Life on the Blue Planet

Biodiversity research and the new European Marine Policies

Portuguese EPBRS meeting, Porto, 6-9 November 2007

Report

Electronic Conference 1-19 October 2007

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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

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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 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.

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

List of contributions

Session I: Interactions between global change and marine biodiversity

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

Session III: Stopping marine biodiversity loss

Session I: Interactions between global change and marine biodiversity

Session I Introduction: Interactions between global change and marine biodiversity

Stephen Hawkins, Nova Mieszkowska and Pippa Moore, Session I Chairs

The debate on climate change has moved on between the release of the IPCC2001 and IPCC2007 Assessments. It is now widely accepted that climate change is occurring and our world is warming rapidly. The seas of the north east Atlantic from Portugal and Spain northwards are showing some of the most marked changes (IPCC 2007). Projections using various societal scenarios suggest that over the coming century there will be an increase in global surface temperatures of 1.8-4.0°C (IPCC 2007). The scale of the problem of reduced alkalinity of the ocean due to dissolved CO_2 ("ocean acidification") has also recently been appreciated.

It has also become clear that because of the inertia in the climate system (IPCC 2007, Stern 2007, UKCIP 2002) society will have to live with climate change for at least the next 50 years. Whilst we await the long-term benefits of new technologies and mitigation measures to reduce carbon emissions, society will need to adapt to climate change in the medium term. This is the key theme of this e-conference and informs the main questions we would like to address:

1. What scientific information is required to underpin adaptational strategies to reduce the impacts of global environmental change on marine biodiversity?
2. What are the key priorities and likely gaps or deficiencies in current research?
3. What key information needs to be developed to inform policymakers?
4. How can we engage the general public to influence policymakers?

Invited keynote contributions will set the scene and hopefully participation from those of you reading this opening address will help inform debate and provide answers to the questions addressed. In organising this e-conference we have separated the first session we are chairing into two:

1. What do we already know about the interactions between global change and marine biodiversity?
2. What do we urgently need to know to integrate global change into existing and new policy and management plans to better protect marine biodiversity and allow the sustainable use of marine resources?

Keynote contributions will develop these points further, but species responses to recent climatic warming have been observed in nearly all major taxonomic groups and from terrestrial, marine and freshwater systems (Parmesan 2006). In pelagic systems, whole assemblage shifts have been observed using data collected by the Continuous Plankton Recorder (e.g. Beaugrand et al. 2003, 2004, Hays et al. 2005). Changes in marine fish species (Perry et al. 2005) and assemblages (Genner et al. 2004) have been observed. Phenological shifts have also been observed in pelagic ecosystems (Edwards & Richardson 2004) and historical data has shown the influence of past climatic fluctuations on squid and fish (Sims et al. 2001, 2004). Distributional shifts of rocky shore species have been shown in Portugal and Spain (Lima et al. 2007, 2006), France (Wethey et al. in press) and the British Isles and Ireland (Herbert et al. 2003, 2007, Mieszkowska et al. 2005, 2006, 2007, Simkanin et al, 2004). Interestingly it would appear that southern species of fish and invertebrates are increasing in abundance and advancing more rapidly than northern species are retreating (Mieszkowska et al. 2005, Helmuth et al. 2006).

Little can be done about the physical effects of climate change operating at the global or hemispheric scale over the next 50 years. Our views are that individuals, society and governments should focus on managing the interactions of climate change with those regional and local pressures that we can do something about by voluntary or statutory means. This requires a European-wide view as issues transcend national boundaries – as do the species, assemblages and habitats we are striving to conserve to reverse the loss of biodiversity (the major theme of the session led by Professor Dr Ricardo Santos and co-chairs in week 2). We favour the approach of focusing on managing interactions of global change with regional and local impacts on marine biodiversity and the consequences for the goods (such as fisheries, aquaculture and mariculture) and services (e.g. nutrient cycling, waste disposal, coastal defence as well as keeping the ocean and atmosphere suitable for life) provided by marine ecosystems.

The e-conference should discuss the kind of scientific information needed to manage the following interactions:

1. Climate change and non-native species (regional)
2. Climate change and fisheries (regional)
3. Climate change and aquaculture/mariculture (local)
4. Climate change and habitat loss/alteration due to inappropriate coastal development and the need for coastal defences (local scaling up to regional in some areas)
5. Climate change and eutrophication (local-regional).
6. Climate change and point source pollution (local).

Mitigation measures which address the global concern of reducing emissions are likely to have local impacts on marine biodiversity and ecosystems. These may scale up to regional impacts if renewable energy production takes off. These impacts will not only be on biodiversity itself but those sectors of society extracting goods from the oceans and coastal seas. Thus the information requirements to understand the trade-offs between local impacts of renewable energy schemes versus the wider gains need to be considered. These considerations will be addressed in session 2 of this e-conference on the effects of different measures of mitigation and adaptation to climate change on marine biodiversity.

RE: Introduction to Session I

Ricardo Lemos, Faculty of Sciences, University of Lisbon, and League for the Protection of Nature

The following is a cursory discussion regarding the two questions placed in Session I. The study carried out by the Fisheries team of project SIAM - Climate Change in Portugal: Scenarios, Impacts and Adaptation Measures (Sousa Reis et al. 2002; 2006) is used as the starting point; further references can be found therein.

1. What do we already know about the interactions between global change and marine biodiversity?

We know that:

- Ocean warming and acidification significantly affect the physiology of marine organisms (Pörtner 2001, 2002; Pörtner et al. 2001).
- Sea-level rise, together with human occupation of coastal areas, squeezes the habitat available for intertidal organisms (Doody 2001).

- Several other pathways of climate change impacts upon marine organisms have been discerned (Sousa Reis et al. 2006). The net effect on a particular population is hard, if not impossible, to ascertain with our present knowledge.
- Environmental changes are unprecedented in their magnitude and/or speed, making past observations of how populations responded to climate variability insufficient for prediction into the 21st century (Bakun 1990, Frank et al. 1990, Murawski 1993).
- Marked long-term changes and sudden regime shifts have occurred in some regions of the ocean (Hare et al. 1994, Reid et al. 2001, Borges et al. 2003, Lemos 2006). How they were related to human activities is not yet clear.
- Some species display interdecadal fluctuations in their distribution and abundance, in response to natural environmental variability (Klyashtorin 2001, Ravier & Fromentin 2001). This blurs the anthropogenic climate change - biodiversity link.

2. What do we urgently need to know to integrate global change into existing and new policy and management plans to better protect marine biodiversity and allow the sustainable use of marine resources?

We need:
- Reliable global climate models, stemming from various social and economic scenarios for the 21st century.
- More knowledge about the thermal and pH tolerance of marine organisms, from bacteria to whales.
- More knowledge about trophic interactions, growth and reproduction.
- Numerical models of ecosystems coupled to the climate models mentioned above.
- Tools to validate predictions; representative marine protected areas and other monitoring systems must be put in place and sustained for decades. More detailed fisheries data sets are also required.
- Guidelines to summarize the resulting information, destined to end-users. Research gaps are numerous and wide, but the scientific community is expected to provide cost-effective, coherent and realistic measures to fight biodiversity loss due to climate change. The reason why scientific advice is often not channelled into proper action is a whole different debate, but should also be reflected upon.

Global adaptive controlled forecasting systems

Zoheir Sabeur, BMT Cordah Limited, UK

Following Stephen Hawkins introduction I would like to present my views on the subject of which particular research will be required for the control and possible reversal in the decline of biodiversity. My views are straightforward. Firstly, I don't believe that we humans have access to information about the state of our biodiversity in a common format and on a global scale. Secondly, we do not yet have the global infrastructure installed to monitor key indices representing biodiversity on a global scale. Thirdly, the scientific community has not yet conclusively and visibly managed to show this biodiversity decline to the rest of humanity. Only portions of the population actually believe in this decline. So there is a big mountain to climb for changing people's perception about global biodiversity decline and what do we need to do to reverse it.

In my view, the only way to convince the wider community about this problem, including the problem of climate change, is to deliver accessible and

believable information about biodiversity to end-users. Furthermore, the scientific community needs to provide systems which are able to track, forecast and control uncertainties on the estimated declines on biodiversity. Also, these systems should be made available within a global framework where alterations to the course of natural processes under pressure should be taken on board by these control systems either for reducing uncertainty on the predictions or reducing the biodiversity decline.

All in all we should produce global adaptive controlled forecasting systems of biodiversity with controlled errors and accessible results to the wide range of communities around the world. The various directives mentioned in the introduction speech do actually refer to the accessibility of information to the public. In my experience, this is difficult to achieve due to the issue of data access and dissemination across the globe. However, we do have the technology and legislation (such as those in the EU) to achieve it in the years to come... but more work needs to be done. I look forward to hearing the participants' opinion about this.

Ocean acidification and benthic biodiversity

Steve Widdicombe, Plymouth Marine Laboratory, Plymouth, UK

Since the start of the industrial revolution (circa 1750) more than 290 billion tons of carbon have been released to the atmosphere, with half of these emissions having occurred since the mid 1970s. This carbon has been in the form of carbon dioxide (CO_2) and most of it has come from burning fossil fuels and the manufacture of cement. As a result the concentration of CO_2 in the atmosphere has increased from 280ppm (parts per million) to around 380ppm over a period of only 250 years. It is thought that this increase is one of the main causes of rising global temperatures and the environmental impacts associated with "climate change". However, global warming would have been far worse had the oceans not absorbed nearly half of all the CO_2 emitted into the atmosphere. When CO_2 enters the oceans it reacts with seawater to form a week acid (carbonic) which quickly disassociates producing hydrogen ions the presence of which cause the acidity of the seawater to increase. In reality acidity should not increase because seawater contains a lot of carbonate ions which bind with the hydrogen ions bringing the system back into balance. This process is known as the "carbonate buffer". Initially it was thought that all the extra CO_2 could be absorbed without any significant changes occurring in seawater chemistry because of this buffer. After all the acidity of the World's oceans has been stable for 25 million years even during periods when atmospheric CO_2 levels have been higher than they are today. However, at approximately 100 times greater than any previous naturally induced increase, the current speed at which atmospheric CO_2 concentrations are increasing is so great that the processes which regulate the supply of carbonate are too slow to prevent the increase in hydrogen ions and the oceans are becoming more acidic. Since the onset of industrialisation, seawater acidity has fallen by 0.1 pH unit equating to a 30% increase in the concentration of H+ ions. The Intergovernmental Panel on Climate Change (IPCC) has predicted that continued rises in the concentration of atmospheric CO_2 will lead to a global surface water pH reduction of up to 0.4 units by 2100, and 0.7 units by 2250.

Our oceans harbour tremendous biological diversity. Of the 29 non-symbiont animal phyla that have been described so far, all but one has living representatives in the ocean and 13 are represented only in the oceans. With all of these phyla having representatives in the benthos and most having representatives in marine sediments, it is considered that the majority of the species diversity in marine ecosystems consists of invertebrates either residing in (infauna) or on (epifauna) the seafloor. Recent experiments have identified significant variability in the pH sensitivity of a number of different benthic groups. Even amongst organisms which depend on calcium carbonate shells and skeletons enormous variability in tolerance has been observed with for example echinoderms showing far less tolerance to pH change than molluscs. Such variability in sensitivity will have considerable implications for the biodiversity of marine sediments in a high CO_2 future.

Ecosystem effects of ocean acidification in times of ocean warming

Hans-Otto Pörtner, Alfred-Wegener-Institute for Polar and Marine Research, Marine Animal Physiology, Bremerhaven, Germany

Ocean warming and acidification occur at global scales and, in the case of temperature, have already caused shifts in marine ecosystem composition and functioning whereas, in the case of CO_2, effects may still be so small that evidence for changes in the field is lacking. However, depending on ecosystem characteristics, future scenarios involve a threatening of marine life forms through the specific or synergistic effects of both factors. A mechanistic cause and effect understanding is required beyond empirical observations, for a secure projection of ecosystem effects and for quantitative scenarios. The identification of the mechanisms through which temperature and CO_2 related ocean physicochemistry affect individual organisms and species is crucial in this research strategy. Available evidence indicates the operation of unifying physiological principles of CO_2 and temperature effects across animal groups and phyla.

At ecosystem level, long term performance and thus fitness are key to survival and success of a species. Initial findings suggest decreased growth and enhanced mortality of sensitive species like among molluscs or echinoderms in response to a doubling of CO_2 levels from pre-industrial to 560 ppm (Shirayama and Thornton 2005), a value which is likely exceeded during this century. Marine invertebrates are hypothesized to be among the organisms most sensitive to anthropogenic CO_2 accumulation, especially those with a hypometabolic mode of life and heavily calcified (Pörtner et al. 2004, 2005). Early life stages with an incomplete development of physiological capacities may be the most sensitive. Thereby, reduced reproductive success may be a key effect of ocean acidification. Furthermore, CO_2 induced limitation may occur through a decrease in the capacity for growth, reproductive output, or diverse behaviours including the ventilation of burrows, bioturbation activities or exercise capacities in general. The sensitivity of lower marine invertebrates may be largely due to their low capacity to compensate for CO_2induced disturbances in extracellular ion and acid-base status. Decreasing calcification rates result and are also expected in reef building corals with the potential that combined warming and acidification effects will cause a marginalization of coral reef habitats (e.g. Hoegh-Guldberg 2005).

However, performance is also limited by temperature. The width and limitation of thermal windows emerge as a basic character defining species success and survival in thermally stressed ecosystems (Pörtner and Knust 2007). This includes their capacity to interact with other species. Thermal windows emerge as a species specific character suitable to explain climate dependent regime shifts (e.g. Takasuka et al. 2007). One key consequence of ocean acidification may be a narrowing of thermal tolerance windows (Pörtner et al. 2005, see figure 1) a hypothesis recently confirmed in a crustacean (Metzger et al. 2007).

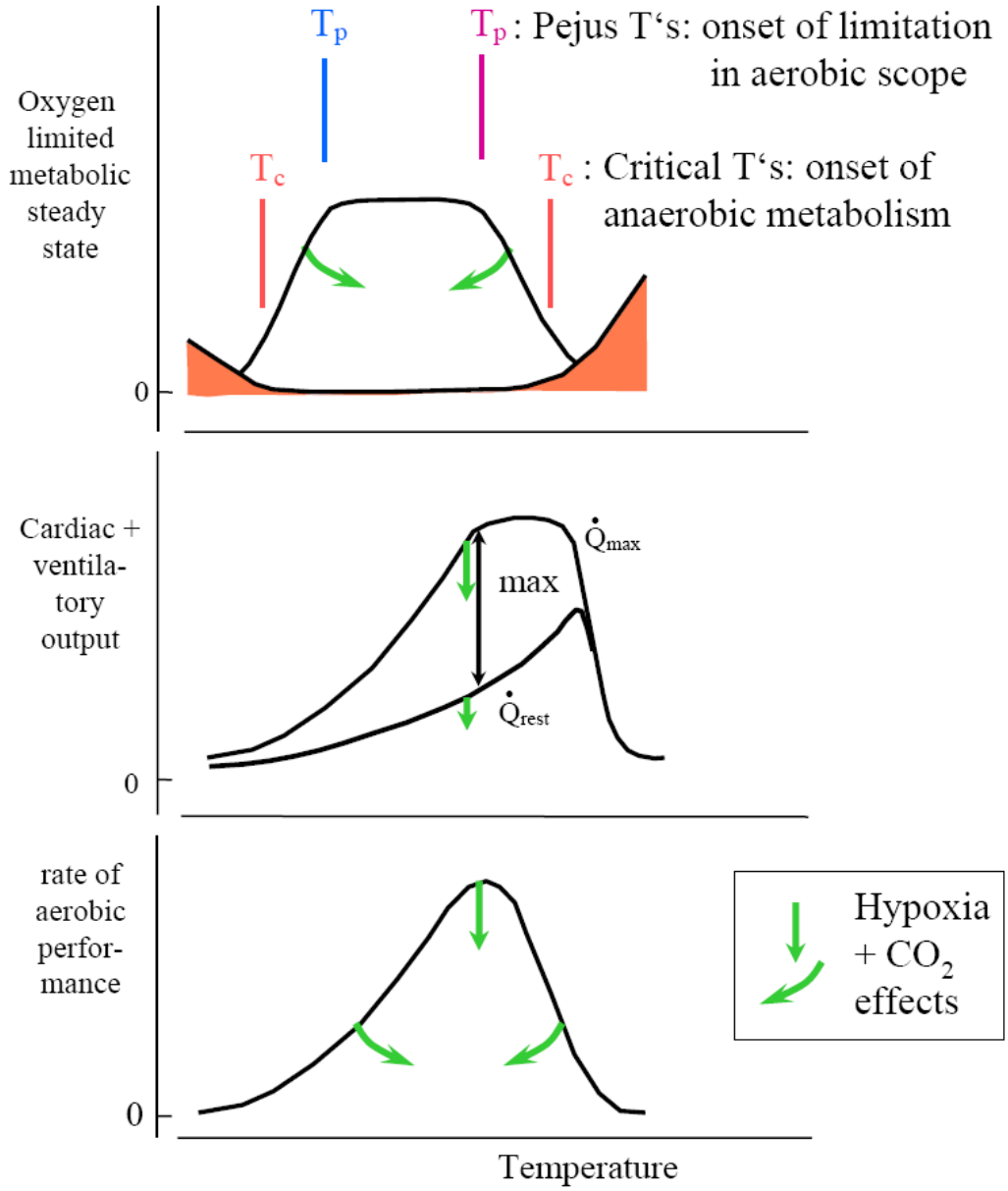

Figure 1: Schematic model of oxygen limited thermal tolerance and performance capacity in fish and other metazoa, set by the capacity of oxygen supply mechanisms (Pörtner et al. 2005). The first limitation at thermal extremes (top) is the onset of a loss in aerobic scope, i.e. the flexibility of the organism to respond to changing energy demands. This loss becomes severe at critical temperatures when anaerobic metabolism sets in due to temperature-induced hypoxia. The maximum scope (Δmax) between resting and maximum rate of oxygen supply (center) through ventilatory and cardiac activity results at the upper pejus temperature Tp, before aerobic scope becomes thermally limited. This supports an asymmetric performance curve of the whole organism (bottom). Arrows indicate how the thermal tolerance window is narrowed under the effects of enhanced CO_2 levels or ambient hypoxia. While CO_2 will support passive but time-limited survival of thermal extremes, it will at the same time cause a decrease in aerobic scope, with prospected decrements in long-term aerobic performance and growth functions as a result, as well as a narrowing of thermal windows.

Since large scale distribution of marine ectotherms is determined by temperature, this may result in a narrowing of temperature dependent zoogeographical ranges. Limits become effective especially where species and firstly, their critical life stages reach their limits of physiological plasticity and also, of acclimation capacity. The physiological principles shaping performance are likely also involved in multi-step processes affecting marine food webs. Here, species specific responses and sensitivities cause various species of an ecosystem to be affected differently, resulting in changes in species interactions, food web structure and associated carbon fluxes.

Much of what is projected here has been extrapolated from present knowledge of the mechanisms of action of ocean acidification and warming effects on organisms. Continued efforts should complete our mechanistic understanding and quantify effects in relation to future scenarios of anthropogenic CO_2 emissions and ocean warming. They should also feed this information into the building of mechanism-based models of organism and ecosystem functioning and response to change.

Is taxonomy of use to the study of biodiversity?

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

Marine biodiversity is poorly known, especially now, in this period of change. If we want to protect something, we have to know it. Of course we cannot wait to know everything to act, but it is paradoxical that everything is promoted besides the science that studies biodiversity at species level: taxonomy. In every country the old taxonomists are retiring and they are not replaced by new ones. Taxonomists are disappearing from universities and from marine stations, and they are now confined to museums. The result is that taxonomy is not taught and that little research is performed in situ, from a marine facility, where one might perceive change in real time. There are lots of projects on marine biodiversity, but they are aimed at identification (production of keys), species lists and providing services for taxonomy, but very little is done to sustain taxonomy by providing funding for, let's say, revision of taxa, exploration of understudied geographical regions (with the exception of the deep sea and the Antarctic), compilation of faunas and floras.

Biodiversity and global change: We should be able to identify impacts. What we can say is that tropical species are increasing. The International Commission for the Scientific Exploration of the Mediterranean Sea (www.ciesm.org) has compiled the atlases of alien species in the Mediterranean, and the greatest majority of the aliens of very representative groups are of tropical origin. The biodiversity of the Mediterranean, in this way, has increased a lot, since many new species arrived. This should be positive! We always complain that species disappear, and then we complain because new ones arrive! Sometimes the newcomers are devastating, like the alien ctenophore *Mnemiopsis leyidi* in the Black Sea, but in most cases they do not do much to the resident species. Sometimes they even become a resource for humans.

If we want to assess the impact of something on biodiversity we should reconstruct the past states of biodiversity (and they are scattered in taxonomic literature, long term data sets are not enough) and then we should check the present-day situation. Strange enough, among all services provided to taxonomists, there is no bibliographic support. Literature is the main tool for taxonomy and biodiversity information is there. How come this has been forgotten, with very few exceptions?

My steps to fulfil the goals above are simple:

1 Make a comprehensive list of European marine habitats
2 Make a comprehensive list of European marine species (we have it, it is ERMS, but only specialists can use it)
3 Match the species with the habitats and make master lists of species per habitat using information contained in the taxonomic literature
4 Check, for all species, the records in the literature and identify the most recent citation (you need good taxonomists for this task, and very good libraries)
5 If the most recent citation dates back to more than 100 years, maybe the species is in distress (especially if there were plenty of records before)
6 Sample the habitats in which the species has been recorded, to see if it is still present and record the population status
7 Raise a case of putative extinction or of threat

In the age of biodiversity, the basic science of biodiversity, taxonomy, is in distress. This needs to be addressed in order to carry on with any kind of biodiversity research.

RE: Is taxonomy of use to the study of biodiversity?

Christos Arvanitidis, Institute of Marine Biology and Genetics, Hellenic Centre for Marine Research, Greece

I would like to make a short point on Ferdinando Boero's views on marine biodiversity.

First of all, I strongly support what Nando says about the "traditional" discipline of taxonomy and the problems associated with this. Taxonomy, in its "conventional" sense, moves towards extinction with most of the human potential already retired and the new folks looking for a post in a Museum or old University Departments, over years or decades.

However, as the traditional discipline tends to decline, new disciplines have already emerged which can make advances in taxonomy. Consequently, the focus of this discussion should be not only on how to engage traditional taxonomy into biodiversity science but also how to create the new European generation of taxonomists: modern taxonomists who have not only the knowledge and skills required obtained by the traditional taxonomy but taxonomists who can integrate these skills with those deriving from the younger disciplines. Young people who can not only identify and create new taxa but who can also design and carry out a population genetics analysis or a community analysis or data integration and management. I have the impression that this urgent need, as marine biodiversity declines, has not been fully understood by national or EU funding agencies.

Finally, although this point seems to be a bit far from the issue introduced by the session chairs it brings forward some of the essential questions:
(a) What kind of marine biodiversity decline can be assessed when floras and faunas do not exist for most of the European waters and,
(b) What kind of ecosystem functioning changes can be modeled when the functional roles are not known for the majority of the species?

RE: Is taxonomy of use to the study of biodiversity?

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

Thanks for this, Christos. I have argued in other forums that modern taxonomists are being formed in the US, with the Partnership for Enhancing Expertise in Taxonomy. The EU is spending lots of money to provide services to taxonomists, but there is no deliberate design on what a modern taxonomist should be. And taxonomy is confused with identification. I concur with you that it is inexplicable why the EU is not enforcing such an obvious policy. The problem is that biodiversity issues are often in the hands of non-taxonomists who can lobby very effectively. Taxonomists simply retire. Decision0makers are advised by the scientific community, therefore it is not their fault. Non-taxonomists all agree that taxonomy is vital to study biodiversity, but then, when money becomes available, they do not give up the possibilities of funding to make money available for people "who are not there".

Taxonomy is very important but that there is not convincing enough pressure to sustain it. It is catch 22. If there are no taxonomists who speak out, then taxonomy

is not important because nobody speaks for it. And, in fact, I am usually alone in this battle against the rubber wall.

Of course, the old taxonomist inspecting corpses in little vials stored in some museum is not what I have in mind. But the PEET has very carefully designed the road to follow. We often copy the US, usually with 20 years of delay. Now they come to us to learn taxonomy, because we know it better than them. They learn it from our old guys. In 20 years we will be forced to send our future taxonomists to the US, to learn from them.

I would like to have a public confrontation with the NSF people running the PEET, the EU people responsible for biodiversity projects, and the EU decision makers who listen to their advice (designing the calls for projects) to compare the EU policy with the US policy. And I would like to be invited to say something, maybe with the company of some of the surviving taxonomist in Europe. I had this experience at a PEET meeting at Berkeley, where one person came to explain the EU policy. I had delivered my talk just before him, and he was very embarrassed because his presentation demonstrated exactly what I had denounced. He soon disappeared from the meeting, but nothing changed in Europe.

Nobody, in these forums, has ever dared say that taxonomy is not important for biodiversity study and management, and that it is flourishing in the EU. All agree that there is a problem. All. But then no measures are taken. The measures are not linked to provide services for taxonomy. The measures are the deliberate training of modern taxonomists throughout Europe, and funding availability for revisionary work and for the compilation of faunas and floras, eventually leading to lists and keys. Instead, we jump the first steps and go straight to lists and keys. Information without knowledge. I have only one adjective for this policy: unwise.

I am still waiting for figures. How many projects aimed at producing faunas and floras in Europe have been financed? Not lists, not keys, please. But what is needed to make a serious list and a serious key and that is not there. How many projects of biodiversity exploration, with all taxa inventories, have been financed? How many new positions for taxonomists in universities and marine stations have been made available? They are not made available for a very simple reason: a taxonomist does not bring in any money, since there are no projects for him or her.

I would like to know why this is not convincing, where are the logical faults. If there are none, then why not make a committee of biodiversity experts (people with publication records on biodiversity exploration at the species level) to study what might be done? The web of science is a very powerful tool. And it is often the case that it reveals that people involved in biodiversity issues, also regarding taxonomy, have no relevant publications on the topic regarding the issue in question.

RE: Is taxonomy of use to the study of biodiversity?

Antonietta Rosso, Department of Geological Science, Section of Oceanology and Palaeoecology, Catania University, Italy

I fully agree with Nando Boero's position about the need for knowledge on biodiversity taking into account habitat and species. And I would strongly remark that this is a task for taxonomists. Particularly, for a better understanding of present-day biodiversity, they have to list species from different habitats and geographical regions and make comparisons with previous data from the same regions. In addition to

historical data sets, a revision of old specimens (and also old, sometimes still unstudied! material) housed in marine stations and museums will be useful. This practice could increase our knowledge on biodiversity and above all could help in evaluating changes really happening in biodiversity in very recent times.

Furthermore, I also think that information from fossils (at least Quaternary in age, i.e. younger than about 1.73 million years) must be taken into account (obviously for systematic groups possessing preservable skeletal parts!) in statements on biodiversity to avoid misunderstandings, mostly relating to invasions of "alien" species into the Mediterranean, for example. Sometimes they could be poorly-known or small, easily-overlooked species, which actually spread into the Mediterranean a long time ago, or the present-day populations could represent the relic or past wider geographical distributions.

