Marine ecosystem consequences of climate induced changes in water masses off West-Spitsbergen (MariClim)

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1 Goal, main hypothesis and objectives

The overall goal of this project is to determine the influence of climate variability and change on the energy transfer in the marine pelagic ecosystem in different water masses on the west coast of Spitsbergen. The project will compare the pelagic food webs in fronts involving Arctic (ArW) and Atlantic water masses (AW) in this high-Arctic region.

The extent of the ice cover in the Nordic Seas in spring has decreased since 1860 due to the net thermal effect of the northbound currents (Vinje 2001). A continuation of this trend is predicted by general circulation models (GCMs, IPCC 2000). If these predictions are correct, a permanent warming of the Arctic's climate and a further decrease of the sea ice extent in the Barents Sea and the Arctic Ocean will occur. Variations in the inflow of AW and outflow of ArW masses are shown to be strongly related to changes in the atmospheric pressure systems over the Arctic Ocean (Proshutinsky *et al.* 1999) and the North Atlantic Oscillation (Dickson *et al.* 2000) on inter-annual and decadal scales. These pressure systems are strongly linked to the atmospheric heat balance, and climate changes may thus alter the strength of the large-scale oceanic circulation in the region. This would change the relative amount of source water (ArW and AW), which is mixed and transformed into water masses on the shelf off West-Spitsbergen and also in the adjacent fjords.

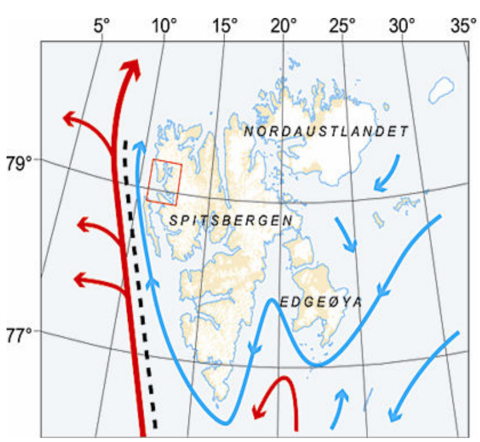

Fig 1. Main currents on West-Spitsbergen with Kongsfjorden-Krossfjorden indicated.

The Kongsfjorden-Krossfjorden shelf and fjord system (Fig. 1) is particularly suitable for studies of effects of climate change on ecosystems because it lies adjacent to both Arctic and Atlantic water masses. In addition, there is a significant amount of observations available from this area (reviews, Hop *et al.* 2002; Svendsen *et al.* 2002). The inclusion of these observations and existing time-series for this area is imperative for the detection of changes. In particular we have long time series of zooplankton composition for this area. The relative composition of zooplankton depends on water masses and sea ice concentration. Changes in the zooplankton composition will result in altered energy transfer within the pelagic food web with potential consequences for growth and survival of seabirds.

The new Arctic Marine Laboratory in Ny-Ålesund, Kongsfjorden, gives this project a unique opportunity to perform controlled experiments on the energy transfer in Arctic marine food chains.

Our main hypothesis is:

> ***Climate change will affect the distribution of warm AW and cold ArW masses of shelf and fjord regimes in West-Spitsbergen. This will alter the zooplankton composition and subsequently change the energy transfer within the pelagic food web with consequences for upper trophic levels.***

Ecological consequences of climate change on the marine pelagic ecosystem, during cold and warm scenarios, are illustrated in Fig. 2. A ***cold climate scenario*** would result from less influx of AW to the shelf and fjord areas in West-Spitsbergen, whereas a ***warm climate scenario*** would occur because of an increased influx of AW. The energy flow in the marine pelagic food web would be dominated by either Arctic or Atlantic zooplankton species. Seabirds such as the Little auk (*Alle alle*), that rely on large Arctic *Calanus* species with high lipid content may decline if their food base diminishes during the warm scenario. The Black-legged kittiwake (*Rissa tridactyla*) may also be negatively affected, but because this species also preys on the Polar cod (*Boreogadus saida*) as well as other large zooplankton such as *Themisto libellula*, it may be less affected. Thus, it is important to understand the predator-prey relationships between Polar cod, *Calanus* and *Themisto* within the intermediate part of the pelagic food web to be able to explain food web effects on Kittiwakes. The ecological consequences of climate variability will be studied within the time frame of the project, and the effects of climate changes will be addressed based on the collected data as well as time-series that exist for the physical environment and marine pelagic ecosystem of Kongsfjorden and adjacent waters.

