NATIONAL ENVIRONMENTAL RESEARCH INSTITUTE
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Summary from the NMR – AEG workshop on

Changing Seas
Workshop on effects of climate change on marine ecosystems

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Introduction

A 2-day workshop on March, 9-10, 2010 in Copenhagen was arranged by Dept. of Marine Ecology, National Environmental Research Institute, Aarhus University on behalf of the Aquatic Ecosystem Group, a working group under the Nordic Council of Ministers.

The aim of the workshop was to bring together scientists, managers and others with an interest in climate change and marine environments. During two days, 22 scientists presented the latest information and the 75 participants had a possibility to formulate new issues and research fields as recommendations to the Nordic Council of Ministers.

This summary presents a synthesis of the presented information and the outcome of the workshop in the form of responses to a series of issues raised by the organisers concerning climate change and marine ecosystems. Presentations from the workshop together with appendixes of relevant papers are available on the web site of the Aquatic Ecosystem group at Nordic council of Ministers www.norden.org/aeg and at NERI's web site http://www.dmu.dk/International/AboutNERI/Departments/MarineEcology/ChangingSeas_UK/PresentationsNMRworkshop.htm.

Scope

The scope of the workshop was to present recommendations to the Nordic Council of Ministers about issues and research fields of particular importance with regards to effects of climate change on marine ecosystems.

The workshop was partly a presentation of the latest research results and knowledge on climate change related effects and partly an effort by the participants to formulate new and important issues based on the presented information and on their respective fields of expertise. Participants segregated into three groups, representing the three marine areas which border the Nordic region and have high importance to the Nordic countries: The Baltic Sea, the North Atlantic and the Arctic. Each group were asked to discuss a series of question and present the outcome of their discussions to the workshop. The questions were as follows:

1. What are the major consequences/threats of a changing climate?
2. New or overlooked issues and new views on old issues?
3. Recommendations for monitoring or research activities – how do we design monitoring programmes for changes which may take place over decades? Can models be used? If yes, how do we validate such models?
4. Recommendations for new research activities – what are the major gaps in our knowledge?

5. Can we assess the costs associated with climate change relating to marine systems?
6. Forming network aiming at future co-operation – funding possibilities?
7. Recommendations for management/politicians – is there anything that can be done to minimise damage to marine systems?

Synthesis of presented topics

The workshop was organised with four sessions. The first session included expected scenarios for emissions and regional climate after the results of COP15 and talks about hydrography and sea ice. The session was setting the scene for the rest of the workshop. Session two and three was dealing with changes in productivity and food webs, acidification and invasive species. The last session was focused on management related issues. The following is a synthesis of the presented issues.

Climate change will affect the marine areas surrounding the Nordic region in a variety of ways. Physical-chemical changes will have profound effects on the marine ecosystems. Some of the most serious climate changes include a temperature increase of sea water and higher precipitation levels which causes increased freshwater run-off from land to sea. Temperature increases will in turn lead to lower concentrations of oxygen in the water and increased freshwater input will decrease sea water salinity. Furthermore, the organic matter in the freshwater will change the energy flux in the marine environment towards more recycling of organic matter that favours certain groups of organisms. Increased CO_2 in the atmosphere will also turn oceans more acidic with potential grave consequences on calcifying organisms. The effects from climate change will be enhanced, as marine ecosystems in the Nordic regions already are under heavy stress from over exploitation of resources, eutrophication effects and effects from contaminants. Effects from these stress factors interact with climate change effects in complex patterns that is not fully understood. One example is the prediction of more hypoxia in a warmer future. The expected temperature increase of marine waters during the 21st century will cause a decline in oxygen concentration during the summer and hypoxic areas may increase by 200 - 300% in the Belt Sea/Kattegat area. Although eutrophication has been reduced during the last 20 years, the oxygen conditions have not yet improved, because positive effects of reduced eutrophication from land have been overshadowed by climate change induced increases in temperature and precipitation.