So my message would be to look at past literature (and materials) but also at data registered in the "rock casket". And finally, support taxonomy and also palaeo-taxonomy!

RE: Is taxonomy of use to the study of biodiversity?

Priscilla Licandro, SAHFOS, UK

I agree with Nando. Taxonomists are fundamental when investigating changes in biodiversity. They should be the first to be supported, as the training of a taxonomist request time and has no immediate output (e.g. quick publications) unless a new species is found. In the process of maintaining the expertise in taxonomy, a key step is the transfer of an expert taxonomists' knowledge before the taxonomist actually retires. This is becoming a really urgent problem.

Science is developing systems to automatically identified marine organisms (e.g. see discussion about identification of marine plankton in the SCOR working group, WG130) but at present these systems are very far from providing useful information on marine biodiversity as they are unable to identify all the species/genera. Again taxonomists are crucial for their improvement.

RE: Is taxonomy of use to the study of biodiversity?

Ole Seberg, Natural History Museum of Denmark

I have with considerable interest read Ferdinando Boero's missive concerning marine biodiversity. May I draw the attention to the fact that apart from charismatic groups like butterflies, birds, and mammals the situation is not much better with respect to terrestrial biodiversity. Taxonomy is dismissed everywhere and most countries that have ratified the CBD have no clue how much biodiversity their countries hold or even a realistic estimate of the number of species they have - how can we possibly live up to the 2010 goals??

Multidisciplinary studies and long-term data

Alexandra Kraberg, Alfred Wegener Institute for Polar and Marine Research, Biological Station Helgoland, Germany

Summary: The author argues that multidisciplinary studies that investigate the genetic and morphological diversity in multiple marine communities and combine these with the analysis of long-term data to assess global change phenomena are required to investigate potential threats of global change to marine biodiversity and to plan and prioritize remedial steps for the protection of marine biota.

The marine environment is undoubtedly undergoing profound changes due to global warming. The consequences of global warming for marine biota include the direct effects of increases in temperature, sea level rise, changes in nutrient regimes or rising CO_2 levels in the oceans and therefore increasing acidification. The latter provides a good example for very direct effects on marine biodiversity as whole groups of calcifying organisms will be impacted, including, for instance molluscs, coccolithophores and corals (Riebesell et al. 2000, Orr et al. 2005). Marine communities, both benthic and pelagic and at a range of latitudes, could therefore be facing considerable changes in biodiversity and potentially a decrease in species richness with unknown consequences for the stability of these ecosystems and their food webs.

Before we can actually assess the consequences of global warming, assessments of the underlying marine biodiversity are vital. Unfortunately the measurement of marine biodiversity is not straightforward:

1. It is difficult to establish the underlying baseline biodiversity in an ecosystem. This is often due to methodological problems but also the fact that much of the literature has never been published. In addition, many species lists are incomplete due to time and financial constraints.
2. The greatest emerging challenge for our efforts to establish this baseline biodiversity is the emerging field of 'genetic diversity'. Numerous studies have shown that 'what you see is not what you get' i.e. that there is a large degree of intraspecific (hidden) diversity in planktonic and benthic species. It has also been shown in some cases that this diversity matters with respect to the physiology of the organisms (Johansen et al. 1990, Lopez-Rodas et al. 1999, Bouicha et al. 2001). Nevertheless its overall importance for marine ecosystems and their stability in the face of global change is unknown.
3. Even if the above problems could be solved, we will still need sufficient long-term data to test emerging concepts and new hypotheses. However, these are rare for the timescales we are looking at.

The result of these problems and considerable gaps in our knowledge is that any future studies investigating potential threats of global change to marine biodiversity have only a very shaky baseline of data for comparison. This also makes the planning and prioritization of remedial steps for the protection of marine biota.

It is argued that to solve the above problems it is essential to establish a larger number of truly multidisciplinary studies that investigate simultaneously the genetic and morphological diversity (including more complete species inventories) in multiple marine communities and combine these with the analysis of long-term data to assess global change phenomena. Even relatively small consortia (reducing

management activities) could make considerable (cost-efficient) progress as long as a ‘mix’ of expertise is assembled and transmitted to all project partners through appropriate training. However, although at least the 7th framework programme encourages such projects, I would suggest that the currently available funding regimes do not sufficiently recognize the value of such studies and that this needs to be addressed urgently.

Use of long-term data sets in understanding the impacts of climate change on marine biodiversity

Doris Schiedek, Baltic Sea Research Institute Warnemünde, Germany

Summary: Documenting the impact of climate change on biodiversity in complex marine systems and understanding if changes in temperature and other environmental variables are naturally or man-induced requires long term quality controlled data sets (Parr et al. 2003). Such high quality data are available (mainly from long-term monitoring programmes) reaching back many decades, even though they are often hidden in reports and other "grey literature". An important objective within the MarBEF Network of Excellence has been to start compiling multi-decadal (environmental, fish, benthos, plankton) and multi-century scale (fish) data as prerequisite to analyse changes in species abundance, distribution and community composition in various marine systems (e.g. coastal waters, the deep-sea).

To separate man-made from 'natural' changes and local from large scale events, adequate baselines have to be established, this may require going even further back in time. In historical and environmental archives relevant information dating back several hundred years is "sitting on the shelves". Using the expertise of historians and marine ecologists sales records or fisheries yearbooks have been studied within the Census of Marine Life (CoML) project "History of Marine Animal Populations (HMAP)". This view back contributes to estimate the "human impact" on recent changes in fish biodiversity (Ojaveer & MacKenzie 2007). However, there are many more potential data sources still "unexplored" and books to be "de-dusted". We have to find ways (and the budget) to make biological and environmental data from historical sources, reports and other grey literature available and compatible to be used in future scientific analyses.

Even though the view back is important there is also a need to improve our projections and predictions and thus modelling power concerning future climate changes and possible impacts on biodiversity. Models and multivariate statistical analyses are as good as the data they are based on. Therefore data collection, e.g. as part of long term observation programmes, need to be continued. However, when collecting biological and hydrographical data new methodologies (e.g. automatic measuring systems, remote sensing devices) should be incorporated and monitoring activities should be closer linked to research and modelling.

Databases and their management are also of importance. Within MarBEF we have started to build up European wide databases on Benthos and Plankton (e.g. MACROBEN, Manuela, LargeNet) as part of the European node of the Ocean Biogeographic Information System (EurOBIS). Financial resources have to be allocated to run such data centres on a longer time scale than a five-year NoE project duration.

The on-going climate change, posing a threat to marine biodiversity and ecosystems functioning and thus goods and services, has clearly shown the need for high quality long term data, their scientific analysis and interpretation also in terms of future predictions. The good news is that such data are available but their value has to be acknowledged. More historical data have to be retrieved, adequate methodologies have to be developed (e.g. taking into account different sampling methods or taxonomical changes). Data collection has to be continued but monitoring strategies

have to be modified. All this requires more communications and interactions across disciplines but also long-term investment in equipment and methodologies, and more importantly into people (i.e. scientists), beyond a 3-5 years research project duration.

The use of long-term data-sets in understanding the impacts of climate change on marine biodiversity

Antonio Terlizzi, Laboratory of Zoology and Marine Biology, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Lecce, Italy

Summary: Despite the increasing concern among ecologists, policymakers, and the general public about the societal and ecological implications of climate change, its possible effects on marine biodiversity are still poorly quantitatively addressed. With this in mind, the author highlights the need to widen the spatial and temporal scales of monitoring programmes, and the important role of taxonomy in quantifying the actual impact of climate change on marine biodiversity.

Global warming and variations of extreme weather conditions result in shift in mean intensity and temporal variance of climatic variables, thus affecting biological systems at different hierarchies of organisation. Changes in physiological response to environmental stress, fragmentation of populations, modification of distributional patterns of key species, and direct or indirect alteration of interactions among population, are only examples of the likely impact of climate change on marine ecosystems. Forecasting the effects of climate change on marine biodiversity is therefore a challenge for a better appreciation of the role of biodiversity in ecosystems functioning and for future EU policies of marine conservation and management.

Reconstructing past changes in biodiversity patterns and modelling potential future variation under a climate change scenario necessarily implies to seek for correlation between long-term data on distribution of taxa and long-term climate data. However, to date, we still do not have a clear understanding of the roles of short- versus long-term environmental stochasticity and population-intrinsic processes on community dynamics. This is mostly due to the spatial and temporal scales of ecological investigation, which, differently from climatology, are usually limited to local and short term. Consequently, it remains difficult to link known biodiversity dynamics to the global-scale studies of atmospheric and oceanic processes.

A first crucial issue is therefore the need to widen the spatial and temporal scales of monitoring programmes. Despite an exponential implementation of long-term programmes since the first half of the past century, most of them were labelled as “merely monitoring” by administrators and stopped during the 1980s. This negative perception has been altered in recent years when the consequences of climate change were seen to be important issues from both scientific and politic perspectives. New advancements in analytical tools represent a chance for analysing and interpreting much more efficiently the existing data-sets. This calls for the implementation of a global database of existing data and, given the recent development of innovative experimental designs, represents a challenge for the quantitative improvement of monitoring plans and for manipulative studies of causal processes.

Key to this issue is the understanding on how the perception of temporal changes of what we define “biodiversity” can be influenced by the way biodiversity is described. There are two main reasons for underlining the role of taxonomy in reanalysing existing data-sets and in planning baselines for future long-term biological studies: (1) when data have been collected at the assemblage level, differences in diversity could be in part due to the various taxonomic updates of the available faunistic lists; and (2) when based on a solid taxonomic basis, well designed

long-term descriptive experiments can inform if abrupt changes have been occurring (a realistic model under major shifts in climatic variables) and which is the taxonomic level that can be used as an effective surrogate for the understanding of how climate change can actual affects marine biodiversity.

Neglecting the collection of baselines for long-term biological studies is strategically reckless under a regime of climate change. Nevertheless, quantifying the actual impact of climate change on marine biodiversity cannot disregard the role of taxonomy. Europe has a shortage of trained marine taxonomists and this pool is aging and is not being replaced. The analysis of existing data-sets through novel analytical tools, the designing of future long term experimental monitoring at large spatial scales, and experimental tests of explanatory models should carefully imply the notion of biodiversity which, as originally conceived, is essentially taxonomic.

Effects of climate change on European marine fish and fisheries

Martin Genner, Marine Biological Association of the UK, Plymouth, UK; and School of Biological Sciences, University of Bristol, Bristol, UK

We are now witnessing unprecedented warming of European seas. Over the last fifty years our marine climate has warmed by over 1ºC. Projections suggest that warming will continue with rises of 2 to 4ºC over the next 80-100 years. Climate change will impact on marine fish populations, and the fisheries on which they depend. We may expect to see changes in distributions, regional abundance, growth rates, fecundity and the timing of life-history events, such as migrations.

Globally, temperature is a one of the main factors that determines where a marine fish species can survive and reproduce. Thus, climate determines the assemblage composition or the 'mix' of species present, and already there is evidence that this is changing regionally in European waters. Warm-water red mullet (*Mullus surmuletus*) has colonised the North Sea, while cold-water eelpout (*Zoarces viviparous*) and sea-snail (*Liparis liparis*) are retreating north. These changes are occurring because the 'thermal niches' that species occupy impose constraints on the temperatures that species can successfully persist within. Thermal niches are determined by physiological adaptations. Some species survive, grow and reproduce better in warmer waters, while other species are adapted to cooler waters. We can expect more reports of distributional changes within our warming European seas. However, because many species have wide thermal niches, distributions of species may be surprisingly resilient.

Although thermal niches are often wide and distributions may not shift immediately, we will see regional abundance changes as temperature influences adult survivorship and larval recruitment. Such of the best evidence of climate-driven regional abundance changes comes from historical data on European herring (*Clupea harengus*) and pilchard (*Sardina pilchardus*) fisheries. These pelagic species respond rapidly to the changing environment. Thermal regimes may affect species directly, for example by shifting the amount of energy that that individuals expend on reproduction and growth, which are often temperature-mediated. Alternatively temperature may influence species indirectly, by influencing food supply and predator abundance.

Our work at the Marine Biological Association in Plymouth has revealed climate-related changes to be common also in demersal species. In the English Channel waters warmed towards the 1950s, cooled towards the 1970s and have undergone dramatic warming from the mid 1980s onwards. The abundance of many of common, small, and non-commercial species have followed these changes. At present we are unsure why only the smaller species have tracked climate change. It may be simply because they have faster life histories than larger species. However, it seems more likely that commercial fishing has stopped larger species responding to favourable climatic conditions. There is strong evidence of overfishing in the area, and sustained removal of the larger, more fecund individuals can reduce the ability of populations to take advantage of conditions for successful recruitment. This may in turn lead to the rapid decimation of formerly healthy stocks.

If fisheries management practices are overhauled and begin to realise their goals, then regional fishing industries can persist during forecasted climate change. However, some species may lose commercial importance locally, but these are likely to be replaced by stocks other species, possibly with higher value. More worrying are

the conservation implications of unprecedented warming, for it may dramatically alter ecological interactions among species. This may benefit some species that are presently rare or threatened, but by the same token may negatively influence others. For example climate change has been implicated in the low sandeel (*Ammodytes marinus*) recruitment in North Sea, which has led to negative effects on seabird and cetacean populations that depend on it as a food resource. We need to further our understanding of ecological mechanisms by which climate change will alter our marine environment.

Impact of climate change on intertidal ecosystems

Alan Southward, Marine Biological Association, Plymouth, UK

The main impact of fluctuating climate on intertidal ecosystems would be through changes in sea level and temperature. There is considerable evidence over past epochs of changes in sea level; deposits of shells of intertidal molluscs and barnacles are found above and below present sea levels, including the well-known 'submerged forests' and 'raised beaches'. There is a raised beach at Saunton Devon, where putative *Semibalanus balanoides* of age greater than 35,000 y BP is present several metres above the present barnacle zone, still in place on the underlying rock beneath a layer of mollusc shells (Kidson and Wood, 1974; Kidson and Tooley, 1977; and pers. obs.). In theory, intertidal organisms should be able to keep pace with changing sea level, providing it was spread over several generations of the organisms. However, we need to put into place a mechanism for recording response of intertidal life to sea level change. This would involve annual surveys of quantitative transects, including photographs, related to geodetically calibrated land survey datums. There is some urgency in this matter.

We have considerable recent evidence of the effects of small changes in temperature on distribution and abundance of intertidal organisms (Southward, 1991; Southward et al, 2004). However, there is a tendency to regard temperature change in the sea as resulting in latitudinal extension or withdrawal of species. This may well be the case for pelagic fish, but the intertidal zone is extremely indented, markedly so in Europe with its many subsidiary seas, bays and islands. Also, owing to the high heat capacity of the ocean, sea temperature is a more 'conservative' parameter, so that at low tide intertidal organisms are exposed to the greater fluctuations of air temperature. Hence, observed changes in intertidal biodiversity can show east/west trends in species range and abundance as well as north/south trends. For example, during rising temperatures in the last two decades, recognised 'southern' species of barnacles and molluscs have moved eastward along the English Channel and from north to south down the east coast of Scotland (Hawkins et al., 2003; Herbert et al. 2003, 2007; Hiscock et al., 2004; Mieskowska et al., 2006 ; pers.comm. M.T. Burrows).

Long term biodiversity data for the intertidal zone are mostly for rocky shores, which are easy to survey with minimal destructive sampling. Unfortunately, a good deal of past information on intertidal organisms has tended to be qualitative or at best semi-quantitative. In addition to routine quantitative monitoring to follow the effects of slow changes in climate, we need to record the effects of acute and chronic disturbances that damage keynote species, e.g. oil spills and clean up operations and the use of tri-butyl tin based antifouling coatings. There is a need for annually repeated quantitative transects of the intertidal zone that will also aim to show these effects and any result of change in sea level. Such fluctuations in the relative abundance of cold water and warm water barnacle species near Plymouth in the second half of the 20thC are paralleled elsewhere in south west England by corresponding fluctuations in intertidal organisms and by changes in distribution of plankton and fish.

Understanding the direct and indirect impacts of global change on marine coastal habitats

Lisandro Benedetti-Cecchi, University of Pisa, Italy

Summary: The ability to preserve marine biodiversity will rest on a mechanistic understanding of the interactions between global change events and localized disturbances.

Understanding the direct and indirect effects of global change on biodiversity will be crucial for management and conservation of natural environments, including marine coastal habitats. A large body of research in the last decade has elucidated the role of biodiversity for the functioning of ecological systems. Many studies have highlighted positive relationships between biodiversity and aggregate ecological responses such as productivity and stability, although the precise mechanisms underlying this positive relationship are still debated. Whilst a synthetic view is emerging that biodiversity is important to sustain fundamental ecological processes, the extent to which this scientific understanding can be translated into management policies beyond the obvious message that we need to preserve species and habitats, is unclear.

Addressing the fundamental question of what we need to know to protect biodiversity and to ensure the sustainable use of the marine environment, requires a closer look at the main drivers of change to marine coastal biodiversity. With extreme climatic disturbances becoming more likely and with an increasing pressure of global processes on marine ecosystems, understanding the interactions between large-scale events and more localized impacts will become a key issue. This is particularly true for marine coastal habitats where most human activities are concentrated. Novel research strategies must be identified to explicitly address how marine biodiversity will respond to the simultaneous influence of global scale processes and local anthropogenic disturbances such as pollution, aquaculture, spread of invasive species and urbanization, just to mention a few.

Our current understanding of biodiversity change is based on the results of a mix of correlative studies and small-scale experiments. Whilst experiments are of fundamental importance to uncover cause-effect relationships, the scales at which experiments are commonly done often do not match the scales at which management decisions need to be taken. Correlative studies, in contrast, can provide ecological information at larger scales at the cost of reduced accuracy in causal inference. Conservation of marine biodiversity in a global change scenario, requires a better integration of the different components of ecological research – i.e. correlative studies, manipulative experiments and modeling. New approaches must be identified to make large scale experiments more feasible and new models must be developed to map the results of small-scale studies to larger spatial and temporal scales. Scale transition theories are badly needed also to predict the outcomes of management decisions at regional scales, such as different designs of MPAs.

Understanding the impacts of climate change on marine coastal habitats will also require a better appreciation of the effects of increasing variability of ecological processes. Models of climate change predict increasing fluctuations in climate variables, in addition to changes in mean trends. There is a large body of literature indicating that environmental variance and autocorrelation in environmental fluctuations may have dramatic effects on the persistence of populations, influencing patterns in abundance and the risk of extinction. This evidence is based mostly on

modeling studies and laboratory experiments, whilst field evidence is limited. Coastal environments such as intertidal habitats and estuaries are likely to experience increasing fluctuations of environmental variables due to their critical position at the interface between marine and terrestrial environments. These are also key habitats for manipulative field experiments and the hope is that they will be increasingly used as model systems to unravel the effects of environmental variability on marine biodiversity. Ultimately, the ability to preserve biodiversity will rest on a mechanistic understanding of the interactions between global change events and local disturbances, so that efficient policies that minimize these impacts can be identified and tested.

Impacts of climate change on intertidal systems and estuaries

Henrique Queiroga, Centre for Environmental and Marine Studies (CESAM), University of Aveiro, Portugal

Summary: Climate change may impact intertidal systems and estuaries through modifications of the recruitment pathways and phenology of the species, with consequences on community structure.

Coastal habitats such as intertidal systems and estuaries are suffering large alterations induced by humans. In order to understand the degree of these alterations and to what extent they are affecting the basic functions of these ecosystems one has to know the way they work. I will argue that we are still far from understanding major aspects of the natural factors that control the ecology of rocky shores, sandy shores and estuaries.

Intertidal systems, such as rocky and sandy shores, can be regarded as differing from estuaries on two grounds: their dimensionality and the origin of the main environmental forces that drive biological processes. Rocky and sandy shores are essentially bi-dimensional systems, where the biological processes are driven by inter- and intraspecific interactions (competition, predation…) among the benthic fauna and flora, and by the influence of the atmosphere and the open ocean. Estuaries are tri-dimensional. Besides interactions among benthic organisms there are important biological interactions within the estuarine plankton, as well as among the plankton and the benthos. Estuaries are also influenced by the atmosphere and the open ocean but, additionally, they receive the input of the rivers that discharge into them (Figure 1).

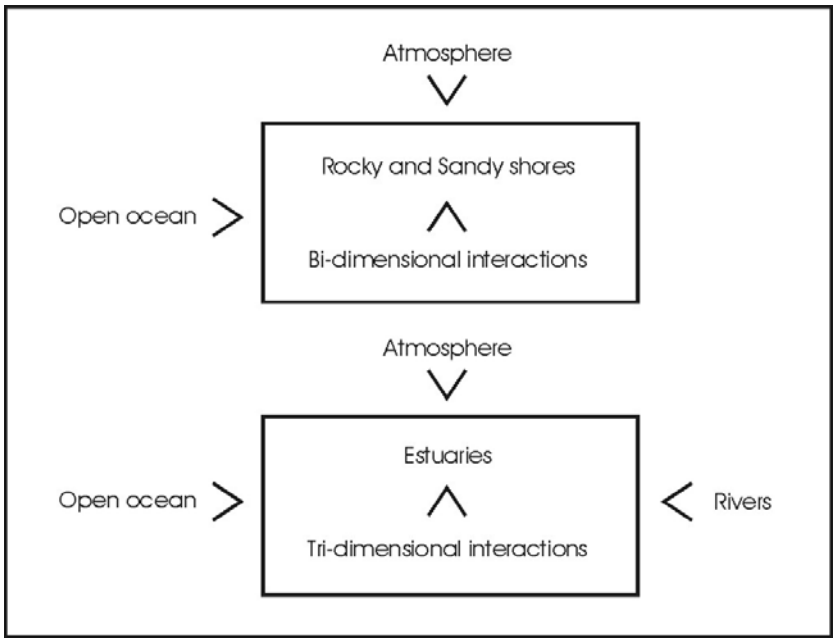

Figure 1: Simple conceptual diagram of the main driving forces that control coastal ecosystems

In this short contribution I wish to concentrate on two aspects related to the influence of the open ocean and the atmosphere: recruitment pathways and phenology. These two aspects do not exhaust the range of possible effects of climate change - for instance, increased frequency of storms may exacerbate the role of

physical disturbance and instability processes, or increased temperatures may decrease oxygen concentration in estuarine waters – but they are frequently overlooked in this discussion.

Most coastal species of modern times have a planktonic phase in their life cycle, which is dispersed by ocean currents and considered to be the main means of dispersal. These propagules are larvae, in the case of invertebrates and fishes, or spores, seeds and vegetative pieces of marine algae and vascular plants. The influence of the open ocean in coastal ecosystems is partially rooted on the interaction between coastal oceanography and propagule transport because supply of propagules is basic for the presence, absence and abundances of species. The argument is that, because mortality rates of propagules are typically very high, small changes in the mortality factors during the planktonic phase result in large changes in the number of propagules that is supplied to coastal habitats.

The future success of a propagule as a seedling or young juvenile also depends on the strength of the biological interactions that take place within the system, which may cause post-settlement bottlenecks that may dampen variations in supply. The present paradigm derived from studies of benthic organisms in both hard and soft substrates is that post settlement survival is not dependent of adult density at low densities, but that high densities of adults cause great mortalities at settlement and immediately afterwards. This view may also hold for other types of communities, e. g. fishes that seek coastal areas as nurseries. The question here is to identify the thresholds above which the post-settlement bottlenecks occur, which may vary according to regions of the world and sites within regions.

A much greater challenge is to determine the mortality factors that operate during the pre-settlement planktonic phase of the propagules. The main difficulty arises from their small size and wide distribution, which makes them difficult to tag and follow individually. Therefore, the assignment of the mortality factors to disease, predation, lack of food, or simply failure to find an appropriate habitat to settle is frequently impossible, except probably in the case of fish larvae that have hard structures that can be used to determine age with a resolution of days.

I propose that climate change may impact the biodiversity, community structure and functioning of intertidal systems and estuaries through two important routes: i) the spatial pathways propagules follow during their planktonic life and ii) the phenology of species, i.e., the sequence and timing of events – growth, maturation, reproduction – in their life cycle. Recruitment pathways depend on reliable physical processes that return propagules from the open ocean to settlement habitats, to which species have adapted during the course of their evolution. These physical processes interact with propagule hydrodynamics and behaviour, and with coastal topography, to determine dispersal radius, connectivity among populations and the distribution of species. Changing weather patterns and hydroclimatic factors, e. g. wind circulation and freshwater discharge, are likely to alter coastal circulation and disrupt the usual recruitment mechanisms. In marine plants, invertebrates and fishes, increasing temperatures may enhance or reduce growth rates and fitness, depending on temperature tolerance. These changes may affect the ability of adult forms to cope with interspecific competition and predation, thereby affecting their latitudinal limits of distribution. Probably more importantly, the shift in the timings of maturation and reproduction may cause mismatches between the production of planktonic propagules in one part, and the usual patterns of coastal circulation or the availability of appropriate food items in the other, as the evidence gathered for some commercial fish species seems to indicate.

Impacts of climate change on benthic communities

Paul Somerfield, Plymouth Marine Laboratory, UK

Summary: We are not in a good position to predict or detect the effects of climate change on marine benthic communities, and at best can only provide educated guesses about potential changes and the consequences of those changes for mankind.

We are not in a good position to predict or detect the effects of climate change on marine benthic communities. We do not know enough. Why is this? Firstly, we must understand the issue of scale. A recent initiative (see www.marbef.org) collected benthic data from across Europe into a single database containing information about approximately 7500 taxa at 25,000 stations. If every station represented a standard 0.1 m2 of seabed, with all organisms identified to an equivalent standard (which is certainly not the case), this only amounts to a total area of 50 by 50m. Filtering the data within the database for comparable seabed samples leaves approximately 1200 samples (about 11 by 11 m) containing about 2500 species. We can hardly consider our knowledge to be comprehensive. It is like trying to understand the scope and development of art by peeking through a keyhole at the Louvre.

These samples are only a fraction of those for which data actually exist, but using additional data, even if it is made available (and generally it is not) is rarely straightforward. Great efforts were made to harmonise the data in the MarBEF database but such work is rarely adequately resourced. More importantly, to understand change we need to be able to disentangle variation associated with natural change from place to place and variation through time at different places. For this we need time series data, but we know that such data are extremely rare and, having been undervalued for far too long, rarely collected over time periods exceeding a decade.

What about our knowledge of the organisms themselves? Can this give us clues about how communities may change with predicted changes in the environment? Perhaps, but the majority of our information about the physiology and life-histories of marine benthic organisms is very outdated. Such studies were considered old-fashioned with the advent of numerical ecology and technology-driven remote observation methods, and have languished in the sidelines for decades. While we may know that in the 1940s a conspicuous species produced larvae in March at Plymouth, we have no idea when it reproduces now, so are not in a position to know how environmental change may affect its reproduction in the future. Work on acclimation – the ability of organisms to regulate their physiology with changes in environmental conditions – has simply not been done. Much is made of links between biodiversity and ecosystem functioning, but the truth is we know little about the functional roles of the vast majority of benthic organisms.

