EUR-OCEANS Foresight workshop

Rapid change in polar ecosystems workshop

Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany
British Antarctic Survey, Cambridge, UK

1. Organizers

Prof. Ulrich Bathmann, Dr. Svenja Kruse, Alfred-Wegener Institute for Polar- and Marine Research, D-27515 Bremerhaven, Germany, Email: ulrich.bathmann@awi.de, Ph: +49 (0)471 4831 1275

Prof. Eugene Murphy, Dr. Rachel Cavanagh, Natural Environment Research Council, British Antarctic Survey, High Cross, Madingley Road, High Cross, Cambridge, CB3 0ET; Email: ejmu@bas.ac.uk, Ph: +44 (0)1223 221614.

Venue: Alfred-Wegener Institute for Polar and Marine Research (AWI), Bremerhaven, Germany
Time: 15-17 November 2010

2. Participating scientists

Participants:
Steve NICOL, Jean-Marie FLAUD , Denis-Didier ROUSSEAU , Paul TREGUER , Bernard QUEGUINER , Ulrich BATHMANN , Antje BOETIUS , Rüdiger GERDES , Michael KLAGES, Svenja KRUSE, Bettina MEYER, Ursula SCHAUER, Victor SMETACEK, Dieter WOLF-GLADROW, Robert HUBER, Jørgen BERGE , Bente EDVARDSEN , Stig FALK-PETERSEN, Egil SAKSHAUG, Rachel CAVANAGH, Simeon HILL, Eugene MURPHY, Eileen HOFMANN,

Guests:
Astrid BRACHER, Thomas BREY, Gerhard DIECKMANN, Hans-Jürgen HIRCHE, Christine KLAAS, Rainer KNUST , Katja METFIES, Barbara NIEHOFF, Eva-Maria NÖTHIG, Ilka PEEKEN, Volker STRASS, Ksenia KOSOBOKOVA

(please see affiliation in Anex)

3. Topic, focus, objective

This proposed foresight workshop addressed the topic of 'Global Change in Polar Systems'. Polar marine ecosystems have global ecological and economic importance. They maintain unique biodiversity, play a major role in climate processes, and support indigenous communities and commercial fisheries. These ecosystems have adapted to cold and highly seasonal conditions, and are thus sensitive to climate and human impacts. Some of the most rapid climate and anthropogenic driven changes of any marine system are occurring at the poles. Although consistent changes are occurring across the Arctic region (e.g. disappearance of sea ice), and the effects are more regional in the Antarctic (e.g. disintegration of ice shelves and rapid glacial melt in coastal areas and the Antarctic Peninsula), they are circumpolar in scale. These recent global climate-driven changes, combined with expanding exploitation of marine bio-resources (e.g. commercial fisheries), threaten the balance of these unique marine ecosystems. By understanding their response, we can use them as a warning system for climate change across the planet. The structure of polar marine ecosystems also makes them an excellent model for analysing the processes that control ecosystem biodiversity and dynamics. These processes may also be relevant to other globally important marine ecosystems.

One of the key successes of the EUR-OCEANS Network of Excellence (NoE) has been the strengthening of the European Research Area in Southern Ocean science. The EUR-OCEANS NoE has been a catalyst for developing a solid sub-network of research scientists in this area. This sub-network has created progressive and lasting integration of the research activities of the NoE, and has significantly advanced scientific capacity in this region by creating crucial links beyond Europe. The development of the 10 year international Integrating Climate and Ecosystem Dynamics in the Southern Ocean programme (ICED, the first regional programme of the Integrated Marine Biogeochemistry and Ecosystem Research programme, see www.iced.ac.uk) and ICED during the International Polar Year 2007-2008 (ICED-IPY, see www.ipy.org Project No 92) was in large part due to the foresight and financial and administrative help of EUR-OCEANS. The continuation and progression of these sub-networks and programmes under the subsequent EUR-OCEANS Consortium is the future for Southern Ocean science, as it will enable the European scientists to link with the international science community to collectively address key questions in the region and produce a step change in the understanding of the role of this ocean in the Earth System. The workshop also build on the EUR-OCEANS Arctic sub-network activities.

This proposed foresight workshop provided a timely opportunity to gather key European scientists to consider:

•**Major changes** in polar marine ecosystems that are occurring as a result of climate and anthropogenic drivers;

•**Important responses** of polar marine ecosystems that may be expected under future change scenarios;

•**Central regions** in polar marine ecosystems to detect the impacts of change and understand the response mechanisms involved (these should encompass the full range of ecological and physical systems and levels of change in these ecosystems);

•**Necessary data** requirements (both historical and future) for detecting change in polar marine ecosystems (e.g. long-term physical and biological monitoring data, biodiversity data).