We are experiencing changes to the structure of marine ecosystems in terms of biodiversity, abundance and distribution of species. Examples of this development are already documented, such as declining occurrences of the brown algae *Laminaria sacharina,* which has been disappearing both in inner Danish waters and along the Norwegian coast during the last decade together with its

associated fauna and flora. Increasing water temperatures seems to be an important factor in this development. Similarly, the size and depth limits of eelgrass (*Zostera marina*) meadows have been drastically reduced in Danish waters, because of light limitation due to eutrophication. However, new data suggests that eelgrass cannot tolerate water with less than 30 % O_2 saturation when temperatures are higher than 20 °C. That means hypoxia is also an important factor and negative effects of eutrophication is enhanced in a future climate with a higher temperature. This has important implications for management of coastal ecosystems with respects to EU's water framework directive and the Marine Strategy Framework Directive where the depth limit of macrophytes is currently one of the main quality elements which define whether a system has reached 'good ecological status or good environmental status, respectively'.

Economically important parts of the marine ecosystem are also subject to future changes. In particular, fish stock distribution and abundances will change. Fishermen in Nordic regions are catching fish species of warmer water origin, while original stocks of economical important species like cod are at a very low level. In the Baltic Sea, the cod population is threatened by the expected changes in temperature and in particular by decreasing salinity due to higher run off from land. The threat is further confounded by heavy overfishing (exploitation) and eutrophication. Cod populations have existed in the North Sea in previous warmer periods. However, if the cod should continue to live in a warmer North Sea, fishing efforts need to be reduced, since the cod populations are more sensitive to environmental stresses (e. g., warm temperatures and high NAO index) when their biomasses already are low. The flow of organic matter that sustains fish stocks, marine mammals and sea birds will also be altered by climate change. Lower production and a less efficient energy transfer towards the higher levels in the food chain, e.g. fish, are to be expected. For instance, even a moderate increased discharge of freshwater may change the concentration and composition of dissolved organic matter which may reduce growth of phytoplankton and cause a decline in fish stocks and the benthic fauna. In the Arctic, similar changes are observed where retreating ice is the driving factor in a shift among important zooplankton communities, where faster growing smaller and less lipid rich species are favoured in a warmer climate.

The impact from hazardous substances on marine ecosystems will change when climate changes come into effect. Several factors are determining the magnitude of contaminant effects including transport and sources, distribution patterns and bioaccumulation. There is a lack of knowledge on biological effects from contaminants and especially on effects from multiple stressors such as contaminants and water temperatures, acidification, eutrophication and decreasing salinities. This

makes it difficult to predict responses of marine ecosystems under stress from both contaminants and climate change effects. The Arctic is seen as an early warning system and valuable comparisons should be made between arctic and temperate system responses.

Outcome of workshop

Based on the on the information presented at the workshop and the participants expertise in the field, three groups, each covering one of the three main nordic marine areas (Baltic Sea, NE Atlantic, Arctic) responded to seven issues raised by the organisers,. The responses are presented in the following table as key words and phrases for every question and for each group. The responses are then synthesised and aggregated into recommendations to the Nordic Minister Council for further action.

Raised issues	Baltic Sea	North Sea	Arctic
Major consequences & threats	• Reduced productivity • Increased differences between Northern and Southern Baltic Sea • Climate change might amplify (negative) effects • Combined effects of eutrophication and climate change on oxygen and ventilation of deep waters • Effects on fish ecology	• Big changes in food web structure and function • Replacement of species • Mismatch primary producers and consumers • Changed food stocks • If deep convection stops; a major impact to Northern regions	• Increased human activity (fisheries, CO_2, shipping, pollution, etc.) • Consequences of human impact (reduced sea ice cover, thawing permafrost, global warming, acidification etc.) • Feedback between Arctic and the rest of the globe (threat from the arctic to the rest of the world, e.g. melting of the Arctic will threaten the rest of the world)
New or overlooked issues New views on old issues	• Nordic high-profile on quality assured long-term monitoring • Need of a baseline study on long-term natural climate conditions and variability • Complexity of systems/non-linear responses. Consequences of actions taken • Feasibility of restocking cod population	• Interdisciplinarity needed, integration of e.g chemists, biologists, modelling • Biodiversity impacts • Potential spatio-temporal data from other sources (e.g. fishing fleet data, VMS vessel monitoring system systems) • Standardisation needed for data • Place fisheries policy at centre of answering issues of climate change	• Increased research/monitoring activity • Future projections in regional system models with complex feedback interactions, quantification of uncertainties and impact studies • Probability studies • Combined stressors, priorities, tipping points. Identify risks and opportunities • Knowledge on ecosystem response
Monitoring or research activities Use of models	• Need for long-term monitoring series • Better validation of regional models • Inclusion of carbon (DOC; DIC), light and pH in monitoring programmes (Harmonized procedures and units measured) • Possibility of common programmes in open sea areas. Take into account climate change-surveillance • Identify and include indicator species in programmes • Increase use of ships-of-opportunity in monitoring • Strengthen littoral habitat monitoring • Increase number of automatic monitoring station, providing high-frequency measurements	• Baseline assessments of present status • Maintenance and availability of historical data and time series • Database for world monitoring data • Strategic risk assessments on regional basis to include coastal zones (terrestrial and marine) • Accept and manage the change. Predict changes and adapt • Assessment of vulnerable species and new consequences • Long term economic value (predictions of overall impacts) • Focus on short and long term impacts • Standardisation of data • Take North sea/Atlantic as “proof of concept”. (e.g Continuous Plankton Recorder) • Interdisciplinary infrastructures for research, time series, predictive experiments, training etc. (ESFRI)	• More monitoring needed • New variables in monitoring: Sea ice thickness, ice categories, ice motion, nutrient fluxes between sediments and the bottom water in the Baltic Sea, carbon fluxes from land • Flexible monitoring (add variable if needed) • Coordinated and standardized effort (take advantage of existing programs and facilities) • Secure Arctic time series • Take advantage of emerging technologies (ROV etc.) • Need data on ecological and mechanistic variables • Ecosystem/system modelling (local scenarios vs. global predictions)