Appeals to increase resources to understand and protect the marine environment are met, at best, with initiatives to co-ordinate, crosslink or recycle existing knowledge. We do know a lot about marine benthic communities, but given a set of climate-change scenarios we are able to provide little more than an educated guess about the changes such scenarios will induce among organisms inhabiting the sea bed, and what the consequences of those changes may be for mankind.

The impacts of climate change on benthic communities: what do we need to know?

Christos Arvanitidis, Hellenic Centre for Marine Research, Crete, Greece

Summary: This contribution attempts to set a conceptual framework for addressing the question "what do we need to know" in order to provide evidence for the impacts of climate change on benthic communities.

After the 1992 Earth Summit in Rio, Biological Diversity was no longer only the concern of taxonomists, ecologists and environmental activists, but, instead, it became a matter of public awareness and of political debate. Many people outside the scientific community are now conscious that marine biodiversity is being eroded at an epic rate with severe consequences for human economy and sustainable development.

In view of the fact that 71% of the biosphere surface –and much more of its volume- is marine, that marine ecosystems are responsible for nearly half of the earth's net primary production, that more than half of the world's population lives within 60 Km from the sea, and that marine fisheries consume at least one fourth of the net primary production, the urgent need to estimate changes in marine ecosystems on a global scale becomes obvious.

Research carried out for over a decade has shown that benthic biodiversity is essential to the ecosystem functioning and that if we wish to understand how marine ecosystems may be shifting from biogeochemically active and rich in biological diversity, towards impoverished, predominantly geochemical systems - entirely uninfluenced by the biota-, intense biodiversity research is necessary. One of the primary challenges for the study of the impact of the climate change upon marine biodiversity and on ecosystem functioning is that of scaling up: climate change is now considered as a driver acting on a global scale and thus our observations on changes in benthic communities should be at the same scale. Here, however, comes the major hurdle which prevents scientists to meet this challenge. Logistical constrains constitute the main part of the problem. The nature of the benthic biodiversity which unavoidably results in multi-scale, multi-disciplinary research activities, is the other, equally important part. For instance, benthic biodiversity is traditionally considered at three levels: genes, species and communities. Additionally, processes have proved to take place at different scales of observation from local to global. Consequently, many disciplines have to be involved in order to meet the challenge of the scaling up, from taxonomy, ecology and biogeography to systems ecology and modeling.

One of the simplest conceptual approaches proposed for the study of climate change impact on benthic communities is to observe patterns, processes and consequences from changes. Yet, the obvious way to go through this conceptual framework is to start from empirical and experimental, mostly small-scale studies, and scale up through modeling. Examples from past mass biodiversity reduction patterns and their consequences on the ecosystem functioning would largely assist this approach. Currently, however, except for the experimental studies on the interaction of the benthic biodiversity on the ecosystem functioning, the existing knowledge covers a few well documented long-term data on benthic communities, and even fewer studies on the drivers of changes and their pressures on these communities. This is in contrast with the plankton communities for which a few studies, at the regional scale, have proved regime shifts and, with experimental studies in terrestrial biodiversity which advance much faster.

Ultimately, the open question for this topic is still “what do we need to know?” From the simplest perspective we need long-term data on climate change and on benthic communities changes in many parts of the world and an appropriate framework, for instance the BioMERGE (Biotic Mechanisms of Ecosystem Regulation in the Global Environment) in order to scale up. This session welcomes other opinions on any of the issues mentioned above or new ones which bring new insights to this vital question.

Interactions between global change and marine biodiversity: impacts on ecosystem functioning

Monika Kedra, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland

Summary: The accelerating global change may not necessary lead to diversity loss, but will certainly affect ecosystem functioning and stability as well as services derived by humans.

The Earth is currently experiencing a period of rapid climate change, primarily driven by human activities. The debate on climate change and anthropogenic influence on climate has a long history. Concerns of this kind have deep roots in our cultures as the climate and its variability has always been a matter of vital interest especially to agricultural societies. However climate change has only become a large public concern recently along with the growing evidence of human impact on the climate.

The key prediction of global warming is that species' ranges should move both polewards in latitude and upwards in elevation. Some may become extinct especially in the high latitudes. Changing environment may also facilitate the invasions of foreign species. However, the changes are neither spatially or temporally uniform and species do not react on the average changes. Extreme climatic events, even if short-lasting, like locally strong temperature rise, may have dramatic consequences on organisms' survival. The global change may affect the timing of seasonal activities of organisms and may lead to "unsynchronization" of the whole system. The changes in species range and species loss may lead to a decrease of biodiversity and may affect the ecosystem stability, however in some cases, species diversity may gain.

The low water temperature in high latitudes favours the K breeding strategy, which with limited number of offspring, increased survival rates and long life span leads to lower diversity. In contrast, the r strategy, with numerous offspring and high mortality leads to interspecific competition that promotes higher diversity. The temperature increase is related to the northward advance of smaller species, which may cause the increase in biodiversity but, because of the energy dispersal, may in consequence mean less wildlife.

Biodiversity loss can affect ecosystem functions and services derived by humans. Removal of one key species may affect a whole ecosystem and lead to collapse. Diminishing sea ice in the Arctic will affect the production of ice dependant algae and therefore copepods and amphipods that form a large part of the Arctic cod diet. The latter is the key species in regional food chain on which most arctic mammals depend. This will have a negative impact on human economics, the marine harvest (maricultures, fishery etc) as well as tourism. The Arctic case is one of the most spectacular but similar scenarios may be written for many marine ecosystems especially the ones that are under strong anthropogenic pressure.

The prediction of ecological responses to the climate change becomes more complicated the more complex the system is. Short-time studies only address the effect of biodiversity on ecosystem functioning at a given point in time and under a particular set of conditions. Therefore long term observations are of great value and allow us to make distinctions between natural ecosystem variability and human or climate-induced changes. Increased knowledge on the ecosystem functioning and the biodiversity role may lead to better protection as well as to wiser exploitation of the marine resources, which are essential for the future generations.

Impacts of climate change on benthic communities

João Carlos Marques, Institute of Marine Research, University of Coimbra, Portugal

Marine ecosystems are presently under the influence of multiple stresses (e.g. eutrophication, organic and chemical pollution, over exploitation of living resources) of anthropogenic origin, which cause a continuous degradation of environmental quality and biodiversity decay. Such processes take place in a scenario of global climate change (e.g. global warming, increase in the frequency of extreme climatic events).

Regarding marine benthic communities, biodiversity is often evaluated through measures of diversity. The two concepts are related but are not coincident. We may consider diversity, which is actually what we can measure directly, as developing from stores of biodiversity, meaning that biodiversity can be looked upon as a dynamic reserve containing a fraction of the results from past evolutionary processes, acting as a genetic information pool and providing the potential substratum for existent diversity. In accordance, ecosystems should continuously accede to genetic materials from the biodiversity store, and natural selection should act upon their active expression. In case any new valuable genetic acquisition occurs, eventually new information provided by the reworked materials returns to the biodiversity store, enriching it. On the other hand, over time, the parts of the biodiversity store that have less and less actual active expression should become obsolescent and eventually disappear, together with much larger fractions of information that are removed as a result of major environmental changes. Nevertheless, difficulties in understanding the dynamics of diversity are so many that it is not pessimistic to say that there is no conceivable "diversity measure" capable of expressing the dynamics of mixed populations, exhibiting stabilised values through space and time. This obviously becomes a constraint when we need a reliable evaluation of ecosystem's response to mitigation or restoration measures.

The impact of climate changes represents an additional constraint for restoration programmes or in preventing ecosystems deterioration. In fact, the effects of measures targeted to reduce relevant pressures must be evaluated, and that evaluation is based upon on the response of relevant biodiversity indicators to pressure reduction. In principle, in a relatively stable climate scenario, if we had a really good biodiversity indicator (and we assume that this is not the case), the necessary pressure reduction could be estimated from the dose-response curve for that indicator responding to increased pressure (degradation). On the contrary, in a scenario of climate change, since benthic communities (as well as other biological elements) tend to exhibit hysteresis and time-lags in their responses to reduced pressures, an estimate of the required pressure reduction based on the response of the biodiversity indicator to degradation will probably be not sufficient. In fact, global climate change may modify the prevailing ecological conditions, affecting the re-colonisation potential and modifying the extent and trajectory of benthic communities' recovery process after pressure intensity has been reduced.

A major research direction is therefore clearly suggested: To assess the responses of different biodiversity indicators to restoration measures, which includes possible time-lags and hysteresis effects. Results are expected to be of major importance to derive suitable environmental management measures able to account for global climate change.

Alternative monitoring networks

Sophie des Clers, Department of Geography, University College London, UK

I was a contributing author for IPCC WG2 last two assessment regarding socio-economic impacts and adaptation for European and world fisheries.

A prevailing impression throughout has been a mismatch between:
- The scientific evidence of global change and marine biodiversity and
- The daily experience of those whose livelihood depend on coastal and marine ecosystems.

Although the mismatch has been in part due to a lag in research publications available for this last assessment, a structural problem lies in the scale mismatch between our current observation networks (predominance of blue rather than coastal waters, research cruise frequencies etc) and the scales of change which have the greatest and most immediate impacts on coastal activities and populations. This is of course not helped by the current IPCC WG1 insistence to use 'long-enough' time series, and the rarity of spatially structured datasets where the same functionality change may be observed across a region in a large number of points, but over a short recorded period of time.

My interest lies in the promotion of alternative monitoring networks to complement existing ones, involving local institutions (including museums, libraries, university research stations, schools...) and local stakeholders as field experts and bringing on board their local ecological knowledge and records. Is there anybody on the list who knows of such initiatives or who would be interested to develop this direction in the future?

Alternative monitoring networks

Sandra Bell, Durham University, UK

Participatory monitoring networks (PMNs) are being studied in an EU funded project EU-wide monitoring methods and systems of surveillance for species and habitats of Community interest. You can find further information at http://eumon.ckff.si/aims.php

I have led the social sciences research and am about to submit a final report on qualitative research into nine PMNs in six EU countries.

The project has also tried to locate and briefly describe monitoring schemes in European countries that use volunteers and invited them to fill in a questionnaire. Response to the questionnaire was not as good as we hoped but our work represents the first stage of building a comprehensive database of and about PMNs in EU member states.

In a nutshell our findings suggest that volunteer's motivations are threatened if they are alienated from their data and not consulted about the uses to which it is put. The social aspects of PMNs are hugely important with volunteers looking to increase their skills and knowledge through social learning and interaction with like minded people. PMNs can benefit from professional organisers and leadership but great care must be taken to ensure that professionalization does not work to the detriment of PMNs. Social, cultural and psychological factors are as important as technological or scientific ones in establishing and sustaining PMNs.

Other interesting work in this field (to which our own work owes a heavy debt) has been carried out by Anna Lawrence at the Environmental Change Institute at Oxford, UK and by Clare Waterton and Rebecca Ellis at the Institute for Environment, Philosophy and Public Policy, Lancaster University, UK.

Impact of climate on small pelagic fish and their environments

Jürgen Alheit, Baltic Sea Research Institute, Warnemünde, Germany

Sufficient evidence has been accumulated to show that marine ecosystems undergo decadal-scale fluctuations which seem to be driven by climate variability. Climate variability can reorganise marine communities and trophodynamic relationships and can induce regime shifts where the dominating species are replacing each other on decadal time scales. One way to predict how marine ecosystems will react to future climate variability and/or to climate change is to search for causal relationships of past patterns of natural variability and to draw conclusions based on retrospective studies. North-east Atlantic marine ecosystems are exposed to the forcing of several climatic phenomena, such as the North Atlantic Oscillation (NAO), the Atlantic Multidecadal Oscillation (AMO) and global warming. The interdependence between these and their individual as well as their combined impacts on marine ecosystems are only poorly understood.

At present, a fascinating natural climate experiment involving small pelagic schooling fish with pelagic eggs, such as sardines, sardinellas, anchovies and sprats, is proceeding in waters surrounding Europe, which has been largely ignored, in spite of its acute and future commercial importance for the European fishing industry. Numerous observations by European fishery scientists over the last 20 years demonstrate clearly that small pelagic fish populations in all shelf seas surrounding Europe from the North African upwelling and the Black Sea in the South up to the Baltic Sea and southern Norwegian coasts in the North are shifting their distributional borders to the North with concomitant dramatic changes in abundance, recruitment and phenology. Spectacular examples are the invasion of the North Sea by anchovies and sardines since the 1990s which have established spawning populations in this northern shelf sea. Other examples include the drastic increase of Sardinella in the Mediterranean (Sabatés 2006) and of sprat in the Baltic the latter of which was initiated in the late 1980s (Alheit et al. 2005). At the same time, biogeographic shifts of calanoid copepod assemblages, the preferred food of small pelagic fishes, have been reported with a progressive increase of warm-water/sub-tropical species into the more temperate areas of the north-east Atlantic, with a concomitant retraction of cold-water assemblages in the southern range (Beaugrand et al. 2002). All these dramatic changes in distribution and abundance of small pelagic fishes and their food environment seem to be associated with recurrent climatic events or periods, oscillations, rather than with global warming.

In the late 1980s, when the Baltic sprat began to increase, a regime shift was observed in the central Baltic Sea involving all major trophic levels, in association with the increase of the NAO index (Alheit et al. 2005). At the same period, a regime shift was described for the North Sea (e.g. Edwards et al. 2007) and indications of similar shifts were reported for the western Mediterranean and in northern and central European freshwater lakes (Straile 2002). However, anchovies and sardines started around the mid-1990s to extend their northern distribution limits into the entire North Sea, several years after the increase of the NAO index. Apparently, they had been spawning there already in the 1940s and 1950s (Aurich 1953), but disappeared again in the 1960s. Interestingly, from about 1930-1960 and again since the mid-1990s, the AMO, which represents North Atlantic water temperature, has been in a positive phase. Consequently, the invasion of anchovies and sardines into the North and Baltic Seas seems to be associated with the dynamics of the AMO. Consequently, the

dynamics of small pelagic fishes and their food environment seem to be driven by different climatic phenomena the different impacts of which have to be disentangled if we want to understand the impact of global change on marine biodiversity.

The EU research community: policy engagement and key issues

Matthew Frost, Marine Environmental Change Network (MECN), Marine Biological Association of the United Kingdom, Plymouth, UK

The last decade has seen significant developments in EU policy for the marine environment. In 2005 the European Commission proposed a Marine Strategy Directive (MSD) with the aim of ensuring that all EU marine waters attain 'Good Environmental Status' by 2021 and which now forms the 'environmental pillar' of the proposed EU Maritime Policy. Other important legislation includes the Water Framework Directive for coastal (and inland) waters and the adoption of the Gothenburg target of halting the loss of biodiversity by 2010. It is imperative, therefore, that policy development is supported by the best available evidence from scientific research. There are, however, two key issues that need to be addressed; namely, how much of our research activity should be targeted at policy issues and the more specific issue of what issues need to be addressed.

There is still some debate over the degree to which research should be 'policy led'. Attitudes from the research community range from those that advocate mainly 'science for science' sake to those who believe science should overwhelmingly be about answering important policy questions. Franklin (2005), for example, refutes the accusation that policy engagement can lead to biased science and concludes that the magnitude of ecological issues with which society is faced means blue-skies type research should remain the "privilege of only a fraction of the scientific community". Others have identified research areas with specific policy relevance on the basis that "it is desirable that research should be more clearly directed at issues that influence policies" (Sutherland et al., 2007). The example of the Common Fisheries Policy (for which scientific evidence was available but misused/ignored in favour of short-term economic or political gain) should not prevent us from making sure that future EU policy is underpinned by the best available scientific evidence.

As regards the second issue, research is urgently needed into marine ecosystem change and its causes (particularly over long time-scales). The MSD states that our definition of 'Good Environmental Status' must be dynamic due to the "dynamic nature of marine ecosystems and their natural variability" (EC, 2005) yet we have little understanding of the interactions between natural variability and anthropogenically driven change. This understanding is crucial if we are to have realistic policy objectives which recognise the inherent variation and dynamic nature of marine ecosystems. There is also an urgent need for scientific research that can support the ecosystem approach (such as work on ecosystem function) as this is the key strategy for implementing EU (and other) environmental policy. Other key areas where research is needed include design of Marine Protected Areas (e.g. How big? How many? Degree of connectivity). On this issue, Lawton (2007) points out that having in place a network of protected sites is a key EU climate adaptation strategy to conserve marine biodiversity yet there is very little scientific evidence as yet showing how this would work.

So, to summarise, two key issues are what degree should EU policy act as a driver for the marine research community to target its research (i.e. balance between blue-skies and applied science) and what scientific questions should we be most urgently addressing in order to inform developing EU policy?

Linking science with policy

Larissa Naylor, University of Exeter, Cornwall Campus, UK

Summary: This keynote has been designed to provide a UK perspective on linking the science (of global change and marine biodiversity) to management and policy. It will provide an overview of recent developments of where and how marine science is being considered or incorporated into Marine Policy and Management on the one hand, and, on the other hand, it will also pose some questions for conference delegates to debate about.

Recent UK Developments:

Since 2000, there have been several new and exciting developments in Marine Biodiversity and Global Change science in the UK. Some of these projects have been funded by our research councils (e.g. SOLAS programme, www.uea.ac.uk/env/solas/welcome.html), whilst others have been funded through multiple stakeholder partnerships (e.g. MarClim, www.mba.ac.uk/marclim/) and/or EU-funded collaborative projects (e.g. ComCoast, www.comcoast.org/ or BRANCH www.branchproject.org/). Alongside these innovative scientific research projects have been new legislative and policy drivers related to coastal and marine environments including the EC Water Framework Directive (EC WFD), the European Marine Strategy and the proposed UK Marine Bill. New scientific tools and scientific evidence has been required to underpin and/or inform these initiatives (e.g. DEFRA prepared an economic evaluation of marine biodiversity report in 2006).

Science into Policy: How and Who?

Scientists in government agencies are regularly asked by their policy counterparts to comment on the scientific aspects of forthcoming legislation such as the UK Marine Bill consultation. They also design new tools, protocols and guidance to implement new directives such as the coastal and transitional waters elements of the EC WFD. Academic scientists can also inform our understanding of marine biodiversity and as part of their project outcomes, disseminate findings to multiple audiences, in a range of formats. For example, visualisation has been used to help people understand how soft coastal habitats may adapt in the 21st century.

Mechanisms to improve translation of science into policy:

Partnership projects that include policy makers and managers have demonstrated that such collaborative approaches yield policy and management benefits within or soon after the initial project is completed – this is much quicker than for projects solely funded by research councils or local government agency teams. For example, MarClim results were far more persuasive as all of the British Isles participated and this led to the Marine Climate Change Impacts Partnership (MCCIP) being formed. Similarly, the ComCoast project results on fish use of estuaries are already being used to help inform the design of Managed Realignments and is being used to influence policymakers to consider classifying some estuaries as Marine Protected Areas (in addition to more conventional offshore sites).

Creating mechanisms by which science can inform policy and practice more rapidly was one of the main findings of the MarClim report for policy makers. Although structural changes were made to a national database for collating marine data (JNCC's Marine Recorder), the various partners felt that more rapid translation of evidence into policy would be useful. This, in part, led to the formation of MCCIP.

Food for Thought:

- Scale matters – studies linking global change and biodiversity are more persuasive and lead to more widespread and rapid policy uptake if they cover as wide a spatial and temporal scale as possible (bearing in mind data quality and budgetary issues).
- How can we improve our evidence-base if adequate funding is not committed to maintain long-term monitoring networks, where the data for 'evidence-based' policies need to be derived?
- As marine organisms respond to a changing climate, some potentially contentious policy and management questions emerge. For example, are southern-species moving northwards invasive species, or merely an acceleration of evolutionary processes?

Museums can provide data to global change studies

Bert Hoeksema, National Museum of Natural History Naturalis, Leiden, The Netherlands

Summary: Natural history collections can play an important role in applying taxonomy to global change studies. Old museum specimens may show that species not present in a certain area may have been found and collected there in the past. On the other hand, species mistakenly recorded as new to an area may appear to have occurred there much earlier thanks to their representation in natural history museums.

Earlier contributions to this session emphasized the importance of taxonomy (Ferdinando Boero), long-term data sets (Doris Schiedek), and a combination of both (Antonio Terlizzi). Scientific museum collections are ideal tools for detecting long-term changes in biodiversity, especially if the specimens are well maintained and accompanied by reliable documentation on locality and date of collecting (labels, catalogue). Some of the oldest natural history museums and herbariums harbour samples that have been stored for over 100 years.

At present such specimens can be important as reference material for historical studies of marine biota, especially in relation to the mortality and possible local extinction of coral reef species as an effect of the El Niño Southern Oscillation (ENSO) events on global change. This is most striking in the case of coral bleaching events, which became obvious during the sea water warming of the 1982/83 and 1997/98 ENSO events at various coral reef localities, such as in Indonesia (Brown & Suharsono,1990; Hoeksema, 1991; Brown, 1997) and in the East Pacific (Glynn 1988, 1993, Feingold, 2001; Glynn et al., 2001). Despite reports on coral recovery, ENSO events may have long-lasting damaging effects on coral reefs, especially when they occur in combination with harmful human activities, such as in West Sumatra (Kunzmann, 1997, 2002; Hoeksema & Cleary, 2004). Animals that depend very strongly on corals for their survival (food, protection, symbiosis) may also become affected.

In contrast, scientific reference collections may also be used to prove that species have much greater distribution ranges and are less vulnerable than assumed after the discovery that species may not depend on geographically limited ranges for their survival. After the 1982-83 El Niño warming event, specimens of the hydrocoral *Millepora boschmai* De Weerdt & Glynn, 1991, were only retrieved dead at its type locality, the East Pacific coast of Panama, and therefore its authors considered the species extinct (Glynn & De Weerdt 1991, De Weerdt & Glynn 1991). Only a year after its description, five living corals of *M. boschmai* were discovered at its type locality (Glynn & Feingold 1992). However, specimens of the same species collected alive from South Sulawesi, Indonesia, have been available for study since 1984, but remained unnoticed until a collection revision of Indonesian Millepora corals was made (Razak & Hoeksema, 2002).

Animals that contain hard skeletons are relatively easy to study, because they can be collected, stored and examined in dried condition without the help of preservatives or special preparations. Besides sea shells, stony corals (scleractinians and hydrocorals) and reef-dwelling foraminifera are ideal for historical studies on species occurrences. On the other hand, material stored in alcohol may even still contain DNA that can be used in studies at population level.

RE: Museums can provide data to global change studies

Antonio Terlizzi, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

I would further support the issue raised by Bert Hoeksema about the role that museum collections can play in the understanding of how biodiversity can be affected by environmental changes. The example provided here does not concern climate changes but is a clear demonstration of how the information contained in messages from the past can provide new insights in our understanding of mechanisms by which organisms response to human threats.

Imposex in marine snails is a very famous phenomenon affecting the sexual apparatus of gonochorist gastropods and has been reported in a huge number of species worldwide. In extreme cases, females are sterilized by imposex, sometimes leading to population decline or to local extinction. Gastropod population declines as a consequence of imposex incidence have been reported in the UK, Ireland, Italy, Netherlands, Canada, New Zealand, France and elsewhere. Local extinction of the dog-whelk Nucella lapillus in the 1980s has been reported in several North European locations. A further example comes from the red-mouth purpura *Stramonita haemastoma*, a widely-distributed Mediterranean gastropod which almost disappeared along Italian coasts from the late 1980s to the mid 1990s. Despite remaining uncertainties, ecotoxicology still reports imposex as one of the few examples of specific response of organisms to a particular compound, namely tributyltin (TBT), a toxic contained in antifouling paints. Indices of imposex incidence have been developed and used as bioassay of TBT contamination in hundreds of biomonitoring programs. In most cases, surveys focused on imposex assessments in new areas and/or new species, with the assumption that imposex occurrence is caused by TBT pollution. Thus, environmental surveys were guided simply by a paradigm of the exclusive relationship imposex-TBT. In a recent study (Garaventa et al. 2006) we reported evidences of imposex occurrence in gastropods prior to the synthesis of TBT. TBT-based antifoulants first came on to the market in the 1960s but became widely used on ship hulls starting in the mid-1970s. We analyzed 55 museum specimens of *Hexaplex trunculus*, a Mediterranean neogastropod species known as an exhibitor of imposex. Samples were provided by a number of museums across Europe. All organisms had been collected between 1845 and 1930, 30-115 years before the synthesis of TBT, in several locations of Mediterranean Sea. Morphological inspection of specimens revealed anomalous imposex incidence in a good percentage of analyzed specimens. These findings are the clearest demonstration that factors other than TBT can induce sexual anomalies in marine snails, challenging the TBT-imposex paradigm. The results call for an exhaustive understanding of the physiological mechanisms leading to imposex occurrence. Nevertheless, given the potential of marine snails to develop imposex at ambient concentration of few nanograms of TBT per litre, separating the effects of TBT from those induced by other stressors would have been virtually impossible without the information provided by museum specimens.

Linking national and European policy and management

Katja Philippart, Royal Netherlands Institute for Sea Research (NIOZ), The Netherlands

The Northern Hemisphere has been warmer since 1980 than any time during the last 2000 years, with a stronger temperature increase at northern than at southern latitudes. Although marine ecosystems have already been influenced by many other global changes such as overfishing and eutrophication, every sea in Europe has shown at least some changes related to recent climate change such as geographic displacement of species northwards, changes in larval transport as a result of changing currents and upwelling strength, and mismatches between predator and prey species. Even moderate climate scenarios are expected to further alter the marine environment. Both the Arctic and the Barents Sea are predicted to be ice-free during summer within the next 100 years. In open systems there will be a (further) northward movement of marine organisms resulting in a shift from Arctic to Atlantic species in the more northern seas and from temperate to more subtropical species in southern waters. Increased river runoff and subsequent freshening of the Baltic Sea will lead to shifts from marine to more brackish and even freshwater species. Temperature-induced loss of endemic species from enclosed systems, such as the Mediterranean and Black Sea, will enhance the introduction of non-indigenous organisms. These changes in species composition will inevitably result in changes in ecosystem functioning (e.g. productivity) and have consequences for possibilities and limits of sustainable use and protection of natural ecosystems and their services.

Coastal waters are the areas where the pressure is highest (due to coastal fisheries, transport routes, exploration of marine resources, large infrastructures, protection of shores) and the ecosystems are already vulnerable as a result of these activities in the past. What we would need foremost is a European integrated coastal monitoring network to keep track of basin-wide variations and trends in the coastal environment. Data on rates of key processes (e.g., primary productivity, grazing, remineralisation) are lacking for most waters, and the knowledge on the biodiversity of the higher trophic levels (with exception of commercial fish species) is often outdated. To adequately deal with the effects of climate change, we should find a way to make better use of new and existing technologies to monitor coastal seas.