Consideration of these aspects will **focus scientific strategy** and outputs required for testing scenarios of future change in polar marine ecosystems.

This workshop will not only enable the European Research Area
to take a lead in driving and coordinating Southern Ocean research under ICED, but it will provide an opportunity to apply the knowledge and experience gained in its involvement with EUR-OCEANS and ICED

to explore the impacts of global change in polar marine systems.

•This latter role is also particularly timely given that climate change research in Arctic marine ecosystems is considerably less **coordinated** than in the Antarctic.

The initiative is also particularly timely given that understanding the impacts of climate change in Arctic marine ecosystems has become an increased focus for European policy makers.

The outcomes of this workshop has not only be of immediate benefit to the international science community, but will build the foundations for (1) planning and coordinating future fieldwork activities to detect natural and anthropogenic change in polar ecosystems, (2) creating a EUROCEANS Flagship in Polar Science and (3) shaping future EUR-OCEANS calls in this research area under the European Framework Programme.

4. Agenda

Monday,
15.11.2010
DAY 1: PRESENTATIONS AND IDENTIFICATION OF MAJOR CHALLENGES
MODELLING & ANTARCTIC
Tuesday,
16.11.2010
DAY 2: CONTINUATION OF DAY 1 AND PRESENTATION OF PLANNED ACTIVITIES
ARCTIC & DATA & FIELD ACTIVITIES
Wednesday,
17.11.2010
DAY 3: FUTURE REQUIREMENTS AND WORKSHOP OUTCOME
WORKING GROUPS & towards a JOINT PROPOSAL

(details are provided in the Anex)

5. Ouput(s)

The report about the main outputs from the workshop is presented to consider and identify key *changes*, *responses*, *regions* and *data requirements* to detect the impacts of climate and anthropogenic driven change in Antarctic and Arctic marine ecosystems. The following is organized as such. At the very end, we have summarised a roadmap of the next steps.

5a. Impacts of a changing Southern Ocean

[i] The importance of Southern Ocean ecosystems

a. There have been rapid climate-related changes in Antarctic oceanic and sea ice systems with impacts on sea-ice cover, seasonality, ice shelves, frontal dynamics, stabilisation, wind forcing and mesoscale eddy activity. Changes are occurring across the whole of the Southern Ocean, but the impacts of change are highly variable with marked regional differences in drivers and impacts. This is most clearly demonstrated by rapid regional warming around the West Antarctic Peninsula affecting upper ocean temperature, salinity and sea ice extent and timing. In contrast, in other areas, for example, across much of the Ross Sea region intense cooling is occurring and sea ice is increasing. There is also marked interannual and sub-decadal variation in upper ocean and sea ice physical processes that has also been linked to climate related variation. Major changes in Southern Ocean physical and biogeochemical processes are expected to occur over the next 50 to 100 years associated with global climate processes. There is an increasing requirement to understand how ecological systems of the Southern Ocean are changing and are likely to respond to future climate-related changes.
b. Southern Ocean ecosystems have a crucial role in global biogeochemical cycles. They are a major component of the global carbon cycle and important as a sink for anthropogenic carbon, although climate related changes may be weakening the capacity of the Southern

Ocean to absorb CO_2. Southern Ocean ecosystems influence the distribution and balance of nutrients in the world's oceans affecting their productive capacity and their role in carbon drawdown. Understanding the role of Southern Ocean ecosystems in moderating globally important biogeochemical processes is a major requirement for refining global coupled ocean-climate-biogeochemical models.

