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# EUR-OCEANS Consortium strategic views

*Understanding key challenging biogeochemical processes and developing scenarios to predict and challenge future marine ecosystems dynamics*

***Executive summary:***
The EUR-OCEANS Consortium (EOC) considers the **relevance and impacts of climate and global change in the oceans for Europe**. Twenty-six marine research organisations from 13 European countries contribute financially and scientifically to EOC, and strong links are established to key international partners and leading international science programmes worldwide. With a series of scientific leadership activities including flagship programmes, foresight conferences and workshops, and summer schools, EOC addresses **hot scientific topics** that will feed into the Joint Programming Initiatives acknowledged by the European Commission. Such hot topics include the changing biogeochemical cycles of the oceans, loss of biodiversity as a consequence of increasing temperature and acidification or harvesting, role of small scale interactions/processes in energy transfer and in carbon export, widening of sub- and anoxic ocean regions and coastal change, and links between ecology and genomics, evolutionary and life history. EOC combines field observations, experimental studies and modelling scenarios, all undertaken with world-leading expertise and new frontier scientific techniques and approaches to build **scenarios** for marine ecosystems under anthropogenic change for the 21st century. The key regions for EOC include the Nordic seas and the North Atlantic Ocean and its shelf seas, the Arctic and Southern Oceans, the Mediterranean Sea and adjacent Black Sea, and the Eastern Boundary Upwelling Systems, all highly relevant for European society. EOC aims to take a leading role in contributing to the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) initiative and the development of IPCC analyses. Thus, Europe can rely and build on the expertise of the EUR-OCEANS Consortium for future inter-disciplinary marine research to address the major challenges resulting from the rapid change in ocean biogeochemical cycles and ecosystem structure and function.

**1-Scientific field and composition of the Consortium:**

The EUR-OCEANS (EURopean research on OCean Ecosystems under Anthropogenic and Natural forcingS) Consortium's (EOC) scientific domain deals with the **impacts of climate/global change on marine biogeochemical cycles and ecosystems**. Progress in the fast-moving field of marine science is revealing new challenges in the basic science needed to assess, project, and manage flows, services and changes of marine ecosystems. EOC pays particular attention to the construction of scenarios relevant to the emerging International Platform on Biodiversity and Ecosystem Services (IPBES) and the Intergovernmental Panel on Climate Change (IPCC).

The EOC builds on the legacy of the EUR-OCEANS Network of Excellence, which contributed to the scientific expertise and dissemination of knowledge on marine ecosystems in the context of climate/global change from 2005 to 2008. The NoE was used as a network to design and launch European Commission (EC) funded programmes, including: METAOCEANS, SESAME, EuroSITES, MEECE, MESOAQUA, EPOCA, and Euro-BASIN. The EOC, launched in 2009, is a **non-legal entity** funded by Research Funding Organisations (RFOs) and Research Performing Organisations (RPOs). Core member organisations are: DTU Aqua (Denmark), SYKE (Finland), Ifremer, INSU-CNRS, IRD, UBO, Univ. Med, UMPC, CLS, Océanopolis (France), AWI, Univ. Bremen, Univ. Hamburg (Germany), HCMR (Greece), CNR, CoNISMA, OGS, SZN (Italy), CEES/Oslo Univ., NTNU (Norway), IO PAS (Poland), AZTI (Spain), BNI/Stockholm Univ. (Sweden), and NERC (UK). EMI (Estonia), BIOR (Latvia), INRH (Morocco) and UCT (South Africa) are invited member organisations that support the scientific efforts of EOC, but are not financial contributors as yet.

**2-The EOC's objective, approach and international links:**

The main scientific objective of the EOC is : *understanding the key challenging biogeochemical processes and developing robust scenarios of the future state of marine ecosystems*

The general approach of EOC is to integrate European efforts and expertise by developing joint initiatives between RFOs and RPOs across Europe, to make significant progress in addressing the major challenges in marine science during the next decade. Through organisation of flagship programmes, foresight conferences and workshops, and summer schools, EOC focuses on **hot scientific topics** that can lead to wider European projects organised within the EC Framework Programmes (FP8) and/or within the **Joint Programming Initiative (JPI)** called "Healthy and Productive Seas and Oceans" (HPSO). Therefore, EOC will develop links with **SeasERA**, the EC ERANet, whose mandate includes the development of joint programming initiatives. The EOC has a science focus that is complementary with the general aims of **IMBER** (Integrated Marine Biogeochemistry and Ecosystem Research, initially called OCEANS), an IGBP/SCOR endorsed international project, that co-ordinates research at global and regional scales, and with **ICES** that concentrates on North Atlantic ecosystems. The EOC has thus developed specific links with these organisations to address the major challenges in marine science.

