twentieth century. VECTORS research focus to provide future projections of key environmental variables and changes in marine life in response to long-term climate change and to offer insight into the possible future distribution and productivity of commercial fish and invertebrates, potential invasive species, animals and plants of conservation interest, in response to long-term climate change.

VECTORS aims to collate the best available data on ocean acidification from IPCC, EPOCA, and ongoing national projects and other published scientific literature and incorporate the effects of ocean acidification into ecosystem models. As an example, VECTORS modelled future scenarios for three regional seas to inform on the relative vulnerability of the lower trophic level of the marine ecosystem to the investigated drivers of change: climate change, ocean acidification and river discharge. Maps of change of key ecological indicators of the system (such as nutrient levels or community production) and the statistical significance of these changes have been made available for simulations representing a ten-year period in the middle of the 21st century. Eleven different modelling applications were undertaken by VECTORS, covering 150 European marine species, towards providing future projections of distribution and productivity in marine organisms. Models have been used to investigate the possible consequences that might follow as a result of future climate change, but other human stressors have also been examined, including various fishery management scenarios, as well as the introduction of offshore wind farms and marine protected areas.

- **Noise**

There is little or no knowledge about possible long-term or population impacts, or about the impact of noise on the base levels of marine trophic webs, with potential consequences on the maintenance of ecosystem balance. Understanding the impact of noise on marine fauna at the population level requires knowledge about the vulnerability of different life stages. SOUNDMAR performed an experiment on the effect of low frequency noise on the development of marine larvae and provided the first evidence that noise exposure during scallop larval development produces body malformations in marine invertebrates.

Abnormalities may be caused by different mechanisms including mechanical or physiological stress and the results will stimulate research to identify noise-induced mechanisms that may be similar across different taxa. Underwater human activities such as seismic surveys, pile-driving, low-frequency sonar and blasting regularly introduce into the environment noise exceeding the levels tested in this study at spatial ranges that will vary for different sources and oceanographic conditions.

These results call for further research to define exposure thresholds and conditions at which noise may affect stock recruitment of wild scallops with important economic and ecological values. Shellfish and other invertebrates provide an important food source for different taxa, it is important to define thresholds of effects of acoustic pollution on marine invertebrate populations and provide a scientific basis for the design of impact mitigation measures of human activities.

Beaked whales live in small social groups and do not tend to mass strand under natural circumstances. However, mass strandings of beaked whales related to naval exercises have been recorded in many places of the world. Whales die with a characteristic pattern of multiorganic haemorrhages consistent with decompression sickness. The most accepted hypothesis explaining the strandings is a behavioural reaction of these extreme deep-diving whales to intense sonar used to detect submarines. SOUNDMAR showed that they overlap in frequency range with mid-frequency sonar related to strandings. The SOUNDMAR fellowship project was part of the collaborative scientific and political effort that ended beaked whales mortalities in 2004, when the Spanish Ministry of Defence adopted a voluntary moratorium to the use of naval sonar within 50 nm of the archipelago. Now, the fellowship is part of an ACCOBAMS (United Nations Agreement for the Conservation of Small Cetaceans in the Black and Mediterranean Seas) initiative to prevent mass mortalities of beaked whales in the Mediterranean in relation to naval exercises.

- **Collisions**

Ship strikes are another important factor of anthropogenic impact on cetaceans. Passive acoustic monitoring of whale vocalisations is used to inform ships of the position of the whales. SOUNDMAR performed a study with acoustic tags of Brydes' whales in the Hauraki Gulf (New Zealand) where ship collisions constitute the highest factor of human impact for this protected species. Results provided the first quantification of the foraging behaviour of this species (and based the

design of impact-risk mitigation measures for ship-strikes in the Gulf. These measures are being developed in a social forum involving stakeholders from the government, academy, shipping companies and social groups.