c. Southern Oceans ecosystems maintain important biodiversity. Across the Southern Ocean there are large numbers of endemic species. The system supports many taxonomic groups and species that are almost totally dependent on the ecosystems of the Southern Ocean for their survival, such as various seabird species including Albatrosses and Penguins. Many of the species occurring here also show marked adaptations to the cold highly seasonal conditions, which combined with their restricted global distributions make them potentially physiologically and ecologically sensitive to the physical changes occurring in the Southern Ocean. A number of these species are also globally threatened, such as the Wandering Albatross, which is showing significant population declines across the region. Developing conservation measures requires a whole ecosystem understanding of the various direct (e.g. climate or oceanic changes or fisheries) and indirect changes (e.g. changes in prey abundance and distribution) affecting individual species and their interactions in the food webs.
d. With increases in atmospheric CO_2 major changes are expected in the carbonate cycle resulting in increasing acidification of the global ocean. The cold high latitude Southern Ocean is an area where some of the most rapid changes are expected to occur, and there have been suggestions that biologically significant reductions in pH may occur within only a few decades. This will likely affect the capacity of calcareous organisms to form hard structures and may also have important effects on the physiology and life cycles of a large number of species. Understanding the direct and indirect effects of changing pH on Southern Ocean species will be important for determining how this may affect food web structure and function and biogeochemical cycles.
e. There is clear potential for increased harvesting of Southern Ocean species, particularly for Antarctic krill. Recent developments indicate that the fishery is currently expanding, which is generating concern about the potential ecological consequences on species that depend on krill as their major prey. European commercial operations in particular are driving this expansion of the krill fishery. The demand for products from krill fishing is driven by the global fish markets, they are used in European aquaculture and are now being exploited for the nutriceuticals market. Southern Ocean fisheries have operated for over two centuries and the effects of the removal of large numbers of long-lived seals and whales are still occurring. The removal of many slow growing long-lived fish species, which do not appear to be showing much sign of population recovery, even though harvesting is now at a low level or stopped, further highlights how these systems have been changed. There are indications that some populations of whales are increasing and effects of recovery of large marine mammal populations are likely to cascade through the food web and impact lower trophic levels. Understanding how higher trophic level species are affected by harvesting and how changes in intermediate and higher trophic level species can affect the overall structure and function of ecosystems is increasingly recognised as a globally important challenge, The Southern Ocean is a particularly valuable system for determining the impacts of such changes in higher trophic level species on overall ecosystem structure and function because the changes occurring are so recent, rapid and relatively well documented compared to most other regions of the world's oceans.
f. There has been an increasing emphasis within CCAMLR of the need to develop small scale management procedures. In addition a process of agreement of Marine Protected Areas (MPAs) has also begun with the first MPA implemented in the South Orkney region in 2009.

Research is required for the appropriate definition of MPAs and for the development of associated conservation measures.

g. The Southern Ocean has been the focus of high profile suggestions for geoengineering and climate change mitigation measures. Understanding the mechanisms involved in processes that may be subject to such manipulations is required to advise on the viability and impacts of different measures that are likely to be considered over the coming decades.
h. In analysing the response of oceanic systems across the global ocean it is important to study places that are particularly sensitive to change. The rapid changes occurring in the Southern Ocean provide a valuable basis for generating fundamental understanding of how oceanic ecosystems will be affected by change. Studies in this region can also help us to understand the multiple direct and indirect influences that affect ecosystem structure and function and can feedback on climate processes.
i. The Southern Ocean is a major component of the wider Earth System. There is an increasing awareness in the international scientific community that ocean scale analyses of what determines ecosystem structure and function are required to develop projections of Earth System responses to change. This requires the development of global comparisons. Developing comparative analyses of how polar ecosystems are structured and how they will respond to change will provide important insights into requirements for future global scale analyses of oceanic ecosystems and how they should be appropriately included in Earth System models.
j. The Integrating Climate and Ecosystems Dynamics in the Southern Ocean (ICED) programme has been developed by the scientific community in recognition of the importance of Southern Ocean ecosystems as part of the wider Earth System, in maintaining biological diversity, and because of the need to develop understanding of how these systems are responding to current change and their likely responses to future change. The programme is a regional programme of the International Geosphere Biosphere Programme (IGBP) Integrating Marine Biogeochemical and Ecosystem research (IMBER) and is supported by the Scientific Committee on Ocean Research (SCOR) and Scientific Committee on Antarctic Research (SCAR). ICED worked in close partnership with the EUR-OCEANS Southern Ocean System and aims to develop analyses of circumpolar Southern Ocean ecosystems to provide the basis for understanding how climate related changes affect the structure and function of the ecosystem and how in turn that will affect wider Earth System processes.

[ii] Building on what we have learned

There is a strong historical basis of European research on Southern Ocean ecosystems over more than a century. European scientists have had a leading role in developing globally important analyses of Southern Ocean ecosystems and in driving and steering international activities to address challenges of major significance for Europe (e.g. within IPCC, CCAMLR, SCAR, IGBP and IPY). European national operations already invest a significant budget into Southern Ocean research. Developing cohesive research activities to address joint goals will maximise the impact of European research funding. Building on the coordination of research that has developed under IGBP, IPY and through EUR-OCEANS will enhance the legacy of the European research effort in the Southern Ocean.

