Life on the Blue Planet

Biodiversity research and the new European Marine Policies

Portuguese EPBRS meeting, Porto, 6-9 November 2007

Short Report

Electronic Conference 1-19 October 2007

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

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Developing the EU Biodiversity Research Strategy

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PORTUGAL 2007

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The publication should be cited as follows:

Young, J., Sousa Pinto, I., Hawkins, S., Serrão Santos, R. and Watt, A.D. (Editors). 2007. Life on the Blue Planet: Biodiversity research and the new European marine policies. Report of an e-conference.

Cover photograph by Paulo Umaru

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Preface

Research on biodiversity is essential to help the European Union and EU Member States to implement the Convention on Biological Diversity as well as reach the target of halting the loss of biodiversity in Europe by 2010.

The need for co-ordination between researchers, the policy-makers that need research results and the organisations that fund research is reflected in the aims of the "European Platform for Biodiversity Research Strategy" (EPBRS), a forum of scientists and policy makers representing the EU countries, whose aims are to promote discussion of EU biodiversity research strategies and priorities, to exchange information on national biodiversity activities and to disseminate current best practices and information regarding the scientific understanding of biodiversity conservation.

This is a summary report of the E-Conference entitled "Life on the Blue Planet: Biodiversity research and the new European marine policies" preceding the EPBRS meeting to be held under the Portuguese EU presidency in Porto, Portugal, from the 7th to the 9th November 2007. To access the full report of the e-conference, including all contributions to the e-conference, please follow the links on: http://www.nbu.ac.uk/biota/BioStrat_page.htm.

Introduction

Isabel Sousa Pinto

Marine biodiversity has been declining and some of the services provided by marine ecosystems are at risk. Even if we don't live at sea, our land and sea-based activities pose very significant pressures and threats to the marine ecosystems. These pressures can be direct, as in the case of fisheries, or indirect, as in the case of climate change.

The initiatives being taken by the EU on marine and maritime affairs reflect an increasing recognition of both the importance and the sensitivity of marine ecosystems. New policies and legislation like the new EU Maritime Policy, that aims at a holistic approach of the maritime activities at European scale, or the Marine Strategy Directive, which aims at achieving good environmental status of Europe's marine environment by 2021, take as their starting point that protection of the marine environment is essential to realise the full economic potential of oceans and seas. Although other EU legislation and policies as the Habitats Directive (Natura 2000 for the marine environment), the action plan associated with the Communication on "Halting the loss of biodiversity by 2010 and beyond", the Common Fisheries Policy, the Water Framework Directive and the discussions on Integrated Coastal Zone Management all have a direct impact on marine biodiversity, their successful implementation still requires information and knowledge produced by the scientific community.

With this policy background in mind the purpose of the EPBRS meeting is to arrive at a set of recommendations for organisations that set research policy and that design research funding programmes. The participants seek to identify gaps in knowledge that currently hinder the design or implementation of policy or management intended to protect biodiversity, to make its use sustainable, and to ensure the sustained provision of ecosystem services to humans. The meeting will also discuss how one might construct a biodiversity-related programme of research to support an EU-wide maritime strategy as well as how the marine research community might be structured in the future to best deliver the desired outputs.

The aim of the e-conference was to start these discussions involving a wide range of researchers, policy makers and other stakeholders. We focussed on 3 themes that are at the heart of the discussion surrounding the policies mentioned above:

- Session I: from the 1st to the 12th of October: Interactions between global change and marine biodiversity: what is already known and what do we urgently need to know to allow for a more efficient protection of marine biodiversity and of the sustainable use of the marine environment within a global change scenario.

- Session II: from the 15th to the 19th of October: Effects of the different measures of mitigation and adaptation to climate change (e.g. coastal defences, renewable energies, algal biofuels, CO_2 storage in the ocean) on marine biodiversity and the role of marine and coastal ecosystems in the mitigation of climate change effects.

- Session III: from the 8th to the 19th of October: Stopping marine biodiversity loss – key scientific issues in the design, management and policy development related with MPAs, integration of biodiversity concerns in the different marine sectors and attaining a good environmental status in the marine environment.

The first 2 sessions were chaired by Steve Hawkins and his colleagues Pippa Moore and Nova Mieszkowska (Marine Biological Association), while the third session will be chaired by Ricardo Serrão Santos and his colleagues Telmo Morato, Ruth Higgins and Fréderic Vandeperre (University of the Azores).

The contributions from participants of the e-conference will form the basis of discussion in the working groups at the EPBRS meeting in Porto.

Summary of contributions

Juliette Young and Allan Watt

Session I: Interactions between global change and marine biodiversity

Week 1: In their introduction to session I of the e-conference, Steve Hawkins, Pippa Moore and Nova Mieszkowska set out the main aims of the session, namely to outline what we already know regarding the interactions between global change and marine biodiversity, and what we need to know to integrate global change into policy and management plans to conserve biodiversity and ensure the sustainable use of marine resources.

Steve Widdicombe and Hans-Otto Pörtner started the session off with contributions on the topic of ocean acidification (the process whereby the oceans experience reduced alkalinity due to dissolved CO_2). In terms of future research needs on this issue, Hans-Otto Pörtner emphasised the need to better understand the mechanisms by which ocean acidification and warming affect organisms and the need to quantify effects in relation to future scenarios of anthropogenic CO_2 emissions and ocean warming. He went on to argue that this information should then feed into the building of mechanism-based models of organism and ecosystem functioning and response to change.