- **Bioinvasions, Invasive alien species and outbreaks**

VECTORS aimed to identify and disseminate the most up-to-date understanding of drivers that create pressures of change which could affect the areas of concern to VECTORS, i.e. invasive alien species, outbreak forming species, and changes in species distribution and productivity in the three European regional seas: the North Sea, the Baltic Sea and the Western Mediterranean Sea. VECTORS has delivered new information to document the distribution of invasive alien species (IAS) and outbreak forming species (OFS), to determine the stochastic and deterministic drivers of proliferations and ecophysiological features boosting regime shifts of marine communities, to discriminate sources and vectors of bioinvasions and to foresee consequences of bioinvasions in terms of impact on ecosystem functioning and services. Outcomes include AquaNIS which represents the most updated database resource available to scientists, coastal managers, stakeholders, and policymakers dealing with aquatic IAS in European seas. This new information from VECTORS has wide implications going far beyond the various study species and geographical areas, representing a model integrative approach towards a better understanding of the mechanisms of bioinvasions.

- **Land-based pollution**

Land-based pollution involves a number of inter-related pressures such as eutrophication, hypoxia, turbidity, redox potential discontinuity, and various types of biological and chemical contamination. VECTORS results are of help in identifying causes and effects of land-based pollution and in suggesting priorities for management and prevention. VECTORS research focused on determining the effect of land-based pollution on population dynamics in coastal areas, and the role of nutrient loads for primary production to assess the effects of land-based pollution on aquaculture activities and to suggest management strategies to mitigate the effects of land based pollution.

- **Maritime transport**

VECTORS research aims to characterise the EU member states' fleets and international vessels navigating in EU waters then determine the main maritime transport related environmental pressures and their impacts.

- **Tourism**

Tourism represents the third largest socio-economic activity in the European Union. VECTORS has shown tourism as an important pressure in the Baltic, Mediterranean, and North Seas but also as an opportunity for the sustainability of certain economic sectors, for the reduction on environmental impacts, for educational values or for scientific platforms. The project has also identified and analysed key interactions between multiple uses and sectors regarding tourism.

Theme 6: Cumulative effects

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>VECTORS</b>	Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors	-Mechanisms of change in species distribution and productivity: combined effects of broad scale and local drivers of change -a subjective assessment of the interactions between multiple users and sectors and possible conflicts in terms of resource exploitation from different sectors, with specific reference to the VECTORS target areas of concern: outbreaks, invasive species, and changes in species distribution and productivity.	Europe	EU - FP7 2011-2015	none	- <i>Publications and results:</i> <a href="http://www.marine-vectors.eu/">www.marine-vectors.eu/</a> & <a href="http://cordis.europa.eu/project/rcn/97826_en.html">cordis.europa.eu/project/rcn/97826_en.html</a>
<b>DEVOTES</b>	Development of innovative tools for understanding marine biodiversity and assessing good environmental status	-Data-based or expert judgement-based analysis regarding cumulative effects	Europe, MSFD	UE FP7 2012-2016	yes	- <i>Publications:</i> <a href="http://www.devotes-project.eu/publications/">www.devotes-project.eu/publications/</a> - <i>Results:</i> <a href="http://www.devotes-project.eu/deliverables-and-milestones/">www.devotes-project.eu/deliverables-and-milestones/</a> & <a href="http://cordis.europa.eu/project/rcn/105613_en.html">cordis.europa.eu/project/rcn/105613_en.html</a>

Cumulative effects (including synergistic and antagonistic) are considered an important topic of debate (e.g. OSPAR 2009 and 2011 by OSPAR Intersessional Correspondence Group on Cumulative Effects, ICES 2013 by ICES Working Group on Integrated Assessments of the North Sea). The DEVOTES review investigated the challenges in moving from a conceptual framework to a data-based or expert judgement-based analysis. These challenges imply identifying all activities, pressures and ecological components and their linkages, indicators availability and their quality or thresholds, the equality of data from different areas, assessment scales and scaling up assessments, and finally confidence in the assessments.

In addition to reporting individual drivers of change, it was critical for VECTORS to consider interactions between multiple users and sectors and possible conflicts in terms of resource exploitation from different sectors, with specific reference to the VECTORS target areas of concern: outbreaks, invasive species, and changes in species distribution and productivity. Drivers or pressures studied through DEVOTES were: Ballast water management, Climate change and related impacts, Fisheries, Interactions between multiple users and sectors, Land-based pollution Maritime transport Ocean acidification and Tourism. The research focussed on combined effects of broad scale and local drivers of change and combined effects of local drivers considered likely to co-occur, particularly in the case study areas.