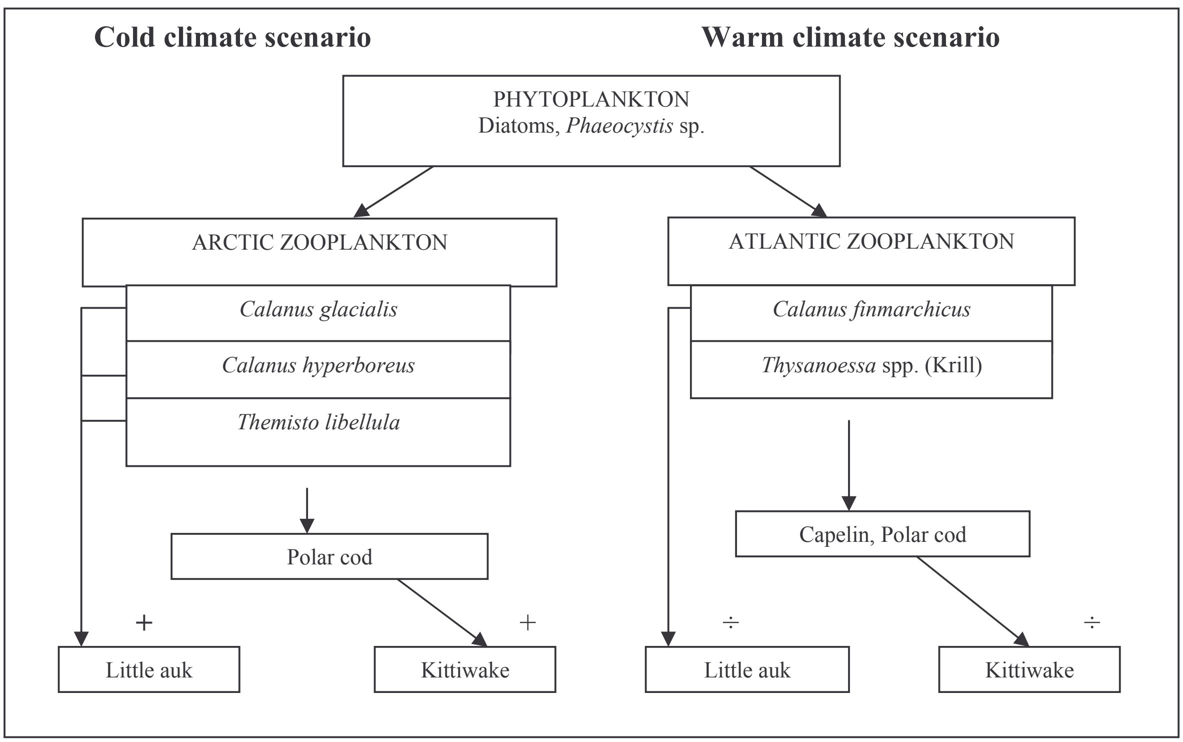

Fig. 2. Cold and warm climate scenarios with potential effects on the structure and energy flow in the marine pelagic food web off West-Spitsbergen. + indicates a positive effect with expected increase in population size. ÷ indicates a negative effect with expected decrease in population size.