In his contribution, Zoheir Sabeur called for the need to develop systems able to track, forecast and control uncertainties regarding biodiversity loss, the results of which should be made accessible to a range of end-users. Although difficult to achieve, he emphasised the need to expand on the current status of data access and dissemination.

Taxonomy was mentioned in a few contributions in the first week of the e-conference. Ferdinando Boero was the first to mention the growing problem of lack of funding to taxonomy, resulting in taxonomists not being replaced when they retire. As such, very little is being done in current marine biodiversity projects with respect to revision of taxa, exploration of understudied geographical regions and compilations of faunas and floras. Christos Arvanitidis took this point one step further and argued for a new wave of taxonomists who would be trained not only in 'traditional' taxonomy, but who could also carry out new disciplines within taxonomy including the ability to design and carry out population genetics analysis, community analysis or data integration and management. Ferdinando Boero went on to argue that taxonomy was particularly needed in the context of global change, in order to reconstruct past states of biodiversity and compare these with present-day situation. The key role of taxonomy in the collection of baselines for long-term biological studies was also stressed by Antonio Terlizzi, who, in addition, called for the need to widen spatial and temporal scales of monitoring programmes to better link known biodiversity dynamics with global-scale studies of atmospheric and oceanic processes.

In her contribution, Alex Kraberg also emphasised the need to have underlying baseline assessments of biodiversity in order to better understand the impacts of current changes, although she acknowledged the difficulties inherent in this, including

incomplete species lists due to lack of funding, methodological problems, data access and lack of long-term data. She called for more multidisciplinary studies that could work on the genetic and morphological diversity in multiple marine communities, and to combine these with the analysis of long-term data to assess global change phenomena. On the same topics of adequate baselines to separate man-made from 'natural' changes, Monika Kedra emphasised the value of long-term observations, while Doris Schiedek also emphasised the need to retrieve environmental data from historical sources, reports and other grey literature and to make these data available and compatible with future scientific analyses (for example projections and predictions of future climate change and impacts on biodiversity). She also called for more interdisciplinarity, as well as long-term funding for equipment, methodologies and human resources beyond the usual 3-5 years.

On the topic of climate change impacts on fish and fisheries, Martin Genner described his work at the Marine Biological association and the finding that different species in the English Channel have reacted differently to climate change, with many of the common, small, and non-commercial species of fish able to track climate changes, whereas larger species have not been able to respond so well (perhaps due to pressure from over-fishing). In addition, climate change may also be responsible for altering ecological interactions among species; for example, low sandeel recruitment in the North Sea affecting seabird and cetacean populations. In view of the complex interactions between climate change, fish, fisheries and wider biodiversity, Martin Genner called for more research to better understand the ecological mechanisms by which climate change alters the marine environment.

Intertidal ecosystems were discussed by a number of keynotes, including Alan Southward who called for the need to carry out routine quantitative monitoring (to show gradual long-term climate change), to record the effects of acute and chronic disturbances (such as oil spills) to intertidal ecosystems, and to carry out annual surveys of quantitative transects of these effects and any impacts of a change in sea level. Also on the topic of coastal habitats, Lisandro Benedetti-Cecchi called for the identification of novel research strategies to explicitly address how marine biodiversity will respond to the simultaneous influence of global scale processes and local anthropogenic disturbances such as pollution invasive species, urbanization, etc. He also called for approaches to make large scale experiments more feasible, and for the development of new models to map the results of small-scale studies to larger spatial and temporal scales (especially needed to predict the outcomes of management decisions such as the designs of MPAs). Finally, Henrique Queiroga focussed on the need to carry out more research on two particular effects of climate on coastal habitat biodiversity: recruitment pathways (coastal circulation may be altered and the usual recruitment mechanisms disrupted) and phenology (changing growth rates and fitness of species, ability to deal with interspecific competition and predation, affecting latitudinal limits of distribution, mismatches between the production of planktonic propagules and the usual patterns of coastal circulation or the availability of appropriate food items).

The last topic addressed in the first week of the e-conference was climate change and benthic communities. Paul Sommerfield started off by stating that we knew too little to be able to predict or detect the effects of climate change on marine benthic communities: we have very little data; the data we have are difficult to harmonise; time series data (to disentangle variation associated with natural change from place to place and variation through time at different places) are extremely rare; data on the marine benthic organisms' physiology and life-histories are outdated;

work on acclimation is non-existent. As such we know little about the functional roles of the vast majority of benthic organisms and can only provide rough guesses as to how changes will impact on such organisms and, in turn, on mankind. In terms of research priorities therefore, Monika Kedra called for more research on ecosystem functioning in benthic ecosystems, while João Carlos Marques stressed the need for research to assess the responses of different biodiversity indicators to restoration measures, which includes possible time-lags and hysteresis effects. Finally, Christos Arvanitidis called for long-term data on climate change and on changes in benthic communities and an appropriate framework to scale observations on changes in benthic communities, requiring the integration of disciplines including taxonomy, ecology and biogeography, systems ecology and modelling.

Week 2: Taxonomy was again discussed in the second week of the e-conference, with Priscilla Licandro and Antonietta Rosso both calling for more support for taxonomy in order to better detect changes in biodiversity and the improvement of systems to automatically identify marine organisms. On the issue of further improving our understanding of biodiversity Antonietta Rosso also called for support for palaeo-taxonomy. Both Bert Hoeksema and Antonio Terlizzi outlined the important role played specifically by museums in applying taxonomy to global change studies.