Theme 7: Analysis of social and economic consequences of management actions

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>FEMS</b>	Framework for the evaluation of management strategies	-Framework to evaluate management strategies that are consistent with the precautionary approach whilst maintaining the viability of the fishing industry	Atlantic Ocean	UE PF5 + National 2003-2011	Spain/Portugal/France/Denmark/USA	<a href="http://cordis.europa.eu/project/rcn/91658_en.html">cordis.europa.eu/project/rcn/91658_en.html</a>
<b>MEECE</b>	Marine Ecosystem Evolution in a Changing Environment	-Management Strategy Evaluation tools to assess the consequences of a range of management strategies or options	Global, MFSD	UE FP7 2008-2013	yes	- <i>Publications:</i> <a href="http://www.meece.eu/documents/MEECE_papers.pdf">www.meece.eu/documents/MEECE_papers.pdf</a> - <i>Results:</i> <a href="http://www.meece.eu/Deliv.html">www.meece.eu/Deliv.html</a> & <a href="http://cordis.europa.eu/project/rcn/89307_en.html">cordis.europa.eu/project/rcn/89307_en.html</a>
<b>CoralFISH</b>	Assessment of the interaction between corals, fish and fisheries, in order to develop monitoring and predictive modelling tools for ecosystem based management in the deep waters of Europe and beyond	-Bio-economic models to assess the impact on fisheries on coral habitat	Europe and beyond	EU - FP7 2008-2013	none	- <i>Publications and results:</i> <a href="http://eu-fp7-coralfish.net/habitat_suitability_modelling_WP6.php">eu-fp7-coralfish.net/habitat_suitability_modelling_WP6.php</a> & <a href="http://cordis.europa.eu/project/rcn/89331_en.html">cordis.europa.eu/project/rcn/89331_en.html</a>
<b>FACT</b>	Forage Fish Interactions	-Estimation of economic effects of forage fish exploitation using integrated economic analysis of ecosystem models -Multispecies models to estimate the biological and economic tradeoffs associated with various exploitation strategies of forage fish stocks in major European fisheries	Europe	EU - FP7 2010-2012	none	- <i>Publications and results:</i> <a href="http://cordis.europa.eu/project/rcn/93618_en.html">cordis.europa.eu/project/rcn/93618_en.html</a> & <a href="http://www.facts-project.eu">www.facts-project.eu</a>
<b>ODEMM</b>	Options for Delivering Ecosystem-Based Marine Management	-Cost and Benefits Analyses of a range of Management Options using appropriate techniques	Europe, MSFD	EU - FP7 2010-2013	none	- <i>Publications:</i> <a href="http://cordis.europa.eu/project/rcn/93904_en.html">cordis.europa.eu/project/rcn/93904_en.html</a> - <i>Results:</i> <a href="http://odemmm.com/sites/odemmm.com/files/ODEMM%20Report_0.pdf">odemmm.com/sites/odemmm.com/files/ODEMM%20Report_0.pdf</a> & <a href="http://odemmm.com/content/resources">odemmm.com/content/resources</a>
<b>EURO-BASIN</b>	European Union Basin-scale Analysis, Synthesis and Integration	-Economic analyse for Ecosystem based Management to fisheries in the North Atlantic	North Atlantic and Arctic	UE FP7 2010-2014	yes	- <i>Publications:</i> <a href="http://www.euro-basin.eu/">http://www.euro-basin.eu/</a> - <i>Results:</i> <a href="http://www.euro-basin.eu/">http://www.euro-basin.eu/</a> & <a href="http://cordis.europa.eu/project/rcn/97329_en.html">cordis.europa.eu/project/rcn/97329_en.html</a>