National and European policies tend to focus on state variables (such as phytoplankton biomass), which are not the best indicators for global changes. There is, therefore, a need to extend conventional monitoring variables with process rates. Since biodiversity and ecosystem functioning comes down to species, we should encourage the pain-staking work of monitoring marine organisms to species level. To be able to tell if a species is already present in basin before it actually settles here ("early warning" system), we should incorporate the larval and post-larval stages as well. To be able to understand and project the consequences of global changes for biodiversity, we have to quantify the sensitivity of (key) species towards environmental conditions (e.g., temperature, pH, salinity, and oxygen) and their capabilities to adapt to it. This knowledge should then be used to construct numerical ecosystem models developed to specifically help manage the marine environment (e.g. examining scenarios of nutrient reduction, protected areas and exploitation of marine resources). Effort should focus on ensuring that the level of detail (complexity) of the models matches what can and will be measured, including species-specific data. The latter will enable appropriate parameter values to be

obtained and ensure that the models are “fit-for-purpose” and not unnecessarily complicated.

As a summary of strategic research topics to adequately understand and project the consequences of climate change for biodiversity and ecosystem functioning of the sea, we therefore need to (1) extend our coastal monitoring efforts, (2) extend our knowledge on sensitivities and adaptation capabilities of key species in the marine environment, and (3) develop “fit-for-purpose” models to manage our marine environment.

The need to focus on important matters

Wiebe Kooistra, SZN, Naples, Italy

To me an important task of this E-conference is to identify -and focus our research on- the most disastrous effects of global change on global biodiversity and global ecosystem functioning. MarBEF developed from mainly a research community studying benthic ecosystems, and not surprising, there are many interesting messages on benthic communities. But to cite [freely] my former professor of phycology, Christiaan van den Hoek, "Seaweeds are very nice, of course, but they are merely the lace of the sea. What counts is the phytoplankton".

So, here are a few questions that come to mind in relation with research priorities:

- Will global change affect the plankton communities, and will changes in these communities affect sequestering of carbon in ocean sediments?
- How will changes in the plankton affect benthic and pelagic marine communities?
- Will global change affect the massive oceanic blooms of coccolithophorids?
- Should or shouldn't we iron-fertilize the high-nutrient-low-biomass oceanic regions to wash carbon dioxide out of the atmosphere?
- What will be the fate of reef communities and polar communities? And will the temperate communities simply shift to higher latitudes or not?

In this exercise we should take some distance from our own particular scientific field of interest.

RE: The need to focus on important matters

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

I think that the questions raised by Wiebe Kooistra are important, and for some we have even got some provisional answers. I concur with him that Phytoplankton is important, but if everything were just phytoplankton we might restrict the world to mucilages and algal blooms. Other people say that bacteria are the most important thing.

We are going from a fish to a jellyfish ocean, this is happening right now and almost all over the world. There is a myriad of records of jellyfish outbreaks, often they are just anedoctical. We know from the story of Mnemiopsis what they can do. If there are blooms of thaliaceans they suck most phytoplankton and diverge it from other routes that might be more interesting for us. We need to define the factors, and focusing on a single trophic level (a very important one, I know) is rather reductive.

The questions posed by Wiebe are the same questions decision-makers pose to the scientific community. The quick method to answering these questions is with a crystal ball. Answering these questions require understanding of the structure and function of marine ecosystem. I have a much simpler question to pose: do we know enough about the structure and the function of marine ecosystems to answer these questions? What are we selling to politicians if we pretend to know the answers? Of course they are disturbed if we say that we need time.

I always say to mathematical modellers that their approach is not leading to proper predictions and is just an exercise. They admit it, but they say that they need

more computing power, and then they will predict the future. You give them the initial conditions and they will tell you the future behaviour of the system. OK, why not, let's give them a chance. It is nice to think that we can dream about these things. These exercises started when D'Ancona gave his data to Volterra, at the beginning of the last century. Modellers have been asking for more computing power to answer difficult questions for a long time now, and they are continuously financed. That's very good. It is a right decision. I dare to say that, besides computing power, we need more knowledge and understanding about the interactions among the components of the systems whose behaviour we want to predict. Sticking to one component and pretending to answer these questions has the risk of taking one part for the whole and in non-linear systems, like ecosystems, even apparently unimportant components might end up having disproportionate impacts.

Benthic communities, anoxia and biodiversity

Michael Stachowitsch, Bettina Riedel and Martin Zuschin, University of Vienna, Austria

Our team from the University of Vienna would like to draw attention to a topic that we feel merits inclusion in the further discussion.

We are referring to what is widely being acknowledged as "the" future threat to shallow coastal ecosystems worldwide, namely hypoxia and anoxia (UNEP 2004). Currently, about 150 so-called "dead zones" have been identified around the world (Diaz, 2001; Diaz et al. 2004) and the number will no doubt increase in the future. These areas, which are subject to periodic, seasonal or even permanent oxygen deficiency can measure up to several thousand square kilometres. Needless to say, such dead zones cannot be good for biodiversity.

Furthermore, we would like to draw attention to a second aspect that has just been wonderfully formulated by C. Sheppard in an editorial for Marine Pollution Bulletin (2007, MPB 54: 1309-1310): it is not the loss of a species per se that needs to be considered under "biodiversity loss" (because the species may not actually be extinct), but rather the decimation to a point of "ecological extinction", i.e. where ecosystem function is lost.

This is precisely what we have been documenting in the Northern Adriatic over the past few decades: the enormous filter- and suspension-feeding efficiency of the benthic fauna on the soft-bottoms is severely impacted, and the important role these organisms play in the overall stability and health of the system is lost. The result is an endless cycle of early successional stages, renewed collapses and additional phenomena like excessive marine snow events (mare sporco, etc).

Of course, this threat to biodiversity is associated with and compounded by eutrophication and mindless fishing activities that physically pulverize whatever remains of the benthic assemblages.

Finally, our take on the role of global climate change in this set of issues is that thermal stratification of the waterbody will increase (Thuiller, 2007). This bodes ill for benthic communities and their oxygen supply here and elsewhere in European waters.

We are looking forward to discussing any of the above issues in greater detail and hope that "low-dissolved-oxygen" events receive their proper due in the final reports of this E-conference and the subsequent deliberations in Portugal.

Study vs. action

François Bonhomme, University of Montpellier, France

When reading the contributions to this forum (and the previous ones) about biodiversity and climatic change I am always struck by one fact: almost invariability one can read colleagues pointing toward our lack of knowledge on this or that, and asking for more means, more studies, before one can accurately understand what's going on and eventually "predict" what will happen.

I am not against scientific studies, by definition, but I have the feeling that "prediction" alone will not make any good to our beloved ecosystems and preferred creatures, and that we are at risk of becoming educated but powerless witnesses of dramatic changes. I feel it dangerous to let the general opinion believe that it eventually will suffice to increase the involvement of science and scientists in environmental problems to find "solutions" that will remedy them, without a drastic reflection on what creates them.

Rather to me the real questions are:

- How can we link the "prediction" to some sort of action?
- How can we speak of the fate of marine biodiversity in the fate of global change, as if this was some sort of cosmological fatality, without speaking of all the local and meso-scales impacts linked to our non-sustainable use of the coastal zones?
- How can we, as scientists, relay the information to the public and ultimately politicians and make them aware that those things are, at least partially, in their hands, when they decide about regulations, urbanisation, transportation, tourism, fisheries and so on?

I know that many will disagree and will insist we require more knowledge or modeling before saying anything. But I would like to recall that it is only with actions like banning the CFCs that the ozone layer has been given a relief, and like the Kyoto protocol that we eventually will reduce the greenhouse effect, even if everything aspect of the climate machinery is not fully understood. For marine biodiversity, it is probably even more complex, because it deals with a more complex network of biotic-abiotic interactions, but if we do not strongly advocate the fact that our coastlines are a fragile and thin linear interface that should be preserved at any price, rather than an ideal place for economical development, things won't go any better....

RE: Study vs. action

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

I cannot resist answering Francois Bonhomme. If the world is sick and if we bought it to the doctor, what would we ask the doctor? We would ask him or her to make a diagnosis and tell us what is wrong and why, then we would ask him or her to issue a prognosis and eventually we would ask to issue a therapy. Of course the therapy is the most important aspect, it equates to the action. But what would you think of a doctor that issues therapies without proper diagnoses and prognoses? Would you go to such a doctor if you were sick? Would you go to a doctor who knows just a little anatomy and physiology but that still issues therapies? Would you accept treatment from a doctor who says that it is a waste of time to understand what's wrong and why, and

who thinks just about remedies? We do not know enough about the structure and the function of the body we want to cure. We do not invest enough in basic science leading to understanding. The prerequisite for a good therapy is a good diagnosis. There are no shortcuts.

We accept this for ourselves, but we think that the world can be cured with a different procedure. There is no need for such a plea for action, this is what we are doing right now. We do action without proper knowledge. We like answers and we do not like questions. Apparently we are annoyed by questions. Just like politicians. In this case, I have the impression that our worst enemies are ourselves. My questions are: do we know enough to issue a proper diagnosis? Is it sufficient to measure the temperature of your body to identify cancer? It just tells us that there is something wrong. Do we know enough to issue a proper prognosis? Do we know enough to issue a proper therapy?

Of course one does not need great knowledge to avoid drinking cyanide, but maybe we are facing more subtle menaces. Some answers can be done right away, I agree, but most answers cannot. Confusing the first ones with the second ones is leading us in a strange direction. Then, we all know that the problem of the world is overpopulation and our way of life. The action is degrowth, both in number of individuals and in quantities of consumption pro capita. But I think that some better understanding of the structure and functioning of ecosystems would not be so harmful to us. If only to evaluate if we are degrowing in an efficient way. If we think that we can continue to pursue infinite growth in a finite world, no iron in the sea and no banning of some chemical will save the world. Things are even simpler! We have to act on two fronts. One is degrowth, the other is the pursuit of knowledge, it is the trademark of our species, the other face of the medal, the good one.

Brief comment on study vs. action

Susanna Lehvävirta, Botanic Garden, Finnish Museum of Natural History, University of Helsinki, Finland

Ferdinand Boero certainly has a point, but so does Francois Bonhomme. The patient might die if the doctor concentrates on making sure the diagnosis is completely correct, for too long a time!

For our actions, we have to rely on the best possible available knowledge. And so do doctors as well. When knowledge accumulates and changes, we can redirect our actions. But if we stand there waiting for the final truth, we will never dare to do anything. Paradigm shifts in the history of science show us that “truth” may change rapidly.

The fact is that there is enough knowledge for much more action than is being taken, while at the same time we need more research about many things. So, the title of this discussion should actually be study AND action. All environmental scientists should keep in mind that every single piece of study should result in applicable guidelines, instructions and action whenever possible.

RE: Brief comment on study vs. action

Betty Stikkers, Fair Isle Shetland, The Netherlands

I'm not a specialist in oceanography, I'm a breeder of Shetland sheep, but there is overlapping regarding biodiversity and extinction. With interest I read the mails of Francois Bonhomme, Ferdinando Boero and Susanna Lehvärirta.

We faced FMD in 2001 that left us with the loss of very valuable and rare bloodlines in many primitive breeds of sheep and cattle. During this catastrophe we formed an alliance with scientists, veterinarians, breeders and interested people to work together on diseases such as FMD, CSF (Classical Swine Fever), BT (Blue Tongue) AI (Avian Influenza). Our intention was to obtain extensive knowledge on diseases, breeding, keeping and at the same time creating a platform for all parties, big and small, in Europe. The idea behind this is that there is incredible knowledge amongst people in general but if those people stay amongst themselves, this knowledge will not spread. In our case bringing all those people together resulted in a lab of almost infinite know how. Next week there is a 2 days conference in Brussels with some 80 people, scientists, politicians, breeders, veterinarians, businessman from all over Europe and even the US. It's called: Towards a Durable Animal Health Policy in a Global World 2007-2013.

Maybe it would be an idea for those who love, respect and study oceans to form such an alliance? I feel strongly that people of all professions should be working together in order to get things moving.

RE: Brief comment on study vs. action

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

What you ask for, dear Betty, is cooperation among scientists, and then between them and the rest of society, the stakeholders. I am with you. I think that cooperation and integration of knowledge is the way we should go. In our business, however, there is competition. We are here discussing priorities for the EU in terms of research policy, and although I saying every five minutes that taxonomy is important, the basic science of biodiversity is dying because other, stronger parts of the scientific community are competing with it in getting money dedicated to the study of biodiversity. And they are more successful. It is very dangerous to cooperate with competitors, which is why the taxonomists who are happy to be included in a project in which they take peanuts and the rest goes to information and technology. EU officials have told me that "of course taxonomy is very important", but there are other things that are more important, and that we, as taxonomists, are not convincing enough. We, with our plea for increasing knowledge, are not as convincing as the people who spread the information on old knowledge.

It is not that I do not concur with the multiple concepts of biodiversity, from the genetic approach of barcoding, to the species of the taxonomist, to the habitats of the ecologist. I think that reality is multidimensional and that a single approach is usually sterile. When I say these things, usually people become offended because they imply that I think that their approach is useless. On the contrary, I think that all approaches are necessary and that none is sufficient. Politicians should be there to

mediate, listening to all components of the multifaceted scientific community. This is not happening. The guys who sustain taxonomy are losers in this game, and their competitors are more successful in competing for resources. Maybe, dear Betty, we are not convincing enough, maybe there is something wrong in our arguments, and they are right in determining the death of taxonomy, equalling it with simple identification. If this is the case, your advice would be much appreciated.

We badly need well informed politicians, who can mediate across all these apparently diverging pressures. And they have to be familiar with our "theories" but, first, we need a solid theory. We do not have it. Evolutionary biologists are often obsessed by genetics, becoming reductionist. Ecologists are obsessed by ecosystem functioning, often equalled to efficiency of biogeochemical cycles, becoming equally reductionistic. And taxonomists are obsessed by their beasts, and collections, also with a reductionistic approach. All these things are extremely important, but they have to be merged into something wider, a theory, shifting from analysis to synthesis. And this has to be inserted in the "real world" of sheep breeders who, apparently, have understood the problem much better than us.

Stakeholders ask us to solve problems, in doing so we split problems into sub-problems and produce sub-solutions. And each one of us considers his or her sub-solution as THE solution. The result is the widespread distrust for science, lamented by the former editor in chief of Nature in his last editorial. My opinion is that, with this lack of cooperation, we are doing a bad service both to science and to society.

RE: Brief comment on study vs. action

Betty Stikkers, Fair Isle Shetland, The Netherlands

I fully understand your frustration, in order to keep your staff at work you need funding. I personally think that it would be better to fund scientists through an impartial group of people, but that is another discussion. I think that impartiality is of great importance.

Taxonomy, being able to identify though DNA that families are linked to another species that was previously thought is fascinating. I feel that taxonomy could be of great importance regarding e.g. farming in third world countries, solving food problems etc. I know the competition in science is very, very high and I don't really like that. For me it's essential that science is unbiased.

I do agree with Nabila Mazouni that a system to improve communication between all parties should be developed. It can be done, it takes some years, but it will work. I will take some of the mails with me to Brussels on Wednesday and see if I can get some politicians and other parties interested. I'm really pleased with all the reactions.

RE: Brief comment on study vs. action

Martin Sharman, Directorate General for Research, European Commission, Belgium

Nando said, "Politicians should be there to mediate, listening to all components of the multifaceted scientific community. This is not happening. The guys who sustain taxonomy are losers in this game..." I have two points:

1. Politicians are very unlikely to mediate or listen to any components of a discussion at this level of detail. Policy-makers, perhaps, politicians no.

2. To struggle for resources between sub-disciplines (taxonomy vs others, marine vs. terrestrial etc) within a broader field of biodiversity (and ecosystems) is entirely misguided. It is a huge waste of energy, and damages the wider cause - everybody loses.

Please raise your sights. You should be struggling to get across to policy makers the idea that human society, human economy and perhaps even human survival cannot be sustained unless we manage to sustain our living environment. This is the message. Politicians can understand that, if it is explained clearly and convincingly. We are in a battle for funds against many other urgent things. We must all understand that. We must put our energy into working intelligently together to get more money for more and better research into the living world, and for ways to make the human use of that world sustainable. Perhaps the money will have to come from research in some other field, but that is not our problem.

We need resources to reach a better understanding of how humans can survive with a reasonable level of well-being. Of course taxonomy is part of that understanding, but so is everything else to do with this scientifically, socially and economically difficult area. No dissention in the ranks.

RE: Brief comment on study vs. action

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

Dear Martin, we had a long correspondence about the policy of the EU towards taxonomy as a way to gain knowledge about biodiversity. And you explained to me the crisis of taxonomy in terms of funding availability with these sentences: “Taxonomy has done rather well in this competition in successive Framework Programmes; but you will no doubt say, not well enough, and not enough alpha taxonomy. Every discipline must argue its case; what is the advantage to the European taxpayer to fund this research, why with European rather than national money, and why now rather than later? And even then, there is no guarantee that one will win funding with such arguments, since frequently other considerations play a part in decisions on the allocation of funding”. and: “Nowadays, however, we must face new challenges every day, and many of them demand money for research. To get some of that money, one must advance convincing arguments. Scientists supporting space telescopes, superconducting supercolliders, security, aeronautics, health and nanotech have all managed rather well to find those arguments”.

Obviously, then, taxonomists are not convincing enough. Politicians and decision-makers find it more convincing to send rockets to Mars than to explore marine biodiversity. Bob May lamented that more money is spent to maintain the Hubble telescope than to study biodiversity all over the world. Maybe these enterprises are more convincing because there are lobbies behind them, like those who build rockets. So, unless we ask for rockets to explore biodiversity, we will always be less convincing. If taxonomy is identification, then you are right, (and it is right that information and technology take the larger slice, giving peanuts to taxonomists) but you admit that alpha taxonomy (the core of taxonomy) is a loser, receiving little if no funding. I do not think that we need to convince politicians about

the importance of preserving the environment. Even those who were not convinced are now convinced (like President Bush). The problems start inside the scientific community. Lots of money for biodiversity, the old generations of taxonomists are retiring and they are not being replaced. Now we think we can solve the problem with barcoding. Throw an animal in a vial, press a button and the name will come out. This is labelled as taxonomic research. Or preparing online keys for identification, where non-experts will give names to specimens. This means equalling taxonomy to identification. In my opinion, the problem is inside the scientific community, and in the type of people who give advice on how to prepare calls for funding. It is again a matter of lobbying. For instance, for how many taxa do we have updated monographs of the European Fauna and Flora? The answer is: very few. Isn't it of interest for the EU to make the inventory of its species, not as a simple species list but by gathering all the available knowledge on each species? What politician or policy maker would argue against the necessity of knowing what our natural capital is before managing it?

It is not a matter of states, we cannot make a French fauna, the Italian fauna, the Spanish fauna and so on, there will be too many overlaps, it will be a waste of money. And then there are no specialists for each group in each country (unfortunately). The Census of Marine Life should be made by making funds available for revisionary and exploratory research on all taxa, leading to monographs that, eventually, will lead to description of new species and, as a by-product, to identification keys. We are acting the other way around: lists and keys are the end product and there are no monographs (or very few, and the few ones are being prepared without dedicated funding, I know it because I just published two of them). But, evidently, I cannot explain my views in an efficient way, and so it is my fault. Since Martian hunters receive money, they are much better than us in merchandising their approach to science. Maybe sheep breeders will help us. They are our last hope.

Today Elvezio Ghirardelli died. He published the first monograph on Italian Chaetognaths a few years ago (when he was retired since ages, and he did it just for fun). He was 89. Now there are no more Chaetognaths specialists left in my country. As a member of the Commission for the Fauna of Italy (we have money to publish monographs but not for financing research to produce them) I urged the few remaining taxonomists to ask for money within the framework of the Research Projects of Relevant National Interest. There were several proposals for taxa that were never covered by monographic research. All projects were turned down with the same motivation: being of taxonomic nature, the proposal is inevitably leading to little innovation. Projects on the building of computer-based identification keys were financed. The computer is the innovation. Taxonomy is obsolete. The referees of the projects came from within the scientific community.

RE: Brief comment on study vs. action

Nabila Mazouni, Cépralmar

Following the previous discussions (Ferdinand Boero, Francois Bonhomme and Suzanna Lehvavira), I think that for decision-makers, the question concerns the acceptable risk (uncertainties). Decision-makers have to decide and act. For that, they try to make a choice between several considerations (social, economic, environmental, and political...). It is really difficult for them to get integrated expertises, and usually access to "knowledge" is quite impossible because the

knowledge is disseminated among several organisms, and couched in a specialized scientific language!

So much scientific knowledge is still sleeping in relevant papers. We need to develop the interface between scientists and stakeholders, which is not (I think) the role of the scientists.

Otherwise, I think that all the studies cannot result in a guideline, we just have to better explain its role in the elaboration of a guideline or its contribution to action. I will add that the question of the scales (spatial and temporal) must be considered. For instance, large scale action cannot be based only on very local studies... and we also have to keep in mind the consequence of action in time (short term, and long term consequences).

RE: Brief comment on study vs. action

Yves Henocque, IFREMER Centre of Toulon, Grance

Dear Nabila, It looks like there is a small contradiction in what you said: “interface between scientists and stakeholders”, which is not the role of scientists? Well, nobody else will make it for the scientists if it is not themselves!

RE: Brief comment on study vs. action

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

Nabila Mazouni is right, but up to a certain point. Scientists MUST learn how to communicate. The Ecological Society of America organises communication courses for its associates, hiring journalists of the New York Times, among others. The risk is that, if it is not the scientists who speak about science, then others will be called upon to do it, and will be confused with scientists.

Environmentalist movements are often perceived as scientists by decision makers and often give scientific advice based more on emotional grounds than on scientific evidence.

The questions of scale are extremely important. I fully agree.

RE: Brief comment on study vs. action

Irina Herzon, Department of Applied Biology, University of Helsinki, Finland

It is indeed true that many scientists are getting engaged into direct communication of their knowledge into policy. However, there still remains a simple problem of time for those of us who’s main duty is to produce knowledge. Unless (some) scientists are specifically allocated working hours for this public service, that is, are encouraged to do it and are rewarded for it, it will remain a tiny fraction of the activity, a hobby. And, of course, this kind of activity does not suit all.

Perhaps, a solution would be for every scientific institution to have an explicit policy of knowledge sharing with policy and the public, which would actively involve those who are interested. It may exist in my institution but have I ever heard of it.

And why not, collaboration with certain NGOs could be similarly encouraged: joint publications, feeding in facts for campaigns etc. Very few big NGOs have funds for actually doing applied research themselves and this enormously benefits their credibility and efficiency of lobbying for solutions (take the RSPB for example).

RE: Brief comment on study vs. action

Nabila Mazouni, Cépralmar

To answer to both of you (Yves & Fernando), what I wanted to say, is that we need to develop a new system to improve communication between scientists, stakeholders and decision makers. But this means a specific action (effort) that (for scientists) is often difficult to carry out conjointly with research. In this context, the scientist did not seem (for me) to be the exclusive "entity" who can communicate to the non-scientist community. As it was underlined by Fernando, the majority of researchers have no particular ability (or training) to communicate. The action of ESA on this topic is really interesting. To my knowledge, we cannot find such "communication courses" in French universities.

So, I think that we need to develop working groups focused on knowledge integration and sharing, composed of scientists and users of the "knowledge". We also need to work towards a better communication of our actions, as environmental movements do, in order to be perceived by the decision-makers as sources of advice.

Research - Action

Sophie des Clers, Department of Geography, University College London, UK

In the UK, the number and size of Science Communication University Departments are growing, which suggest possibilities for fruitful collaborations, which could be proposed - for example - in Research Funding applications.

I agree with the previous contributions arguing for a full engagement of primary researchers. This is particularly important for the development of ecosystem-based management of coastal and marine resources that seems to be taking so long.

However, the emergence of sustainable use is not just in the hand of primary researchers, but rather in the emergence of a multi-disciplinary science-based common understanding that can be advocated as a base for political action.

The more complex the research question, the stronger the case for science communication that involves stakeholders - resource users, managers, members of the public, from a very early stage.

RE: Research - Action

Marion Gosselin, Institute for Agricultural and Environmental Engineering Research (Cemagref), France

Just an example to illustrate this issue of communicating between scientist, stakeholders and policy makers: As an engineer at the Cemagref, I'm in charge of a project to elaborate Practical Guidelines for Good Forest Practices for Biodiversity. This project is being funded by the French Ministry in charge of Forests (policy maker) as an element of the Forest Action Plan within the National Biodiversity Strategy.

In my right hand, I have ecological knowledge on the relationships between forest management and biodiversity, as a result of forest ecological research projects taking account of forest practices in the hypotheses to be tested as well as the scientific literature on the subject.

In my other hand, I have results from social science projects according to which I understand that the word "biodiversity", although often employed in the media, doesn't make sense for forest stakeholders (especially forest owners) - this word can even alarm them, although many of them actually apply practices favourable to biodiversity or even have arguments that are close to biodiversity protection perspectives.

So, my job is to assemble knowledge from different disciplines and to find the right words to be scientifically exact and socially acceptable (or convincing) to make forest practices for biodiversity be applied in a broader extent. Maybe I'll have to avoid the term "biodiversity" to be efficient!

I'm not explicitly trained for that..., but it surely will be a very interesting project (both from a human and a technical point of view)! For sure, there is a longer term crucial objective which is to increase people knowledge and awareness on biodiversity issues.

Study, action and official reports

Cristian Kleps, Romanian Academy of Agricultural and Forestry Sciences

In many cases, the official reports based on previous research and survey results may suggest valuable ideas about the ways/direction of study to be followed in the future. Such reports also emphasize the particularities and existing differences among different marine ecosystems, requesting to take into consideration different approaches. A good example is represented by the fourth EEA assessment of the pan-European environment presented at the Belgrade Conference on 10-12 October 2007, about environmental progress in 53 countries, including Eastern Europe, Caucasus and Central Asia, South Eastern Europe as well as Western and Central Europe (www.eea.europa.eu), from which have been extracted some key messages related to marine and coastal environments:

- The overall picture in 2007 has hardly changed from that in 1995: pressures on the seas and coasts continue to be high. The Black and Caspian Seas are generally in a poorer state than western seas. This is partly due to their natural vulnerability and partly because modern environmental policies have not been sufficiently introduced, adopted or implemented across the EECCA region.

