Big Black Box: Marine ecological processes during the polar night

Location: Tromsø, Norway, 19 and 20th January, 2015, UiT The Arctic University of Norway

The workshop had been organized in conjunction with and as part of the annual Arctic Frontiers conference, Tromsø 18-23 January 2015, entitled “Climate and Energy” (http://www.arcticfrontiers.com/). The conference was divided into a political (19-20 January) and a scientific (21-23 January) part. Within the biological section, the session “Ecological winners and losers in future Arctic marine ecosystems” was convened by two of the organizers of the Big Black Box workshop (Dr. Søreide and Dr. Gradinger).

Workshop organizing committee: Janne E. Søreide (UNIS), Bodil Bluhm (UiT), Rolf Gradinger (IMR) and Barbara Niehoff (AWI), and Tove M. Gabrielsen (UNIS)

Participants: 26 scientists (incl. 8 early career scientists). Overview of participants and their contact information is given on the last page. Workshop agenda see Appendix 1.

The BBB workshop in Tromsø was initiated during a first workshop in Fairbanks in February 2014 within a Norwegian-USA project with the same title, i.e. Big Black Box: Marine ecological processes during the polar night, funded by the Norwegian Research Council (PolarProg, 2013-2016). The workshop in Fairbanks aimed to gather scientists and students from Norway and USA and present recent and new results from studies on Arctic winter biology and ecology. The goal was also to discuss new methodology to study trophic interactions, particularly in winter when the organisms potentially feed at low rates to sustain basal metabolism and do not invest in growth. During this very fruitful workshop (for summary see http://www.mare-incognitum.no/index.php/big-black-box) it was decided to apply for additional funding from IASC for a follow-up open workshop to discuss possibilities for a larger international research project on marine ecological processes in Arctic seas during the poorly studied polar night, as an own initiative and as part of other, already existing initiatives, such as the proposed MOSAiC project (Multidisciplinary drifting Observatory for the Study of Arctic Climate, http://www.mosaicobservatory.org/). We also proposed to develop a white paper with a brief overview of the current knowledge status on Arctic winter ecology and an identification of the most important knowledge gaps. This white paper is intended as a strategic document to stimulate scientific discussions and motivate potential funding agencies to initiate relevant science programs to encourage larger marine Arctic winter research projects.

Background

Marine ecological processes during the polar night – **the big black box**! *What do we know and how to proceed to improve upon our poor knowledge on physiology, biological processes and trophic interactions during the polar night*?

The extended period of Arctic darkness, known as the polar night is defined by the sun being between 6-12° below the horizon (Berge et al. in press). The sun can be below the horizon for as long as 4 months, but Arctic marine environments may experience complete darkness for an even more extended time period (8-10 months) due to extensive sea ice cover and heavy snow conditions, efficiently preventing light transmission into the underlying water column. Even though the polar night is characterized by primary production close to zero, new data indicate that this part of the year may hold important keys that may eventually open for a more comprehensive understanding of the marine Arctic ecosystem (Berge et al. in press). First, the polar night is not a period void of biological activity, but is rather characterized by a number of processes and interactions yet to be understood, ranging from the sea-surface to the water-column and at the seafloor. The long "dark winter" and the comparatively brief growing season are likely to be the main barriers for "temperate/lower latitude" species to establishing sustainable populations in the high-Arctic. On the other hand, Arctic organisms have evolved unique life history adaptations to cope with extreme seasonality and food shortage. Currently though, data are insufficient to confirm or reject these common assumptions. Our knowledge is extremely poor when it comes to winter ecology. Our understanding of the Artic marine ecosystem and its key biological processes is so far mainly based on data from the light-season. Gathering additional information on polar night ecology and biological processes is therefore crucial, especially in light of expected impacts of climate change on Arctic marine ecosystems.

Main workshop tasks 19 and 20th January in Tromsø

1) Develop a white paper summarizing existing knowledge on winter ecology in the Arctic;
2) Identify the most critical knowledge-gaps;
3) Discuss ideas for a new international initiative/program on polar night ecology.