[iii] Big Question

How will change affect the structure and function of Southern Ocean ecosystems and biogeochemical cycles?

[iv] Secondary questions

Across the Southern Ocean key differences exist in the structure and function of regional ecosystems.

However, given its unique circumpolar nature, this is a highly connected ocean. The structure and function (states) of each particular ecosystem affects its operation and that of connected ecosystems, and hence impacts the services the Southern Ocean provides. These include fisheries, the export of carbon and maintenance of higher predator populations (tourism interest). Furthermore, marked changes are occurring in physical, biogeochemical and ecological processes across the Southern Ocean, and these changes vary between the different regions and ecological systems (e.g between ice or open water ecosystems or krill or fish dominated ecosystems). Understanding the differences between such systems - the variation in underlying physical and biogeochemical properties, and food web structure – will allow us to make projections of how changes in drivers will affect the circumpolar ecosystem in terms of structure and function and feedbacks to the wider Earth System. In short, these different regional systems potentially provide a view of the range of possible ecosystems that can occur in the Southern Ocean and are thus valuable natural laboratories for studying change.

To focus the effort to compare regional ecosystems across the Southern Ocean we identify a series of sub-questions:

a. How do current differences in physical and biogeochemical processes (e.g. iron cycling, sea ice dynamics and advection) explain current differences between regional or trophically different ecosystems (e.g. a diatom-krill system as opposed to a recycling-copepod dominated system)?
    i. Can we identify the underlying determinants of regional ecosystem structure?
    ii. Can we use the contrasting differences in ecosystem structure and function as a proxy for understanding the effects of different climate conditions?
b. How did the structure and function of Southern Ocean ecosystems vary over the last 200 and 1000 years as a result of climate variation or fishing?
c. How will future climate driven change affect regional physical/biogeochemical drivers and in turn ecosystem structure and function?
d. How will future changes in fishery practices affect ecosystem structure and function?
e. How does the structure of Southern Ocean ecosystems influence how they affect and feedback physically, chemically and biologically on climate processes?

[v] Need for comparisons to understand the controls on ecosystem structure and function

To address these questions we need to develop understanding of the key drivers and mechanisms involved in determining the structure and functioning of the different regional ecosystems that make up the Southern Ocean. Below we present the current view of the key drivers. We will need to consider how these may change in the future. We have also considered ways of identifying and defining the key regions that will allow us to examine and contrast the effects of these different drivers. We will determine how we can quantify differences in structure and function to facilitate comparative analyses. This process will form the basis for developing projections of the future change.

[vi] Drivers of ecosystem structure and function, and of change

We identify major drivers of change that are likely to have a significant impact on Southern Ocean ecosystem structure and function over the next 50 to 100 years.

a. Major drivers of change
    i. Positive trend in SAM: increased wind forcing
    ii. Changing sea-ice distribution
    iii. Ocean warming and stratification
    iv. Changing ocean circulation and frontal dynamics
    v. Ocean acidification
    vi. Past and future harvesting of marine biomass

b. Minor or poorly understood drivers of change
    i. Invasive species into pelagic ecosystems
    ii. The development of tourism
    iii. Disease/parasitism

[vii] Key regional ecosystems

In defining key regions for developing comparisons, distinctions between regional ecosystems could be based on large scale views of biological zonation, for example the view of circumpolar zonally consistent ecological systems of Hempel and Longhurst (ref), or the more detailed geographic definition based on physical and chemical bioregionalisation (Grant et al. *). These could be further refined to define regions, for example the circumpolar zonal pattern provides a hypothesis for analysing circumpolar structure, and could focus on deviations from that zonal pattern. This would be useful to understand the resultant impact of such deviations on ecosystem structure and function. The bioregionalisation methodology could also be further developed, for example, chlorophyll a concentration could be included as a proxy for high iron regions.

Alternative comparative analyses could include:

A gradient based analysis from permanently ice covered regions to open ocean regions encompassing for example the West Antarctic Peninsula, Scotia Sea, South Georgia and Kerguelan areas.

A system based comparison between different types of ecosystem including for example the Polar Front, open ocean, Marginal Ice Zone, shelf and ice ecosystems and could be expanded to consider regional variations within these types of systems?