- Eutrophication remains a problem in all enclosed seas and sheltered marine waters across the pan-European region. There have been some improvements in the western seas, extending to the north-western shelf of the Black Sea, as a result of large cuts in point sources of nutrient pollution from industry and wastewater by EU 15 Member States. However, diffuse nutrient sources, particularly from agriculture, remain a major obstacle for recovery and need increased control throughout Europe.
- Overfishing is still widespread in all pan European seas. Stocks in the North and Celtic Seas and probably the Black Sea, are in the poorest condition, whereas stocks around Iceland and east Greenland are in the best. However, most commercial fish stocks are not assessed and fishing quotas tend to be beyond limits recommended by scientists. Improved fisheries policies and stricter enforcement are needed, especially to stop illegal fishing.
- Destructive fishing practices continue, though it is hard to assess their extent. Bottom trawling keeps benthic ecosystems in a juvenile stage with low biodiversity. This also affects fish and the whole marine ecosystem negatively. By catch and the discard of non-target fish, birds, marine mammals and turtles also contribute to the large-scale impacts of fisheries on the ecosystem.
- Measures taken to reduce concentrations of some well-known hazardous substances, such as heavy metals and certain persistent organic pollutants (POPs), have generally been successful in the western seas. Sparse data indicate high levels of hazardous substances, particularly POPs, in the Black and Caspian Seas. POPs, which can have serious detrimental effects on marine organisms, are transported over long distances and can be found even in the remote Arctic.
- Major accidental oil spills have generally decreased in pan-European seas. However, oil discharges from regular activities, such as transport and refineries, are still significant along major shipping routes and at certain hot spots along coasts, for example in the Caspian Sea.
- Alien species are a major cause of biodiversity loss and continue to invade all seas in the pan-European region mainly via ships' ballast water. The highest numbers are found in the Mediterranean Sea. The collapse of the Black Sea ecosystem in the 1990s demonstrates how alien species can aggravate other pressures and cause great economic losses.
- Climate change will very likely cause large scale alterations in sea temperature, sea level, sea-ice cover, currents and the chemical properties of the seas. Observed biological impacts include altered growing seasons, and shifts in species composition and distribution. Further impacts could also include the loss of marine organisms with carbonate shells as a result of acidification.
- Lack of comparable data across all seas still presents a major obstacle for pan European marine assessments, even of well-known problems such as eutrophication and overfishing. More and better data are needed to develop a pan-European marine protection framework that addresses environmental issues in a cost-effective way.

Top predators as pelagic biodiversity and oceanographic process indicators

Maurizio Wurtz, Biology Department, University of Genoa, Italy

The multidimensional nature of the pelagic ecosystem needs a multidimensional approach to be understood and assessed. The pelagic environment, because of its variability, can be evaluated only through long term global scale measures of its dynamic structured habitats. Of course the species and habitat lists are the basic information to be obtained first. But most likely, to obtain a more reliable picture of the pelagic diversity and heterogeneity, we have to develop an easier approach which would allow us to map and to monitor the process dynamics and their effects on the biological component. One possible solution could be to identify one or more species whose food webs can summarize the results of all the derived effects from the natural and anthropogenic variability of the pelagic environment.

Obviously this group of species have to be long living high level predators, high biomass consumers with high energy budget needs. To evaluate this hypothesis, the relatively small pelagic domain of the Mediterranean Sea because of its oceanographic features, abundance of high level predators (i.e. cetaceans) and strong human impact, could be a reliable case study. Also because global warming is generally recognized to affect the biodiversity and the oceanographic processes in the Mediterranean.

The abundance of predators in the pelagic Mediterranean incites other consideration related to upper trophic levels than the primary production, particularly about the timing of the energy turn over through the biomass formation and transportation from the surface to the deep bottoms and vice-versa. For example, hundreds of thousands of tonnes per year of euphausid krill can be consumed by the Mediterranean fin whales and ten thousands tonnes of various pelagic and bathy-pelagic cephalopods are eaten by odontocetes. Thus a new idea about the trophic potential of the pelagic ecosystem has to be developed not only to explain the top predator biomass, but also the prey biomass formation and turnover in a relatively short time period.

The bottom morphology and hydrodynamic features of the Mediterranean Sea explain the organic matter flow from the coastal zone to the pelagic, from the surface to the bottom and from the deep water to the entire water column. Nevertheless the reasons why the energy flow through the biomass formation has such a fast turnover have to be investigated within the food webs. The effect of the very fast biomass formation by prey on the energy flow is enhanced through the space by the amplitude of their daily vertical migrations. These factors affecting the predator distribution patterns are not well defined and mapped, because they are not time-space constant. The crossing over of strong temperature gradient (frontal zone) and depth or bottom morphology (slope gradient, canyons, sea-mounts) do not always determine the prey presence and abundance, but when this happens the predators are there, as indicators of a past or actual particular oceanographic and high biological diversity. For these reasons I believe that some predators species (such as cetaceans) could be an effective tools to define the boundaries of ephemeral pelagic habitats and to proceed towards marine biodiversity cadastre.

Invasive species between science and politics

Frederico Cardigos, Government of the Azores

1. An "Invasive" species is one that is introduced by action of man in a new environment and causes or is likely to cause economic or environmental harm or harm to human health (Official U.S. definitions regarding invasive species were provided in Executive Order 13112 signed by President William Clinton on February 3, 1999). Although the first part of this statement is not clear, because "action of man" does not directly include the changes in latitude caused by global warming, the second part is even worse. Where does environmental harm begin? Any introduced species will be harmful to the environment, at least because it is occupying space. Thus, the classification of harmful to the environment is discretionary and subject to the sensibility of the observer. There are simple cases, when the invasiveness degree is obvious or the story of other invaded areas, by the same species, immediately points towards the need of a very dynamic approach. Nevertheless, a clear definition demarcating the border between "invasive" or "not invasive" is of major importance. Scientists must work in order to define the level of impact that demands administrative action. The lack of a clear border is a simple argument for politics to argue that "the diversity of species has increased in "1" because of the so-called invasive species".

2. How much should be invested in the eradication of invasive species? For scientists the value is always high, but for administration this needs to be clearly defined and justified. What is the risk? And what are the economic consequences of inaction? These are very common questions.

My professional experience has developed from a career as a marine biology researcher to a high level environment administrative position in the Azores government. From the person that was drawing attention to the problem, I am now the one responsible for solving it. Now, I have a better understanding that a simple and unfair equation of "risk" vs. "available budget" and the related factors (i.e. "budget needed") is vital for the "go" decision. The strangest thing is that the risk is not the determining factor. What drives the administrative decision is the relation between availability of financial resources and the actual resources needed for action. If the "necessary budget" is clearly within the "available budget" the "go" decision is simple and it will happen. But, when the "necessary budget" is over the "available budget" the decision is dependent on "risk" and, several times, is denied. This means that administration will say "yes" to a decision on eradication of an introduced species, even if not clearly defined the risk, if the "necessary budget" is low. But it will ask for long lists of details and will hide in obscure arguments if the budget is close to or over the "available budget".

3. While working as a researcher at the University, I had the chance of detecting the marine algae *Caulerpa webbiana* in Faial island, Azores (Cardigos et al., 2006). Immediately, I made an internal alert where several statements were made: a) The species is not reported as invasive elsewhere, but the genus is a well known invader; b) More research is needed; c) There is an evident threat to other species; d) The danger of ecosystem disruption exists; e) There is a need for a precautionary approach; and f) Action is mandatory. After my transfer to the administration, and as soon as I was aware of the existing budget, the previous statements immediately changed to questions: a) Even if not invasive, what is the behaviour of this species in other areas where it was introduced? b) What budget will need to be allocated for

research? c) What species are endangered and what are the consequences for them? d) What is the probability for the ecosystem disruption to happen? e) Is there a possibility that the environment will naturally react? f) What does “action” precisely mean?

4. There is a need for an intermediary step between scientists that are studying a problem and the administration that has to solve it. Someone has to interpret the scientific data and put an “economical” value or, at least, to clearly identify the “risk” factors. It is a mandatory task, for both ends, to find a common ground where the communication happens.

Linking natural heritage with cultural heritage to emphasize European responsibility

Jan Jansen, Radboud University, Nijmegen, The Netherlands

In an earlier message to this forum, Martin Sharman said "You should be struggling to get across to policy makers the idea that human society, human economy and perhaps even human survival cannot be sustained unless we manage to sustain our living environment".

I fully agree with that statement. Over the last few years I have been interested in linking natural heritage with cultural heritage. Europe has a high responsibility for the conservation of both our natural and cultural marine common heritage. Policy makers should use the bridge between cultural and natural heritage.

Portugal, Spain, the United Kingdom, France and the Netherlands were amongst the first to experience the sea as a means of transport and discovery of new worlds. Before that, the Vikings also explored new marine territories. The combined Exclusive Economic Zone (EEZ) of the European Union amounts to 25 million km², over twice the size of the United States' zone, the largest of any single country. Due to its numerous overseas départements and territories scattered on all oceans of the planet, France possesses the second-largest EEZ in the world, covering 11,035,000 km² (4,260,000 mi²), just behind the EEZ of the United States (11,351,000 km²). Portugal has the 3rd largest EEZ of the EU and the 11th in the world with 1,727,408 km². The United Kingdom has 3,973,760 km². For more info see http://en.wikipedia.org/wiki/Exclusive_Economic_Zone

Europe not only has a direct responsibility for its own territorial waters but also for other areas in the world. A network similar to Natura 2000 should be designed for onshore areas. This should be done as soon as possible. We cannot allow pirates to empty our treasures.

I am also interested in terrestrial farming systems related to biodiversity. The infield-outfield farming system was a system with high biodiversity in which people sensitively worked the land. For varied reasons (especially technological ones) that land-use system collapsed and the result was a sharp decline of biodiversity. In marginal areas abandonment led to tree plantations and subsequently to wildfires. Marine areas are, to a certain extent, comparable to outfields. There is no one in the vicinity to keep a close sensitive watch on them. The marine areas should be politically connected to the terrestrial homelands in a sustainable way, economical, social and ecological.

I studied some marine biology but I am not a specialist. However it seems to me that research priorities should include investigations, inventories and a reliable monitoring system of the whole offshore territorial waters with respect to distribution of species, habitats, effects of fisheries and other uses.

The challenge is that just because we as Europeans have a rich marine common heritage, we should take our responsibility to secure biodiversity of these natural resources.

Long-term monitoring of intraspecific biodiversity

Anne Chenuil, Didier Aurelle, Thierry Hoareau, Jean-Pierre Féral, CNRS-DIMAR, Station Marine d'Endoume, Marseille, France

We agree with Doris Schiedek, Sophie des Clers, Sandra Bell (and others) with the absolute necessity of building a survey of the evolution of marine biodiversity spanning much more than 4 years (the limits of usual calls within European Framework Plans). For this, there is a strong need of a perennial framework [cf. LIFE WATCH proposal]. In the absence of an infrastructure, at least a European permanent position needs to be affected the task of coordinating the collections, their curation and their use including species identification, genotyping and data analyses. This need of a coordinated long term monitoring is true from the community study level (habitat, faunistic, floristic and microbial) to the intra-specific genetic level (aspect developed below).

Genetic markers characterized within populations in different geographical locations provide crucial information. If they are repeated in time, they may allow to estimate: (i) Effective sizes of populations and species (more reliably than counting, and more useful for conservation biology purposes); (ii) Gene flow across space, allowing to estimate the geographic scale relevant for local adaptation (the same scale is relevant for assessing the geographic span of damage caused by a local environmental perturbation, surface and location of marine protected areas); (iii) The date of the last population bottlenecks or expansions; (iv) The origin of populations, colonization routes and timings...

These parameters, associated with ecological studies, are of primary importance to detect when a population is endangered, and to predict the influence of environmental change on individual species.

Genetic markers are easily characterized from tiny pieces of tissue (owing to the PCR reaction) which can be generally conserved in ethanol, though cooling is recommended for long term storage; therefore constituting collections of numerous samples is feasible. It is also possible to envisage whole genome amplification (WGA) of individual samples (pooling individuals) which can be reamplified subsequently, and therefore could be used an infinite number of times.

Characterizing the level of expression of genes, identified individually, is a means of assessing the impact of external factors on individual organisms, via the quantitation of proteins (HSP and others) or messenger RNAs. Traditionally, tissues should be conserved frozen for such purposes. However, libraries of cDNA constitute a perennial collection (reamplifiable) of the set of genes expressed at a given time in an individual (or a set of individuals). These recent techniques are now robust and widespread. Constituting the collection to apply those techniques to environmental monitoring should start as soon as possible.

A network of sites should be defined and could be based on those established by the European Marine station network MARS (BIOMARE LTBR sites, and NATURA 2000 sites), include Marine Protected Areas and locations submitted to heavy anthropogenic pressure, as well as sites of biogeographic interest and sites across putative barriers to gene flow. A minimum set of species should also be defined though we think the system should be able to evolve, allowing additions of species and sites. Frequency of collection may vary according to site/species. To build such an infrastructure and then to insure that temporal surveys and collections of tissue for DNA markers are constituted, are proprietary goals.

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

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

Stephen Hawkins, Nova Mieszkowska and Pippa Moore, Session I Chairs

IPCC 2007 predicts continued warming over the next 50 or so years even if levels of greenhouse gas emissions stayed at current levels. This will occur because of the inertia in the Earth's climate system. Measures to reduce carbon dioxide emissions will need to be put in place to meet various targets on reduction of emissions set by the EU and the international community in post-Kyoto agreements. These will inevitably lead to an increase in renewable energy production by wind, solar power, waves and tides. Offshore windfarms are proliferating in the shallow seas of Europe with the Danes taking the lead but with much activity in the Netherlands, Belgium and UK waters. Various trials of wave energy production are underway (e.g. Portugal hosts the world's first wave energy farm and the go ahead had just been given for a wave energy testing facility off Cornwall, the wave hub www.wavehub.co.uk). There is renewed interest in barrage schemes such as on the Severn to harness tidal power. Blue-biofuels are already being explored as an alternative to using valuable food producing land for fuel production. Nuclear power generation is likely to undergo a renaissance in many countries where no new commissioning has occurred for some time (i.e. the UK).

All these mitigation measures will have long-term environmental gains in combating global warming. They will also have short and medium term impacts and in the case of nuclear power long-term waste disposal and storage issues. The next session of this e-conference will focus on the consequences for marine and coastal biodiversity of mitigation measures. We will also consider how adaptational policy to deal with global environmental change should seek to minimize impacts on biodiversity. As an example, rising sea levels and stormier seas will inevitably lead to greater demand for coastal defence to protect property and infrastructure. How can this be done sensitively? When should defences be abandoned (current UK policy in some coastal rural areas)?

We call on participants to consider the difficult trade-offs between long-term climate gain versus potential short-term biodiversity pain. In particular:

- What are the positive and negative impacts of offshore energy generation by winds and waves?
- Are barrages for tidal energy generation across major estuaries an acceptable solution? Could smaller scale schemes be effective and minimize impacts?
- How can we adapt to climate change by managing the impacts of climate change with regional (e.g. fishing, eutrophication) and local scale impacts (habitat loss due to coastal development, pollution).
- Will blue biofuels play a role in the future?
- What research do we need to better understand these difficult decisions?

Effects of coastal defences on the marine environment: are we factoring them into management decisions?

Laura Airoldi, University of Bologna, Italy

Summary: It is not possible to build defence structures without their being severe impacts on natural habitats and assemblages. Appropriate consideration of whether or not to defend an eroding coast requires robust understanding of these environmental costs at both local and regional scales, and should not rely on uncritical claims that breakwaters and groynes are reasonable replacements for the natural habitats that they damage

Urbanization is recognized as an important and growing threat in the marine environment, but has not been as much a focus of science and conservation as in terrestrial environments (Bulleri 2006). This lack of attention contrasts with current trends of urban development of coastal areas. A review of the status of European coastlines (Airoldi and Beck 2007) has shown that nowadays 22000 km2 of the coastal zone in Europe are covered in concrete or asphalt, and urban artificial surfaces (largely consisting of defence structures such as breakwaters, groynes, seawalls and dykes), have increased by nearly 1900 km2 between 1990-2000 alone. Similar examples occur in other parts of the world - e.g. California (Davis et al. 2002) and Japan (Koike 1993) - where hundreds of kilometres of coasts are hardened to some extent.

Urbanization is a major cause of the degradation and loss of marine coastal habitats. Surprisingly little attention has, however, been paid to the ecological consequences of coastal defence. Recent research (e.g. DELOS project - Environmental Design of Low Crested Coastal Defence Structures, EVK3-CT-2000-00041) shows that the construction of coastal defence structures not only causes the obvious local loss of natural soft bottoms, but also severely disrupts surrounding soft-bottom environments (Martin et al 2005). Further, urban structures introduce new artificial hard-bottom substrata. These artificial substrata are not analogues of natural rocky habitats (Bulleri 2005, Moschella et al 2005), and in most instances create unnatural changes in species composition, abundance and diversity (Bacchiocchi and Airoldi 2003). The downstream effects of the proliferation of defence structures can propagate up to affecting regional species diversity (Airoldi et al. 2005). A high number of nearby defence structures can act as stepping stones, disrupting natural barriers to species distribution, and providing new dispersal routes that permit the invasion of non-indigenous species, including pests (Glasby et al. 2007). For example, along the north-east coast of Italy, coastal-defence structures, which run almost uninterrupted for about 300 km, have promoted the expansion of numerous introduced species, offering particularly favourable conditions for their growth (Bulleri and Airoldi, 2005). The consequences of these major changes in species distributions on ecosystem functions (e.g. productivity, nutrient cycling, detritus pathways) and services to humans are virtually unexplored areas of research. This information is a major need to ensure effective planning and management of defence and other urban structures.

In the past coastal defence have often proceeded with localised emergency actions, without a larger spatial or temporal perspective of the problem. Nowadays there is increasing concern about the ecological implications and the long-term sustainability of sea defence, and urban development in general. However, there still

seems to be limited public, political and even scientific awareness of the extent, importance and consequences of the resulting changes to native coastal habitats and assemblages. Defence structures are often uncritically claimed as reasonable mimics of natural rocky habitats and valuable replacements for the habitats that they damage, while the consequences of the major unnatural changes in species and habitat distribution and diversity are ignored.

It is not possible to build defence structures without their being severe impacts on natural habitats and assemblages, and these impacts should be carefully factored in to management decisions. Appropriate consideration of whether or not to defend an eroding coast, how to defend the coast, and at what socio-economic cost requires a clear statement of goals and a robust knowledge and consideration of the environmental consequences at local and regional scales. If structures are deemed necessary and appropriate, then sound monitoring before and after construction is required to assess their effectiveness at meeting management goals.

Acknowledgments: The ideas presented are the results of stimulating discussions and contributions from many colleagues. There is no room to thank all here, but I would like at least to mention MW Beck, F Bulleri and SJ Hawkins.

RE: Effects of coastal defences on the marine environment

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

There is an interesting booklet on coastal erosion that can be downloaded from the web page of CIESM www.ciesm.org/online/monographs/Tanger.html. I strongly advise to get it. The strategies to face coastal erosion are analysed. When possible, the best solution appears to be: back up.

Offshore wind energy: a useful measure for the mitigation of greenhouse gases but, what about its effects on the marine environment?

Benjamin Burkhard, Ecology Centre Kiel, Germany

Summary: Offshore wind energy can provide an important contribution in future energy provision and a lot of information, data and methods are available today and should be used to plan their installations in order to reduce negative effects on the marine environment.

Installations of wind turbines for electricity generation are part of the landscape in many countries. As space for further expansions on land is limited, wind parks are nowadays planned and installed offshore. What kind of effects on marine and coastal biota are to be expected if thousands of turbines are installed? Which interactions with further human activities will occur? Already today, European seas are under increasing pressure from human activities like shipping, fisheries, raw material exploitation, waste disposal, tourism or military operations. Additional effects on coastal and marine systems are to be expected due to global environmental changes like sea level rise, temperature changes or increasing storm events.

Seabed insertion of thousands of wind turbine fundaments and scour protections means a disturbance of marine ecosystems. During the construction period, an increase of suspended particular matter in the water column, disturbances of local flora and fauna and sediment dislocations take place. Due to the lack of long term monitoring data from existing wind farms, little is known about ecosystem dynamics after the erection of turbines. On the one hand, one could expect that insertion of hard structures in sea bottom areas rather homogeneous before will provide substrate for the emergence of artificial reef-like ecosystems. Compared to the situation without turbines, these systems could be more productive, more efficient regarding energy and matter cycling and could be more diverse. On the other hand disturbances during construction phases could lead to irreversible degradations. To test these hypotheses, simulation models and first monitoring results from existing wind parks can be used. Results at Danish offshore wind parks showed the establishment of epifaunal communities during the first years after installation. Effects above water surface, e.g. on migrating and resting birds, are more difficult to assess. Nevertheless, first results suggest that many species avoid wind park areas while some others seem to be attracted. Effects on bird migration could not be assessed on a larger scale so far but, due to the high expansion plans of offshore wind parks for example in Germany, impacts have to be assumed.

Beside direct effects on marine systems by introduction of new structures, some indirect effects also have to be taken into account. For example, as fishing will be prohibited in wind park areas, parks might serve as future recruitment areas for depleted fish stocks. But, risk of ship collisions and disturbances due to maintenance actions of the turbines have to be considered in integrative assessments also. The European Maritime Strategy under development should take into account newest scientific knowledge and develop appropriate environmental quality objectives. Offshore wind farms can contribute to the mitigation of green house gas emissions by providing new ways of energy conversion. Knowledge, data and methods of integrative environmental impact assessments should be used to carry out human activities and management of natural resources in a responsible manner.

Key questions:

- How can offshore wind parks as a new form of human activity be integrated into the dense pattern of anthropogenic marine uses?
- Which effects of offshore installations on marine biota are more likely to occur: emergence of artificial reef systems or continuous degradation?
- How can science and decision makers interact in order to support optimal environmental management decisions?

RE: Offshore wind energy

Andrew Gill, Cranfield University, UK

The message concerning offshore wind energy posted by Benjamin Burkhard raises some questions that are important to address. I would add that the advent of offshore renewable energy, in general, and not just offshore wind represents a huge opportunity to develop a coastal industry in concert with the marine environment.

The questions that Benjamin highlights could form a starting point for discussion but the crucial point is that all involved get the opportunity to hear, understand and discuss the issues. So rather than wait for the renewable energy developments to get to the point of installation there needs to be open discussion. Whilst we do not have all the answers we can anticipate where we might see changes occurring in the environment (both positive and negative) and put in place rigorous (and properly funded) research and monitoring. Importantly the research needs to have an element of dynamism to ensure that it is adaptable to determining effects on the coastal environment.

Furthermore, there needs to be a focus more onto the potential effects on ecosystem processes and function rather than just population status and effects on individual biota. So research and analysis needs to look at what determines the resultant ecosystem over appropriate time scales.

RE: Offshore wind energy

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

The impact of wind farms, in theory, should be similar to that of oil or gas platforms, with the advantage that there is no drilling of the bottom, after the platform is in place. So, if this comparison is correct, we might not need simulations, we can simply look at the impact of gas extraction platforms (their leakage is less impacting than that of oil platforms) on benthic biota. I am studying this right now, in the Ionian sea, and the preliminary results are that the impact is not so much, if the platforms are on homogenous soft bottoms. Their presence is discouraging trawling and this is some sort of advantage for the integrity of the surrounding bottom, something like what is being achieved with artificial reefs. The sessile fauna on the structures is very rich and it attracts lots of nektonic life, just like wrecks. Fishermen like to go fishing near these platforms because the sea is richer. Studies on the composition of bottom fauna at places where the sand has been sucked for beach replenishment (this activity causes a lot of resuspension, probably more than the set up of a wind mill) showed that the

situation at the impacted sites went back to that of control sites in a short time. But this depends, probably, on the type of communities that are present on that bottom.

In theory the wind mills should not have a chemical impact on the environment (besides antifouling paints). One problem is the cable that links them with land, and the habitats that it has to pass through, but this is similar to any other form of cable. Surely, the landscape impact is great, but we have to choose something, unless we decide to live without electricity.

I am very ignorant about birds and I refrain from considering this problem that, of course, is to be taken into serious consideration. Also airports disturb birds, and night lights, and ... hunters. But I concur with all of you that this is not a good reason to add another stressor on their populations.

Near here, at Cerano, there is the biggest power plant of the whole Europe, in terms of production of... carbon dioxide. It runs on coal. Italy refused to become a nuclear power, with a referendum, and we do not have the problem of nuclear waste. Of course we can solve it by making some presents to some African country. Eventually, I prefer offshore windmills. But this depends on their number to have a significant advantage.

RE: Offshore wind energy

Andrew Gill, Cranfield University, UK

The points being made by Ferdinando Boero are all valid to a degree but I would suggest that making comparisons with offshore oil and gas is only part of the answer to address our understanding of the potential impacts (Either positive or negative). We should try to learn from other examples but lessons and data from the oil and gas platforms do not fully translate.

The reasons that they have some limitations relate to three things: the spatial extent of each wind farm (or renewable energy structure), the cumulative extent of multiple developments and the output which is in the form of electricity.

To illustrate, one single wind farm will take up a proportion of the coastal environment based on the number of turbines. In the UK at the moment we have relatively small wind farms of around 30 turbines which take up around 5-6 sq. km. However a 2nd phase of developments has resulted in single development consent for up to 300 turbines which takes up over 200 km^2. This is substantially different to an offshore oil or gas platform. Add to this the plans for multiple offshore wind farms (both within single countries borders and transboundary as in the case of the Baltic and North Seas) and we have a significant difference in scale when compared to oil and gas. So we need to be aware of this as we know that in ecology scaling is not always simple and linear.

The other factor is that all the turbines (or subsea tidal devices) are interconnected with cables which come together at some form of collector which is then connected to shore through one or more cables. These cables are generally buried in the seabed and serve to transport the electricity generated. In the process they emit both magnetic and induced electric fields. The current knowledge base is too patchy to determine whether this change in the electrical environment is of environmental significance (it is something that we are currently addressing through some research). However it goes to illustrate that we have to think fully about the human activity that we are considering and break it down into those aspects that we may have some

relevant prior information on and others that we do not. If we just accept that offshore renewable energy is the same as oil and gas (or some other coastal activity) we may miss something and also we may constrain ourselves into thinking too negatively for example owing to the perceived reputation of oil and gas. We need to be fully informed and open to discussing the pros and cons.

RE: Offshore wind energy

Gergely Torda, Institute of Ecology and Botany of the Hungarian Academy of Sciences, Hungary

As Andrew Gill has pointed out, there are many potential effects of offshore wind farms which we still cannot properly estimate. Several contributions to this discussion mention that fishing will be prohibited in offshore wind farms, hence that such parks might serve as future recruitment areas for depleted fish stocks. However, some preliminary studies (e.g. Thomsen et al. 2006) suggest that many fish species are highly sensitive to the frequencies that build up piling noise and operational noise of wind turbines. For example, for cod and herring, the operational noise of small (1.5 MW) wind turbines can be detected up to a distance of app. 4 km, and app. 1 km for dab and salmon. Within this distance, behavioural effects are expected, and physiological (stress) effects cannot be ruled out either. These studies suggest that the establishment of fish stocks under wind farms is unlikely.

Also, marine mammals are sensitive to noise. Growing acoustic pollution of oceans in the lower frequencies have demonstrated altered behaviour and distribution patterns of Cetaceans (e.g. Czech and Jedlicka 2002). Such effects need to be studied thoroughly in EIAs.

RE: Offshore wind energy

Doris Diembeck, Ecology centre, Kiel, Germany

Nowadays we need renewable energy like wind and wave power. Sure there are some positive and negative impacts for the marine fauna in these areas, but I think we can do a lot of things to minimize the negative ones. In Germany, e.g. within the areas of the planned offshore wind farms, there will be no fishery. So wind farms may be a resting area or a protected area for many fish to recover the fish stock. Perhaps the effect will not be seen on the local scale but it might on the regional (whole North Sea) (Ehrich, 2005).