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>VECTORS</b>	Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors	-Impact of ecological changes on economic results of different marine sectors -Mechanisms of change in human behaviour regarding the spatial interactions between different human activities or uses (e.g. between fishing activities and maritime traffic, offshore wind farms, aggregate extractions)	Europe	EU - FP7 2011-2015	none	- <i>Publications and results:</i> <a href="http://www.marine-vectors.eu/Publications">www.marine-vectors.eu/Publications</a> & <a href="http://cordis.europa.eu/project/rcn/97826_en.html#">cordis.europa.eu/project/rcn/97826_en.html#</a> & <a href="http://www.marine-vectors.eu/">www.marine-vectors.eu/</a>
<b>Myfish</b>	Maximising yield of fisheries while balancing ecosystem, economic, and social concerns	-Maximum Sustainable Yield (MSY) to achieve a balanced trade-offs between ecosystem, economic and social objectives	UE FP7	2012-2016	yes	- <i>Publications:</i> <a href="http://www.myfishproject.eu/media-centre-2/myfish-publications">www.myfishproject.eu/media-centre-2/myfish-publications</a> - <i>Results:</i> <a href="http://www.myfishproject.eu/myfish-regional-studies/myfish-decision-support-tables">www.myfishproject.eu/myfish-regional-studies/myfish-decision-support-tables</a> & <a href="http://cordis.europa.eu/project/rcn/101745_en.html">cordis.europa.eu/project/rcn/101745_en.html</a>

FACTS has estimated the economic effects of forage fish exploitation through a model describing economic gain of fishing while using ecosystem models to describe the abundance of both forage fish and interactions with other components of the ecosystem. Integration of a model of species interactions and a model of market price of landings and costs of the fishery is unique and has provided an estimate of economic consequences which takes account of species interactions in contrast to traditional bio-economic single species models.

In ODEMM, a number of approaches were explored that can be used in trade-off analysis of management options, in terms of cost-benefit analysis. Cost-benefit analysis (CBA) is an economic decision-support tool that evaluates the changes in costs and benefits that occur when a Management Option (MO) is applied, typically measuring these changes in monetary terms. In ODEMM, Management Strategy Evaluation tools provide a methodology for assessing the consequences of a range of management strategies or options and presenting the results in a way which helps the decision maker to make a rational decision, in the context of their own objectives, preferences, and attitudes to risk.

VECTORS has increased understanding of the economic implications of ecosystem changes and multiple human activities. VECTORS has analysed the impact of ecological changes on the economic results of the different marine sectors, identified and analysed key interactions between multiple uses and sectors, analysed different strategies for mitigation and adaptation and analysed the incentives for international, interregional, and intersectoral cooperation in managing the marine environment. VECTORS has also improved understanding of the key processes driving the behaviour of human agents utilising a variety of EU maritime domains. Particular attention has been paid to the spatial interactions between fishing activities and other human uses (e.g. maritime traffic, offshore wind farms, aggregate extractions), but the behaviour of non-fishing sectors of activity has also been considered. Various quantitative and semi-qualitative approaches were pursued to gain better insight into behavioural drivers based on past data, and also to forecast how human agents would react if access was constrained by either management (e.g. Marine Protected Areas – MPA), or the installation of a new operator.

Theme 8: Maintaining the legitimacy and credibility of science for evidence based policy