New research activities	• Increase focus on impacts of extreme events	• Knowledge on processes and changes • Microbial component needs investigation • Effects on productivity changes, lower trophic levels (e.g. ciliates), meiofauna • More study sites on a wider range • New opportunities for sampling and analyses	• Changing extremes of physical parameters • Combined impacts of various stressors
Cost assessment	• Feasible for fish stocks • Difficult to estimate costs of eutrophication and abatement • Need for multi-disciplinary cooperation	• Not possible • Information on "value" through education • Not only money involved, also socioeconomic aspects • Adjust and adapt to new situations. What is valuable and what is value? • Value of ecosystems and ecosystems services as carbon sinks	• Doubt if it is the job of natural scientists • Complicated by the presence of possible benefits due to climate change in Arctic regions • Risk assessment contains a lot of uncertainties, probability studies useful
Network forming Funding possibilities	• Emphasise HELCOM MONAS possibilities when coordinating monitoring/evaluation • Improve dialogue between Baltic Sea oceanographers and North Sea meteorological/hydrographical expertise	• Need of integrated network of infrastructures and scientists • Need global framework • Need to develop marine sphere more in climate research to balance studies • Do not forget existing networks • Need MPAs at Nordic International level since climate zones and fish stocks can (will) shift • Need to have common understanding of MPAs as useful tools • Better cooperation between fisheries and basic research	• Special calls are recommended with focus on interdisciplinary research on impacts of climate change on the environment, like BONUS for the Baltic Sea. • System approach rather than smaller grants • Interdisciplinary approach • Funding to meet and organise (produce policy documents / education & outreach) • Global network on infrastructures / monitoring • Need better collaboration contacts with Russians and access to their data
Recommendations for management/politicians	• Political pressure on need for securing national monitoring programmes • Continue to reduce nutrient loadings • Set fishing efforts at appropriate levels • Improve communication, dissemination and evaluation of scientific results to general public and decision makers • Existing knowledge need to be coordinated and communicated • Keep focus on small improvements can increase resilience and robustness of marine systems	• Marine planning needs to be integrated • Use EMBRC within ESFRI network	• Take climate change into account in future planning • Take actions now • Need to educate in the Arctic to understand the local and global aspects • Develop sustainable way of living, Arctic should develop without repeating our mistakes

Conclusions and recommendations

Marine ecosystems in the Nordic region are already under stress from human exploitation, eutrophication and pollution and will be further threatened from climate change effects. More knowledge is needed in many areas to be able to predict effects of climate change which will interact with present stressors and to understand both processes and dynamics of the marine ecosystems, but also on development over time. The workshop recommends implementation of interdisciplinary efforts to be able to understand measure and model these complex feed-back systems and include probability studies for risk assessment. A main conclusion from the workshop is to consider the combined effects of the three main stressors in the future as illustrated in figure 1.