Specific bi-lateral comparisons or analyses could include:

a. Kerguelen vs South Georgia
b. West Antarctic Peninsula vs Dumont d'Urville
c. Open ocean vs Antarctic Circumpolar Current
d. Scotia Sea vs Polar Front
e. Eastern Pacific vs Atlantic

Sea-ice focused studies could compare regions of high vs low sea ice and consider structure and function in different regions and what is the potential for ice systems to become ice free ecosystems?

f. Dumont d'Urville and West Antarctic comparisons
g. Along West Antarctic Peninsula from Marguerite Bay, Elephant Island, South Orkney Islands, South Georgia and Bouvet
h. West Antarctic Peninsula vs East Antarctic Peninsula

Iron recycling

i. Across zones/gradients
j. High nutrient low chlorophyll (HNLC) vs natural iron fertilised regions
k. Across different macro nutrient regimes
l. Other questions to further focus effort could include:
    i. What is the impact of iron in high chlorophyll region?
    ii. What are the regeneration rates of major nutrients

Carbon export

m. Contrasting productivity regimes

Fisheries

n. Contrasting fishing regimes or histories

Ecological based comparisons

o. Trophic level based differences e.g.
   i. Diatom vs none diatom
   ii. Krill vs salps (amphipods, copepods, mesopelagic fish)
   iii. Different types of top predators e.g. Emperor penguin vs King penguin

Frontal systems

p. West Antarctic Peninsula, South Georgia, Kerguelan vs more stable open ocean or coastal frontal regions.

Other comparative bases

q. Ross Sea as an end point for comparison, because it is so far south it can be considered as the most polar oceanic/shelf region.
r. Boundary regions will be particularly sensitive to change, such as the marginal ice zone or fronts could be an important focus for effort.

[viii] How to compare?

There will be a need to consider how to describe, represent and quantify the different ecosystems to allow comparative analyses. This will require the development of methodologies for comparing different systems. This will need to consider different approaches to analyses of aspects of ecosystem operation that will need to be considered in developing ecosystem comparisons. For example, how to include: vertical links in analyses of ecosystem structure (e.g. pelagic-benthic or pelagic-mesopelagic-benthic), connections between subsystems (oceanic-coastal or ice to open water), different levels of biological organisation in determining responses to change (e.g. genetic basis for physiological responses of individual species, population responses or food web level outcomes) and issues of spatial and temporal scale in analysing and modelling interactions?

[ix] How to make projections?

A series of reconstructions of past and projections of future change in the key drivers will be required to allow hindcasts and projections of ecosystem structure and function. This will require the development of appropriate species and ecosystem models that represent the major differences in ecosystem structure and function.

[x] Implementation

An implementation plan will be required to develop analyses of regional ecosystem structure and function. This will require focused research in key areas underpinned by large scale and long term analyses based on remote sensing and monitoring. This will require a combination of approaches including:

a. Process studies focusing on:
   i. Key and alternative species life cycles
   ii. Quantifying food web structure and dynamics
   iii. Biogeochemical-trophic links
   iv. Scientific manipulation/experimentation
b. Monitoring
   i. A focused development of biological monitoring is required to allow comparison analyses of ecosystem structure and variability and response to change. This will require views at two scales: circumpolar and regional, to ensure appropriate coverage. This should link to the developing SOOS programme. The regional studies could be the basis for the development of locally intensive observation and

monitoring programmes. These *Intensive Ocean Ecosystem Observation Sites* could be built around current capacity (e.g. moorings that are in place, krill biomass surveys or predator monitoring sites). Developing observation and analyses of seasonality and its variation will be important. These sites would be the appropriate basis for developing and deploying new technologies (e.g. biosensors on gliders, optical profilers or molecular analyses.

c. Data syntheses & data management
    i. Develop data mining and syntheses of historical data
        1. Key regions
        2. Circumpolar
    ii. Connect available electronic databases
d. Modelling
    i. ICED has focused on developing modelling of Southern Ocean ecosystems. A particular focus has been on the development of food web models, which will be a valuable basis for developing comparative analyses of regional ecosystems.
e. Integrating/coordination

Ensure parallel development and integration of research effort.

[xi] Antarctic-Arctic comparisons of ecosystem structure and function

The general concept of identifying the key drivers determining ecosystem structure, comparing these structures and projecting how these may change could also be applied in the Arctic to facilitate comparisons of the effects of change at the two poles. For example, what is the structure and function of ecosystems in high production, high diatom environments in the Arctic? Are the underlying structures similar between the Southern Ocean and the Arctic Ocean even if species vary?