The project tasks are centred on working hypotheses with associated objectives:

Working hypotheses and objectives:

H1: *Climate change will alter the volume transport and characteristics of AW, the recirculating deep ArW and Arctic surface water. Subsequently the exchange of water* *masses in the gradient shelf slope -West-Spitsbergen fjords will be affected, and by that also the fast ice condition in Kongsfjorden.*

Objective 1.1: Investigate a-geostrophic processes in the shelf slope current West-Spitsbergen Current (WSC) and in the coastal current boarding the fjord mouths that govern the exchange between AW, ArW and the adjacent West-Spitsbergen fjords.

Objective 1.2: Verify the effect of climatic variability on fjord-shelf circulation, exchange patterns, and fast ice evolution.

***H2:** Variability in water circulation patterns is the main mechanism regulating the distribution and size structure of zooplankton and pelagic fish.*

Objective 2.1: Determine how variations in water mass characteristics affect the spatial and temporal distribution of zooplankton.

Objective 2.2: Determine the changes in abundance of zooplankton and Polar cod across the main fronts of the Kongsfjorden – Kongsfjord shelf.

***H3**: Changes in size and energy content of key zooplankton prey will influence the energy transfer in the pelagic food web with consequences for growth and survival of Little auk and Black-legged kittiwake chicks.*

Objective 3.1: Determine predator-prey relationships in selected components of the pelagic system.

Objective 3.2: Determine experimentally if changes in energy content of zooplankton prey influence the energy transfer to juvenile Polar cod.

Objective 3.3: Determine how the availability of suitable prey affects the foraging behaviour, energy transfer and chick survival in Little auk and Kittiwake.

2 Scientific background

Inter-annual and decadal variations in the atmospheric pressure systems (AO and NAO) cause variations in the transport of water masses in the Nordic Seas and the Arctic Ocean. Mostly the volume transport, and to some extent also the characteristics of the water masses get affected while the circulation pathway is determined by the strong topographic steering at high latitudes. Variations in the large-scale atmospheric pressure system may also affect the "local" pressure system, especially the position of the low pressure track in the area, which has great impact on both the direction and strength of the fjord wind (Argentini *et al.* 1999; Hansen-Bauer *et al.* 1990).

The water masses found along the west coast of Spitsbergen can be traced back to both Atlantic and Arctic origins. The warm, salty AW in the WSC is the northernmost surface extension of the Atlantic inflow to the Nordic Seas. In addition, a northward coastal current on the shelf brings cold and relatively fresh Arctic-type water originating from the northern Barents Sea. AW remnants found on the shelf provide evidence of irreversible exchange across the front between AW and ArW (Saloranta & Svendsen 2001). Upwelling along the West-Spitsbergen shelf slope may introduce plankton communities from deeper water masses onto the shelf. These water masses may originate from the Arctic Oceans and are guided to the West-Spitsbergen coast by topographic steering in the Greenland Sea (Jones *et al.* 1995).

The annual temperature at Longyearbyen airport (Svalbard) has increased by 0.14°C per decade since 1912, and, given continuation of the warming trend, the projected increase is 0.61°C per decade from 1961-2050 (Hansen-Bauer 2002). In recent years the sea ice-extent has become reduced in the Northern Seas (Vinje 2001), and the temperature of the AW in the WSC has increased (Saloranta & Haugan 2001). The AW currently makes the area west of the West-Spitsbergen shelf essentially ice-free (Aagaard *et al.* 1987; Gascard *et al.* 1995), and the fjords on West-Spitsbergen could be characterised as sub-arctic. However, another scenario predicts a reduction in the flow of AW to the Nordic Seas with subsequent cooling and more sea ice (Hansen & Østerhus 2000). In Kongsfjorden, landfast sea ice formation usually starts between December and February/March, and melting usually starts in the beginning of June (Gerland *et al.* 1999). Maximum ice thicknesses are observed to be below 1 m, which is substantially less than locations with seasonal fast ice in Arctic Canada (Gerland *et al.* 1999). Superimposed ice near the surface contributes to the firstly formed fast ice and extends the lifetime of the ice (Nicolaus *et al.* 2003). Furthermore, the optical surface properties play an important role for the energy balance and the timing of the decay of the ice (Gerland *et al.* 1999; Winther *et al.* 2004).

