ARCTIC CHALLENGES

Climate and petroleum resources.

Figure 1: Polar cod (Boreogadus saida) under the arctic sea ice. Photo: Peter Leopold.

The general interest in the Arctic has increased considerably during the last two decades following the discoveries of some of the largest remaining oil and gas reserves on the planet. Also, shipping and tourism in the Arctic increases every year as the Arctic summer sea ice gradually retreats, with September 2012 having the record minimum sea ice extent since satellite measurements commenced in the 1970s. This is paralleled by the concern of direct and indirect consequences of climate change in Polar Regions, where effects are believed to be most severe. Arctic ecosystems are therefore under a dual pressure; on one side from impacts of the ongoing global warming and on the other side from its doppelgänger - the expansion of industrial activities in a still considered pristine and remote environment. In the Barents Sea, the limits of exploration are still safeguarding the Northern part of the Arctic, but for how long?

At the Faculty of Biosciences, Fisheries and Economics at the University of Tromsø (UiT), as well as within the Tromsø based Fram Centre (www.framsenteret.no) and ARCTOS (www.arctosresearch.net), there is an emphasis on actively working towards a better and more comprehensive understanding of this remote environment. Predicting effects of climate change and increased pollution, as well as designing solutions and technologies to safeguard this region while keeping the realistic prospective of exploration and exploitation of this region, are core elements of our research. Importantly, it is not within one single field of science or one institute that such an ambitious goal may be reached. Rather, in order to achieve this, we need everyone from ecologists, oceanographers, ecotoxicologists to modellers. Ultimately, we need basic understanding of our ecosystems with solutions and technologies built on that knowledge to meet our common responsibility to safeguard this unique and remote environment. Finally, but not the least, we need to prepare future generations.

Three projects funded by the Norwegian Research Council (NRC) and led from the Faculty of Bioscience, Fisheries and Economics at the UiT are currently striving to reach these goals, working in partnership with a wide range of national and international partner institutions from universities, R&D companies and the industry:

1. POLARISATION

Basic research, the fundaments for long-lasting solutions.

Fundamental research is key for providing the necessary knowledge to develop technologies hand in hand with the industry. As such, fundamental research should not be neglected and seen as a "dead-end" curiosity driven research. POLARISATION (Polar cod, lipid metabolism and disruption by polycyclic aromatic hydrocarbons; http://site.uit.no/polarisation) is such a project aiming at answering basic questions in the prospective of providing a basis for industry driven solutions and technologies. The 4-years project (2012-2015), co-financed by the NRC and UiT through the FRIPRO programme, deals with understanding both the basic biology of a true Arctic fish species and its sensitivity to petroleum related pollution. Although polar cod (Boreogadus saida, Figure 1) is rarely considered for human consumption, it is considered THE key fish species in Arctic ecosystems, both due to its abundance at a pan-Arctic scale and

its central role in the food chain. It is therefore not only crucial to understand potential man made impacts on this species, it may also become an actor as a bioindicator species in environmental management. However, at present, current status of knowledge and few scientific studies on this important species are not sufficient to allow this to become a reality.

The project has been making great progress concerning its ecology and biological characteristics, both of which are important factors to evaluate its response to pollution and climate impacts. Through the project we have gathered a unique dataset on the life cycle of polar cod in different climatic domains, which provide an unprecedented insight into its sensitivity to climate impacts. Preliminary results also suggests that the particular physiology of this species together with the environmental characteristics of the Arctic may significantly influence the uptake and effects of oil related compounds through routes and pathways until now considered negligible for other fish species. With world leading experts in environmental toxicology and physiology we are investigating how petroleum compounds enter the organisms and lead to long-term effects on energy metabolism and reproduction. For instance, in collaboration with the cell biology group at the University of the Basque Country (Spain), we aim at understanding the molecular mechanisms disrupting lipid homeostasis, the processes involved in storage and use of lipids. This is a crucial aspect for polar cod, which experiences long winters where food availability is scarce and where high amounts of energy are invested for reproduction. Any effects leading to the reduction in population fitness in this species, even at a local scale, could have severe consequences for the ecosystem. POLARISATION goes even further to reach its goals, by implementing in vitro methods in collaboration with the University of Bergen and sequencing the polar cod transcriptome with the Norwegian Institute for Water Research. For a full list of national and international partners, see site.uit.no/polarisation/.

POLARISATION is not there to provide the knowledge that will help design applied solutions to the industry. Rather, POLARISATION will help understand the importance of this species in the ecosystem and its sensitivity towards pollution from the petroleum industry. Thereby, the project will provide insights that ultimately may allow the use of polar cod as a bioindicator for the Arctic and provide data for risk models both for climate impacts and the petro maritime industry.