For **Tasks 1 and 2**, we focused our discussion on ecological processes at the base of the marine food web, including the sympagic, pelagic and benthic realms and covered all organisms from bacteria, protists, to invertebrates to fish. We briefly discussed marine mammals as a marine mammal scientist (Cormac Booth) joined the workshop. In Fairbanks in February 2014, we also included discussions on viruses and fungi. The outline of the white paper that is now in preparation is presented in Appendix. 2. This document builds upon the newly published paper by (Berge et al. in press) entitled "In the dark: paradigms of Arctic ecosystems during polar night challenged by new understanding".

Three main breakout groups were organized during the workshop in Tromsø: 1) sympagic 2) pelagic and 3) benthic. The cross-cutting synthesis of sympagic-pelagic-benthic couplings and importance of the boundary layers, i.e. sea ice-water and sea floor-water interfaces, was discussed in plenum.

In **Task 3**, several ongoing, new and planned projects were presented during the workshop, including suggestions for contributions to the international MOSAiC program. Ilka Peeken presented the status/progress of the MOSAiC program. She is the contact person for biological work in MOSAiC. So far, MOSAiC primarily focuses on physical processes, but as part of the Big Black Box initiative we participated in commenting on the MOSAiC science plan and asked for including more biological aspects into the program (http://www.mosaicobservatory.org/). MOSAiC handed in a proposal using RV Polarstern for a year-round study in the Arctic Ocean, which would provide an ideal opportunity for studying ecological processes during winter. We also discussed several other potential work platforms, both ship-based using larger icebreakers (RV Oden, RV Kronprins Haakon – new Norwegian research vessel, ice strengthened, ready in 2017-18) as well as land based field-stations in the circumpolar Arctic. See page 9 for summary and relevant links.

Notes in bullet points from the breakout groups and plenum discussions.

Very few dedicated polar night studies have been conducted so far in the high-Arctic, so in general all information from this time of the year is valuable. Recent research indicates that this part of the year may be more active than previously assumed (Berge et al. 2012; Berge et al. in press). In the breakout groups we discussed key research questions for forthcoming Polar Night studies, based on what is known from the sympagic, pelagic and benthic realms.

The overall question discussed was “Is the Arctic truly dormant during the polar night?” with sub-questions as follows:

- Which species are active – why and where? And which species are not – why and where?

- Which species continue to reproduce in mid-winter?

- What is the timing of overwintering and awakening, and how does it relate to light and/or food/primary production?

- What is the buffer for sustaining the dark period, e.g. how long do the organismal energy stores last?

- How does the trophic structure change from summer to winter?

- What carbon sources are available and who uses which carbon source?

- What is the fate of boreal species that are advected to the Arctic? Do communities revert to an “Arctic state” each winter due to high mortality of advected species?

Sympagic group discussion

Sea ice algae are primary producers and not abundant during the polar night. However, for their vernal bloom to occur there must be a seeding population that most likely is trapped in the ice during its formation (Niemi et al. 2011; Leu et al. in press). How these algae survive in sea ice in the darkness is poorly known, but they must be in a state that allows viability as soon as favourable growth conditions are developing in late winter/early spring (Zhang et al. 2003). In general very little is known about the taxonomic composition of winter sea ice communities, and even less about their physiological activity. (Collins and Deming 2011b) reported exceptionally high virus-to-bacteria ratios in seawater (45–340) and sea ice (93–2,820) during the autumn freeze-up. Also, the concentrations of particulate extracellular polymeric substances (pEPS) increased significantly with time and with decreasing temperatures in winter, which may lend support to the argument that sea ice bacteria produce EPS in situ as a cryoprotectant (Collins et al. 2008).