Climate change effects on water masses in the Svalbard area can be sought in West-Spitsbergen fjords because the water masses in most of these fjords are to a large degree determined by exchange with modified AW. In Kongsfjorden, observations repeatedly show that the outer fjord is heavily influenced by AW, whereas towards the inner fjord the influence of freshwater runoff and sediment input from large tidal glaciers contributes significantly (Svendsen *et al.* 2002). Kongsvegen, the largest of the glaciers that circumscribes Kongsfjorden's inner coast, has a peak discharge of 139 $m^3 s^{-1}$ (Svendsen *et al.* 2002).

Kongsfjorden's pelagic food web is composed of both boreal and Arctic species (Hop *et al.* 2002), as a consequence of the presence of both AW and ArW masses as well as glacial inputs. Because Kongsfjorden receives variable climatic signals between years, it functions as a climate indicator on a local scale. A marked shift in the zooplankton composition has been observed between years with cold water and warm water. In the "warm year" of 1997, *C. finmarchicus* dominated, whereas in the "cold year" of 1996 the much larger *C. glacialis* made up 50% of the *Calanus* community (Kwasniewski *et al.* 2003). The amphipod *Themisto libellula* has been shown to rely on Arctic water masses to thrive (Dalpadado 2002).

The size spectrum and energy content of the key zooplankton species in Arctic ecosystems determine their value as food sources for intermediate and upper trophic levels. For example in the dominant herbivorous *Calanus* species, *C. glacialis* and *C. hyperboreus* contain 10 and 25 times more energy (lipids), respectively, than *C. finmarchicus* (Scott *et al.* 2000). Also, the large Arctic *Calanus* species contain 50% more energy (per unit dry weight) than juvenile *Themisto libellula* (Hop *et al.* 1997). The ingestion of different prey types therefore has consequences for the energetic values of Polar cod (Hop *et al.* 1997). The availability of prey and their energy values subsequently influence the growth and survival of seabird chicks that are fed these organisms.

The main pelagic feeding areas for seabirds that occupy Kongsfjorden include fronts between water masses (AW vs. ArW), upwelling areas along sea ice edges and in the confluence zones of discharged glacial melt water (Hop *et al.* 2002). Seabirds may fly long distances to feed outside the fjord, targeting coastal frontal areas where water masses meet and prey species are concentrated, but this is energetically costly. Dependent on availability of suitable prey, Little auks and Kittiwakes forage both within Kongsfjorden and in offshore waters. Little auks dive within 40 m depth and feed mainly on Arctic copepods (Mehlum & Gabrielsen 1993). In Hornsund fjord, south of Kongsfjorden, Little auks have been found to avoid feeding in Atlantic derived water (Karnovsky *et al*. 2003). Analysis of food samples from Kittiwakes, collected in Kongsfjorden, show that they feed mainly on pelagic fishes (Polar cod and Capelin) and crustaceans (amphipods *Themisto* spp. and Krill *Thysanoessa inermis*) (Mehlum & Gabrielsen 1993; Gabrielsen pers. obs.). The seabirds require access to abundant and energy-rich zooplankton and fish in order to raise their chicks successfully.

Climate related changes in water masses would be expected to indirectly affect these seabirds through changes in their prey base and associated energy transfer.

3 Proposed research

The proposed research is listed as tasks (numbers referring to objectives) with methodical approaches. Scientists responsible for performing these tasks are listed in Appendix 1.

T 1.1.1: Use numerical models, historical data and observations of physical parameters during the project to study climatic effects on shelf-fjord exchange processes and identify the mechanisms governing the lateral exchange of AW and ArW masses in the gradient shelf slope-shelf-fjord.