2. COOPENOR

Set the baselines while we still can.

Life is full of routines, both for humans and for all living organisms around us. These routines may follow different temporal schedules, e.g. the diel migrations of marine zooplankton or the annual biological cycles linked to reproduction and winter survival. These routines are intimately linked with predictable changes in the environment such as light, temperature or access to food, and may be regarded as key adaptations of any given organism towards its changing, yet predictable habitat. Changes in such routines, small or big, enable us to see when things are out of place. In environmental monitoring, the knowledge of a species' routines, usually referred to as baselines, is therefore critical in order to monitor how anthropogenic influences are potentially affecting organisms. The Arctic is often considered as a pristine environment, with little human activities. This however, is likely to change in the near future, and it is thus of paramount importance to establish relevant and useful baselines while it is still possible. COOPENOR (Combined effects of Petroleum and the Environment on bivalves from the Norwegian-Russian Arctic, http://site.uit.no/coopenor) has as its primary goal to provide relevant and useful baseline data on two common species of marine bivalves – the blue mussel and Icelandic scallop. Bivalves are used as bioindicators worldwide, due to their sessile life style and capacity to bioaccumulate large amounts of pollutants, which inform about pollutant levels and effects in local areas. Along the Arctic shelf seas, however their

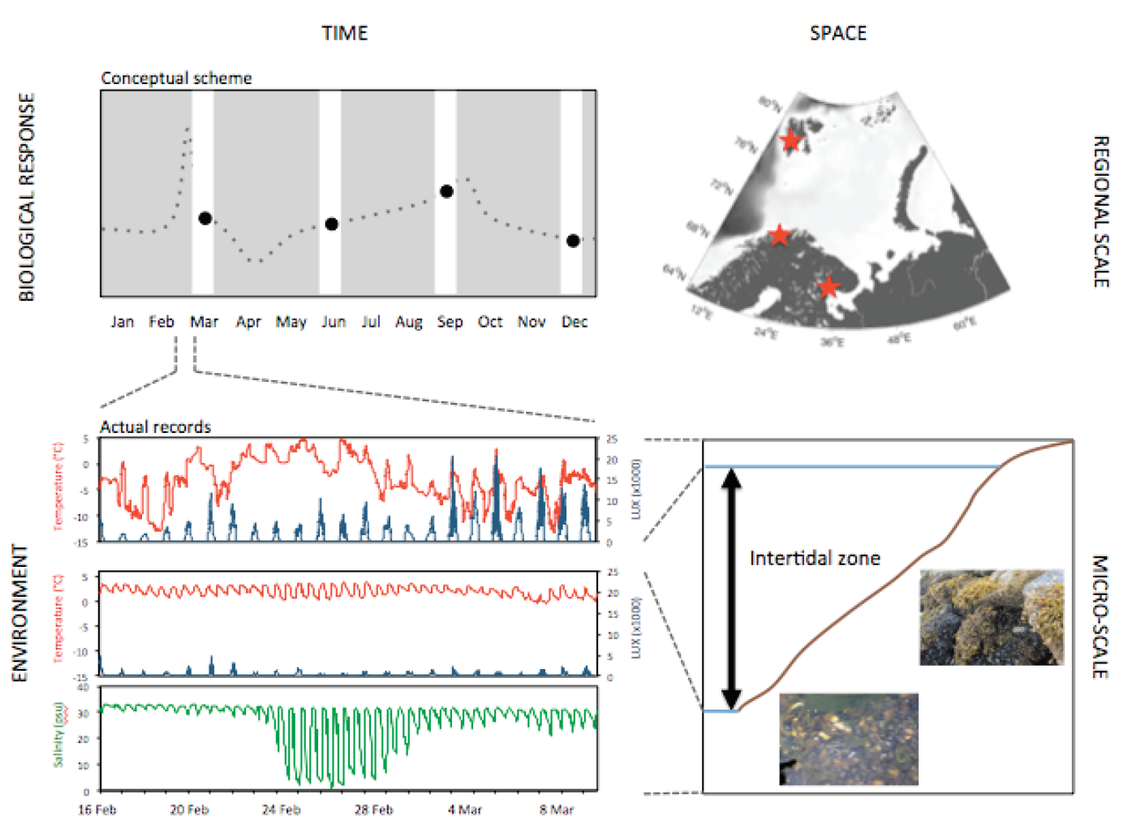

Figure 2: Schematic representation of the goals and challenges of COOPENOR. Current knowledge (see Nahrgang et al., 2013) of selected seasonal baseline levels in blue mussels from the Barents Sea are summarized as white area (top left), while grey areas represent the yet unknown. A low sampling frequency increases the probability of missing important variations in the baselines. Continuous recording of environmental factors including temperature, light and salinity will help the interpretation of biological data. For instance, in February-March (lower left), salinity levels showed increased daily fluctuations due to increasing temperature and snow melt. The biological response during this period of time is still being analysed. The biology of Arctic bivalves is investigated across the Barents Sea, White Sea and Greenland Sea (top right) and at a microscale (Lower left): subtidal and intertidal mussels experience marked differences in environmental factors (e.g. temperature, light and food availability).