If scientists, politicians, engineers, stakeholder work together, the offshore wind power will be a chance to stop/reduce climate change.

Offshore wind farms are a good opportunity for regional monitoring, e.g. if they are built in adequate areas and if these areas have been of small importance for science during the last years. Then it will be much easier to say if an alien species is only able to live in that area due to the wind farm (artificial reef) or if it lives there for a long time and is detected the first time (Blaufeld, 2006). And to find out if it is harmful or just using the niche of an extinct endemic species.

The fundaments of the piles will work as artificial reefs. Artificial reefs are used all over the world to manage fish stocks or to protect the environment.

Depending on the place where the offshore wind farm is built it may help to get back to a sustainable fishery. Furthermore, in Germany there are investigations concerning breeding of mussels and algae within the wind farms (advantage: no need for additional food, no accumulation of faeces) (Buck, 2003).

If scientists agree to all use the same method for monitoring and sampling and place all the data in a databank which is free for public use then I think that offshore wind farms may be a chance to 'fight' climate change.

Iron fertilization of oceans as a means to sequester carbon dioxide

Gergely Torda, Institute of Ecology and Botany of the Hungarian Academy of Sciences, Hungary

In some open ocean areas high nutrient availability is paired with low primary production - these areas are therefore termed High Nutrient Low Chlorophyll areas (HNLC). Studies have demonstrated that the primary cause of low production in HNLC areas is the limitation from low concentrations of iron, a micronutrient in marine ecosystems. There have been eleven major iron enrichment experiments conducted around the world, starting from 1993, which have confirmed iron being the limiting factor for plankton growth in HNLC areas and have shown that by adding iron to these waters, primary production rapidly and substantially increases for a short, usually two-three weeks period(e.g. Martin et al. 1994; Coale et al. 1996). According to the hypothesis, iron added to the system will continue recycling until it finally sinks below the depth of the photosynthetic layer, bound in organic particles. First trials suggested that each atom of iron added to the sea could thus pull between 10,000 to 100,000 atoms of carbon out of the atmosphere (Bishop et al. 2004; Sunda & Huntsman 1995). Such a boost to the biological pump represented by sinking organic matter from the surface to deep sea is one of several ways carbon dioxide is intended to be sequestered from the atmosphere in order to decrease the rate and speed of global climate change.

There are, however, several unknowns in the process of iron fertilization regarding its efficacy and ecological consequences:

None of the previous ocean fertilization studies lasted long enough to follow the effects of iron fertilization through the food web. How does fertilization influence the species composition of the phytoplankton community and the productivity of the ecosystem? By relieving nutrient stress in HNLC regions, will phytoplankton communities respond ‘normally’, according to genetic, behavioural or ecological criteria as they have done for millions of years? Would nitrogen fixers bloom? What would be the ecosystem response if they did and what would be the impact on the nitrogen cycle?

Is excess organic matter due to iron enrichment really consigned to the depths of the ocean? What will its effect be on deep-sea ecosystems? When organic carbon is delivered to the deep, its decomposition consumes oxygen. Is there a risk of extended anoxic zones to form due to increased decomposition in deep ocean waters? What is the end-product of decomposition: is it methane or carbon dioxide? In the latter case, how much does it add to ocean acidification?

There remains a need for adequately long, multidisciplinary, holistic in situ studies to answer these crucial questions to see clearly the efficacy and ecosystem effects of iron fertilization, before accepting or rejecting it as a means to sequestering carbon dioxide. Past studies have called for iron fertilization experiments by one order of magnitude larger to adequately measure all the effects of iron fertilization on the environment and optimize carbon sequestered to the deep ocean. With slated commercial and government sponsored projects on the horizon, the opportunity for international scientific collaboration will allow for the most comprehensive study and assessment of this emerging global climate change mitigation strategy.

The effects of wind energy generation on the marine environment

Andrew Gill, Cranfield University, UK

Summary: Offshore wind energy developments will affect the marine environment; we need a coordinated approach to maximise beneficial and minimise detrimental effects.

A global requirement for renewable energy sources has created much interest in the ability of offshore wind energy to deliver sustainable energy generation. Offshore wind is currently an underutilised asset but plans for an extensive increase in its exploitation are at an advanced stage in many countries. Although renewable energy systems are often seen as environmentally benign such is the scale of offshore wind developments that we should consider them as major industrial activities, and be prepared to judge their impacts on marine and coastal ecosystem accordingly. It is imperative therefore that we determine ecological costs and benefits that may arise from all aspects of off-shore wind generation.

To date we have relied on the Environmental Impact Assessment (EIA) processes to identify positive, negative and nil impacts as well as plan mitigation where required. However, our lack of knowledge of the interaction of offshore wind development and the coastal/offshore environment severely compromise the EIA process. Furthermore, there is an inherent bias within the EIA process in that the focus is frequently on the most visible and 'charismatic' megafauna. This imbalance has influenced, to a large degree, the progress of research into the effects of wind energy generation on the marine environment. Although existing research is limited, effects have been observed on waterfowl (both resident and migratory species), marine mammals, some fish species and community colonisation and composition. The short-term nature of most of this research makes judgement as to whether observed effects are positive, negative or neutral difficult to determine, however current opinion would suggest that there are generally no significant negative effects, except for a few examples linked to site specific issues.

We should not be complacent as coastal environments are already under significant stress and degradation from past and existing human activity. Our understanding of the offshore wind farm and coastal environment interaction needs to focus on the processes and factors that allow the coastal ecosystem to function effectively and efficiently with minimal intervention. If this is set as the objective then there is potential to minimise any negative effects from developments and possibly work towards benefiting from the 'newly' created environment. The only way to meet this objective is by bringing ecologists, engineers, developers, planners and policymakers together to identify and agree on where there are potential conflicts and/or enhancements at the start of the process of developing offshore wind farms. This coming together may at first result in more questions than answers, but the crucial point in this process is that those involved are aware of the questions early enabling the development of plans that are able to adapt to as a result of targeted research and monitoring programmes. For some countries this is a little too late; however, it is a reasonable suggestion for future developments and for administrations that have not yet consented development. With offshore wind energy, we have an opportunity to make significant improvements to the global climate and potentially local ecosystems, but only if all involved promote a coordinated approach and implement it now, as a worldwide 'best practice'.

Implications of offshore renewable energy

Magdalena Muir, Arctic Institute of North America and Board Member, Climate, EUCC-The Coastal Union

It is with interest that I have followed the debate on offshore energy and impacts on biodiversity. I concur with all the prior statements, but I would also like to highlight some additional energy related aspects. As well as wind and offshore hydrocarbon infrastructure and projects, I think it also important to consider tidal and wave projects.

Tidal projects are already being proposed in estuaries and tidal loughs in England and Ireland, and are likely to expand significantly in certain regions of Europe. Wave projects are being contemplated on the Atlantic coast of the UK and Portugal. Each of these types of renewable energy generation will target and affect different aspects and strata of the coastal and marine ecosystems and biodiversity. For example, wave generation may require structures on or near the surface of the water column while tidal generation may require fixed structures and transitions from tidal to brackish water environments. Additionally there will be air and marine servicing, and related electricity cables.

Existing infrastructure in the North Sea, at least, is likely to be used to re-inject carbon dioxide and other greenhouse gases into the hydrocarbon formations, extending the life of these facilities and delaying or precluding abandonment. Additionally, new facilities may be built, there will be ongoing air and marine servicing requirements, and there will also be the additional risk of accidental release of carbon dioxide and other greenhouse gases and additional acidification of local or regional waters. This is all to emphasize that while existing experience and knowledge for hydrocarbons and even offshore windfarms are useful, this is not all encompassing or determinative of all the impacts of renewable energy on biodiversity in coastal or offshore waters.

On a science, policy and regulatory interface, it is likely that these existing, new and cumulative impacts on biodiversity will have to be addressed within European energy and environmental policies, as well as the Marine Strategy Directive, the Maritime Policy, and the Green Paper on Adaptation to Climate Change. There will have to be parallel integration of science, policy and regulation at the national and local level.

Biofuel production from marine algae

Carole Llewellyn and Stephen Skill, Plymouth Marine Laboratory, Plymouth, UK

Summary: There is now an urgent need for research aimed at harnessing the capabilities of photosynthetic microorganisms to provide clean alternative energy sources (Donohue & Cogdell, 2006).

Reducing accumulation of CO_2 in the environment is now a major priority and there is worldwide effort to replace petroleum sourced fuels with a sustainable source of bioenergy. The large amount of land needed to fulfil the requirement for crop based biofuel makes this an unrealistic route forward, and it is becoming increasingly apparent that microalgae have many advantages over using land crops for the production of biofuel (Chisti, 2007). Like plants, microalgae use sunlight to produce oils but they do so more efficiently than crop plants. Often called the most productive biochemical factories in the world, microalgae can produce up to 30 times more oil per unit of growth area than land plants (Haag, 2007). This together with the non-competitive use of land for food crops makes biofuel from microalgal an attractive proposition.

Microalgae can provide feedstock for several different types of renewable biofuels. Biodiesel from oil has recently become the focus of much activity. Depending on the species, microalgae contain a variety of different lipids, hydrocarbons and other complex oils. Most species of microalgae contain relatively high percentages of lipids, with average contents 20-40% dry wt, whereas some species, most notably *Botryococcus braunii* produce up to 75% of their dry wt as hydrocarbons (Borowitzka, 1988). There are several pathways for producing biodiesel from microalgae oil, however the most commonly employed route is via direct solvent extraction followed by transesterification.

For economic production of biofuels one of the main challenges is the solar energy to fuel conversion efficiency. Currently cellular lipid levels need to be increased and the process of lipid accumulation needs to be better controlled. This is likely to be achieved through development of genetically improved strains. Of particular importance here is the enzyme acetyl-CoA carboxylase (ACC) which plays an important role in controlling the levels of lipids accumulated in microalgal cells. The gene encoding the enzyme acetyl-CoA carboxylase (ACC) has been isolated and characterized (Roessler et al 1994) and research is underway to assess the effects of ACC overexpression (Dunaway et al 1996).

Microalgae also have potential in the production of gaseous biofuel. Hydrogen can be produced via a number of photobiological processes either using hydrogenase through direct or indirect photolysis or using nitrogensase (Benemann, 2004). Currently one of the most practical and achievable routes to production of biofuel from microalgae is the production of methane from anaerobic digestion of microalgal biomass. The most promising route forward for the production of biogas is through integration with additional value generating services or products, such as waste water treatment and nutrient removal and recovery. The production of ethanol from fermentation of carbohydrates is another possibility, although carbohydrate levels are generally low in microalgae.

Another possibility is the direct pyrolysis of microalgae. Wu et al. (1999) report the direct pyrolysis of marine nanoplankton as a source of methane and oils with *Emiliania huxleyi*, a widely distributed coccolithophorid species in world oceans

with the authors suggesting this as one of the most promising candidates for the production of biofuel.

Producing biofuel requires large scale cultivation and harvesting systems. Just as in the natural environment, growth conditions on a large scale have to be carefully controlled providing optimum nurturing environment. Light, nutrients, temperature, turbulence, CO_2 and O_2 levels need careful adjustment to provide optimum conditions for oil content and biomass yield. The challenge here is the cost per unit area. Such processes are most economical when combined with sequestration of CO_2 from flue gas emissions and /or with waste water remediation processes.

Currently business investment is driving hype on the promises of producing algal biodiesel and superior production systems. There are a large number of companies claiming that they are at the forefront of the technology and will be producing algal biodiesel economically within the next few years. However most of these companies have limited technical expertise and few have actually made biodiesel from algae. It is clear that before this can become a reality there needs to be considerable investment in molecular and biochemical research to enhance the physiological properties of algal strains. This together with optimisation of algal production and harvesting systems will ensure the most favourable route forward to economic production of biofuel.

Session III: Stopping marine biodiversity loss

Introduction to Session III: "Stop Marine Biodiversity Loss"

Ruth Higgins, Telmo Morato, Frederic Vandeperre, Ricardo Serrão Santos, Session III Chairs

Biodiversity has really come to the fore as an international priority following the Earth Summit in Rio de Janeiro in 1992. A key outcome of the summit was the establishment of the Convention on Biological Diversity. By the end of 1993, more than 150 countries had signed up to the Convention, demonstrating a strong international commitment to preserving and protecting the planet's biodiversity. Among the Convention's goals were the conservation of biological diversity, sustainable use of the planet's biological components, and the fair division of benefits from the use of its genetic resources. An important commitment was made in 2002 by parties to the Convention, to the significant reduction of the current rate of biodiversity loss by 2010 on a global, regional and national level.

Human society as we know it depends wholly on the Earth's resources. Pressure on these resources has been increasing steadily throughout history. Although much attention has been given to changes in biodiversity in the terrestrial environment, changes in the marine environment have certainly not gone unnoticed. The loss of marine ecosystems, from coastal habitats to the high seas, and the associated loss of species has largely unknown consequences. The marine realm provides a wide variety of goods and services to society, not least in terms of sustenance from the world's many and diverse fisheries. Devastation of these resources through is not something we can afford to sanction.

Marine biodiversity is sensitive to exploitation, pollution and habitat destruction. Often, the extent of these impacts has been underestimated due to the cryptic nature of the sea and seabed. Pressures such as fisheries, but also aquaculture, have significant impacts on the oceans. Such practices are largely linked to habitat destruction, which in turn has been concurrent with the damage of entire biological communities. Many traditionally exploited fish stocks in Northern Europe have shown huge declines in recent years, experiencing as much as 90% biomass reduction since the beginning of the Twentieth Century (Christensen et al. 2003). Considering that the true biodiversity of such populations and stocks is largely unknown, such losses are unacceptable. It is certain that the demise of the marine biota and the associated threat to biodiversity is impairing the quality of the marine environment and the capacity of the ocean to provide as it has done in the past (Worm et al. 2006).

Society has devised a number of strategies to protect our valued resources, both through management and prohibition of extractive and non-extractive uses of the sea. In recent years Marine Protected Areas (MPAs) have gained greater regard as a promising tool for promoting and restoring the biodiversity of the marine environment. Within their boundaries, marine reserves conserve biota and valuable habitats from anthropogenic pressures. Beyond their borders, MPAs have been shown to enrich the surrounding unprotected environment through the processes of adult "spillover" and juvenile and larval "export" (Gell and Roberts 2003). Benefits to the genetic richness of exploited fish stocks around MPAs have also been detected (Perez-Ruzafa et al. 2006).

This session of the e-conference aims to explore the extent of biodiversity loss in a variety of marine environments, exploring the drivers of change in each regions: coastal areas, estuaries, the deep sea, and the high seas. The effects of fisheries and aquaculture practices and their associated effects on species richness will also be

discussed. Finally, we will approach the topic of the role of marine protection and marine reserves in protecting biota and look at the steps needed to reconcile policy with the health and diversity of the oceans.

Invited keynote contributions will instigate discussion in each of the aforementioned themes. Contributions by other participants are expected to instigate further debate and dialogue on each topic. This e-conference should address the state of our knowledge in respect of the biodiversity in European waters, and advance our understanding of the steps needed to halt species loss. Policy considerations that transcend national boundaries should also be considered in a move towards a more integrated approach to biodiversity conservation.

Treating management decisions as large-scale experiments

Lisandro Benedetti-Cecchi, University of Pisa, Italy

Summary: The goal of halting marine biodiversity loss can be effectively served by treating management decisions as large-scale experiments.

Halting loss of marine biodiversity is a complex, albeit necessary goal to improve the quality of human life. Pursuing this goal requires a more balanced dialogue between scientists and policy makers to ensure that the research priorities needed to underpin adequate environmental policies are correctly identified and supported. Too often ecologists are requested to provide answers they cannot give or to offer oversimplified and unrealistic descriptions of nature so that non-scientists can understand. The issue is whether this approach is any useful for management and conservation of biodiversity and if ecologists in general, and marine ecologists in particular, are doing the right thing in assuming that environmental problems can be solved by making ecology an easy science.

Of course policy makers must understand what ecologists are talking about, but improving communication at the expenses of realism will not be very useful. I believe marine ecologists and policy makers should redefine the nature and objectives of policy driven research. Scientists should make clear that unlike other disciplines, ecology is not a science of laws and generalities because natural ecosystems are extremely variable and context-dependent. This is not a failure of ecology, it is an inherent feature of natural systems that everyone engaged in the analysis and conservation of biodiversity, policy makers included, should recognize. Because of this variability, it is very difficult for marine ecologists to deliver what politicians ask: simple ways to classify environmental quality and simple indicators of biodiversity change.

These indicators are usually thought as combinations of simple ecological measures (e.g. abundances of populations) that are interpreted with reference to threshold values chosen a priori to reflect different levels of environmental quality. Although desirable, indicators of change based on absolute reference values are unrealistic because they neglect a fundamental property of ecological systems: variability in space and time. This approach also revolves around an illogical argument because reference values for these indexes are derived from observations: the combination of species A, B and C is often observed in degraded environments, hence, if A, B and C are found together, the environment is classified as degraded. Of course there may be many other reasons why species A, B and C may occur together and the procedure cannot eliminate the logical alternative that exactly that particular value of the index would have been observed in the absence of anthropogenic disturbance.

Halting loss of marine biodiversity requires more focus on the drivers of change. Assessment of impact and environmental quality require hypothesis-driven analyses at the relevant spatial and temporal scales at which human activities occur. For example, the effectiveness of different networks of MPAs could be assessed by comparing alternative configurations in a large-scale experiment at the basin scale (e.g. the entire Mediterranean). Although marine ecologists are doing their best in using available information, existing case studies are not designed experiments and they violate the fundamental requirement of experimental design that replicate units must be assigned to experimental treatments at random. This problem seriously limits

our ability to identify cause-effect relationships. This argument also applies to the analysis of human impacts, including effects of aquaculture, spread of invasive species and urbanization. Marine ecologists should dare more in pursuing adaptive management strategies and should be more proactive in persuading politicians of the need of large-scale experiments for environmental problem solving. Our goal of biodiversity conservation could be effectively served by treating management decisions as designed experiments at the appropriate spatial and temporal scales.

RE: Treating management decisions as large-scale experiments

Louise Scally, BEC Consultants, Ireland

In response to Lisandro Benedetti-Cecchi, University of Pisa, Italy, I fully agree with the statement "Halting loss of marine biodiversity requires more focus on the drivers of change. Assessment of impact and environmental quality require hypothesis-driven analyses at the relevant spatial and temporal scales at which human activities occur".

The Irish government has, at a national level, attempted to investigate this approach by funding an integrative, multi-disciplinary research framework to support and inform national and local biodiversity policy in Ireland through the Biochange project. Core research within the cluster directly addresses the protection and management of ecological resources in the context of pressures that might lead to environmental change by focusing on habitat fragmentation and loss, impacts on non-native species, climate change, pollution and resource management both in marine and terrestrial habitats. The underlying aim of the project is to provide an Irish policy framework to address the most significant biodiversity policy in Europe- halting the decline of biodiversity by 2010. Further aims of the project include developing fundamental biodiversity research and capacity building in taxonomic skills, as well as development of biodiversity indicators and biomonitoring tools.

In particular, one cross-cutting project within this collaborative network aims to address the issue of effective biodiversity planning based on hypothesis-driven analyses and a well developed experimental design of the politics of policy making. While effective biodiversity planning involves a detailed understanding of natural processes and ecosystem functioning it is becoming increasingly apparent that successful protection and enhancement of biodiversity will also require a clear conception of the politics of policy making and a supportive public.

While assessments of impacts and environmental quality can provide information on possible actions, it's important to include the people involved in causing the impacts in the first place...that way you can incorporate the social and political requirements of the drivers of environmental damage into the scientific management prescription and policy. When this doesn't happen the science has a tendency to get watered down after the fact. The issue of scale is also key, while large scale maybe necessary for marine, feeding the science back into local policy making processes can be really effective for adaptive management.

In order to inform management practices in Ireland, key actors and publics are being engaged in discussions concerning the protection and enhancement of marine and terrestrial biodiversity through an integrative, multi-disciplinary research framework to support and inform national and local biodiversity policy in Ireland. This qualitative data will provide essential information on fundamental issues of power, politics and participation in biodiversity planning and detailed analysis of the

data will generate recommendations for improved mechanisms to promote positive biodiversity management.

The up scaling of such an integrative approach to a European level would provide valuable information in assessing both the drivers of change and the politics of policy making

RE: Treating management decisions as large-scale experiments

Sotiris Orfanidis, National Agricultural Research Foundation, Fisheries Research Institute, Greece

If I am not late two points more on this topic:

a) Beside time and space aggregation is also a feature of scale. My question then is why we should not try to develop new functional indicators of ecosystem that could be experimentally verified either in field and/or in the lab? In my opinion using functional groups instead of only species as a more predictive approach of ecosystem changes might be achieved. As a result a reduction of the apparent complexity allowing comparisons between communities with little species overlap at local, ecoregion or global scales could be achieved. In addition, an understanding of community changes along pollution gradients could be very difficult without using laboratory ecotoxicological tests.

b) Long-term periodicity and slow recovery of perennial species from extreme meteorological (storms) and hydrological (river floods) events, as well as angiosperm diseases, e.g. in Zostera, indicate the need for consistent monitoring of environmental parameters, such as water and sediment nutrient concentrations, and light attenuation, to better interpret community variability.

c) Coexistence, at the scale of kilometres, of species of known ecophysiology, along with certain environmental conditions or pressures, could be used as valid bioindicators.

What can we do to curb biodiversity loss?

Wiebe Kooistra, SZN, Naples, Italy

What can we, as scientists, do about biodiversity loss and global warming? Focus on relevant questions! Produce sound results! Get the conclusions out into the popular press! Arouse public awareness. What can we as part of the general audience do about biodiversity loss and global warming? At an international symposium I attended on biodiversity loss, the audience, brimming with enthusiasm, applauded the speaker who had just finished. Before walking off the podium, she took the mike again and asked. “OK, fingers up, those of you who arrived here by train, bus, bike, on foot, or in a car with all seats occupied”. Embarrassed silence. Only 20 fingers went up among an audience of ca. 500. Curb biodiversity loss, curb global warming - begin with yourself! Give the good example and only then will the public and the press take the message serious (This e-conference is a good start in saving airplane fuel).

Marine Natura 2000 sites and fisheries

Søren Anker Pedersen, ICES

The increasing human activities in the marine environment call for integrated impact assessments of the multiple pressures on the marine environment and marine spatial planning (e.g. Eastwood et al., 2007; St. Martin and Hall-Arber, 2007; Marine_Guidelines, 2007). Fisheries exert a particularly strong impact on marine ecosystems. Ecosystem effects of fishing includes biomass removal of the target species; bycatch of marine mammals, seabirds, and fish; discarding of by-catch; and mechanical disturbance and damage of benthic communities by bottom trawling (Sewell and Hiscock, 2005; Kaiser et al., 2006; Hiddink et al., 2006, 2007; MAFCONS, 2006; ICES, 2006a, 2007a). Moreover, fisheries are believed to have fundamental long-term impacts on fish stocks such as shifting towards smaller and faster growing, but less fecund fishes, with victims of possible irreversible harm spanning from particular genotypes to the ecosystem function as a whole (Daan et al., 2005).

In EU Member States, two EU Nature Directives have been the driving force for nature conservation and biodiversity protection: The Birds Directive and the Habitats Directive (e.g. English Nature et al., 2001a,b; Ritterhoff et al., 2004; von Nordheim et al., 2006a,b). The Habitats and the Birds Directives obligate EU Member States to develop coherent European ecological networks of well managed Natura 2000 sites (MPAs) to protect threatened and declining species and habitats. In the marine environment these networks are to be in place by 2012 and their objectives are to stop the loss of marine biodiversity and to preserve/restore the structures and functions of the marine ecosystems.

According to Article 6(1) of the Habitats Directive the Member States shall establish, if need be, appropriate management plans specifically designed for the sites. The management plans shall contain detailed descriptions of the site, the environmental assets, the conservation objectives as well as technical measures of conservation and restoration based on monitoring or scientific data (Czybulka and Bosecke, 2006).

The European Marine Strategy and the Common Fishery Policy require EU Member States to improve their fisheries management through their legislations. To be in compliance with the goals of Natura 2000, additional specific modifications to fisheries management practices are to be added with the Natura 2000 sites. The Habitats Directive/Natura 2000 sites have proven to be effective instruments for the establishment of MPAs in European seas (von Nordheim et al., 2006b; Anon., 2007; De Santo and Jones, 2007).

Analysis and visualization of fine scale spatio-temporal data and information are useful in order for stakeholders, the public and managers to have informed debates on the ecological and socio-economic consequences of the human activities in the marine areas (e.g. Eastwood et al., 2007; St. Martin and Hall-Arber, 2007).

The fine scale distributions of the international fishing efforts have shown the potential conflict/no-conflict zones in relation to the demarcated boundaries of SPAs and SACs. The presented fine scale fishing patterns by fishing metier will be a basis for more detailed investigations of the fisheries and the conflicts with conservation objectives in the German Natura 2000 sites (ICES, 2007c,d).

In the future it will be important to assess the interactions between fishing fleets and the conservation objectives of the Natura 2000 sites. Environmental Impact

Assessment (EIA) is a key instrument of European Union environmental policy, and has been used to assess the effects of a range of human activities on the ecosystem. There has recently been an attempt to make this EIA process specific to fisheries (ICES, 2006a) as fisheries may exert a strong effect on species and habitats in marine Natura 2000 sites (Jennings and Kaiser, 1998; Kaiser and de Groot, 2000; Kaiser and Jennings, 2002; Kaiser et al., 2005, 2006; ICES, 2006a, 2007b). All types of fishing techniques which have contact with the seabed have potential to cause adverse effects on benthic species and habitats (Kaiser et al., 2005, 2006; ICES, 2006a, 2007a,b). Recent reviews, meta-analyses, and assessments of the potential for adverse effects of fishing in the North Sea suggest that dredges and beam trawls are the most damaging gears, but that the consequences of their use for benthic habitats depends on the intensity of trawling, the design of the trawl and mesh and the habitat/bottom type and structure (e.g. Hiddink et al., 2006, 2007; ICES, 2006a, 2007a,b).

With respect to the structure and function of the habitats, the Habitats Directive requires that a habitat has to persist in the long term. With current ecological theory, and knowledge gained from the use of benthic community indicators in assessment and monitoring of environmental quality, it should be possible to find community indicators that could be used in the assessment of habitat quality in the Natura 2000 sites (ICES 2007c). For example the presence of long lived species and/or how large individuals get relative to the potential for the species may be good indicators of the degree to which fishing gears (or other causes of disturbance) are altering benthic habitats. It should be a priority to see if it is possible to use existing information to determine two points. First, are the current benthic communities in the Natura 2000 areas in states which will persist in the longer term or in states where they are unstable and likely to get worse? Second, even if the current state is stable and particularly if it is already poor, is the rate of impact of fishing activities on these habitats likely to hinder an improvement of its status to more favourable one. If it is concluded that the communities are in states that may well not be able to persist in the long term but get worse, or being impacted at unsustainable rates, all impacts of these communities by mobile bottom contacting towed fishing gears must be addressed in the management plans.