Methods: Hydrographic surveys of the fjord and adjacent shelf will be made, and one mooring, (three Aanderaa RCM) measuring currents, temperature and salinity will be deployed at a location in Kongsfjorden. In addition, the oceanographic mooring stationed in outer Kongsfjorden and operated by Dunstaffnage Marine Laboratory (Scottish Association of Marine Science, Oban) will become part of this study. It carries current metres, temperature and salinity recorders, sediment trap and an Acoustic Doppler Current Profiler (ADCP). A 3D-hydrodynamical model will be established for the Kongsfjorden-Krossfjorden system and the adjacent shelf area. An already existing setup using the Bergen Ocean Model (BOM) will be developed further. However, another model system will also be considered; the Regional Ocean System (ROMS) including a sea ice module. Relevant existing data will be analysed and also used to validate the models. Climate scenarios will be provided for the numerical models.

T 1.1.2: Estimate local production of water masses in Kongsfjorden from winter cooling and the effect of climate variability on fast ice evolution in Kongsfjorden.

Methods: Hydrographic surveys, data analysis and modelling with validations will be carried out (Methods in Task 1.1.1). Measurements from a bottom mounted ADCP, with temperature and salinity sensors, will be transferred via cable from the instrument to the new Marine Laboratory in Ny-Ålesund. Ice production/decay and ice concentration data will be collated and derived using weekly Synthetic Aperture Radar (SAR) satellite images (ENVISAT ASAR and RADARSAT) during times when fast ice is forming and decaying. Regular snow and ice thickness observations (drillings and indirect measurements) will be performed as well as daily fjord photography from the Zeppelin Mountain (visibility permitting), the latter two being part of an ongoing sea ice monitoring project in Kongsfjorden (NPI)), and advanced modelling (Univ. Bergen, NPI and AWI). Time-series of data from three thermistor chains during the fjord ice season will be obtained. Snow and ice surface properties (snow types, crystal sizes, liquid water content, density, surface albedo, occurrence of superimposed ice) during melt, which play significant roles for the lifetime of the fast ice, will be studied in detail with high temporal resolution (NPI and AWI).

Atmospheric energy balance data (e.g. incoming and reflected solar radiation) from the research station of the NPI at Ny-Ålesund will be used to distinguish influences on sea ice development related to either atmospheric or hydrographic forcing. Results from another NFR project (Atmosphere-Ice-Ocean Interactions studies, Programme Polar USA – Norway) will support the detailed hydrographic and sea ice studies, as well as climate data from the AWI Koldewey station in Ny-Ålesund.

T 1.2.1: Gather relevant historical data and new observations in databases to be used for analysis of climate variability and model validations.

Methods: Relevant data are: Historical hydrographic data from the ICES data bank (1905-1992), hydrographic data (1993-) and sea ice data (1997-) collected by NPI, GI, UNIS and

IOPAS; current measurements from the shelf slope (AWI) and current measurements by ADCP (SAMS); a tide gauge in Ny-Ålesund (NMA); meteorological data from the hindcast data bank (met.no) and from the weather stations in Ny-Ålesund (met.no) and melt-onset and superimposed ice data (1997-) by AWI.

T 2.1.1: Determine zooplankton abundance and advection relative to water mass characteristics in Kongsfjorden-Kongsfjord shelf.

Methods: The zooplankton community will be sampled, depth-stratified, with Multi Plankton Sampler (MPS, 5 closing nets) at standard stations in Kongsfjorden, Kongsfjordrenna, and out over the shelf into deep water (1125m). The larger zooplankton fraction, including the amphipod *Themisto libellula* and Krill *Thysanoessa* spp., will be sampled with MIK net. The water mass characteristics will be obtained simultaneously with ship based CTD. Advection and vertical migration will be determined by a moored ADCP with continuous recording of vertical and horizontal movements of particles (zooplankton) during a 12-month period. In addition, temperature, salinity, currents and chlorophyll will be monitored at this mooring.

T 2.1.2: Relate changes in zooplankton community to variation in water masses, for data collected during the period of 1995-2007.