In terms of threats to marine environments that needed to be studied in more detail, Michael Stachowitsch discussed "low-dissolved-oxygen" events such as hypoxia and anoxia that are already affecting marine environments worldwide, resulting in loss of biodiversity and ecosystem function. Another threat described by Wiebe Kooistra was the potential impact of change on phytoplankton communities. He outlined research needs including the impact of global change on plankton communities and the sequestering of carbon in ocean sediments, the impacts of plankton change on benthic and pelagic marine communities, the effects of global change on oceanic blooms of coccolithophorids, the issue of whether or not to iron-fertilize the high-nutrient-low-biomass oceanic regions to wash carbon dioxide out of the atmosphere and the impact of global change on reef communities and polar communities. In response Ferdinando Boero warned against focussing on one trophic level, and instead advocated research on the interactions between different trophic levels.

In his contribution, Jürgen Alheit discussed the impact of climate on small pelagic fish, and called for more research on the interdependence between climatic phenomena such as the North Atlantic oscillation, the Atlantic Multidecadal Oscillation and global warming and their individual as well as combined impacts on marine ecosystems in order to better understand the impact of global change on marine biodiversity. Still on the topic of pelagic biodiversity, Maurizo Wurtz highlighted the need to better understand and assess pelagic diversity and heterogeneity, and discussed the role of top predators as potential indicators of pelagic biodiversity and oceanographic process.

Ricardo Lemos and his colleagues came up with a comprehensive set of research recommendations including the need to develop reliable global climate models stemming from various social and economic scenarios for the 21st century as well as numerical models of ecosystems that could be coupled to these climate models, the need for more knowledge on the thermal and pH tolerance of marine organisms and on trophic interactions, growth and reproduction. They also called for the development of tools to validate predictions, the creation of representative marine protected areas and other monitoring systems, more detailed fisheries data sets and

guidelines to summarize the resulting information destined to end-users.

The focus towards the end of the second week was very much on policy. Matt Frost started the discussion off with a brief recap of current EU policy for the marine environment and discussed the debate over whether or not EU policy should act as a driver for the marine research community to target its research (i.e. balance between blue-skies and applied science). In terms of research needs, he highlighted the need for research on marine ecosystem change and its causes (particularly over long time-scales), particularly the interactions between natural variability and anthropogenically driven change. He also called for research that could support the ecosystem approach (such as work on ecosystem function), and for research on the design of Marine Protected Areas. Still on the topic of linking science and policy, Larissa Naylor argued for more mechanisms by which science could inform policy and practice more rapidly. Some examples included studies linking global change and biodiversity covering as wide a spatial and temporal scale as possible, and increasing funding to long-term monitoring networks (to derive 'evidence-based' policies). Katja Philippart also emphasised the need to extend our coastal monitoring efforts, as well as the need to extend our knowledge on sensitivities and adaptation capabilities of key species in the marine environment, and to develop "fit-for-purpose" models to manage the marine environment. Still on the topic of monitoring, Sophie des Clers outlined the scale mismatch between current observation networks and the scale of the biggest changes affecting coastal activities and populations. Her open question regarding knowledge of alternative monitoring networks that could complement existing ones was responded to by Sandra Bell, who presented some of her findings on Participatory Monitoring Networks (PMNs) in six EU countries and warned that taking into account social, cultural and psychological factors was crucial to establishing and maintaining PMNs.

Frederico Cardigos, speaking from his experience both as a scientist and working in a government position, highlighted the different responses to biodiversity issues such as invasive species from scientists and policy-makers perspectives. He concluded that there was a need for intermediaries between scientists and policy-makers, who could interpret the scientific data, and put an "economical" value on or, at least, clearly identify the "risk" factors involved. The links between research and action was also the topic of Francois Bonhomme's contribution. Although knowledge is required to take adequate action, as outlined in Ferdinando Boero's contribution, Susanna Lehvävirta argued that while we already have a wealth of knowledge that could result in action, we still needed more research about many things. Her recommendation was that all environmental scientists should keep in mind that every single piece of research should result in applicable guidelines, instructions and action whenever possible. Cristian Kleps also reminded participants of the use of existing official reports that contained important information collated at the pan-European level that could provide valuable insights regarding future research priorities and action. In terms of possible action, Betty Stickers described an initiative to form an alliance with interested parties impacted by diseases affecting the farming community and voiced whether this could work to tackle the problems affecting the marine environment, with the creation of an alliance between scientists and all other sectors of the community with a stake in the marine environment.

Week 3: Taxonomy came back as a point of discussion in the last week of the e-conference, starting with Ole Seberg, who emphasised the need for taxonomy in view of the 2010 target. In addition, communication between scientists, policy-makers and

stakeholders was predominant in the third week of this session. Ferdinando Boero started off the debate by calling for more cooperation between scientists that could lead to a solid theoretical framework incorporating different branches of science such as evolution, ecology and taxonomy. Only then, he argued, could the current distrust for science be reversed and communication with policy-makers improved. Martin Sharman emphasised that scientists should show a united front in communicating the simple message to politicians that human society cannot be sustained without the sustainable management of our natural resources. As a response Ferdinando responded that the message was already understood by politicians and that the problems started within the scientific community, with fierce competition between disciplines for funding, invariably resulting in essential but unglamorous disciplines like taxonomy being under-funded. Also in response to Martin Sharman, Jan Jansen called for policy-makers to link natural heritage with cultural heritage and for the creation of a network such as Natura 2000 for onshore areas.