The benefit of using independent data like the VMS to analyse the distribution of the fisheries is that it shows where fishing vessels operate. However, no matter how detailed the information from the VMS or other data collection systems might be, there are more detailed and necessary information available from the users, i.e. the fishers. In the cooperation process with the stakeholders, finer scaled information on the spatial and temporal distribution of different fisheries should be analysed. The fisherman or their representatives, fishers have the option to feed information into the process. Important data from fishers would be that fishers present their own plotter tracks from specific areas. In comparison to VMS, which only update positions every 1-2 hours, such data is more precise and will complete the picture of how the areas are used and further clarify if there are conflicts between fishing interests and conservation objectives. The actual fishing activity, i.e. trawling in sensitive areas with reefs can then be revealed.

Stopping biodiversity loss in coastal environments

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

Summary: Habitat diversity is a good operational descriptor of biological diversity, whose loss in coastal systems can be contrasted by measures considering the habitat level of biodiversity organization: coastal habitat types must be listed, mapped, and ranked in terms of vulnerability to human impact, species richness, relevance for ecosystem functioning and uniqueness. Management tools should cover the whole array of peculiarities of habitat heterogeneity. Biodiversity loss cannot be stopped by implementing a one-size-fits-all strategy.

Coastal zones are highly productive due to high nutrient availability (from both terrestrial run-offs and upwellings), but they are also very sensitive to human pressures. The threats to coastal marine biodiversity are well-known: development, urban and industrial pollution, fisheries, aquaculture, alien species, global warming etc. In other words: us.

Biodiversity loss occurs at various levels. Extinction of marine species is rarely recorded; strong data show devastating pressures on target species which, however, represent a small fraction of marine biodiversity at the species level. Habitat-level biodiversity loss is easily documented, and it is also very insidious: the degradation of a single type of habitat leads to the loss of hundreds or even thousands of species. Most species diversity, in fact, is made of inconspicuous forms that are difficult to detect, and whose population viability is mostly unstudied.

Biodiversity evaluation, management and protection are most effective at the habitat level, since good habitat conditions automatically also cover the species-level of biodiversity. Protection at species level is necessary however when human impact on target species is direct.

Marine Protected Areas show that the removal of direct impacts can improve the state of biodiversity, but action against biodiversity loss cannot be limited to MPAs. The first and most urgent need to stop biodiversity loss is the inventory of biodiversity itself. How can the loss of something be stopped when we don't know what that something is, and where it is? Terrestrial habitats are easily mapped, e.g. by satellites, but it is operationally difficult to do so in marine domains: there is even disagreement about the simple list of marine habitat types! After habitat mapping, each habitat should be explored in order to list all the species inhabiting it. This will lead to the evaluation of biodiversity at species level.

A strategy of habitat mapping in coastal areas will re-open a season of marine exploration, as will the study of the species pool of each habitat. In these last decades, biodiversity research was based on the presumption that everything was already known and that it was just necessary to transfer knowledge from scattered papers to a computer. It is time to go back to the field to explore and monitor biodiversity with the presently available tools. These efforts, so far, have been negligible for coastal areas, leading to the paradox that we know more of far away habitats (from the Poles to the abysses, not to speak about other planets) than of the environments from where we extract resources, draw amenities, discharge waste, and spend our lives.

‘Good’ or not-so-good ecological status – and then?

Peter Herman, Netherlands Institute of Ecology

Summary: ‘Good ecological status’ is a reference for marine management in the coastal zone. In the Water Framework Directive, the concept holds a central place; this also applies to the narrow coastal strip. In defining indicators for ‘good ecological status’ huge problems are encountered. ‘Pristine’ reference areas for estuaries and coastlines are virtually non-existent in Europe; historical data are too scarce to replace geographic references; few or no physical-based theories are available to define the ‘good’ distribution of habitats in coastal environments. Moreover, a number of changes in coastal areas are not manageable at a local or regional level. Thus, detection of less-than-good ecological status does not necessarily lead to improvement measures. It will be necessary to accept some unavoidable changes in coastal communities; however, some other problems can be tackled if management is performed at the right spatial scale.

Good ecological status: This concept occupies a central place in the Water Framework Directive. Since this Directive also includes a very narrow coastal strip, plus all estuaries and ‘transition waters’, some experience in the marine area has been built up with defining this good ecological status. We have evaluated the status of Dutch coastal waters, based on macrobenthos. While doing this exercise, we were faced with a number of fundamental problems that are also relevant to a possible extension of the concept to the whole marine area.

Reference state: One of the most fundamental problems encountered is: what is the reference state? For Dutch waters the problem is probably more pronounced than anywhere else, since one can state that all coastal waters in The Netherlands are man-made (as is the coast itself). It implies that, from a physical and geological point of view, finding ‘pristine’ reference areas elsewhere is meaningless. In fact, ‘pristine’ and ‘reference for the Dutch coast’ are incompatible terms! The alternative is to use historic data. However, apart from some incidental observations, systematic sampling of the coastal benthos in The Netherlands only started in the ‘60-’70’s. We do not have good reference data on a more or less undisturbed (whatever the word may mean in our country) coastal system, at least not for macrobenthos. The best we can do is to rely on the oldest useful data set for the different water bodies. These data sets usually are collected some 20-30 years ago. Often it is likely that they were actually more affected by eutrophication than present-day data. The consequence is that we can demonstrate statistical changes in species composition of the benthic communities, but when these are found must make arbitrary decisions on whether they have changed for the better or the worse. Our solution? We have called all changes decreases in quality. As such the government has to further investigate the change, and decide based on proper study whether management should be adapted or not. I must say our government is not happy with the proposition, and will probably not accept it.

Good physical-based theory on spatial variability: One of the essential characteristics of estuarine benthos is the large spatial variability in the communities. They range from species-poor inhabitants of very mobile clear sands, to biomass-rich but rather species-poor communities on highly productive tidal flats, to species-rich communities (relatively speaking) in intermediate habitats. Plus, of course, exceptional biogenic structures such as seagrass beds, mussel beds or oyster reefs. In

order to produce a proper reference for a water body, it would be of very good help to have a physical-based theory on where to find what type of habitat, depending on tidal range, influx of freshwater and other physical-chemical boundary conditions. Although physical-biological interaction studies are popular nowadays, we are still lacking a sufficiently developed theory to base expectations on.

Non-manageable changes: Some of the most important changes we observed for Dutch waters are related to changes in the physics of the system. Due to dredging and dumping, and consequent changes in the hydrodynamics, we observe loss of specific habitat types (e.g. relatively undisturbed shallow sublittoral waters, some types of intertidal flats). Further, we observe a number of changes in communities related to eutrophication, or to decrease of intensity of eutrophication with concurrent disequilibrium in nutrient stoichiometry (much more P than N reduction). These types of changes can, in principle, be mitigated by proper management. However, other significant changes (e.g. in the Dutch coastal zone) are related to invasion by species that have known an explosive development in the last two decades. Notable examples are *Ensis americanus* and *Crassostrea gigas*. With these invasions, whole benthic communities have changed over very large areas. It is totally unclear, at this moment, whether management by any authority will be able to reverse these invasions. We may have to accept the change, redefine the reference and start anew (until the next invasion?). It is already hard to detect community changes; distinguishing between manageable and non-manageable changes is even much harder. The evaluation and management system must accommodate these problems. Also the communication to the public must make clear what can and what cannot be done about changes in communities.

Manageable changes – if attacked at the right spatial change: Some of the most important problems of habitat loss and degradation in estuaries and coastal zones in NW Europe are related to dredging and dumping. Most of our harbours are situated in relatively shallow waters, and extensive dredging is needed to provide access of the ever bigger ships to these harbours. There seems to be no end to this deepening, and we are dredging away all our estuaries (Elbe, Weser, Ems, Schelde, Thames…). Also along coasts (e.g. harbours of Rotterdam, Zeebrugge...) extensive dredging is needed. For local authorities, it is impossible to stop this trend. They have to choose between stopping the harbour activity or destroying the coast. The choice is easily made. Mitigation measures (e.g. compensation areas) can often not solve the problem of degrading specific types of habitats. New areas are physically incomparable to what is being lost. However, at a European level it would be quite feasible to deny access to the whole of the European coast to ships that are too large or too deep. This would provide a structural solution to the problems of (almost) all European harbours and their surrounding coastal area. A similar reasoning can be made for fisheries practices. Beam trawling may suspend itself in times of expensive fuel, but apart from that a European regulation on how one fishes, could easily accompany regulations on how much one can fish. It is strange to see that European regulations are taken for nutrient and pollution emissions, while physical habitat degradation is invariably handled at a too small local level.

Some conclusions: Assessing ‘good ecological status’ confronts us with many problems. It is probably not possible to define what the good status is for most ecosystems. 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, including the European one.

Let's have a mildly critical look at some claims

Wiebe Kooistra, SZN, Naples, Italy

As scientists seeing dramatic changes in the environment, possibly caused by global warming, we are easily carried away. Thereby we run the risk of making exaggerated claims. If these are debunked, then the issue as a whole may be discredited. Even worse, we would inadvertently provide ammunition to the contention that global warming and the impending biodiversity crash are scientific hoaxes invented by unscrupulous scientists to further their personal visibility and mop up easy research funds thrown at them by scared authorities.

Let's have a mildly critical look at some claims:

"Ocean warming and acidification significantly affect the physiology of marine organisms": Work by Ulf Riebesell (now in Kiel) and colleagues have shown negative effects on coccolith formation in e.g., *Emiliania huxleyi* in a high carbon dioxide world. Bad news; these organisms are believed to sequester carbon in ocean sediments along continental fringes. Are all coccolithophorids equally badly affected? Apparently not according to results obtained by John Raven and his co-workers. Can results of our models and experiments predict what will happen? We can perform mesocosm experiments starting with samples of present day communities exposed to (future) high CO_2 and low pH. But what about adaptation to new conditions by means of natural variation and selection of the fittest? That might work nicely over a period of decades or centuries, and I do not know how to simulate such processes in these experiments.

"Sea-level rise, together with human occupation of coastal areas, squeeze the habitat available for intertidal organisms": To me, flooding of low-elevation coastal plains on passive continental fringes will create extra space for coastal marine ecosystems, as it did at the end of Pleistocene cool periods. On rocky shores, don't things simply move upwards? And mudflats, won't they establish themselves higher up? Dikes and levees might frustrate that for some time, but maintaining dry land deep below sea level goes at a horrific cost, and no technical solution is fail-safe.

"The net effect [of global change] on a particular population is hard, if not impossible, to ascertain with our present knowledge. Environmental changes are unprecedented in their magnitude and/or speed, making past observations of how populations responded to climate variability insufficient for prediction into the 21st century": Right! But will more research and data lead to better knowledge, and will more precise models of the intricately interlinked and potentially chaotic systems really give us more accurate predictions of what is going to happen? And even if we have the answer, would that knowledge curb the processes?

"Invasive species are a bad thing for local ecosystems!" Is this really an issue in the spotlight of biodiversity and climate change, or is it more a result of cheerful ballast water management, bad mariculture practices, and irresponsible aquarium keepers? I know there is a depressingly long list of cases of terrestrial species gone extinct because of invasive species, but are there such cases in marine systems? And are many of these invasions not due to pole-wards moving distribution ranges? And how much harm is done, if any, to ecosystems in the long run? Are changes bad for biodiversity or are they bad for our economy? That's two connected but different things. See also points made by Ferdinando Boero.

RE: Let's have a mildly critical look at some claims

Peter Herman, Netherlands Institute of Ecology

In his 'mildly' critical contribution, Wiebe Kooistra essentially states that a number of reported problems related to global change are either hoaxes (i.e. non-existent problems) or not amenable to scientific study and therefore not worth studying. Among the hoaxes he classifies the problems of coastal squeeze and physiological changes in phytoplankton due to warming and acidification. Among the irresolvable problems he classifies ecosystem adaptation to global change and invasions.

In my opinion Kooistra misconceives the different roles played by science in the complex process of identifying, characterising and solving important environmental problems. He should take a closer look at these roles in some of the past (and now more or less controlled or even solved) problems, e.g. heavy metal pollution, eutrophication, ozone hole etc. During these processes at least three distinct phases can be distinguished.

The first phase is identification of a problem. After initial alarming signals, science typically takes a number of years, and many studies, to positively identify that a problem exists, that there are causal links to human activity, and that something can be done about it. For global change, this phase is now more or less coming to its end.
In a second phase, science makes an inventory of all the ramifying aspects of a problem. Scientists start to link diverse observations to the problem, or actively search for new and as yet unknown aspects of it. Ocean acidification is a good example: from theory one can expect that it should happen when CO_2 concentration in the atmosphere raises, but it takes a while to proof it, and an even much longer while to appraise its consequences for the ecosystem. During this phase, typically a number of possible ramifications are claimed that afterwards appear as less problematic, but without the ramification the risk that important topics remain unnoticed would be very high. In a third phase, science is used to help political authorities to get a grip on the problem. Typically, research is oriented towards detailed mechanisms, technology, setting of standards and to societal implementation techniques. This phase is only starting up now for global change.

If Kooistra reproaches science that it produces hoaxes, he implicitly states that the inventory phase of the problem is not essential in the process. He is wrong in two aspects. First, he does not prove that the reported potential problems are really hoaxes, which would be his duty as a scientist if he wishes to stop further exploration in those directions. Second, he fails to see that a complete inventory of important aspects of a problem can only be made if people have the freedom to search in many directions, including directions that are, after closer study, to be closed as only minor problems.

If Koooistra states that other reported problems are too difficult to study, he fails to use his imagination well enough. Identification of a problem as an important topic for further study is not a guarantee that significant results will be obtained in the next month. However, I know of no scientific result that has been obtained without someone asking the right question! It is indeed a right question to ask whether adaptation and evolution can compensate for the physiological stress due to acidification. Why would it be impossible to study? For slow-growing organisms like birds, who face the problem of wrong timing of reproduction now that their prey come out earlier due to warming, people have been able to prove that the trait (time of reproduction) is under selective control. Why then would it be impossible to prove similar things for fast-reproducing populations of phytoplankton? Ecosystem models,

also at global level, are much and much better nowadays than they were a decade ago. True, they still are far from being good enough, but what would limit their further improvement? A little positive imagination would surely help more than sour disbelief!

Frustration is not the way ahead. Science has proven in past crises to be extremely helpful to society, and it will prove this again in the case of global change. If only we keep reserving the right for ourselves to be wrong every now and then, and keep believing that our scientific system is resilient enough to stimulate significant contributions and filter them out with time from the less-significant ones. There are no signs that this is impossible.

RE: Let's have a mildly critical look at some claims

Wiebe Kooistra, SZN, Naples, Italy

First and for all I want to congratulate you with this excellent addition to the discussion. No need to convince me that with our meddling with the global climate, humanity has created yet another very serious problem. Of course we should do everything in our power to do something about that and it is our task to take action.

A problem I wanted to point out is that we have to be very careful about our statements because there are those who, out of certain interests, desire to see "the whole global warming thing" as a scientific hoax. Of course it is incorrect to assume that I believe it to be a hoax, too. That is like setting up a straw man and then attacking it. To cite Brian in the Monty Python movie 'Life of Brian', in his despair 'Brothers, let's fight the common enemy!'

For the remainder of your arguments, after we take the emotional aspect out, I perfectly agree with your three phase-approach and I believe it a very good thing that you summed these up. Recognising the weaknesses and problems in our scientific approaches is an important step towards overcoming them.

You state that 'For slow-growing organisms like birds, who face the problem of wrong timing of reproduction now that their prey come out earlier due to warming, people have been able to prove that the trait (time of reproduction) is under selective control. Why then would it be impossible to prove similar things for fast-reproducing populations of phytoplankton? Ecosystem models, also at global level, are much and much better nowadays than they were a decade ago. True, they still are far from being good enough, but what would limit their further improvement? A little positive imagination would surely help more than sour disbelief! We are working very hard on that, Peter! Sexual reproductive cycles in many plankton organisms appear to be as slow as those in birds or ever slower. On a positive note, populations of plankton organisms are huge, and so, genetic variation and selection processes may act in much larger populations than those of birds. In the mean time, let us hope that the plankton keeps on mopping up CO_2 out of the atmosphere and sequestering it in ocean sediments along continental fringes.

Of course I know our narrow escape from the ecological disasters of 'Silent World' and ozone depletion and the role of science in it. The latter one is one of incredible serendipity, that depended on a chance meeting of two scientists from two very different fields.

Stopping biodiversity loss in estuaries

Henrique Cabral, Institute of Oceanography, University of Lisbon, Portugal

Summary: Estuaries have been subjected to an increasing human pressure, resulting in a considerable habitat degradation and loss, which have affected biodiversity and ecosystem functioning.

Estuarine systems are amongst the most productive and valuable aquatic ecosystems on Earth and have been subjected to an increasing human pressure. Many authors have emphasized the importance of estuaries as feeding grounds or wintering areas for birds, as nursery for fish and invertebrates, or even as a sink of pollutants in particular habitats such as saltmarshes or mangroves.

Despite their ecological importance, estuaries are not particularly rich in species, when compared to other coastal environments. Abiotic and biotic conditions in these systems are extremely variable, according to different spatial and temporal scales, which introduce significant constraints to the use of estuarine habitats by aquatic organisms. The high resilience that usually characterizes estuarine organisms is generally pointed out as an argument for the general idea that estuarine species are less vulnerable to human impacts, when compared to species living in more predictable environments. However, the extent of human pressure in estuaries is so high that their impacts collide with the ecological function and biodiversity of estuarine systems, and evidence of biodiversity loss in estuaries has been noticed more and more often.

Fisheries have been considered as one of the most threatening anthropogenic pressure concerning fish and invertebrate populations. In recent years there has been an increasing concern about the role that other anthropogenic factors might play in the decline of species richness and ecosystem functioning. Agricultural, industrial and engineering projects can alter the shape and nature of the estuaries. Domestic and industrial discharges along with other pollution sources and heavy fishing pressure have a significant effect on abundance and structure of estuarine communities. Recent studies are now considering habitat loss as a greater problem than pollution itself. Several studies have documented that estuarine habitat loss, especially seagrass beds, saltmarshes, mangroves, tidal flats, among other habitats, was the cause for biodiversity loss in estuaries.

Scientists can aid in the environmental management of these conflicts by providing technical information to decision-makers, yet knowledge for a large number of estuarine systems is scarce. For those systems where a large number of studies have been conducted, reliable time series data and cause-effect relationships between impacts and biotic response are lacking, which makes an accurate assessment of impacts of habitat change difficult. Climate change impacts on biodiversity patterns in estuaries should also be deeply studied, since several cases describing its implications in biological communities' composition and functioning have been reported. Future research should be directed to the establishment of a strong scientific background in order to promote management plans in order to preserve these highly valuable ecosystems.

The knowledge of deep-sea biodiversity: A new challenge

Daniel Desbruyères, Ifremer, Centre de Brest, France

With more than 307x106 km², the deep-sea covers two-third of the blue Planet and represents 76% of the area of the European maritime OSPAR countries EEZs. The average depth of the ocean is 3.8 km and there is no terrestrial equivalent of the huge pelagic ocean inhabited by countless organisms. The deep-sea benthos, with some dramatic exceptions (see below), is a food-limited environment with >95% of the food reaching the seafloor deriving from primary production in sunlit surface waters. During its descent to the abysses, organic matter is cycled several times through macro- and microorganisms and decays. Thus the benthic deep-sea biomass is generally low (<1 g wet weight.m-2) and the turn-over rates slow. Conversely the specific faunal diversity of the deep-sea realm is high and a recent publication considered it as one of the most diverse habitats on Earth.

Our knowledge of the deep ocean is directly dependent of our skills to sample, measure and observe through the filter of kilometres of waters. This statement accounts for the poor knowledge that we have after about 150 years of scientific exploration, not only of the deep-sea specific diversity but also of the distribution of the main macro-habitats. The recent discoveries of hydrothermal vent and cold-seep lush and productive communities, which changed our views not only of the deep-sea but also of the whole marine realm, are a dramatic demonstration of our myopia on the marine environment. Our perception of the marine micro-world (microbes and viruses) is still in its first infancy. The 21st century is still the time for exploration and mapping of our blue Planet and this stimulating challenge requires new technologies and cooperation between countries as did Space Adventure during recent decades. The European Union can be a leader of this venture not only for the study of biodiversity in its EEZ, but also in the Area beyond National jurisdictions (see CBD), due to its present technological skills (deep ROVs are operated by three EU countries and a manned 6000m submersible is operated by France), interests for new biological or mineral resources but also due to our common past history in the exploration of the sea.

While scientists had just begun to catch a glimpse of the patchiness of the deep-sea habitats, of their biological diversities and turn-over, new concerns arose from industry (deep-oil and gas exploitation, mining …) and from commercial fishing (deep-sea bottom trawling) on fragile and unique ecosystems such as cold deep-corals, sponge and oyster reefs, hydrothermal vent, cold-seeps, but also canyons on continental margins … The importance of deep-sea food web contamination by natural and anthropogenic pollutants is almost totally ignored. The role of the deep-sea benthos in the sequestration of the carbon, often underestimated due to the low dynamics of these communities, might be profoundly affected by global changes and ocean acidification.

The reinforcement of EU deep-sea scientific research through EC and ESF instruments not only on European Margins but also on the whole European Atlantic Region is a prerequisite for a sustainable use of the deep-sea; nevertheless without delay, drastic decisions (i.e. establishing large deep-sea MPAs) must be taken to protect endangered habitats such as deep corals and other natural reefs, seamounts, cold-seep and hydrothermal vent communities.

Reconciling fisheries with stopping biodiversity loss in the deep-sea and high seas

Telmo Morato, Ruth Higgins, Fréderic Vandeperre and Ricardo S. Santos, University of the Azores, Portugal

Historical data from marine ecosystems clearly suggest that overfishing has had, for thousands of years, a major impact on target species and have fundamentally altered marine ecosystems (Jackson et al., 2001). Recently, fisheries exploitation has spread from coastal areas to the open ocean and a general decline in fish biomass has been reported (Baum et al., 2003; Christensen et al., 2003).

With the decline of shallow coastal waters resources, increasing demand, and new technology, fisheries are evidently expanding offshore and into deeper waters. In fact, global landings of fishes have shifted in the last 50 years from shallow to deeper water species (Morato et al., 2006a). Deep-water fish resources are generally considered to have high longevity, slow growth, late maturity, and low fecundity (Morato et al., 2006b). Thus, they have been considered more vulnerable to exploitation than most species exploited on the continental shelf, upper continental slope or in open ocean pelagic ecosystems (Koslow et al., 2000; Morato et al., 2006b; Cheung et al., 2007). Deep-water stocks can be rapidly depleted and recovery can be very slow, although this will not apply to a few deep-water species with life history traits comparable to shallow water species (Large et al., 2003). Moreover, deep waters act as the last refuge for some coastal stocks with an extensive vertical distribution where no fishing was occurring some decades ago (Caddy, 1993). With a fisheries expansion to deeper waters those refuges will no longer operate.

There is a recent tendency in fisheries development to argue for a diversification of target fish species, mainly through the exploitation of 'under-utilised' deepwater species. In fact we are already seeing the well-documented declines observed for shallow water fish stocks repeated in deepwater stocks (see Roberts, 2002 for some examples). Because of their life-history characteristics this phenomenon will be much faster with a smaller likelihood of recovery after collapse.

In the high seas many of the fisheries are virtually unregulated. It has been estimated that deep-water trawlers may account for about 80% of the bottom fishing catch from the high seas. Here, massive nets that drag the bottom can destroy the seabed, deep-sea corals and sponge beds that have taken centuries or millennia to grow. Because most deep-sea and high seas fishing occurs far from shore its impacts on species and ecosystems is generally neither monitored nor controlled. Hence, deep-sea and high seas fisheries cannot be seen as a replacement for declining shallow-water resources; instead, deep-water habitats should be considered as the new candidates for conservation.

Ironically, this highly destructive form of fishing would be unprofitable without heavy government support (Sumaila et al., 2007). Sumaila has recently found that over US$152 million are paid to deep-sea fisheries around the world. Without these subsidies (mostly for fuel), global deep-sea fisheries would operate at a loss of $50 million a year. Eliminating global subsidies would render these fleets economically unviable and would relieve tremendous pressure on over-fishing and vulnerable deep-sea ecosystems. Rashid Sumaila once said "from an ecological perspective we cannot afford to destroy the deep-sea. From an economic perspective, deep-sea fisheries cannot occur without government subsidies. And the bottom line is that current deep fisheries are not sustainable."

Beyond restricting fishing activity, high seas marine protected areas (MPAs) and no trawl areas are being called for in order to protect the biodiversity of these regions. Although efforts to protect the high seas and deep environments have been growing during the past years, with the entry into force of the United Nations Convention of the Law of the Sea (UNCLOS) in 1994 and more recent endeavours such as the High Seas Task Force (HSTF) 2003, we are still far from a satisfactory situation. Since the first International Congress on Marine Protected Areas in 2005 the scientific community has been calling for a Global Oceans Commission to assume custodianship of these remote marine environments. Developments have been slow, however, and efforts are restricted to some degree since our knowledge of the biodiversity and habitats is incomplete. It is a fallacy, however, to concede that we have insufficient scientific information on these areas to at least begin to establish protective measures. Adaptive management approaches allow for the incorporation of new knowledge as it becomes available. As a priority, now, we as a community should be more forthright in communicating the knowledge we possess rather than getting mired in the false testimony that we have almost everything to learn, focussing our efforts on defining what we know with some degree of certainty rather than floundering in the face of gaps in our knowledge.

RE: Reconciling fisheries with stopping biodiversity loss in the deep-sea and high seas

Asta Audzijonyte, University of Helsinki, Finland

I want to express support for the Morato et al. contribution. As scientists who earn money through research we are inclined to continuously point out the lack of knowledge and importance of additional research. While that is surely important, I believe in most cases ways to slow down (I doubt we can stop it) biodiversity loss are quite obvious. It is quite obvious that deep-sea trawlers cause tremendous damage to the deep-sea ecosystems, and such fisheries should be abandoned. It is obvious that if coastal habitats are trawled and dredged several times a year, the impact on biodiversity is severe. It is also rather obvious that if many fish stocks are overexploited, fishing pressure must be decreased, or be stopped completely. What is needed, in most cases, is not more information, but political action. There are sufficient examples of how large scale industrial fisheries has depleted fish stocks in a few decades, but there are also examples of sustainably managed fisheries. The absurdity of modern industrial fisheries is even more obvious, when one considers that many of them are only economically viable because of governmental subsidies.

As far as I know governmental subsidies to fisheries are quite common in EU. Perhaps slashing them would be a rather straightforward approach to reduce fishing? Especially when prices of fossil fuels are going up. Are there any estimates as to which fisheries in EU would remain economically viable without subsidies (for fuel, building ships, etc)?