Considering sea ice macro-fauna, it was not until the pioneering work of I. Melnikov (Melnikov 1997; Melnikov et al. 2001) and B. Gulliksen (Lonne and Gulliksen 1991) that amphipods, previously categorised as pelagic were associated with sea ice. Since then, it has been a well-known fact that the Arctic sea ice is host to a high number of marine invertebrates, with more than 1000 different species recorded (Bluhm et al. 2011). The sympagic macro-fauna is commonly divided into two groups, the autochtonous and allochthonous species (Lonne and Gulliksen 1991; Arndt and Swadling 2006). The former consists of the species that are believed to live their entire life connected to the sea ice, whereas the latter consists of species that are connected to the sea ice only during parts of their life cycle. However, new observations during the polar night suggest that sea ice amphipods classified as autochtonous may survive ice free conditions in late autumn/winter by migrating down to depth and "hitchhike" with the Atlantic current back to the Arctic Ocean (Berge et al. 2012).

The following questions and knowledge gaps came up during our discussions:

- When organisms are incorporated into sea ice?
- Life cycles and strategies of key diatom species are yet unknown (*Melosira arctica*, *Neodenticula seminae*, *Nitzschia frigida*). Do they form resting spores or do they have dormant states? Can some of the algae survive three years of transport through the Arctic (Rozanska et al. 2008)? Can advected Atlantic and Pacific phytoplankton species cope with severe Arctic winters?
- Are nutrients available during winter for the start of the spring bloom? Do sea ice algae store nutrients during winter, do they have internal quotas and do they take up nutrients in the dark? Can they use organic nutrients? Ronnie Glud and his group at University of Southern Denmark and the Greenland Climate Research Centre are doing some studies relevant for answering these questions.
- How much Particulate Organic Carbon (POC) and bacterial activity are found in sea ice during winter? (Collins and Deming 2011a; Miller et al. 2011)

Species succession/selection (see e.g. (Niemi et al. 2011))

- When does ice form in different regions and is the timing of sea ice formation important for biodiversity and abundance?
- Do we find mixotrophic species, i.e. species switching from autotrophy to heterotrophy, in winter and what are their basic metabolic rates (Seuthe et al. 2011)?
- How do communities differ in Multi-year ice (MYI) and first-year ice (FYI)? Do these two different habitats reflect selection and life strategies of the species?
- What happens with ice-amphipods (and other sympagic meiofauna) during winter? (see alternative strategies presented by (Berge et al. 2012).
- How do populations cope with high rates of mortality when reproductively inactive?
- Which genes are expressed during winter? Are any algae active (see (Vader et al. 2015))?
- How do seeding populations from existing ice floes "colonize" other ice floes (lateral transfer of species between ice floes)?
- Can sea ice maintain its own populations (internal recruitment) or does it depend on recruitment from the pelagic realm?

- How does the sea ice algal bloom seed the pelagic bloom? Can pelagic species use the sea ice as a refuge during the winter?
- What is the carbon balance in the ice during winter (transparent exopolymers, Dissolved Organic Matter (DOM) and Particulate Organic Matter (POM)? How and to what extent are the refractory materials, left behind after the productive season, used up during winter?
- What are the roles of bacteria, meiofauna and zooplankton in the sea ice – water boundary layer in recycling the organic matter left in the ice?
- Is there a carbon export flux below the ice in winter? Is there brine convection (e.g. (Miller et al. 2011)?
- Are there events (brine convection, grazing, fecal pellets production, and melting events through advection of Atlantic water) that can cause sedimentation bursts during winter?

Pelagic group discussion

During the polar night, no light is present, providing photosynthetic organisms with the challenge of how to survive several months of darkness. Molecular studies show that *Micromonas pusilla* and *Phaeocystis pouchetii* are widely distributed in Svalbard waters also at the height of the polar night, and PCR screening of RNA samples, which can detect whether cells are viable or not, shows that these two phototrophs are indeed active in winter (Vader et al. 2015). This is so far the only systematic study on the persistence of these important photosynthetic organisms through the polar night.