Methods: Information on zooplankton community structure (species, developmental stage, spatial distribution) obtained from samples along a station grid in Kongsfjorden (annually 1995 – 1998; 3 to 5 times each year from 1999 to 2007) will be compared with water mass characteristics to reveal the relationship between zooplankton community and influence of different water masses.

T 2.2.1: Determine distribution and abundance of pelagic fishes in cold and warm water masses and their relationship to zooplankton prey abundance.

Methods: Hydroacoustic transects will be performed with EK-60 from inner Kongsfjorden out to the shelf to determine spatial distribution in biomass of pelagic fishes. Both fish and zooplankton will be surveyed by means of transducers with different frequencies (38-120 kHz). Index sampling of zooplankton will be done with WP-2 nets and MPS, and fish will be sampled with a pelagic trawl.

T 3.1.1: Determine predator-prey relationships and transfer of energy, as marine lipids, within the pelagic food web.

Methods: Stable isotopes $\delta^{15}N$ and $\delta^{13}C$ will be determined in tissues from different organisms in the pelagic food web. Trophic levels will be assessed with $\delta^{15}N$, and carbon sources (i.e. terrestrial vs. marine) in the fjord-shelf system will be determined with $\delta^{13}C$. Stomach analysis will be used to determine feeding habits of pelagic fishes, such as Polar cod and Capelin, and sea birds. This will give short-term feeding information compared to stable isotopes. Fatty acid composition of different organisms in the marine pelagic food web will be determined at UNILAB Analyse and in the laboratory of AWI. Biomarkers will be used to determine predator/prey relationships, and multivariate statistical techniques will be used to determine differences between fatty acid signatures in components of the pelagic food web.

T 3.2.1: Relate zooplankton energy synthesis to environmental variation, such as temperature and food availability.

Methods: Lipid accumulation in calanoid copepods will be studied by field sampling as well as via experiments testing temperature-dependent biosynthesis. Dry weight, total lipids and lipid class composition will be measured at all growth stages and will subsequently be related to the growth of the population. Rates of biosynthesis will be studied in the lipid fraction.

T 3.2.2: Determine experimentally, in the Arctic Marine Laboratory in Ny-Ålesund, how the energy content and lipid composition of prey are transferred to the predator.

Methods: Controlled experiments will be performed with two prey types (*Calanus glacialis* vs. juvenile *Themisto libellula*) and juvenile Polar cod as predator. Differential growth rates will be determined for Polar cod fed different diets at different temperatures. The resulting change in energy content and lipid composition will be determined in the Polar cod, and their increased or decreased value as food for seabirds will be assessed.

T 3.3.1: Determine the spatial distribution and feeding behaviour of Little auks and Kittiwakes from inner part of Kongsfjorden out to the shelf slope and relate this to the oceanographic conditions, sea ice and distribution and abundance of prey.

Methods*:* The spatial distribution of Little auks and Kittiwakes at sea will be determined by ship-based surveys following standardised methods (Tasker *et al.* 1984). Comparison with background data on prey distribution will be used to determine selective feeding by different species. Tracking devices will be deployed on Kittiwakes to study their feeding activity and time allocation in relation to changes in oceanographic conditions and prey abundance.

T 3.3.2: Study changes in diet and reproductive success of Little auks and Kittiwakes in relation to the availability of zooplankton and the distribution of ArW and AW masses. Long-term data from seabird colonies will also be analysed to determine relationships between environmental conditions, chick growth and survival of the two seabird species.

Methods: Determine breeding success, chick growth rates, food habits, energy expenditure, foraging trip-lengths and foraging locations of Little auks and Kittiwakes from colonies in Kongsfjorden, Krossfjorden and Prins Karls Forland. Long-term population data (1988-) exist for Kittiwake in the sea bird database of the NPI. Data on productivity of Kittiwakes in Kongsfjorden exist from 1998. Trends and variations in these data will be compared to existing environmental data (sea and ambient temperature) and atmospheric conditions (including atmospheric oscillation indices). Data on productivity from Little auks exist from the Hornsund area from 1997 (Karnovsky, pers. comm.). Data on growth, food habits and trip-lengths from Little auks in Hornsund will be collected simultaneously in order to make comparison to the Kongsfjorden study.