[xii] Next steps

- Prepare workshop report and short summary statement
- Consider options for influencing FP8 – state clear benefits for Europe
- Articulate key questions for European and international polar research (based on the above), and focus on certain aspects of the comparisons to form a central focus (bring in focus for national efforts as well as joint European efforts, plus outside Europe efforts).
- Develop concepts and approach for Antarctic/Arctic comparisons.
- Organise a meeting in Brussels to inform the commission on important science issues and questions – with input from colleagues from USA, Australia and elsewhere
- Hold a project-oriented meeting to construct a science plan towards a proposal

5b. Impacts of a changing Arctic Ocean

i. Summary

The main focus will be on the impact of the changing climate in the Arctic oceans: Consequences for Europe

- Where are the largest changes, what are the causes, which consequences and opportunities will they have?
    - How do systems operate and change at the gateway to the arctic, in the central Arctic and on the shelf?
    - What is the impact of freshwater, nutrients, light?
    - What is and how operates the transport of energy and its dissipation

- How do Arctic Ocean organisms and ecosystems respond to environmental transitions including temperature, stratification, ice conditions, and pH?
- How will biogeochemical cycling respond to transitions in terrestrial, gateway and shelf-to-basin fluxes?

ii. Background

Time is running out for the Arctic. The ecosystems of the immense continental shelves of the Arctic Ocean are presently impacted by what is forecasted to be one of the most abrupt climate shifts in the history of Earth. Already, spectacular ecosystem changes are observed at the periphery of the Arctic Ocean in response to the changing ice regime. This transformation will alter biological productivity with large consequences for the unique and charismatic Arctic marine fauna. This will occur in parallel to increased anthropogenic impacts linked to the industrialization of the Arctic Ocean.

Forecasting the response of Arctic Ocean ecosystems to these amplifying climate and industrial stresses requires pan-Arctic syntheses of existing knowledge and the circum-Arctic coordination of new research efforts. Research in the Arctic is typically conducted, and, thus funded, on a national level. Consequently our scientific understanding of the Arctic is often restricted to geographical regions. The aim of this proposal is to outline the general principles governing the response of Arctic ecosystems to climate change to enable Pan-Arctic integration and cooperation through synthesis of existing data and coordination of existing and future research programs. We wish to move away from conducting “backyard” science of regional interest towards pan-Arctic science that has international significance.

We propose to achieve such circum-polar syntheses by further integrating national efforts in the study of the changing Arctic Ocean. EUR-OCEAN is an umbrella program that is driven by science, for scientists that will inform the decisions of governments, local populations, and industries facing these changes.

Activities to achieve this Pan-Arctic integration include:
- Utilization of existing research data against hypotheses
- Identification of knowledge gaps and design initiatives to fill these
- Integrate national research programs
- Mobility and exchange of scientists, particularly students
- International outreach projects
- Agreements for sharing of logistics and facilities

iii. Aim and Research Questions

Main Aim:
Relate the observed and predicted changes in Arctic sea ice (in terms of its extent/thickness/age) to ecological impacts by studying the coupled physical and biological processes.

This main aim leads to a set of over-arching research questions which address the nature of the links, feedbacks and scale of action:

R1. What is the cascade of physical and biological processes through the Arctic marine systems that is initiated by climate cycles?

R2. How important is synchronisation and at what spatial scales do we find synchronisation in biological and physical processes within the Arctic?

R3. How do the consequences of climate change in the Arctic affect the functioning of the marine food web, particularly the productive hotspots and the impacts on harvested species?

iv. Themes, Tasks and Hypotheses

Climate change will initiate cascading effects, regime shifts and non-linear feedbacks of physical and biological processes in Arctic ecosystems.

- Climate change will modify/change/affect the timing and location of key physical and ecosystem processes in the Arctic
- Sea ice change, as a key link between physical and biological systems, regulates key ecological functions through mediation of primary production (quality, quantity/magnitude, timing, and location) and changes in extent and thickness alter the habitat for consumers.

Theme 1. Ice and snow thermodynamics and dynamics
What are the relationships between ice morphology, snow distribution, radiative transfer, ice-algal distribution and abundance/biomass of ice-associated organisms in a FYI dominated Arctic Ocean?

Theme 2. Stratification and upwelling
Changes in stratification will induce shifts or changes in the productivity along the shelf break.

Theme 3. Advection
Advection of ice, water masses, species, contaminants

Theme 4. Light environment
Changes in sea ice cover/coverage (+snow) will change the light regime of the Arctic Ocean, with implications for physical, chemical and biological processes.