In polar seas, zooplankton species have evolved several adaptations to survive long periods of continuous darkness with insufficient food supply (Conover and Huntley 1991; Hagen and Auel 2001). Diapause, a state of reduced metabolism, combined with build-up of large lipid reserves are major features of polar life cycles (Hagen 1999; Varpe et al. 2009). Our knowledge about the physiological state and behaviour of zooplankton during the overwintering period is, however, very restricted (but see (Conover and Huntley 1991; Conover and Siferd 1993; Kosobokova and Pertsova 2005; Hirche and Kosobokova 2011; Morata and Søreide 2013). Some recent polar night studies on zooplankton ecology (see e.g. (Daase et al. 2014; Webster et al. 2015) demonstrated that marine zooplankton are not necessarily quiescent during the polar night. Some populations are also found to still undergo diel vertical migration (DVM) during the darkest months (Berge et al 2009, 2012). There is a need for studies of polar-night physiology and energy use combined with knowledge of behaviour and life cycle strategies. This will improve our understanding of the trade-offs inherent in the annual routines of polar zooplankton (Varpe 2012) as well as the role of the polar night in shaping the schedule of activities also at other times of the year. Small omnivorous/detritivorous copepods, that numerically dominate Arctic zooplankton, contribute substantially to recycling organic carbon in the surface layer and to the attenuation of the vertical POC flux (Hopcroft et al. 2005). Predominance of small fecal pellets in the vertical POC flux in fall and winter (Forest et al. 2008; Lalande et al. 2009) suggests that these small copepods also are active and important carbon recyclers during the dark season.

The discussion in the pelagic group during the two-day workshop was very broad, covering the whole range from micro- to mesozooplankton. The main points/questions addressed were:

- Smaller species are important, often overlooked and deserve more attention (Svensen et al. 2011)

- There is indication of (low) feeding activity in some species during winter e.g. (Kraft et al. 2013)
  - Robert Campbell (URI) has data on copepod and euphausiid feeding rates in November-December (2011) from the Chukchi and Bering Seas.
  - Tove M. Gabrielsen (UNIS) has data from molecular analyses on the gut contents of *C. glacialis* and *Pseudocalanus* spp. reflecting ingestion of algal cells in winter.
  - Fecal pellets have been found in sediment traps samples from winter (Forest et al. 2008; Lalande et al. 2009). Winter sediment trap samples also have been taken by UNIS/SAMS moorings but are not analyzed yet.
  - What is the role of appendicularians during winter (efficient filter feeders of small particles)?

- Microorganisms
  - What is their carbon content/biomass contribution in winter?
  - The cells/species present during winter are not necessarily the same species that constitute the spring bloom (preliminary results from Tove Gabrielsen, UNIS; see also (Sorensen et al. 2012)
  - Some of the cells/species present during winter might contribute to a pre-bloom before the main spring bloom (preliminary results from Tove Gabrielsen, UNIS; Lovejoy et al. 2007).
  - The transition from winter to spring should receive more attention, (for review see (Leu et al. in press). What are the main overwintering strategies of the dominant phytoplankton spring bloom species (i.e. resting spores in sea ice or on the sea floor versus vegetative cells suspended at very low concentrations in the water column)?

The following three key questions were addressed in more detail

Q1) Which species are active during winter?

- The small zooplankton size fractions (e.g. *Oithona*, *Microcalanus* spp., *Pseudocalanus* spp.) need to be studied in greater detail as information on them is limited year-round.
- Copepods actively feed and reproduce in January-February in Kongsfjorden (high numbers of nauplii found mid-winter) but at a lower level than during spring.
- *Calanus* ascends already in November in Svalbard fjords and are active before the primary production starts.
- How do euphausids and amphipods sustain their metabolism in winter?
- Do pteropods overwinter as juveniles?

Q2) What are the mortality rates?

- What are the causes for winter mortality - energy limitation or predators?
  As an example we discussed *Calanus* spp. in Svalbard waters which drop in abundance. Drop during the winter-spring transition. Could this be caused by predation or do they run out of storage lipids.

- What is the predation pressure during winter?
- Little is known about the feeding activity of main zooplankton predators such as *Themisto* and omnivorous krill.
- Do non-visual predators such as gelatinous plankton cause a significant pressure on zooplankton in winter? The abundance of gelatinous plankton is basically unknown throughout the year in the high-Arctic.
- What is the fate of the advected species – do they survive the winter (Weydmann et al. 2013)?
- Data on key species survival rates and life history traits are essential, but yet unavailable, inputs for modelling.