Nabila Mazouni advocated the need for an interface between scientists and stakeholders. Who should communicate science to the politicians and stakeholders was then debated, with participants (e.g. Yves Hencocque and Ferdinando Boero) stressing that scientists had a duty to communicate their science, while others (for example Irina Herzon) cautioned that not all scientists might be suited for this sort of activity, and that funding was still very much geared towards the production of knowledge, rather than the communication of that knowledge to a broader audience. Irina Herzon went on to suggest that scientific institutions could work towards a policy of knowledge sharing, with training opportunities and involvement of those scientists interested in communication activities. Sophie des Clers stressed that such communication between scientists and policy-makers, but also crucially with stakeholders should be a real priority, particularly in the case of complex research questions such as the development of ecosystem-based management of coastal and marine resources. An example of such communication was given by Marion Gosselin, who presented a project aiming to produce guidelines for good forest practices for biodiversity.

Monitoring was again mentioned in this session, this time by Anne Chenuil and her colleagues, who argued that in addition to community level monitoring, there was also a need for long-term monitoring of intra-specific genetic biodiversity and gene expression in order to study the impact of global change and anthropogenic effects.

Vladimir Vershinin chose in this contribution to address the increasing problem of the invasion of marine organisms into freshwater areas due to changes in temperature and salinity of freshwater habitats. He called for more research on the impacts of these marine invasions on freshwater biodiversity.

Finally, in addition to climate change, Henn Ojaveer listed a number of human activities that needed to be addressed in the marine environment, including the impact of new chemicals and synthetic materials and compounds on the structure and functioning of marine ecosystems, and increased marine traffic resulting in a higher frequency of chemical/oil pollution incidents, and the spread of alien species.

Session II: Effects of climate change mitigation and adaptation measures on marine biodiversity and the role of marine biodiversity in the mitigation of climate change effects

The first keynote on this topic was by Laura Airoldi, who discussed the changes caused by coastal defences such as: the local loss of natural soft bottoms; disruption of surrounding soft-bottom environments; impacts of new artificial hard-bottom substrata on species composition, abundance and diversity; the downstream effects of the proliferation of defence structures on regional species diversity, e.g. through the expansion of introduced species. She stressed the need for increased research on the consequences of these major changes in species distributions on ecosystem functions and services to humans in order to ensure effective planning and management of defence and other urban structures. In addition, she argued for sound monitoring before and after construction in order to assess their effectiveness at meeting management goals.

Benjamin Burkhard discussed offshore wind energy in his contribution, describing some direct and indirect impacts of wind farms on biodiversity. He concluded his contribution by asking a) how offshore wind farms could be integrated with other marine uses; b) what the most likely effects of offshore installations on marine biota might be and; c) how can science and decision makers best interact to support optimal environmental management decisions? In response to his contribution, Andrew Gill called for open discussion between ecologists, engineers, developers, planners and policy-makers prior to the development of such projects, and for rigorous and adaptable research and monitoring to be put in place in order to detect and understand environmental costs and benefits (especially the effects on ecosystem processes and function) resulting from these new renewable energy developments. Doris Diembeck concurred with the need for increased communication between all involved in these developments, and for increased and standardised monitoring in these areas. She also called for negative impacts of wind farms being offset by positive ones, such as preventing destructive bottom-fishing near wind farms. Ferdinando Boero added that we could already gain a clear picture of possible impacts of wind farms on benthic biota by looking at the effects of oil or gas platforms (minus the drilling). Andrew Gill warned against such comparisons due to the spatial extent of wind farms and cumulative extent of multiple developments (for example a recent development consent in the UK would result in 300 turbines covering 200sq km), and the cables connecting the turbines to the shore, which can emit magnetic and induced electric field, the effects of which are as yet poorly understood but could influence fish and cetacean behaviour. In addition to these issues, Gergely Torda also added the issue of noise pollution, potentially affecting the successful establishment of fish stocks under wind farms and altering the behaviour and distribution patterns of cetaceans. In a last contribution on this topic, Magdalena Muir emphasised the need to also consider the impacts of tidal and wave projects on marine biodiversity.

In another contribution, Gergely Torda discussed the possibility of sequestering carbon dioxide through iron fertilisation, and called for long-term, multidisciplinary, in situ research to determine the effectiveness of iron fertilization and the long-term impacts of such fertilisation on the marine food web.

Moving to the role of marine resources in the mitigation of climate change effects, Carole Llewellyn and Stephen Skill discussed the potential of microalgae (that can produce up to 30 times more oil per unit of growth than land plants) in producing

clean alternative energy sources. Although this option shows great potential, the authors called for more molecular and biochemical research to enhance the physiological properties of algal strains, as well as optimisation of algal production and harvesting systems.

Session III: Stopping marine biodiversity loss

The session started off with an introduction from the Chairs in which they set out the main aims of the session, namely: to explore the extent of biodiversity loss and the drivers of change in coastal areas, estuaries, the deep sea, and the high seas; to discuss the effects of fisheries and aquaculture practices and their associated effects on species richness; to explore the role of marine protection and marine reserves in protecting biota; and to identify the steps required to reconcile policy with the health and diversity of the oceans.