**3-Scientific priorities for the next decade:**

**3-1-Impacts of climate change on the biogeochemical cycles of a changing ocean:**

Climate change is not only modifying the physics (temperature, stratification, circulation), but also the chemistry (dissolved gas concentrations, pH decrease due to increased $CO_2$ transfer from the atmosphere and the consequent impact on the carbonate system, transfer of nutrients and contaminants from the geosphere, terrestrial biosphere, and anthroposphere) and the biology (impacts on primary production and life history traits, shifts in trophic structures and sensitivity of anthropogenic stressors) of the ocean from global to very localised scales.

A key aspect of the impact of climate change on the ocean biogeochemistry is the efficiency of the **biological carbon pump**, not only in offshore areas but also in coastal zones where there is high phytoplankton activity. It requires a focus on carbon burial and organic matter transformation processes that occur in the ocean sediments. This is of particular importance as organic matter mineralization changes the $O_2$ concentration.

EOC focuses on **new frontiers** of knowledge in biogeochemistry. The biological and chemical processes in the surface micro-layer influence air-sea fluxes, especially gas exchange. This "surfactant" effect on gas transfer is poorly constrained, but is believed to be the main source of error in gas transfer velocity parameterisations. A major challenge is to better understand and predict the consequences of global warming on the dissolved oxygen concentration of the world oceans. On the one hand, ocean warming and increased stratification of the upper ocean due to global climate change will likely lead to a decline in dissolved $O_2$ in the interior ocean. On the other hand, decreased primary production in a more stratified ocean should decrease export production and thus reduce oxygen consumption in the interior ocean. Currently, we do not know if the two processes are balanced or whether one is more dominant. Ocean models predict declines of 1 - 7% in the global ocean $O_2$ inventory in the next century, with further declines continuing for 1000 years or more into the future. An important consequence could be an expansion, in area and volume, of the so-called Oxygen Minimum Zones, where $O_2$ levels are too low to support most macrofaunal life and where profound changes in biogeochemical cycling occur. The potential for larger $O_2$ declines in the future suggests the need for an improved observing system to track ocean $O_2$ changes. Evidence is growing that **ocean deoxygenation** is ongoing. If this is verified there are profound implications for ocean productivity, nutrient cycling, carbon cycling, and marine habitats. The trend of ocean deoxygenation is reinforced in coastal areas due to eutrophication as a result of the large input of nutrients and organic matter from the land.

One of the most exciting challenges of the decade is to better describe, understand, and model the **heterogeneit**y of the ocean at different scales. In the upper 500m of the ocean, sub-mesoscales (such as 10km-wide filaments that are ubiquitous on high resolution satellite images) explain more than 50% of the vertical velocity field, that is so important for nutrient transfer from depth and thus for ocean biological systems. Evidence is growing that **small scale** interactions/processes play a crucial

role in energy transfer in the ocean and strongly affect carbon export not only at local but also at global scale. Existing satellite altimetry data is unable to resolve the smaller scales (20-100km) that are a major feature in high resolution optical, infrared and radar images. However, the SWOT mission involving NASA and ESA will soon address this need which will enable a much improved description and quantification of oceanic processes at the sub-mesoscale.

**3-2-To develop links between ecology and genomics, evolutionary and life history:**

A long term ambition of EOC is to integrate a robust biogeochemical approach which is a qualifying trait of EOC community, with an understanding of the biological responses to drivers, e.g., genetic or evolutionary factors which do not necessarily follow proximate abiotic factors. Such responses are likely to control behavioural traits, trophic interactions, life cycles, etc. They would therefore be essential factors for predicting change in ecosystem functioning under the above pressures and to implement robust end-to-end ecosystem models. To develop links between ecology and genomics/metagenomics, evolutionary and life history factors, is another priority of the EOC community for the next decade.

**3-3-To build scenarios of the impact of climate/global change on the marine ecosystems:**

While facilitating progress in fast-moving areas of science, EOC also aims to improve the **science-policy interface**, using existing relevant assessments and the best available multidisciplinary scientific knowledge (encompassing physics, ecology, biology and natural, social and economic sciences). Consequently, the EOC intends to develop, integrate, and promote the development of scenarios for marine ecosystems under anthropogenic and natural forcing in the 21$^{st}$ century. The scientific coordination of the EOC will direct and develop activities in the context of the post-Aberdeen process, the Millennium Ecosystem Assessment and the structuring of the European Research Area, together with key groups and programmes (e.g. ICES, IMBER, MarBEF+, SeasERA).