Q3) What are the distribution patterns/structures in winter?

- LOPC (Laser Optical Plankton recorder) and LOKI (Light frame on-sight key species investigation - an optical system to survey zooplankton abundance) could be used to detect different distribution layers & patches (e.g. marine snow and zooplankton) in winter.
- How does the size distribution change during winter – is it shifted to smaller, active organisms in winter?
- How is the pelagial structured in winter, i.e. stratification versus mixing and how does that affect distribution patterns of POC (marine snow), protists and zooplankton?

Benthic group discussion

Benthic communities have rarely been studied during the polar night, and lack of adequate data was highlighted as one of the main gaps in knowledge in a review of Arctic marine benthos (Piepenburg 2005) (Berge et al. in press). Nevertheless, the studies that do exist indicate that the polar night is a key period for invertebrate activity and reproductive processes, kelp growth, and elemental cycling processes in Arctic sediments (e.g. (Morata et al. 2015). Winter kelp growth, for instance, provides an enhanced food resource and settlement substrate for benthic grazers and epifauna (Dunton et al. 1982). Continuous growth throughout the year without a change in total energy content in the amphipod *Onisimus litoralis* suggests year-round feeding at significant levels (Nygard et al. 2010). This species is part of a guild of scavenging amphipods active throughout the year and common in Arctic shelf waters, although different taxa appear to specialize on different prey items (Nygard et al. 2012). Such high levels of activity imply high levels of nutrient regeneration during the polar night at a time when benthic nutrients are easily mixed to surface waters due to lack of water-column stratification.

The following questions came up and were discussed:

- What are the dominant life strategies among benthic organisms to survive the winter? Business as usual or living on stored energy resources (carbohydrates, fat???), the role of stored food in sediments (the sediment food bank theory, e.g. (Glover et al. 2008)).
- Knowledge of physiology and reproduction from deep-sea organisms are critically poor
- Nutrient replenishment: how does winter biology affect nutrient cycles?
- Refractory carbon: what is the role of bacteria in recycling organic matter? (Middelboe et al. 2012)
- Do macro algae grow in winter?

- How does the activity on multiple trophic levels change with season? Does the food web depend on microbial recycling? (Seuthe et al. 2011)
- What are the consequences of strong seasonality in light climate at the deep sea floor where temperature and light are always low?
- What is the resilience of communities to oil spills in winter versus summer / shelf versus basin situations?

Synthesis – plenum discussions

- We agreed that the boundary layers sea ice - sea water, and sea water – sea floor, as well as any stratification of the water column would potentially be places for food/organisms to concentrate in winter. We also asked ourselves if seasonality is less pronounced for benthic versus pelagic and sympagic habitates (anyway dark and cold at depth).
- Knowledge on fluxes is scarce, but there are 10 years of data on sedimentation rates from the AWI Hausgarten mooring (Fram Strait) which can be looked into. Seasonal flux rates are also available from some fjords in Svalbard, but have not yet been worked up. If there are some winter data available, they are mainly from Arctic marginal seas and fjords. Information on biological processes in the deep Arctic basin is in general very poor, and from winter almost non-existing.

How to get data from the Arctic Ocean in winter?

Due to the difficulties to access the Arctic Ocean in winter, autonomous observatory systems such as moorings and drones would provide ideal platforms for measuring many basic data. Sampling of organisms, especially larger ones, is however usually not possible. Therefore, we suggest larger sampling winter campaigns with icebreakers. Also historical data from previous sea-ice drift stations and from more recent year-round ship-based IPY initiatives receive more attention.

Targeted research areas:

- Overwintering strategies of key Arctic herbivores, omnivores and carnivores in sympagic, pelagic and benthic realms (behaviour, energy investment/reproduction, feeding)
- Metabolic costs and overall energy budgets in winter
- Fate of advected boreal species in winter
- Identify boundary layers where food concentrates and determine the trophic importance of these "biotopes" in winter.
- Importance of marine snow and stored "food" in sediments
- Directions and magnitude of carbon and nitrogen flows in winter

An outline of the white paper in progress is seen in Appendix 2. We aim to have a draft ready by summer 2015 and the final document ready in autumn 2015. Most of the remaining work will be done by e-mail and Skype, but if necessary we aim for a final "writing-meeting" in late summer 2015.