In the first contribution to this session, Lisandro Benedetti-Cecchi emphasised the importance of developing a balanced dialogue between scientists and policy makers to ensure that research priorities are correctly identified and supported, taking into account the nature of ecological research. He went on to argue that halting biodiversity loss required more of a focus on the drivers of change, and called for the need to treat management decisions as designed experiments at the appropriate spatial and temporal scales. In addition to space and time, Sotiris Orfanidis added aggregation as a feature of scale and questioned the possibility of trying to develop new functional indicators (rather than species) as a more predictive approach to detecting ecosystem changes. He also emphasised the need for consistent monitoring of environmental parameters (e.g. water and sediment nutrient concentrations, light attenuation) to better interpret community variability; and the use of coexistence of species of known ecophysiology with certain environmental conditions or pressures as valid bioindicators.

Søren Anker Pedersen highlighted the analysis and visualization of fine scale spatio-temporal data and information as useful in terms of informing debates on the ecological and socio-economic consequences of human activities in the marine areas, highlighting the example of how fine scale distributions of the international fishing efforts had led to the identification of potential conflict/no-conflict zones in relation to the demarcated boundaries of SPAs and SACs. In terms of future research related to Natura 2000 management plans, he called for the need to determine the current and predicted future state of benthic communities in Natura 2000 areas and how fishing activities could impact on these communities.

Ferdinando Boero discussed biodiversity loss in coastal environments and called for the mapping, listing and ranking of coastal habitats types in terms of vulnerability to human impact, species richness, relevance for ecosystem functioning and uniqueness. With habitat heterogeneity in mind, he warned strongly against the "one size fits all" strategy for biodiversity conservation. Henrique Cabral focussed his contribution on biodiversity loss in estuaries. He discussed threats to estuarine biodiversity, including fisheries, agricultural, industrial and engineering projects, pollution, and habitat loss, and called for more strategic research to be undertaken on estuarine systems, such as reliable time series data and cause-effect relationships between impacts and biotic response, and climate change impacts on biodiversity patterns in estuaries.

Peter Herman discussed the concept of "good ecological status" referred to in the Water Framework Directive, and the fundamental problems associated with it,

including, for example, the definition of "reference state". While it may be impossible to define "good status" for most ecosystems, he argued that "the system should evolve towards one that detects change and then assesses what are the causes and whether they are amenable to management. At the same time, an operational system should also investigate what is the proper institutional scale for management, by comparing problems all over Europe and deciding whether they are local, regional, or continent-wide. Reporting of 'bad' state in some area should not necessarily be followed by 'punishment' for the local authorities, but by the consideration and implementation of mitigation strategies at the most effective scale".

Finally Wiebe Kooistra sparked off a debate by warning against making exaggerated claims about climate change that could then be used and turned against the scientific community by those who view climate change as a scientific hoax. In response Peter Herman stressed the importance for scientists to concentrate on all aspects of the three-step approach used in science, namely the identification of a problem, the inventorying of all ramifications of a problem and finally finding ways to deal with the problem.

The contribution posted by Lisandro Benedetti-Cecchi in the opening week of this session sparked a number of responses. Describing a multi-disciplinary research framework funded by the Irish government, Louise Scally argued with Lisandro's comment that assessing the drivers of change was essential, but emphasised the need for a dual approach in the conservation of marine biodiversity, requiring an understanding of the drivers of change on natural processes and ecosystem functioning as well as incorporating the key actors and publics in the discussions about marine biodiversity conservation and gaining their active support for any measures taken. Michel Kaiser picked up on Lisandro's comment that few existing MPAs had been designed in a way that would ensure a measure of the "effect" after implementation, and highlighted potential problems with creating permanent MPAs. These included the difficulty in accounting for environmental change, and the problems inherent in the protection of mobile and widespread species. He called for the first network of MPAs to be treated as large-scale experiments in management, allowing for the re-design of MPAs following proper assessment and critique. Peter Herman did however warn against too flexible an approach in the design of MPAs, arguing that the effects of MPAs might only be visible over decades, and that taking only temporary measures that can be reversed every few years, might impeded on the successful, long-term, implementation of MPAs.

Still on the topic of MPAS, Ángel Pérez-Ruzafa and his colleagues called for more research on the actual effects of marine reserves on the genetic structure of populations, the spatial scales involved, and the suitability of islands as reserves in terms of connectivity. They therefore called for the design of MPAs to take into account the spatial heterogeneity in the genetic structure of populations and the connectivity between protected and non-protected populations as well as between MPA network constituents, adopting a multi-scaled approach in detecting connectivity processes. Adriana Vella supported the need for molecular genetic assessment and monitoring, arguing that this should be at the heart of management practices whether for an MPA or for targeted controls of human activities affecting marine species.

Daniel Desbruyères focussed his contribution on the deep-sea, emphasising our currently poor knowledge of deep-sea specific diversity and distribution of main macro-habitats. He called for more research to be carried out on these habitats, as well as more information on the impacts of industry, commercial fishing, and pollution on

deep-sea environments. Finally he called for the creation of large deep-sea MPAs to protect habitats such as deep corals and other natural reefs, seamounts, cold-seep and hydrothermal vent communities. On the specific topic of the threat of commercial fishing in the deep-sea and high seas, Telmo Morato and his colleagues called for the restriction of fishing activities through the elimination of global subsidies, the creation of high seas MPAs and no-trawl areas. The establishment of protected areas will, however, in the first instance, require more knowledge on the ecology and functioning of biodiversity in the high seas. Asta Audzijonyte agreed with the notions expressed by Morato et al, supporting, for example, the need to cut down on subsidies for fishing activities in the high seas. She also encouraged participants to use the information we already have in order to make recommendations to encourage political action. Ferdinando Boero warned against action without sufficient knowledge, using the example of how other organisms (e.g. ctenophores) can also impact on fish and fisheries. Adriana Vella advocated a middle ground by arguing for the integration of effective, detailed and long-term knowledge with precautionary policy-making flexible enough to be able to incorporate new knowledge.