Theme 5. Timing and life cycle strategies
Climate change will modify/change/affect the timing and location of key physical and ecosystem processes in the Arctic.

Theme 5. Trophic structure of ecosystems
The trophic structure of ice-associated ecosystems will change based on changes in energy flow (bottom-up), introductions (new species to the Arctic) and altered predation (top-down). The

intermediate part of the food web will likely expand (e.g. pelagic fish), whereas the upper trophic levels may be reduced (or altered).

6. Relevance to the Consortium objectives

The workshop met the objectives of the EUR-OCEANS Consortium including the promotion and coordination of (1) *Top-level scientific research* on the impacts of anthropogenic and natural forcings on ocean ecosystems and (2) Optimal use of *shared technical infrastructures and scientific facilities.* The objectives also met the scientific themes and priorities set out in the EUR-OCEANS Consortium Scientific Perspective document. The objectives of this workshop addressed the integration of population and food-web dynamics with environmental and anthropogenic forcing to understand and predict changes in marine ecosystems. Science discussed relevant in polar regions ensures that EUR-OCEANS will have a strong input to identify and quantify ecological and social-economical controls and their dynamics. The workshop addressed the requirements for scenario testing in polar marine ecosystems under anthropogenic and natural forcing in the 21st Century.

7. Links / synergies / added value with respect to existing programmes or projects

This workshop strengthened existing links between EUR-OCEANS and ICED scientists and ensured to develop climate change research in polar marine ecosystems. The workshop built on upon the work of ICED and its emerging sub-programme Sentinel, which aims develop a suite of biological monitoring sites and predictions for climate change on Southern Ocean ecosystems (see http://www.acecrc.org.au/drawpage.cgi?pid=antarctica_climate_change). The workshop linked and aided the development of the Southern Ocean Observing System (SOOS), an international collaborative programme for monitoring physical change in the Southern Ocean (see http://www.noc.soton.ac.uk/CLIVAR/organization/southern/expertgroup/SOOS.htm). In developing such research in the Arctic, this workshop has also forged links with the Ecosystem Studies of Sub-Arctic Seas programme (ESSAS, see http://www.globec.org/structure/regional/essas/essas.htm).

9. The budget and funding level requested from EUR-OCEANS

The funding received from EUR-OCEANS= **€12,000** was supplemented by extra funding from AWI and ICED to ensure wide participation of key scientists.

ANEX 1: Participant list EUR-OCEANS Workshop 15-17th November 2010 (9:00-18:00), Bremerhaven,

Country	Organisation	Name
Australia	AAD	Steve NICOL
France	INSU-CRNS	Jean-Marie FLAUD
France	INSU-CRNS	Denis-Didier ROUSSEAU
France	UBO	Paul TREGUER
France	UnivMed	Bernard QUEGUINER
Germany	AWI	Ulrich BATHMANN
Germany	AWI	Antje BOETIUS
Germany	AWI	Rüdiger GERDES
Germany	AWI	Michael KLAGES
Germany	AWI	Svenja KRUSE
Germany	AWI	Bettina MEYER
Germany	AWI	Ursula SCHAUER
Germany	AWI	Victor SMETACEK
Germany	AWI	Dieter WOLF-GLADROW
Germany	UniHB	Robert HUBER
Norway	UNIS	Jørgen BERGE
Norway	Uni Oslo	Bente EDVARDSEN
Norway	NPolar	Stig FALK-PETERSEN
Norway	NTNU	Egil SAKSHAUG
UK	BAS	Rachel CAVANAGH
UK	BAS	Simeon HILL
UK	BAS	Eugene MURPHY
USA	ODU	Eileen HOFMANN
Guests:		
	AWI	Astrid BRACHER
	AWI	Thomas BREY
	AWI	Gerhard DIECKMANN
	AWI	Hans-Jürgen HIRCHE
	AWI	Christine KLAAS
	AWI	Rainer KNUST
	AWI	Katja METFIES
	AWI	Barbara NIEHOFF
	AWI	Eva-Maria NÖTHIG
	AWI	Ilka PEEKEN
	AWI	Volker STRASS
	Uni. Moscow, Rus	Ksenia KOSOBOKOVA

EUR-OCEANS Workshop - Agenda

15-17th November 2010 (9:00-18:00)