Societal relevance and application

We also briefly touched upon social relevance of winter biology studies. One important aspect is that the winter may not be devoid of life and many important reproductive processes occur in winter. Thus, harmful human impacts, such as an oil spill, may do the same harm in winter as in the peak productive season, but would be less visible and potentially more challenging to redress. We therefore need to know more about winter biology and processes to be able to evaluate the impact of human activities in winter.

Ongoing, new and planned projects in the near future

The 2nd day started with a videoconference with Ny Ålesund, Svalbard, where the Norwegian Research project Marine Night and a UNIS student course in marine robotics were conducting field work. Presentation of three new larger Norwegian projects were given by the PIs (Berge and Leu from Ny Ålesund and Assmy in Tromsø – see below). The start for all three projects is 1. April 2015.

Arctic Ocean ecosystems - Applied technology, Biological interactions and Consequences in an era of abrupt climate change (Arctic ABC), *PI Jørgen Berge UiT/UNIS*, NRC 2015-2019

Autonomous observation systems under the ice, focusing on the Arctic Ocean, acoustic and optical data of ice and ice-associated systems, semi-controlled undulating systems under ARGOS might also implement drones to collect data, 50 million NOK funding, 3*PhD, 4*Postdocs, 2015-2019; submitted to infrastructure programme ABCD -> for developing another platform, clear overview of where and when is not yet developed, prototype perhaps in January 2016, first buoys in 2017, "UHI" (phytoplankton classes to be detected by optical measurements) ->development of a sea-water battery - which is constantly being resupplied, to solve the energy supply problem. For more information see http://www.mare-incognitum.no/index.php/64-new-member-of-the-mare-incognitum-family

FAABulous: **F**uture **A**rctic **A**lgae **B**looms **–** and their role in the context of climate change. *PI Eva Leu Akvaplan-niva*, NRC 2015-2019.

Mechanistic understanding of factors controlling blooms in sea ice and water, comparing an ice-free with an ice-covered fjord in Svalbard. Collaborating closely with PROECO (Arctic phytoplankton under multiple stressors: from process understanding to ecosystem functioning), an AWI-funded 3-years project (PI: Clara Hoppe, AWI). Joint winter campaign in Kongsfjorden, January 2015. Total funding: 24 million NOK, from the NRC: 16.3 million NOK. 2 PhD positions. Aim of the project: Understanding the ongoing shift in the Arctic primary production regime which is a result of a combination of three major processes: (1) altered light conditions (2) ocean acidification (3) northward shift of temperate species. An integrated assessment of the combined effect of these changes (1-3) on algal blooms in sea ice and water at high latitudes, with respect to bloom phenology, efficiency of primary production, nutritional quality and carbon cycling.

Ice algal and under-ice phytoplankton bloom dynamics in a changing Arctic icescape. *PI Philipp Assmy***,** *Norwegian Polar Institute*, NRC 2015-2018.

The main aim of the project is to improve our understanding of the key physical, chemical and biological drivers governing ice algal and under-ice phytoplankton bloom dynamics in a rapidly changing Arctic icescape.

Funding for 1 PhD Algal physiology, 1 PostDoc Algal taxonomy and ecology, 1-year PostDoc Ecosystem Modelling The project is mainly based on the Norwegian Young Sea ICE cruise (N-ICE2015) where RV Lance is frozen into the pack ice north of Svalbard from January through the end of June and Micropolar cruise in spring 2016() to the same general area. Core parameters include: metazooplankton with sampled with Hydrobios multinet, zooplankton respiration rates, short-term sediment trap deployment, primary production measurements (Mar Fernandez), implementation of automated phytoplankton imaging (imaging Flow CytoBot, Samuel Laney, WHOI), response of ice algae and phytoplankton to seasonally changing and experimentally perturbed light fields, remote sensing of ice algae, ice fauna and under-ice zooplankton, measurement of the transmitted light field and melt-water distribution with an ROV (CJ Mundy, University of Manitoba).