Project acronym	Project title	Main results	Scale & Policies	Funding & Duration	Canada or USA involved	Links
<b>MEFEPO</b>	Making the European Fisheries Ecosystem Operational	-Governance, scientific, social, and economic issues required to introduce an ecosystem approach to European marine fisheries: an operational framework for three regional seas	Europe, MSFP, CFP	EU - FP7 2008-2011	none	- <i>Publications and Results:</i> <a href="http://www.liverpool.ac.uk/mefepo/reports-and-outputs/">www.liverpool.ac.uk/mefepo/reports-and-outputs/</a> & <a href="http://cordis.europa.eu/result/rcn/159565_en.html">cordis.europa.eu/result/rcn/159565_en.html</a>
<b>MARCOM+</b>	Towards an integrated marine and maritime science community	-The European marine and maritime science and technology forum.	Europe	EU - FP7 2010-2012	none	- <i>Results:</i> <a href="http://cordis.europa.eu/project/rcn/94699_en.html">cordis.europa.eu/project/rcn/94699_en.html</a> & <a href="http://www.MarineMaritimeScienceForum.eu">www.MarineMaritimeScienceForum.eu</a>
<b>EUROMARINE</b>	Integration of European marine research networks of excellence - Euromarine	-Source of the best expertise and innovation available in European Marine Research that can respond rapidly to societal needs, environmental demands, well-being and sustainability	Europe	EU - FP7 2011-2013 then 2014-ongoing	none	- <i>Results:</i> <a href="http://cordis.europa.eu/project/rcn/97379_en.html">cordis.europa.eu/project/rcn/97379_en.html</a> & <a href="http://www.euromarinenetwork.eu">www.euromarinenetwork.eu</a>
<b>STAGES</b>	Science and Technology Advancing Governance of Good Environmental Status	-Identification of knowledge gaps regarding the implementation of The Marine Strategy Framework Directive and the achievement of Good Environmental Status (GES)	Europe, MSFD	EU - FP7 2012-2014	none	- <i>Publications</i> <a href="http://cordis.europa.eu/result/rcn/164326_en.html">cordis.europa.eu/result/rcn/164326_en.html</a> - <i>Results:</i> <a href="http://www.stagesproject.eu/stages-results/stages-deliverables">www.stagesproject.eu/stages-results/stages-deliverables</a>
<b>DEVOTES</b>	Development of innovative tools for understanding marine biodiversity and assessing good environmental status	-To reinforce the role of R&D projects in supporting the implementation of the MSFD from a scientific perspective -Identification of main shortcoming and needs for improvement for some of the MSFD biodiversity descriptors -Key barriers that can prevent achievement of good environmental status within the Marine Strategy Framework Directive (MSFD) -Operational definition of Good Environmental Status for the Marine Strategy Framework Directive (MSFD) implementation	Europe, MSFD	UE FP7 2012-2016	yes	- <i>Publications:</i> <a href="http://www.devotes-project.eu/publications/">www.devotes-project.eu/publications/</a> - <i>Results:</i> <a href="http://www.devotes-project.eu/deliverables-and-milestones/">www.devotes-project.eu/deliverables-and-milestones/</a> & <a href="http://cordis.europa.eu/project/rcn/105613_en.html">cordis.europa.eu/project/rcn/105613_en.html</a>

As the last frontier on planet Earth our seas and oceans are still relatively unexplored, but are being increasingly exploited for their oil, gas, mineral, and biological resources. Exploration and sustainable exploitation of the marine environment are enormous challenges that require new knowledge from the natural sciences together with good management approaches based on social, economic, and political sciences. Many questions in marine research can only be answered using multidisciplinary methodologies, from the molecular level with genomics and other new emerging technologies integrated together with an ecological, physical, and biogeochemical ecosystem approach. This will allow to address novel questions in marine research, paving the way to new and more integrated knowledge systems that impact the way human society deals with the oceans.

EuroMarine is a FP7 coordination and support action designed to bring together the three FP6 marine Networks of Excellence (NoE) communities, EUR-OCEANS, MarBEF, and Marine Genomics Europe. In doing so, EuroMarine will provide a rich and diverse source of the best expertise and innovation available in European Marine Research, that can respond rapidly to societal needs, environmental demands, well-being, and sustainability.

This European marine science network was launched in 2014. It is a bottom-up organisation designed to give voice to the entire European marine scientific community. Key activities directly deliver products and services for the benefit of the European marine and research communities in relation to science-policy interfaces, infrastructures, training, education, communication, and expertise.

Through coordinated activities and wide interaction with MSFD stakeholders, STAGES produced a number of resources and tools to access MSFD relevant knowledge and demonstrated and recommended ways to improve the structural aspects of harnessing existing knowledge, identifying new knowledge and transferring knowledge from science to inform policy and decision making in support of MSFD. The knowledge harnessing exercise turned out in two innovative user friendly tools: the MSFD component of the Marine Knowledge gate that represents the most extensive look today into MSFD related research and the STAGES clustering tool, a visualization tool that allows the users to search for projects and research surveyed by STAGES by GES descriptor and marine regions.

At the same time, DEVOTES project was set up to reinforce the role of R&D projects in supporting the implementation of the MSFD from a scientific perspective. Applied research allows the DEVOTES project to provide scientific recommendations helping to clarify uncertainties and fulfil several gaps.