T 3.3.3: Integrate diet information from seabirds, and their prey, into energetics models.

Methods: Dietary information, caloric content of prey consumed, population sizes of the predators, abundance and distribution of prey etc. will be integrated into foraging energetics models to explore how predicted changes in lower trophic levels due to climate change are likely to affect the population dynamics of Little auks and Kittiwakes in the Kongsfjorden/Krossfjorden area.

Sampling and measurement design

The positions of the two moorings, the SAMS mooring and the mooring carrying the three Aanderaa RCM, will be decided based on some preliminary simulations with the BOM. Main sampling transects will be conducted along the established hydrographic/zooplankton transects in Kongsfjorden (Hop *et al.* 2002) and down the shelf slope to the deep waters of the eastern Fram Strait. Data from the established sampling programmes will also be made available for this study. Hydroacoustic and seabird surveys will use zig-zag transects to obtain proper spatial coverage of zooplankton, pelagic fish and seabird distribution or biomass. In addition to the measurements taken by the bottom-mounted ADCP linked to the Arctic Marine Laboratory, a late winter (early spring bloom) survey will be focusing on the interaction between the fjord ice cover, local production and intrusion of water masses. For practical accomplishment of the proposed research, we will involve research vessels from participating institutions. R/V "Håkon Mosby" (GI/UNIS) will be used for oceanographic surveys for 10 days each year. R/V "Oceania" (IOPAS) will be used for oceanography and zooplankton research 7 days each year. R/V "Lance" (NPI) will be used for acoustic surveys, zooplankton-, fish-, seabird- and oceanography studies 10 days each year 2006-2008. Fieldwork will be carried out from Ny-Ålesund, using the well-established scientific infrastructure at site. Seabird studies are planned for 8 weeks in 2005-2008, with 4 weeks use of the new Arctic Marine Laboratory. Marine biology experiments and labwork is planned for 4 weeks in 2006-2007, using the new marine lab. One week of sea ice studies will be conducted in Kongsfjorden each year.

4 Innovations

Hydrographic ice-ocean model for Kongsfjorden and adjacent waters (GI): An advanced regional hydrographic model for the Kongsfjorden-Krossfjorden area will be developed based on the Bergen Ocean Model (BOM) and Regional Ocean System (ROMS), which include a sea ice module.
ADCPs in trawling resistant pyramids (NPI): Bottom trawling is generally a problem on slopes where current observations are most desirable. Trawling resistant pyramids have been developed for ADCPs (by GI) and will be put on the bottom mounted ADCP in the inner part of Kongsfjorden.
Seabird tracking transmitters (NPI): Tracking transmitters will be used to study the feeding areas of Kittiwakes in the Kongsfjorden-Krossfjorden area.
Energy transfer (NPI): Lipid biomarkers, stable isotopes and fatty acid signatures will be used to study the transfer of energy within the ecosystem. Field studies that include an ADCP mooring, which can monitor seasonal and daily vertical migration of zooplankton as well as physical variables, will be combined with experiments carried out in the new Arctic Marine Laboratory in Ny-Ålesund. Multivariate statistical methods, such as correspondence analysis, canonical correspondence analysis and log-ratio analysis, will be used to analyse food web prey-predator relationships.