In addition to the three projects outlined above, there are a number of ongoing research initiatives, which address topics related to the polar night:

Carbon Bridge, PI Marit Reigstad, UiT, http://site.uit.no/carbonbridge/
North of Svalbard January 2014 & 2015 transect west-north of Kongsfjorden. Effect of the inflow of the Atlantic Water. Reproduction during winter (based on observation of high numbers of nauplii in January). Inter-annual difference, 2014 large inflow of Atlantic water on the west coast of Svalbard. In 2015, more dominated by cold coastal (Arctic) water masses.

Marine Night PI Jørgen Berge, UiT (http://www.mare-incognitum.no)
Hyperbenthos and their feeding rates. The Institute of Oceanology Polish Academy of Science; IOPAS has a benthic component in Marine Night, conducting year-round benthic sampling in Kongsfjorden (meio- and macrofauna) related to lipid content and diets. No cruise activity next year in 2016. Cruise have been conducted north of Svalbard and Kongsfjorden in winter 2014 & 2015

CIRCA, PI Jørgen Berge UiT/UNIS (http://www.mare-incognitum.no)
DVM during polar night (players), effect of DVM on carbon flux
No cruise next year in 2016

MICROFUN, PI Tove M. Gabrielsen, UNIS (http://www.mare-incognitum.no)
Protist, diversity (who is present when), temporal & geographic time-series
Time-series from Adventfjorden (monthly-weekly sampling last 3 years)
Rijpfjorden, Kongsfjorden and Adventfjorden (geographic)
Flow cytometry (count of different groups of microorganism from one season)

CLEOPATRA II, PI Janne E. Søreide, UNIS(http://www.mare-incognitum.no/index.php/cleopatra-ii)
Plan to continue year-round fjord studies in Svalbard, e.g. *C. finmarchicus* in Isfjorden, start summer 2015 ends autumn 2016. Aim to compare monthly physiological parameters of *C. finmarchicus* and *C. glacialis.*

Big Black Box (http://www.mare-incognitum.no)
Use molecular tools to see what different organisms feed on during winter. Currently analyzing data of *C. glacialis* from surface water in Kongsfjorden in January. Will use the same method to look into diet

for *Pseudocalanus* spp from Adventfjorden & *Calanus glacialis* from Billefjorden. Molecular tools are a good approach for these small organisms since they do not assimilate their potential prey to significant extent in winter, and thus other trophic markers such as fatty acid trophic markers may fail to capture winter-feeding.

German projects (AWI)

RV Polarstern Cruises to the Fram Strait and the Arctic Ocean from spring through autumn 2015 studying the impact of sea-ice on pelagic communities, biodiversity and trophic interactions.

USA projects

So far, no new projects in 2015 & 2016

Canadian projects

GreenEdge (http://www.greenedgeproject.info/objectives.php). Green Edge is the first study that addresses the Arctic Phytoplankton Spring Bloom (PSB) from the level of fundamental physical, chemical and biological processes to that of ecosystem (including Humans), from small to pan-Arctic spatial scales, and from seasonal to multidecadal temporal scales in the past, present and future. The project includes 6 work packages and will target the following **specific objectives**:

- Understand the key physical, chemical and biological processes that govern the PSB in the Arctic Ocean.
- Identify key phytoplankton species involved and model their growth under various environmental conditions.
- Predict the fate of the PSB and related carbon transfer through the food chain (from plankton to humans) and toward the bottom sediments over the next few decades.
- Determine how the PSB responded to past climate variations.