There will never be enough data to completely understand the behaviour of natural systems. Yet, action is needed now, and I believe we must use the existing information the best way we can and have courage to make firm statements and recommendations to encourage political action.

RE: Reconciling fisheries with stopping biodiversity loss in the deep-sea and high seas

Ferdinando Boero, Department of Biological and Environmental Science and Technologies (DiSTeBA), University of Salento, Italy

I find it always strange that scientists are happy with what we know. Nobody says that we must do nothing until we know everything, but saying let's stop adding to knowledge and let's act is so strange!

As for fisheries, I concur that trawling, fisheries of fodder species for aquaculture (we rear carnivores) and so on are obvious things that should be discarded.

The big issue is that we have usually considered fisheries as if it were a matter regarding man and the target species. Fisheries science is now realizing that fish are not alone in the sea. Strange enough, a ctenophore in the Black Sea succeeded in doing something that industrial fisheries hadn't done yet: deplete fish populations almost completely. The link between gelatinous plankton and fish production is far from being understood. Salps deplete phytoplankton and are a shortcircuit in food chains, jellyfish deplete zooplankton and are another short circuit. Both are seen as freaks. They are not and they do have an enormous impact on fisheries. We might end up blaming the wrong agent, or blaming completely one of the many agents. Maybe jellies are growing because we removed fish, but there is a lot to study yet.

In the ecosystem approach, the officially accepted one, there is no hint to the impact of gelatinous plankton on fish populations. We are very far from knowing everything. And it is our duty, as scientists, to reduce ignorance. Pretending that we have reduced it all is scaring me, especially if this comes from the scientific community, and especially if it is not true! In the last years, there was a sharp decrease in anchovy populations in the Ligurian Sea. Of course the blame fell on fisheries. In the former periods, there are anecdotal sightings of enormous swarms of *Velella velella*. These guys feed on anchovy eggs and larvae. No fishery scientist has ever dreamt of connecting the two things.

RE: Reconciling fisheries with stopping biodiversity loss in the deep-sea and high seas

Adriana Vella, Conservation Biology Research Group, University of Malta, Malta

It is important to integrate effective, detailed and long-term research with precautionary policy-making which needs to be in constant contact with updates in knowledge. I agree with Ferdinando Boero, with regard to the inadequacy of stating that further knowledge is not required and that action is required instead, when indeed the two must work hand in hand. Science and scientific research are an essential tool that we should all accept is the fundamental basis on which we may improve efficiency and reduce impacts. This may only become more so as we admit the synergistic impacts of increasing human activities affecting our seas. Indeed fisheries science needs to make use of the highest quality of research in both techniques and technologies. On the other hand policy making needs to be able to take on board not only basic dogma of responsible and sustainable fishing but also put in place actions

that would allow for efficient ways of increasing enforcement and research, where both these activities would feedback to policy to constantly improve effectiveness.

Fishing activities and developing businesses exploiting marine natural resources, which are recognized as vulnerable or endangered, should already have translated to effective policy, legislations and actions, as rightly indicated by Asta Audizijonyte. Cases in point include trawling at any depth and over-exploitation of resources for aquaculture when the latter should be there to reduce exploitation and impact on all wild stocks. These activities must be considered within the ecosystem approach and the impacts on species which are not the target interest. Allowing such activities to continue would be at the expense of biodiversity impoverishment and degradation of natural environments or habitats. Vulnerable/Endangered species, Biodiversity and Habitats have been recognized as deserving protection and serious consideration, but the great gaps still present in knowledge of the diversity of life forms, life histories, life requirements, communities' structures and function may be a reason leading to the usual simplistic considerations of fisheries management which still show great weaknesses. The example of Bluefin tuna fisheries worldwide is a good example. In the Mediterranean this species is specifically targeted in every way possible, with ineffective monitoring of the fishing activities being undertaken offshore in International waters. New methods to further exploit the fish species through tuna penning has made the efforts to monitor exploitation and impacts on the Bluefin tuna stocks even more difficult. Why aren't fisheries-related advancements in gear technologies and methods rigorously researched and assessed prior to allowing the full-blown growth of such activities to have their harmful impact on marine species? Why is science mostly used to recognize our impacts, at times late in the day, rather than to assist us in preventing them?

The ecosystem approach must demand greater knowledge not only of target species but the complexity of marine biodiversity and dynamic mechanisms of our seas. Managing fisheries within such an approach remains simply words on paper unless much more research will target the variety of issues pertinent to our required understanding for improved human actions and marine life conservation.

For a wheel to go forward and function it needs all parts of its circumference, equally fisheries management should function by making use of diverse and updated knowledge hand in hand with translation of relevant information into effective action through policy and enforcement. This process should not stop but move forward too.

RE: Reconciling fisheries with stopping biodiversity loss in the deep-sea and high seas

Juliette Young, CEH Edinburgh, UK

A participant has just brought the following article to my attention, which might be of interest to you:

ENDS Europe DAILY 2410, 17/10/07: The European commission has proposed measures to protect deep sea ecosystems from harmful fishing activities such as bottom trawling. Under a plan announced on Wednesday EU high sea vessels would be banned from fishing unless they hold a permit demonstrating that their fishing will not cause "significant adverse impacts". All vessels would also be banned from fishing at depths of more than 1,000 metres. The plan is intended to implement recommendations made by the UN's general assembly in December. It is part of a

wider strategy announced last week. See commission press release http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/1506 and UN recommendations (www.un.org/News/Press/docs/2006/ga10551.doc.htm)

Fisheries and stopping biodiversity loss

Nick Dulvy, Reinhold Hanel, Jan Geert Hiddink, Priscilla Licandro, Pascal Lorance, Brian MacKenzie, Gui Menezes, Uwe Piatkowski, and Remment ter Hofstede.

Marfish, a subproject of the EU Network of Excellence MarBEF, has prepared the following statement for the e-conference topic "Reconciling Fisheries with Stopping Biodiversity Loss".

Threats to marine biodiversity: The Ocean contains most of the phyletic diversity of life on earth. The main factor that has threatened marine biodiversity globally hitherto is fishing (Dulvy et al. 2003, Garcia et al. 2006). For example, worldwide over 40 local populations of marine fishes have gone extinct as a result of overexploitation (Dulvy et al. 2003). Fishing also has impacts on non-target species via their capture and it damages benthic habitats and communities (Kaiser et al. 2006). Removal of target fish species can indirectly affect abundance and diversity of organisms at lower trophic levels leading to changes in ecosystem functioning (Frank et al. 2005, Myers et al. 2007, Daskalov et al. 2007), and can impact the availability of prey for fish and seabird predators (Frederiksen et al. 2006). Disturbance by fishing increases vulnerability of populations and ecosystems to other stresses such as climate variability (Brander 2005) and invasive species (e.g. Shiganova & Bulgakova 2000) which can subsequently affect marine biodiversity.

What the EU and its citizens can do to promote conservation and recovery of fish biodiversity: The EU has made substantial progress in recent decades in developing the legislative framework for conservation and recovery of fish biodiversity: the European Parliament and Council have passed several regulations designed to protect fish stocks, conserve fish biodiversity, and move towards an ecosystem-based approach to fisheries management. The EU is also committed to many international fishery and biodiversity agreements (EU 2005). Despite the legislative progress, 22-53% of the exploited fish populations in north-east Atlantic waters have fallen below safe biological limits (EEA 2005) and some of the populations have not recovered, partly because of high by-catches (e. g., North Sea cod).

These observations suggest that some of the well-intentioned legislation does not work in practice, or is not being fully implemented and enforced by political and national authorities. Options to complement these actions should include:

- Reductions in fishing mortality on overexploited stocks (aiming both to reduce over-exploitation and minimise the impact of impending climate change);
- Broadening the range of conservation measures based on improved scientific knowledge and process understanding (e. g., more and larger MPAs where and when appropriate, restoration of habitats, encourage the use of less habitat-damaging fishing practices);
- Ensuring effective, prompt implementation and enforcement of fishing regulations and effort control. This action alone would probably have greatest positive impact on marine biodiversity.
- Move towards fishery management framework that discourages over-capacity and wasteful fishing methods, and that encourages energy efficient and responsible fishing methods; in particular the advantages of individual quotas should be considered

Fish consumers in the EU have increasing opportunity to choose fish from sustainable sources. By doing so, they have the power to drive market demand and

influence businesses and politicians, which in turn supports moves toward more widespread sustainability. Identifying such fish at the local fish shop would become easier if a sustainable fishery certification mechanism were developed and became available in all European countries.

The objective of the e-conference session is to discuss relevance of the proposed actions that policymakers, stakeholders and consumers can take to reduce the likelihood of losing marine biodiversity and guarantee that marine ecosystems can continue to provide the goods and services that support human well-being.

RE: Fisheries and stopping biodiversity loss

Henn Ojaveer, Estonian Marine Institute, University of Tartu, Estonia

A few thoughts have arisen since reading the contributions on the topic of 'Reconciling fisheries with stopping BD loss'. I think the problem in fisheries is serious and it is high time we did something. If we cannot stop declining trends in commercial stocks, then how can we seriously talk of stopping biodiversity loss at higher trophic levels?

One of the practical solutions (however, unpopular, I assume) is to totally change the basics of fisheries management by moving towards simple and commonly understandable and acceptable approaches. Can't we say "Don't catch juvenile fish and let them spawn!", so that the management target would be that 100% of fish caught should be mature? Currently, a lot of money and time is being spent for performing fish stock assessments and formulating management advice, but several internationally managed fish stocks in Europe are overexploited and therefore at risk. Reduction of fishing effort has been shown to be an effective method to protect the commercial fish. However, what is the result if the catch still consists of substantial amounts of immature fish?

Another point is that our knowledge is mostly confined to commercial fish. But fish communities consist of non-commercial fish, the species diversity of which might actually be much higher than that of the exploited component. How much do we know of the dynamics and status of non-target fish that play major roles in ecosystems by acting as intermediate hosts of parasites or being essential prey and/or predator or food and/or niche competitor for commercial fish? I would say that this is the place where scientists can seriously say that more research is needed.

The Ecosystem Approach to Fisheries management (EAFM) is currently commonly accepted within EU. However, there is no common understanding regarding what this precisely means and what should be done now. The problem partly is that it is difficult to include ecosystem knowledge into the current fisheries models. And this perhaps gave Ferdinando Boero reason to say that fisheries scientists don't use knowledge and information from food-web processes. So, the re-marrying of the divorced fisheries and marine biology/ecology science is more difficult than expected/believed.

RE: Fisheries and stopping biodiversity loss

Pascal Lorance, Ifremer, Nantes, France

The discussion on reconciling fisheries with biodiversity loss have focused on two main topics, i.e. which fisheries management action are required to slow down/stop biodiversity loss? And what scientific research is needed?

The introduction statement by MacKenzie et al. pointed out the threat and listed a series of fisheries management action to be taken at EU and national levels together with opportunity for EU citizens to consume responsibly. Some of these actions are already being partly/poorly implemented. They do not need more science to be taken/better enforced.

Some contribution dealt upon the other topic, required scientific research and stressed we don't know much about the patterns of biodiversity the drivers of changes and the relevance of some actions (e.g. MPAs see contribution from M. Kaiser: Future-proofing MPAs: a warning) for conserving biodiversity. Can we conclude that (i) we know enough to take basic actions that would provide both significant improvement of fisheries performance (much less fishing effort for little less landings in the short term and more landings in the long term) and reduced impact of biodiversity and (ii) research is required on patterns and processes of marine diversity as well management tools required to further reduce impact of human activities on marine biodiversity.

Future-proofing MPAs: a warning

Michel Kaiser, Bangor University, UK

In an earlier contribution to this session, Lisandro Benedetti-Cecchi highlighted an important issue in respect to existing MPAs, i.e. that few if any have been designed in such a way that would enable a robust estimation of their 'effect' after implementation. He rightly suggested that scientists should continue to lobby policy makers to ensure that future MPAs should be designed in such a way to overcome this shortfall.

I wish to highlight a somewhat worrying issue. It is certain that within the EU, the commitment to implement networks of MPAs to achieve the objectives of the CFP and other conservation legislation will result in an increase in the number of areas closed to human activities. When MPAs are used as a means of protecting specific species, in some cases the location and the size of the MPA can be a reasonably simple issue to determine (e.g. soft-corals stuck to rock substratum). However, the location and size of MPAs designed to protect more mobile and wide-spread species is much more problematic. In addition, we need to ensure that we account for environmental change within the design. Some conservationists argue that a network does just that - accounts for future fluctuations in the environment. However, this is a supposition that is not tested and is a dangerous assumption to make. Until the first network of MPAs is implemented and studied we have no idea exactly how biota or systems will respond, even if we can have a pretty good guess. Our ability to estimate responses under environmental change is even less certain.

At a recent meeting organised by Natural England (UK Conservation Agency) a senior management official announced that we would see PERMANENT MPAs within the next 12 months. This desire to create permanent MPAs is folly for the following reasons:

- In a situation in which we do not know how effective our intervention will be we should ensure that we implicitly include a timetable to review the effectiveness of the intervention.
- If we find the intervention is not effective then we should reassess the situation and have the ability to be adaptive and alter the configuration/size/location of our MPAs.
- If we pin all our faith in MPA network Version I on day 1 and this subsequently fails to deliver the proclaimed benefits/improvements - then we run the risk of MPAs becoming discredited in the eyes of the general public and other stakeholders alike.
- The first networks of MPAs need to be treated as large-scale experiments in management with appropriate assessment and critique and the opportunity for re-design.

RE: Future-proofing MPAs: a warning

Peter Herman, Netherlands Institute of Ecology

I fully agree with Michel Kaiser that it would be foolish to install MPAs once and then refuse to review and/or adapt the design afterwards, based on evidence about their success. However, I want to warn of the dangers of too adaptable an approach. MPAs, surely, are a kind of (usually badly designed) natural science experiment. However, they are also experiments in social interactions and governance. What we

want to do is implement an entirely new instrument, and it is difficult to predict future resistance against, or support for the whole idea. That factor should be taken into account when designing the whole strategy.

From a natural science point of view we know that MPAs will not show an incredible increase in ecological quality, diversity etc from day 1 onwards. In fact, taking into account the usually long lifetime of the organisms we want to protect, the time scale for a review of the success of MPAs is decades rather than years. From a social perspective, we know that acceptance of a new structure is usually slow, and is not fostered at all by the feeling that in a few years time the whole scheme may be changed anyway. Taken together, these two elements (we need a lot of time to evaluate MPAs; we should not suggest that MPAs are just for a few years) should encourage us to plea for a system that pretends to be permanent. An additional argument to take that line is that it will put pressure on a high-quality planning before installation.

If, in twenty years time, our current PhD students - then professors - conclude that we have done a bad job (something they are quite likely to do) the basic idea of MPAs will probably be accepted and there will be ample opportunity for them to make their own mistakes in designing better MPAs. However, if we decide now that we only take temporary measures that may be entirely reversed in the next years, there is very little chance that any successful MPA will ever be installed.

The role of MPAs in the protection on the genetic structure of fish populations

Ángel Pérez-Ruzafa, Mercedes González-Wangüemert and Concepción Marcos, Murcia University, Spain

Marine reserves have been identified as an important tool in the management of fishery resources and their number is increasing rapidly, most of them being on islands. However, knowledge on the real effect of protection from fishing on the genetic structure of populations, the spatial scales involved, or the suitability of islands as reserves in terms of connectivity, is scarce. Recent data analyzing the effects of fishery protection on the genetic structure of populations of *Diplodus sargus*, show that Protected Areas have significantly higher allelic richness (Pérez-Ruzafa et al., 2006). Three MPAs together (Tabarca and Cabo de Palos at southern Spain and Banyuls in southern France) provided 97.3% of the total number of alleles found in all the western Mediterranean populations studied and 9.5% of this area's genetic pool is shut away in these marine reserves. It is clear that fish sanctuaries act as reservoirs for rare alleles, thus precluding their extinction. These alleles are also important because they may increase fitness under unusual conditions.

However, a high genetic differentiation between populations at spatial scales from 102 to 103 Km has been reported. There are exclusive alleles in the Southwestern Mediterranean that are not present in the North and vice versa. Such differences in genetic structure are probably related to speciation processes and low connectivity among geographic regions. Furthermore, finding exclusive alleles in the SW Mediterranean populations of *D. sargus* with regard to NW populations, although shared with Atlantic subspecies (González-Wangüemert et al., 2006) could mean that some allelic input from the Atlantic gene pool could currently be taking place in the south-western Mediterranean region.

The lack of a positive relationship between genetic and geographic distance at small spatial scales while such relationship is positive and significant at Western Mediterranean scale suggests that the interchange of individuals between close populations probably responds to complex paths through oceanographic currents (González-Wangüemert et al., 2004) that can change among years (González-Wangüemert et al., 2007).

On the other hand, 10.8% of the total allelic pool was not found on islands, as opposed to only one allele being absent in coastal zones. In addition, the lower levels of heterozygosis and higher heterozygote deficit showed by islands compared with coastal areas reinforces the idea that island populations tend to display an impoverished genetic structure and makes clear the importance of considering the connectivity processes when designing a MPA.

Connectivity depends on the habitat's characteristics and its fragmentation, the distance between patches and species-dispersal capability, being therefore scale dependent. Therefore, protection of dispersal and migratory patterns should be based on the recognition of their spatial connections and, in marine ecosystems, local measures are insufficient when the scale of the connections encompasses large areas of territory.

Here, development time in larval phases, the pattern and velocity of currents and water mass characteristics involved, are factors to be considered when pelagic dispersal occurs, and for some species, medium and large scale connectivity can depends more on the main currents in the water column than on habitat characteristics in some potential coastal corridors.

In conclusion, the design of MPAs must 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. In this sense, a multi-scaled approach in detecting connectivity processes is necessary.

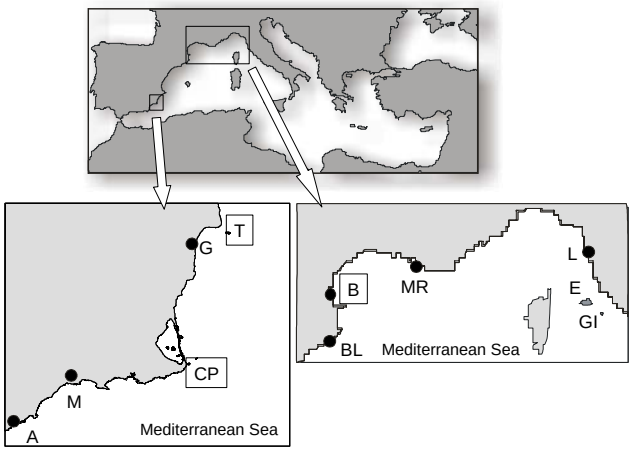

Figure 1. Location of marine protected areas (CP: Cabo de Palos, T: Tabarca, B: Banyuls) and fishing areas in a study on the Effects of fishing protection on the genetic structure of fish populations in the western Mediterranean (Pérez-Ruzafa et al., 2006).

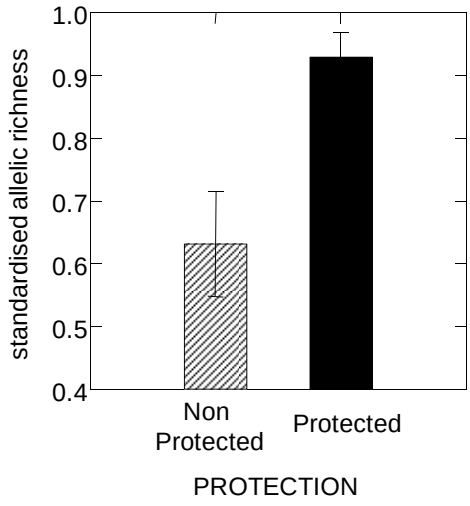

Figure 2. Mean standardized allelic richness in protected and non-protected populations (Pérez-Ruzafa *et al*., 2006).

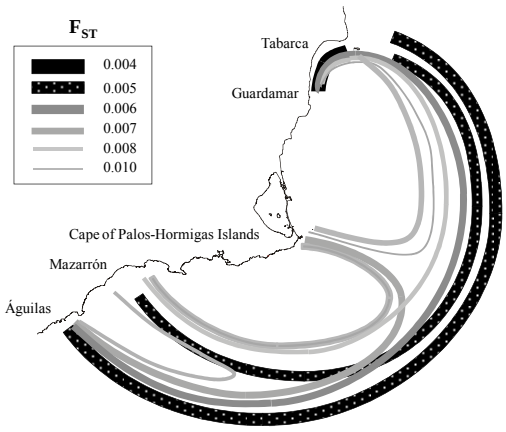

Figure 3. Patterns of genetic connectivity (FST values) inferred from the surveys of *Diplodus sargus*. Width of lines is proportional to gene flow. Data suggest that interchanges of individuals takes place through open sea currents and not through coastal areas (González-Wangüemert et al., 2004).

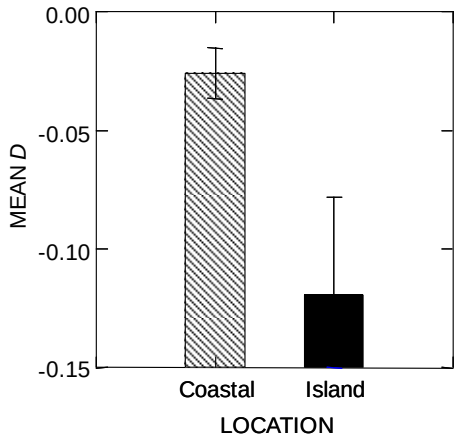

Figure 4. Mean deficit of heterozygotes (*D*) in coastal and island populations (Pérez-Ruzafa *et al*., 2006).

RE: The role of MPAs in the protection on the genetic structure of fish populations

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Slowing biodiversity loss: MPA or targeted controls of human activities toward the protection of genetic diversity and populations' potential to evolve in changing environments.

Angel Perez-Ruzafa et al. give a good and important overview of why marine biodiversity and its conservation and sustainable use need molecular genetic assessment and monitoring. This should be at the heart of management practices whether for an MPA or for targeted controls of human activities affecting marine species. Various genetics studies of marine organisms found around the Maltese

Islands (at the centre of the Mediterranean Sea) have been found to show low genetic diversity highlighting the need to be more cautious when considering species and not populations and subpopulation structuring in our seas. Too general Mediterranean-wide conclusions based on few samples or sampled groups may often give a limited picture of a more complex scenario. A species or population, intricately linked to the physical parameters of the habitats utilized at each stage of its life, is in turn also affected by a cascade of other biological parameters that affect survival, selecting diverse or uniform genetic constitutions which need to be studied for their long-term implications on population and species conservation.

Conservation genetics needs to contribute further to the fields of fisheries and marine protected area planning and management. With increased sophistication of fishing gear, fishing effort and marine resource exploitation, greater use of detailed and efficient investigative technologies and techniques will need to be used too.

The Conservation Biology Research Group, is not only looking into the importance of various molecular techniques to assess population structure and genetic diversity for local species conservation planning but also toward the need to combine such techniques to population DNA integrity assessment techniques, such as the Comet assay, to recognize the status of habitats we are planning to include in MPAs or for species we plan to protect.

Research and practices toward improving biodiversity research strategies for conservation is necessary. Adapting our scientific research strategies effectively according to the needs and rates of change in natural environments is a great challenge we need to take up.

Marine invaders

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In the context of the influence of global changes on marine biodiversity I want to mention the backward process - i.e. the influence of marine fauna on freshwater organisms because of climate changes.

Over the last few years an invasion of marine dwellers has been detected in the Volga River. Some fishes (for example black-striped pipefish) from the Caspian, Black, Azov and Baltic seas are now living in this Russian river. In the last century water temperature in the Volga has increased by two degrees. Salinity has also increased. Some researchers think the process may be connected with climate changes, while others suggest different reasons behind this change in temperature and salinity.

The fact remains that we need investigations not only on marine biodiversity changes due to climate, but also on the impact of marine species invasion on freshwater biodiversity due to climate change and water salinity in connection with global changes.

Other threats to marine biodiversity

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When addressing global change, in addition to climate change and living resource exploitation, several other topics should be dealt with. I am not trying to list all of them below, but rather stress a few of them which are truly global-range human activities which all rather unidirectionally contribute to changed ecosystems.

1. Intensification of maritime traffic with ships being faster and covering new areas in the world. This substantially elevates the risk of accidents at sea and consequently may end up with chemical/oil pollution. In addition to this, invasion of alien species should be mentioned here.

2. Production of new chemicals and synthetic materials/compounds. Their impact to the structure and functioning of marine ecosystems is not known just because there hasn't been time yet to perform the impacts studies.

Policy challenges to stop biodiversity loss

An Cliquet, Maritime Institute, University of Ghent, Belgium

There are several challenges to stop biodiversity loss. In my view the biggest challenge is to find support amongst politicians, stakeholders and the general public to take measures. For years the major causes of biodiversity loss have been well known and often there is a clear view on the management measures to be taken. On the international, national and regional level legal instruments exist to stop biodiversity loss. However, biodiversity loss continues. All too often, implementation and enforcement of legislation is lacking, often measures provide for 'paper' protection only. In recent years, mechanisms for participation and involvement of stakeholders, the general public and local authorities have been set up, in order to increase the support. We see shifts in governing style from government to governance. The challenge will be to maintain high ecological standards in taking conservation measures.

Specifically for marine nature conservation, we will need a better adaptation of certain legal instruments to the specificity of the marine environment (e.g. extension of the number of marine habitats in annex 1 of the Habitats Directive). There might also be a need to further adapt nature conservation policies and instruments to a wider variety of functions that is provided by nature. The recent focus on the goods and services provided by ecosystems (see Millennium ecosystem assessment) and adaptation to climate change, might require a broadening of classical nature conservation measures.

At an institutional level, there is need for integration and coordination on the international, national and regional level. The diverse instruments for nature conservation should be further fine-tuned. The combination of international, national and regional legal instruments often lead to a very complex regulatory framework, with different procedures for permit systems, assessments of plans and projects, designation procedures etc. Users of the natural environment are often confronted with a multiplicity of protection layers. Integration of environmental issues with other sectors has been accepted e.g. at the EU level. However, the concrete realisation of integration is often lacking. One example in the marine environment is the integration between nature conservation and fisheries measures. When limitation of fisheries is required in order to protect a marine protected area, there is still uncertainty over what level and by whom restriction of fisheries can be imposed (at the EU-level, member state level, within common fisheries policy, within nature conservation policy?). One final aspect of integration that needs our attention is the integration of the marine environment with the land part of the coastal zone (e.g. the integration of marine spatial planning with planning procedures on land).

Taking into account these challenges, gaps in our knowledge include ecological, social and legal issues. Important research will have to focus on all of these aspects: ecological research is needed on the specificity of the marine environment. This includes research on adaptation of existing instruments, research on working out appropriate management measures. On the level of social sciences we need mechanisms to increase support for nature conservation, without compromising the ecological goals. From a legal point of view we need research on integration aspects (integration within nature conservation instruments and integration with other sectors).

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