The result of MARCOM+ is the establishment of the European marine and maritime science and technology forum. The forum had the task of creating and sustaining effective interactions with the broader stakeholders groups (European Member States, regional authorities, industry and civil society). The vision of the forum was based on the premise that no matter how effective and efficient individual science networks may be, their value is multiplied through the synergy that comes with cross-sector cooperation. The vision was a marine and maritime science network which provides a forum for dialogue between Europe's marine and maritime science organisations. The mission was to facilitate identification, definition of cross-cutting topics across the entire marine / maritime science and technology community; through, e.g. undertaking foresight analysis, assessing societal, governmental, and industrial needs and assist in mobilising actors and resources to support identified cross-cutting topics.

The European research networks dealing with the marine and maritime research sectors transport and maritime industries, ocean energy, tourism, coastal development, security, living resources, fisheries, and aquaculture decided to join forces and create the forum in order to take further steps in integrating their science activities.

The forum aimed to guide the implementation of the European strategy for marine and maritime research and serve the two-way feedback needs of dialogue between marine science and maritime policy.

## Conclusion

Human activity impacts ecosystems in many ways and over the past decade, marine and maritime policies have embraced the ecosystem approach (EA) as a way to manage human impacts on our seas and oceans. The EA addresses both ecological, economic, and societal needs and objectives. The EA recognises that human activity in oceans and seas needs to be managed in an integrated way in order to secure the sustainability of the services (e.g. fish, shipping, tourism, and leisure) provided by marine ecosystems. Establishing societal objectives for ecosystems can be difficult when there are multiple interests present. However, this is an important task for successful management (ICES, 2016<sup>17</sup>).

Approximately 44 projects [ANNEX 1] have been selected regarding the 8 themes considered as current keys of the ecosystem approach to ocean health and stressors in the AORAC-SA project. These projects have been considered in this inventory which is not exhaustive.

Numerous projects focus on “technique for assessment” and “management tools” topics. Several management tools have been developed. It reflects the emerging need to take into account governance, policy, economic as well as social and natural science challenges to balance sensibly, goods and services of the ecosystem with pressures and impacts.

In contrast, while better understanding of the interactive and cumulative effects of multiple stressors as well as carrying capacity and ecosystem tipping points is critically needed, these topics remain almost unexplored.

Through this inventory and mainly through VECTORS project, knowledge acquisition about ocean stressors are centred on impacts of climate change, fisheries and aquaculture, invasive species, tourism, noise and marine transport, especially collision with marine mammals. Renewable energy, coastal construction, offshore structures, navigation dredging, telecommunications, aggregate extraction, military activities are not addressed within this inventory.

Several projects consider impacts of climate change on ecosystems. In doing so, global ocean models have been developed and knowledge improved. However, there are no links between human activities and their potential impacts on climate change which should be examined within an ecosystem approach to better ecosystem management. Other recent research specifically focused on deep water has also improved knowledge on ecosystem structure and functioning. The next challenge will be improving our understanding between ecosystem structure and functioning and food-web interactions.

Regarding the development of indicators and targets for biodiversity, DEVOTES project has been a major contributor. DEVOTES is a cross-cutting project addressing many topics of this inventory. It also raises a wide variety of needs and gaps in particular to meet the MSFD requirements at the European scale. Further review of DEVOTES outputs and identified gaps and knowledge transfer may be relevant.

There are certainly links to be established between the results of the various projects. There may be some overlaps between projects topic research, which can be appropriate to respond to identified gaps, to upgrade existing knowledge, and to generate new research topics. A more thorough analysis would allow to link the projects results more closely together. However, this can legitimately lead to the main following questions:

- What is the best and the most up-to-date available knowledge outputs or results and how we can know it?
- How to ensure that knowledge transfer and co-creation of science occurs between projects and beyond?

## References

Many publications and resources have been produced by the projects presented in this report. To consult projects publications or results, please refer to the links in each tables.

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<sup>17</sup> ICES. 2016. AORAC-SA FAO workshop: Making the ecosystem approach operational, 21-22 January, Copenhagen, DK. 55 pp.