Still on the topic of fisheries and biodiversity loss, Nick Dulvy and colleagues outlined a number of measures to complement the current legislative framework for the conservation and recovery of fish populations, including: reducing fishing mortality on overexploited stocks; broadening the range of conservation measures based on improved scientific knowledge and process understanding; ensuring effective, prompt implementation and enforcement of fishing regulations and effort control; and moving towards fishery management framework that discourages over-capacity and wasteful fishing methods, and that encourages energy efficient and responsible fishing methods. Fish consumers in the EU should also ensure they increasingly choose fish from sustainable sources. In this respect, a sustainable fishery certification mechanism should be developed and become available in all European countries. Henn Ojaveer concurred with the fact that we need better controls to prevent over-fishing (such as a ban on catching juvenile fish) and suggested more research on the dynamics and status of non-target fish species, which can, of course impact on commercial fish species. Together with Ferdinando Boero, Henn Ojaveer also emphasised the need for improved communication and cooperation between fisheries and marine ecologists.

Finally An Cliquet discussed challenges to stop marine biodiversity loss, the biggest one being finding support amongst politicians, stakeholders and the general public to take measures. Although the legislation exists, implementation and enforcement of legislation is lacking. In addition, certain legal instruments and nature conservation policies and instruments need to be better adapted to the specificity of the marine environment and the recent focus on ecosystem goods and services. At the institutional level, there is also a need for integration and coordination on the international, national and regional level. As such, An suggests ecological research on the specificity of the marine environment, as well as research on adaptation of existing instruments, on developing appropriate management measures, and finally research on integration within nature conservation instruments and integration with other sectors.

Research priorities

Juliette Young, Stephen Hawkins, Ricardo Serrão Santos

Session I: Interactions between global change and marine biodiversity

An overarching theme throughout the e-conference was that integrated monitoring with a long-term perspective operating on a European scale would lead to a better understanding of the effects of climate change on marine biodiversity. In summarising the research priorities suggested by contributors we have tried to organise them into categories (some priorities obviously could have been placed in multiple categories, but have been placed in a single category to reduce duplication). In order to better understand the effects of climate change on marine biodiversity, the e-conference participants suggested the need to carry out research to:

1. Global drivers

- Understand the interdependence between climatic phenomena such as the North Atlantic Oscillation, the Atlantic Multidecadal Oscillation and global warming and their individual as well as combined impacts on marine ecosystems.
- Quantify the effects of ocean acidification in relation to future scenarios of anthropogenic CO_2 emissions and ocean warming
- Develop models to map the results of small-scale studies to larger spatial and temporal scales (especially needed to predict the outcomes of management decisions such as the designs of MPAs).
- Widen spatial and temporal scales of monitoring programmes to better link known biodiversity dynamics with global-scale studies of atmospheric and oceanic processes
- Develop reliable global climate models stemming from various social and economic scenarios as well as numerical models of ecosystems that could be coupled to these climate models

2. Systematics and taxonomy

- Revise taxa
- Compile comprehensive catalogues of faunas and floras
- Analyse the genetic and morphological diversity in multiple marine communities and combine these with the analysis of long-term data to assess global change phenomena

3. Baselines, monitoring and indicator species

- Explore understudied marine geographical regions
- Determine baselines in order to better understand the impacts of ongoing and future changes
- Long-term monitoring of intra-specific genetic biodiversity and genetic expression to improve the knowledge base of studies on the impacts of global change and human activity
- Carry out quantitative monitoring to record the effects of acute and chronic disturbances to intertidal ecosystems

- Expand long-term monitoring networks (to derive 'evidence-based' policies)

4. Mechanisms by which species respond to climate change

- Determine the thermal and pH tolerances of marine organisms
- Better understand sensitivities and adaptation capabilities of key species in the marine environment
- Determine the effects of climate on recruitment pathways and phenology of coastal habitat biodiversity
- Understand the mechanisms by which a warming climate affects marine organisms
- Understand the mechanisms by which ocean acidification affects marine organisms
- Understand the ecological mechanisms by which climate change alters the marine environment

5. Variability in climatic and biodiversity responses

- Better understand the interactions between natural climate variability and anthropogenically driven change

6. Invasive species

- Quantify the impact of marine species invasion on native biodiversity
- Determine the role of climate change in invasion success

7. Ecosystems consequences

- Understand the effects of climate change on ecosystem functioning in benthic communities
- Understand and assess pelagic diversity and heterogeneity (e.g. by using top predators as potential indicators of pelagic biodiversity and oceanographic processes)
- Determine the effects of "low-dissolved-oxygen" events such as hypoxia and anoxia on function and status of the marine environments

8. Validation and prediction

- Develop systems that can track, forecast and control uncertainties regarding biodiversity loss
- Develop tools to validate predictions

9. Historical ecology, data acquisition and data access

- Expand on the current status of data access and dissemination
- Retrieve environmental data from historical sources, reports and other grey literature and to make this data available and compatible with future scientific analyses
- Create more detailed fisheries data sets

10. Restoration and mitigation

- Assess the responses of different biodiversity indicators to restoration measures
- Determine the impact of global change on planktonic communities and the sequestering of carbon in ocean sediments.