5 Competence and network building

We plan to gather some of Europe's best-qualified scientists in the fields of marine ecology and bioenergetics, lipid chemistry, and polar oceanography, and with long experience in Arctic marine biology and physical oceanography. The work will involve a strong international collaboration based on the newly established ARCTOS network (ARCTic marine ecOSystem research network). The network has active links to major national and international institutions conducting research in the Arctic, and makes an effort to actively increase the interest in the effect of climate change on Arctic ecosystems among students. With the support of leading European, Canadian and US-American specialists, ARCTOS has established a virtual scientific trainee school with training courses and workshops (2-3 per year). The project will include competence building through 3 PhD students, 1.3 Post doc/guest researcher positions, and several Master students. The principal investigators have extensive Arctic experience, good publication records, and experience with university teaching and supervision of graduate students.This program is a direct result of our previous multidisciplinary programmes, e.g., ICE-BAR, BIODAFF, OAERRE (EU), Variability of the Barents Sea system and participation in ENVINET (EU-network), Large Scale Facility (EU-LSF), Marine Systems Working Group (NySMAC), *Calanus* and climate Nordic network (NARP), and two Kongsfjord Ecosystem Workshops. The principal investigators have lead and participated in assembling the extensive information that exists for Kongsfjorden (Hop *et al.* 2002; Svendsen *et al.* 2002).

6 Use of the infrastructure in Ny-Ålesund, Svalbard

Ny-Ålesund (78^{o} 55' N, 11^{o} 56' E) has developed into an international research platform. The biological research platform consists of the Arctic Marine Laboratory (from 2005), a seabird energetics laboratory as well as other wet and dry laboratories. The project plans to

use the facilities extensively for field- and labwork.
http://www.kingsbay.no/english/marine_lab.htm or
http://www.kingsbay.no/info/Description_marine_lab_facilities.pdf).

Kongsfjorden is an established reference site for Arctic marine studies, and in many regards it functions as a natural laboratory in the Arctic. The EU's 5th Framework Concerted Action BIOMARE (2000- 2002) generated the idea of European Marine Biodiversity Sites (EMBS) - a selection of localities where marine biodiversity research will be focused in the coming years. Both Kongsfjorden and Hornsund have been declared European Flagship Sites of Biodiversity, which will be of importance for long-term research and monitoring of biodiversity in these fjords. (http://www.iopan.gda.pl/~sweslaw/BIODAF/).

There is a significant amount of observations available from the Kongsfjorden area including historical and recent databases on: oceanography of Svalbard waters (1905-), meteorology (1911-), tide gauge measurements (1974-), hard-bottom benthos (1980-), seabirds (1988-), CTD -measurements (1993-), zooplankton (1995-), stable isotopes and lipids (1996-), ice concentration, snow and ice thickness (2003-, occasionally 1997-) and radionucleides as tracers of C-flux and mixing processes (1996-).

7 Contributions to Norwegian Polar Climate Research

The proposed project directly addresses a number of the central foci of the NORKLIMA Programme (NFR). We have taken an energy transfer approach in the design because the biotic responses to climate changes will most likely involve structural changes, such as altered zooplankton composition, which will affect the energy flow through the pelagic marine ecosystem. The proposed project will increase our ability to predict ecological consequences of climate change for the marine system, including seabird populations. This will be of importance for the management of sustainable Arctic biodiversity since some populations are likely to be substantially reduced. In addition, new information concerning the circulation system will be important for our understanding of the oceanic system off West-Spitsbergen, and our understanding of fast ice scenarios in Svalbard fjords will be improved. The results of this research will be relevant to both the Norwegian and international aspects of the Arctic Climate Impact Assessment (ACIA Assessment Steering Committee 2000).

8 Plans for dissemination of knowledge

Knowledge from the project will be disseminated to the target groups 1) the scientific community, 2) the public and 3) students/Universities, through different channels. For the scientific community, knowledge and results will be disseminated through scientific papers in peer-reviewed international journals; the project web page; symposia and workshops. Information will be passed on to the public through popularised articles; photographic- and artistic documentation; TV-performances (Norwegian TV such as the popular science programme "Schrödingers Katt"); TV, radio and newspapers (reporters/journalists will be invited to participate on some research cruises). Students will be informed through video education at UNIS, and through ARCTOS workshops (part of the ARCTOS student recruitment and science trainee school).

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