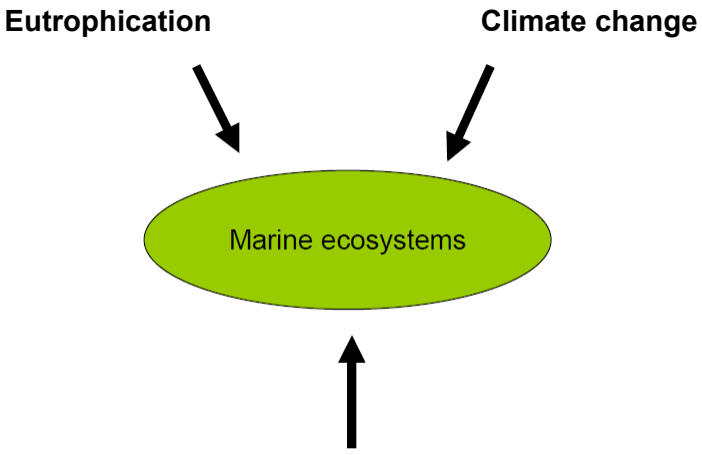

Figure 1. The main stress factors on marine ecosystems in the Nordic Region. The importance of the three stress factors vary among the regions, with eutrophication being particular important in the Baltic Regions and climate changes in the Arctic Region.

However, this lack of knowledge must not stop acting where possible, because action can help. If human induced strains on marine ecosystems are relieved, for example through less exploitation of fish stocks and further reducing nutrient releases from land, marine ecosystems may be better to adapt to the inevitable climate change effects.

A general agreement emerged on the need to establish new monitoring programmes and secure existing monitoring programmes and time series of data. Long term monitoring series are imperative to assess the current status of ecosystems, to establish baseline conditions and as tools for predicting future developments and evaluate mitigation efforts. Especially baseline studies were emphasised as important in order to get a better understanding of the present status of marine ecosystems as a starting point for long term variability studies. Furthermore, it was recommended to

make monitoring programmes more flexible and to include contributions from other sources (e.g. commercial shipping) and new technologies like ROV's (Remotely Operated Vehicles) and automatic sampling. There was a strong wish to work in an interdisciplinary context with a systems approach. New variables should be included to estimate carbon dynamics including sources from increased land run-off, cycling in biological systems and fluxes between primary and secondary production. Biological parameters such as development of indicator species and identification of vulnerable species must be addressed in order to study ecosystem responses. The continuous plankton recorder system was put forward as an example which obtains useful data and is easy to implement on a global scale.

Impacts of extreme events were identified as a new research area, as was studies of combined effects from multiple stress factors. Microbial respiration and metabolism is likely to be more prominent as climate changes progress, and it was recognised that efforts should be directed to gain more knowledge on the microbial components in marine ecosystems. Generally, insight is still lacking on vital processes and dynamics of marine ecosystem production.

In terms of assessing the cost of climate changes, serious doubts were put forward about its feasibility or if it should be done by natural scientists. To some extent, it is possible to put economic value on changes in e.g. fish stocks, but it is a complex issue where the value of many factors is inherently difficult to estimate and where positive economic benefits can occur in some areas like the Arctic. Certainly, it requires a multi-disciplinary effort to achieve anything useful.

The workshop participants agreed on the need for larger frameworks of cooperation, where scientists can share infrastructure and data across disciplines to obtain high quality research on a system level and which can be standardised and extended to a global scale. It was emphasised that existing programs can be expanded and programs like the BONUS program in the Baltic Sea and the ESFRI network were listed as examples to follow. Improving cooperation between fisheries and research, between regional research and monitoring programmes and between nations were also emphasised as important for network improvement.

In summary, the workshop propose the following recommendations which are imperative for legislators and decision makers in order to take action and maintain a sound management of marine ecosystems in the face of a climate changed future.

Recommendations

- Continue to reduce CO_2 emissions and keep taking action to reduce nutrient loadings
- Maintain and secure existing monitoring programmes and time series of data and start new where needed
- Make monitoring programmes more flexible by collaborate between institutions and others and include new variables
- Construct interdisciplinary research programmes with a system approach to be able to assess climate effects properly and effectively (e.g. ESFRI roadmap)
- Implement carbon variables and more biological parameters in monitoring programmes
- New research on effects of extreme events and combined stress factors are vital
- Research is encouraged on structure and function of microbial components in marine ecosystems
- Cost assessment of climate change effects requires a multidisciplinary effort
- Focus on large frameworks of cooperation sharing infrastructure and data with a system approach
- Increase education and communication of local and global effects to the general public

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