11. Policy relevant priorities

- Develop guidelines to summarize and effectively disseminate scientific results to end-users
- Develop mechanisms by which science could inform policy and practice more rapidly
- Promote the training of intermediaries between scientists and policy-makers, who could interpret the scientific data, and put an "economical" value on or, at least, clearly identify the "risk" factors involved.

- Develop better communication systems between scientists, policy and stakeholders
- Promote the development of multidisciplinary studies in the field of marine resource management
- Create representative marine protected areas which factor climate change into their design

Session II: Effects of climate change mitigation and adaptation measures on marine biodiversity and the role of marine biodiversity in the mitigation of climate change effects

In order to better understand the effectiveness of mitigation and adaptation measures with respect to the impacts of climate change on marine biodiversity, and the role of marine and coastal ecosystems in the mitigation of climate change effects, participants to the e-conference suggested the need to carry out research to:

- Determine the consequences of coastal defences on ecosystem function and services
- Conduct sound monitoring before and after construction of coastal defences in order to assess their effectiveness at meeting management goals.
- Determine the effects of coastal defences on non-target systems and species, including promotion of range extensions on non-natural habitat
- Establish the environmental benefits and costs of wind farms, especially the long-term effects on ecosystem processes and function
- Determine the impacts of tidal and wave projects on marine biodiversity
- Determine the effectiveness of iron fertilization and the long-term impacts of such fertilisation on the marine food web.
- Carry out molecular and biochemical research to enhance the physiological properties of algal strains, as well as optimisation of algal production and harvesting systems.

Session III: Stopping marine biodiversity loss

1. Current status and trends:

- Map, list and rank coastal habitats types in terms of vulnerability to human impact, species richness, relevance for ecosystem functioning and uniqueness
- Understand the cause-effect relationships between impacts and biotic response in estuarine habitats
- Develop knowledge of deep-sea specific diversity and distribution of main macro-habitats
- Develop current knowledge on the ecology and functioning of biodiversity in the high seas

2. Drivers of biodiversity change in marine environments:

- Assess the main drivers of change by addressing impact and environmental quality at the relevant scale
- Develop consistent methods for monitoring environmental parameters (e.g. water and sediment nutrient concentrations, light attenuation) to better interpret community variability
- Determine the impact of new chemicals and synthetic materials and compounds on the structure and functioning of marine ecosystems
- Understand the links between increased marine traffic and the spread of alien

species
- Determine the impacts of industry, commercial fishing, and pollution on deep-sea environments
- Develop new functional indicators (rather than species) as a more predictive approach to detecting ecosystem changes

3. Biodiversity management:
- Develop a framework that allows MPAs to be treated as designed experiments at the appropriate spatial and temporal scales, allowing for the re-design of MPAs following proper assessment and critique.
- Analyse fine scale spatio-temporal data and information (e.g. on fisheries) in the creation of MPAs
- Determine current and predicted future state of benthic communities in Natura 2000 areas and how fishing activities could impact on these communities
- Determine the actual effects of marine reserves on the genetic structure of populations, the spatial scales involved, and the suitability of islands as reserves in terms of connectivity
- Promote the creation of large deep-sea and high sea MPAs to protect habitats such as deep corals and other natural reefs, seamounts, cold-seep and hydrothermal vent communities.
- Promote the development of an EU sustainable fishery certification mechanism

4. Linking research with policy:
- Develop a balanced dialogue between scientists and policy makers to ensure that research priorities are correctly identified and supported
- Develop mechanisms to better incorporate key actors and publics in the discussions about marine biodiversity conservation to gain their active support for conservation measures
- Develop mechanisms to integrate effective, detailed and long-term knowledge with precautionary policy-making flexible enough to be able to incorporate new knowledge
- Carry out research on the adaptation of existing legislative instruments
- Carry out research on integration within nature conservation instruments and integration with other sectors

Annex - List of contributions

Session I: Interactions between global change and marine biodiversity

Title of contribution	Author(s)
Session I Introduction	Session I Chairs
RE: Introduction to Session I	Richard Lemos
Global adaptive controlled forecasting systems	Zoheir Sabeur
Ocean acidification and benthic biodiversity	Steve Widdicombe
Ecosystem effects of ocean acidification in times of ocean warming	Hans-Otto Pörtner
Is taxonomy of use to the study of biodiversity?	Ferdinando Boero
RE: Is taxonomy of use to the study of biodiversity?	Christos Arvanitidis
RE: Is taxonomy of use to the study of biodiversity?	Ferdinando Boero
RE: Is taxonomy of use to the study of biodiversity?	Antonietta Rosso
RE: Is taxonomy of use to the study of biodiversity?	Priscilla Licandro
RE: Is taxonomy of use to the study of biodiversity?	Ole Seberg
Multidisciplinary studies and long-term data	Alexandra Kraberg
Use of long-term data sets in understanding the impacts of climate change on marine biodiversity	Doris Schiedek
The use of long-term data-sets in understanding the impacts of climate change on marine biodiversity	Antonio Terlizzi
Effects of climate change on European marine fish and fisheries	Martin Genner
Impact of climate change on intertidal ecosystems	Alan Southward
Understanding the direct and indirect impacts of global change on marine coastal habitats	Lisandro Benedetti-Cecchi
Impacts of climate change on intertidal systems and estuaries	Henrique Queiroga
Impacts of climate change on benthic communities	Paul Somerfield
The impacts of climate change on benthic communities: what do we need to know?	Chritos Arvanitidis
Interactions between global change and marine biodiversity: impacts on ecosystem functioning	Monika Kedra
Impacts of climate change on benthic communities	João Carlos Marques