Am Handelshafen 12, Bremerhaven, Germany – Room: E-4005

Monday, 15.11.2010	**DAY 1: PRESENTATIONS AND IDENTIFICATION OF MAJOR CHALLENGES**	
10:00 – 10:30 10:30 – 10:45 10:45 – 11:00	Ulrich Bathmann Eugene Murphy Egil Sakshaug	Outline and aims of the workshop Perspectives in Antarctic research Perspectives for future Arctic research
11:00 – 11:20	Coffee break	
11:20 – 11:40	Dieter Wolf-Gladrow	Modelling of biochemical cycles in polar oceans
11:40 – 12:00	Eugene Murphy	Food web dynamics under change
12:00 – 12:20	Rüdiger Gerdes	Sea ice dynamics in the Arctic compared to the Antarctic and perspectives of future scenarios
12:20 – 12:40	Eileen Hofmann	Coupled physical-biological models for the Southern Ocean
12:40 – 13:00	Discussion	
13:00 – 14:00	Lunch	
14:00 – 14:20	Victor Smetacek	The mystery of missing silica in the Southern Ocean
14:20 – 14:40	Bernard Quéguiner	Natural iron fertilization and pelagic ecosystem structure in the Southern Ocean: Lessons from KEOPS 1 and new questions for KEOPS 2
14:40 – 15:00	Bettina Meyer	Focus on Antarctic key stone species - The impact of climate change on biodiversity, biogeochemical cycles and food web processes in the marine pelagic system
15:00 – 15:20	Steve Nicol	Potential for change in East Antarctic marine ecosystems
15:20 – 15:40	Discussion	
15:40 – 16:00	Coffee break	
16:00 – 16:20	Paul Tréguer	Is the silicic acid leakage hypothesis supported by facts?
16:20 – 16:40	Simeon Hill	Rapid change as a challenge to sustainable fisheries management
16:40 – 17:00	Summary: Identification of important changes, responses, regions and required data for Antarctic research (Rachel Cavanagh and Svenja Kruse)	
17:00 – 18:00	Discussion Antarctic research	

Tuesday, 16.11.2010	DAY 2: CONTINUATION OF DAY 1 AND PRESENTATION OF PLANNED ACTIVITIES	
09:00 – 09:20	Ursula Schauer	Physics set the scene in the Arctic – Will it change?
09:20 – 09:40	Bente Edvardsen	Diversity and distribution of nano- and pico-plankton in polar waters
09:40 – 10:00	Stig Falk-Petersen	Timing of the blooms determines the life strategy of Arctic *Calanus*
10:00 – 10:20	Jørgen Berge	Circadian rhythms of Arctic zooplankton during the polar night – Patterns, processes and implications
10:20 – 10:40	Discussion	
10:40 – 11:00	Coffee break	
11:00 – 11:20	A. Boetius/M. Klages	Biological and biochemical response of Arctic deep-sea to current change
11:20 – 11:40	A. Boetius/M. Klages	New technological innovations open fields of polar research
11:40 – 12:00	Ulrich Bathmann	Sustainable use of polar systems
12:00 – 12:20	Robert Huber	Data management and archives – How to improve
12:20 – 12:40	Discussion	
12:40 – 13:00	Summary: Identification of important changes, responses, regions and required data for Arctic research (Stig Falk-Petersen)	
13:00 – 14:00	Lunch	
14:00 – 15:40	Discussion Arctic research	
15:40 – 16:00	Coffee break	
16:00 – 18:00	Presentation of planned field activities by all participants	
18:30	Dinner at “Alfreds”	

Wednesday, 17.11.2010	DAY 3: FUTURE REQUIREMENTS AND WORKSHOP OUTCOME
09:00 – 13:00 (coffee break in between)	What are the future requirements for polar EUR-OCEANS research? The participants will split into groups that focus on Arctic and Antarctic. They • will reformulate the "keys" (#2) 1. State of the art – Do we have a good handle to record the major changes in polar regions? 2. Outlook – Which responses do we expect to ongoing environmental changes? What are the key questions? Which geographical regions in polar marine ecosystems are of particular interest? Which data do we need to improve our models? • suggest combined activities/ future fieldwork How can they be linked to existing programmes and projects?
13:00 – 14:00	Lunch
14:00 – 15:00	The outcome of the working groups will be summarised in terms of major challenges, coordination of planned field activities (including ICED) and future requirements.
15:00 – 17:00 (coffee break in between)	Towards a joint EU-Proposal
17:00 – 18:00	Close up in formulating next steps and activities

ANEX 3: Expeditions related to EUR-OCEANS to the Arctic (ARC) and Antarctic (ANT) colour coded for the different nations as compiled during the EUR-OCEANS workshop in Bremerhaven Nov 2010.