The importance of **biodiversity** in maintaining ecosystem structure and function has long been recognised. In all the world's ecosystems, loss of biodiversity is seen as a major threat to the sustainability of human communities and ecosystem services. There is an urgent need to develop methodologies to efficiently manage human impacts on biodiversity and the services that ecosystems provide (e.g. if we are to progress at all towards the as yet unattained targets set during the 2002 Johannesburg World Summit, of restoring fish stocks to maximum sustainable yield by 2015 and of significantly reducing the rate of biodiversity loss by 2010).The Reykjavik Declaration of 2001, reinforced at the World Summit on Sustainable Development in Johannesburg in 2002, requires nations to base policy related to marine resource exploitation on an ecosystem approach. The **Ecosystem Approach to Fisheries** (EAF) aims to reconcile conservation and exploitation of renewable resources in an ecosystem context. Such a framework requires the integration of ecological analyses to provide the scientific basis for understanding human impacts on whole ecosystems. To provide the basis for mitigating and managing human impacts on ecosystems, and the biodiversity they maintain, ecological understanding must be integrated with economic and societal views. Analogous to the IPCC, the newly launched **IPBES** aims to provide the stimulus for the scientific community to build scenarios of biodiversity change, thus providing the basis for decision-making for management and advice for policy makers. The EOC aims to provide the scientific and policy-related integration to address these issues for Europe.

There is an increasing demand for predictions of ecosystem response to anthropogenic and climate change, made more urgent by the fact that marine ecosystems are changing at rates that defy human inventiveness. This highlights the need to develop and improve predictive capabilities of a hierarchy of ecological models up to the full development and use of a suite of integrated end-to-end models. Efforts to assess and possibly reduce model uncertainties will also be required. While we cannot see the future, we can influence it by assigning desired objectives and exploring innovative solutions. Building scenarios can help in delivering plausible stories on ecosystem responses to global change but also on how humankind will reach assigned objectives. EOC focuses on new frontiers of knowledge in developing understanding and models to build **scenarios of future marine ecosystem change**. A scientific strategy to reconcile **projection-like scenarios** that extrapolate fundamental trends with **pathways scenarios** that integrate policy options is proposed. Model development will then help to improve our capacity to make projections of future change under different scenarios. Improving ecosystem models while coupling them to long-term policy scenarios will, as in the case of IPCC, improve the interest and usefulness of end-to-end models as management tools. For future

scenarios we will need: (1) Models that integrate across social, economic, environmental and ecosystem dimensions using the scenarios and which quantify interactions and trade-offs among ecosystem services; (2) To include a broader range of ecosystem services, especially cultural services, and social and economic adaptation; (3) Desegregation across multiple scales, from global patterns down to regional scale; (4) Consideration of long time horizons (50 - 100 years) and global perspectives that aim to understand complex interactions between human and ecological systems.

**4-Regional focus:**

To accurately assess the future evolution of biogeochemical cycles and marine ecosystem dynamics, continued **data acquisition** and **process studies** of regional ecosystems of importance to Europe as well as analyses of climate/global change, must be strongly encouraged and supported. A regional focus allows comparative analyses of the determinants of ecosystem structure and function that will provide a more general and global scientific perspective of the effects of global/climate change. This will provide a major European input into wider international analyses on the role of the impacts of change within programmes such as IMBER, IPCC and IPBES.

The EOC regions include:

-The *Arctic and Southern Ocean*: the two polar oceans have a profound influence on the Earth's climate. They have already been affected by ocean acidification. The Arctic regions *sensu lato* are new targets for economic activities that will have a huge impact on the environment. Because they are particularly sensitive to climate change, serious consideration should be given to undertaking comparative studies of these two areas if we are to better understand the impact of climate change of marine ecosystems *sensu lato*. The Southern Ocean plays a major role in the biogeochemical dynamics of the entire Earth System. The effects of the Southern Ocean on the global ocean include controlling primary production and biodiversity of low latitudes and northern hemisphere regional basin ecosystems. It is also one of the few areas where expansion of commercial fisheries is still possible and anticipated in the near future. Thus, Antarctic studies are important for Europe particularly as several European countries have already implemented national activities with high international profiles and potentially significant scientific impact, upon which the EOC will build.

-The *Nordic Sea*s and the *North Atlantic Ocean and its shelf seas* are of great importance for European fisheries and for developing sustainable growth scenarios. The outputs of EURO-BASIN, an EC-funded programme, to which EUR-OCEANS NoE and EOC scientists are contributing, will be particularly useful for building scenarios at basin-scale.

-The *Baltic Sea*: through the BONUS+ efforts, this regional system is becoming a model for European nations which aim to build convergent efforts in a perspective of sustainable development.

-The *Mediterranean Sea* (MS) and *adjacent Black Sea* (BS) are subjected to strong and increasing demographic and anthropogenic pressures. Climate change is affecting the biological, chemical and physical characteristics of the marine, atmospheric and watershed environments of these southern European seas, with significant impacts on human populations. Topics of immediate concern are coastal zone management, fisheries, invasive species and ocean acidification. Large programs to understand these problems are underway, including SESAME (European Commission) and the Chantier Méditerranée (France), EU programs Medsea (acidification MS & BS), VECTORS (invasive) and PEGASO (Integrated Coastal Zone Management MS & BS).

- *The Eastern Boundary Upwelling Systems* (EBUS) including Moroccan, South African, Namibian, and Peruvian coastal upwelling systems are key areas for global fisheries. Management efforts already use an ecosystem approach for fisheries and sustainable growth, thus making EBUS of peculiar importance to develop scenarios at regional scale.