Title of contribution	Author(s)
Alternative monitoring networks	Sophie des Clers
RE: Alternative monitoring networks	Sandra Bell
Impact of climate on small pelagic fish and their environments	Jürgen Alheit
The EU research community: policy engagement and key issues	Matthew Frost
Linking science with policy	Larissa Naylor
Museums can provide data to global change studies	Bert Hoeksema
RE: Museums can provide data to global change studies	Antonio Terlizzi
Linking national and European policy and management	Katja Philippart
The need to focus on important matters	Wiebe Kooistra
RE: The need to focus on important matters	Ferdinando Boero
Benthic communities, anoxia and biodiversity	Michael Stachowitsch
Study vs. action	François Bonhomme
RE: Study vs. action	Ferdinando Boero
Brief comment on study vs. action	Susanna Lehvävirta
RE: Brief comment on study vs. action	Betty Stikkers
RE: Brief comment on study vs. action	Ferdinando Boero
RE: Brief comment on study vs. action	Betty Stikkers
RE: Brief comment on study vs. action	Martin Sharman
RE: Brief comment on study vs. action	Ferdinando Boero
RE: Brief comment on study vs. action	Nabila Mazouni
RE: Brief comment on study vs. action	Yves Henocque
RE: Brief comment on study vs. action	Ferdinando Boero
RE: Brief comment on study vs. action	Irina Herzon
RE: Brief comment on study vs. action	Nabila Mazouni
Research – Action	Sophie des Clers
RE: Research – Action	Marion Gosselin
Study, action and official reports	Chrsitian Kleps
Top predators as pelagic biodiversity and oceanographic process indicators	Marizio Wurtz
Invasive species between science and politics	Frederico Cardigos
Linking natural heritage with cultural heritage to emphasize European responsibility	Jan Jansen
Long-term monitoring of intraspecific biodiversity	Anne Chenuil

Session II: Effects of climate change mitigation and adaptation measures on marine biodiversity and the role of marine biodiversity in the mitigation of climate change effects

Title of contribution	Author(s)
Session II Introduction	Session II Chairs
Effects of coastal defences on the marine environment: are we factoring them into management decisions?	Laura Airoldi
RE: Effects of coastal defences on the marine environment	Ferdinando Boero
Offshore wind energy: a useful measure for the mitigation of greenhouse gases but, what about its effects on the marine environment?	Benjamin Burkhard
RE: Offshore wind energy	Andrew Gill
RE: Offshore wind energy	Ferdinando Boero
RE: Offshore wind energy	Andrew Gill
RE: Offshore wind energy	Gergely Torda
RE: Offshore wind energy	Doris Diembeck
Iron fertilization of oceans as a means to sequester carbon dioxide	Gergely Torda
The effects of wind energy generation on the marine environment	Andrew Gill
Implications of offshore renewable energy	Magdalena Muir
Biofuel production from marine algae	C. Llewellyn & S. Skill

Session III: Stopping marine biodiversity loss

Title of contribution	Author(s)
Introduction to Session III	Session III Chairs
Treating management decisions as large-scale experiments	Lisandro Benedetti-Cecchi
RE: Treating management decisions as large-scale experiments	Louise Scally
RE: Treating management decisions as large-scale experiments	S. Orfanidis
What can we do to curb biodiversity loss?	Wiebe Kooistra
Marine Natura 2000 sites and fisheries	Søren Anker Pedersen
Stopping biodiversity loss in coastal environments	Ferdinando Boero
'Good' or not-so-good ecological status – and then?	Peter Herman
Let's have a mildly critical look at some claims	Wiebe Kooistra
RE: Let's have a mildly critical look at some claims	Peter Herman
RE: Let's have a mildly critical look at some claims	Wiebe Kooistra
Stopping biodiversity loss in estuaries	Henrique Cabral
The knowledge of deep-sea biodiversity: A new challenge	Daniel Desbruyères
Reconciling fisheries with stopping biodiversity loss in the deep-sea and high seas	Telmo Morato et al.
RE: Reconciling fisheries with stopping biodiversity loss in the deep-sea and high seas	Asta Audzijonyte
RE: Reconciling fisheries with stopping biodiversity loss in the deep-sea and high seas	Ferdinando Boero
RE: Reconciling fisheries with stopping biodiversity loss in the deep-sea and high seas	Adriana Vella
RE: Reconciling fisheries with stopping biodiversity loss in the deep-sea and high seas	Juliette Young
Fisheries and stopping biodiversity loss	Nick Dulvy et al.
RE: Fisheries and stopping biodiversity loss	Henn Ojaveer
RE: Fisheries and stopping biodiversity loss	Pascal Lorance
Future-proofing MPAs: a warning	Michel Kaiser
RE: Future-proofing MPAs: a warning	Peter Herman
The role of MPAs in the protection on the genetic structure of fish populations	Ángel Pérez-Ruzafa
RE: The role of MPAs in the protection on the genetic	Adriana Vella

Title of contribution	Author(s)
structure of fish populations	
Marine invaders	Vladimir Vershinin
Other threats to marine biodiversity	Henn Ojaveer
Policy challenges to stop biodiversity loss	An Cliquet