Figure 3: Students of the course BIO 2008 Introduction to ecotoxicology at UiT sampling blue mussel tissue within the COOPENOR project.

biology and routines are less well known and relevant baselines are generally lacking.

Baseline levels are not trivial and they have to be redefined for each new region. For most living organisms, the environment plays the conductor's role by defining both the tone and rhythm – the individual orchestra members, in our case bivalves, are choosing their instruments and playing their melody according to the conductor's (environment) instruction. One of the questions we pose in COOPENOR, is how different environmental factors affect the mussels, both at a local scale and across the Arctic (Figure 2). Defining the biological and environmental boundaries and trade-offs by these indicator species be of paramount importance in order for them to be used in monitoring programmes.

The project (2013-2015) is co-financed by the NRC and the Russian Federation for Basic Research, and is thus a bilateral collaborative effort with a Russian co-lead, Dr Igor Bakhmet from the Institute of Biology, Karelian Research Centre (Russian Academy of Science). We carry out field and experimental studies in the Barents Sea and the White Sea in parallel to compare the same species in two very different environments. In addition, following the recent establishment of blue mussels on Svalbard (Greenland Sea), the project will expand its activities to also involve the northernmost population of blue mussels on the planet. By this beyond collaborative effort we secure a common understanding of the environment and we combine and share the best methods available.

Education is one of the keysforsuccess in this project. Bachelor and master students through courses given both at the University of Tromsø, the University Centre In Svalbard and the Petrozavodsk University, are actively participating in the field and experimental studies each year. The integration of real research into courses has been a big hit. Students are motivated as they see that their work is being used for research (Figure 3). It is a great tool to recruit future doctoral students who get the chance to go the book theories.

3. EWMA

From University knowledge to industrial applications and education.

The Environmental Waste Management (EWMA, http://site.uit.no/ewma/) project is a multidisciplinary competence group that focuses on improved and sustainable industrial waste management in cold environments. EWMA was initiatedin 2010 and focuses both on questions introduced by the industry itself as well as basic research. As much of the scientific work of EWMA is on industrial introduced research questions, produced knowledge is directly transferable to the industry. EWMA also educates PhDs, postdocs and gives university courses from introductory to PhD level. Candidates are highly relevant both for the industry and/or governmental authorities as well as academic careers.

EWMA is composed of seven different work packages, focusing on a wide array of scientific themes ranging from environmental science, capping and electrochemical remediation techniques, deposition of drill cuttings, waste treatment and bioremediation, and guidelines for development of best practices for industrial waste management in Arctic and sub-Arctic regions. Through its broad perspective and involvement of a high number of key research institutions, EWMA strives towards its main objective; to build a new knowledge platform on how to handle waste from petro-maritime industries in a sustainable manner in the high north region and in cold environments. Furthermore, the environmental research group, focusing mainly on ecotoxicology, constitutes a major component in the recently established Petroleum Centre at UiT. Through the involvement of this centre and through a stepwise building-up of a course portfolio covering all relevant aspects of environmental impact and monitoring topics, EWMA plays an important link between research and industries as well as a necessary competence-network for an environmentally sustainable development of oil and gas industries in the high north.
EWMA was originally established with the main motivation of building up a strong competence cluster within fields of sciences relevant for industrial waste management in cold climates, rather than building upon an existing platform of expertise. As such, EWMA was not initiated primarily on a specific set of hypothesis or concrete deliverables. Hence, a major part of the deliverables from EWMA is to create a platform from which new basic and applied research projects such as POLARISATION and COOPENOR may be initiated. Also the Barents Sea drilling research initiative (BARCUT, see http://site.uit.no/ewma/) is a direct result of EWMA. BARCUT is a newly initiated 5-year project funded by ENI Norway AS, that aims to identify the environmental impact of drill cuttings released to the sea.

Together with EWMA, both POLARISATION and COOPENOR are important steppingstones on our path towards a comprehensive and predictive understanding of the Arctic marine systems and the precautions needed to retain its natural and pristine state. Neither of these projects will provide the final answer, but they will fill important gaps in knowledge concerning key species and processes. The knowledge from all these projects is important both for the petroleum industry and governmental authorities for decision-making and for predicting effects and consequences of petroleum activity in the high north.

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