Other ongoing relevant project activities

- FRAM: year-round sampling monthly, autonomous sampling devices (AWI, GEOMAR, Jacobs Univ.)
- AWI-HAUSGARTEN: a long-term monitoring deep sea observatory in the eastern Fram Strait, recently (2014) expanded to the east Greenland shelf, comprehensive sampling of water column, sediment traps and benthos for more >10 years, cage experiments throughout the year (manipulating food input)
- Pan-Arctic network of field stations
- UNIS regular students courses (www.unis.no)
- Goliath related benthic winter sampling (Akvaplan-niva, Norway)

Cruise and general field opportunities in autumn and winter the coming years

Cruises

Institute of Marine Research, Norway, annual winter surveys to the Barents Sea (shelf sea)

N-ICE RV Lance, North of Svalbard (Nansen Basin), responsible Norwegian Polar Institute (NPI), Harald Steen (www.npolar.no)
Polarstern, late legs (August-October) planned for almost every year. Alfred Wegener Institute (AWI)
TransArc II 2015 PI Ursula Schauer, Antje Boetius's Cruise to the Aurora Vent field in 2016
ABC-project, PI Jørgen Berge, UiT, 2016-2019 multiple winter cruises
New Norwegian Icebreaker "Kronprins Haakon" ready in 2017 (possible calls in 2018 and onwards?)

Land stations (Coastal)

Barrow Alaska: Ten year time series (since 2005) including physical, chemical and biological measurements in the nearshore and shelf region during autumn. Sponsored by numerous U.S. agencies. Currently, funded under the Arctic Observing Network (AON) by the National Science Foundation (NSF).
Several stations in Svalbard: Van Mijenfjorden, Kongsfjorden_Marine night project, Cleopatra II, AWI works at different stations Rijpfjorden
Resolute Bay_ Contact CJ Mundy to check if possible

INTERACT – visit field stations in Greenland to do research, funding may also be available. For more information see: http://www.eu-interact.org/about-interact/. Greenland: Nuuk, Young Sound and Station North (note: winter data are available, some have even not been evaluated yet e.g. acoustics)

Autonomous sampling programs

- Arctic Buoy program: North Pole observatory (and they aim to get biological sensors into that)
- Fram Strait, AWI Hausgarten observatory: Thomas Soltwedel (coordinator; benthos, landers, ROV) Eva-Maria Nöthig, Eduard Bauerfeind (sediment traps, phytoplankton), Barbara Niehoff (Zooplankton), Ian Salter (microbial work)
- ABC Buoy program (PI Jørgen Berge, UiT) this project has a biological focus.

Winter Ice camps

- BARNEO ice camp, ca 1 degree from North Pole, established each year in April for tourists (Sergei Pisarev)
- Drift ice camp NP 41, Russia
- Vagabond sailboat frozen in every year, in 2015-16

Other activities

EU coordination and support action Polar net, led by AWI but also includes many large European research institutions) starts in spring 2015 (web page and press release are in progress). This network will assist the EU commission in all topics related to polar regions and aims at developing the first Integrated European Polar Research Programme. The network mainly addresses stake holders i.e. society, politics and also science and will develop future funding strategies in the frame of EU calls. The focus will be on infrastructure and applied research, which needs to have societal connection. Thus, there will be no funding of basic research. The contact person at AWI is Nicole Bibow, Head of the International Cooperation Unit.

MOSAiC is the "Multidisciplinary drifting Observatory for the Study of Arctic Climate", a proposed international Arctic research initiative that is outlined at www.mosaicobservatory.org. The research plan as published on the web site has been developed as a result of multiple workshops via a coordinated international writing team. Central part of this project is to study atmospheric processes in the Arctic Ocean over an entire year; our own initiative (BBB) could contribute in studying biological processes. Ilka Peeken (AWI) is the contact person for biological studies within MOSAiC and she has been participating in the BBB-workshop. In September 2014, MOSAiC has applied for deploying RV Polarstern (Germany) for one year in the Arctic, the decision is, however, still pending. In addition, many other questions as to how will the MOSAiC initiative be funded (fuel, transport to and from the ship during winter, second ice-breaker) have not yet been resolved. If RV Polarstern will indeed remain in the Arctic sea-ice over winter this would be an ideal opportunity for our proposed winter studies and within the BBB-community there is great interest in participating in this study.

Canadian-Greenland-Danish research cooperation, Arctic Science Partnership, ASP-ICE, www.asp-net.org, new call, 1.5B over 7 years, March, 2015, presented by coordinator/PI Søren Rysgaard 12:30 day two.

Big Black Box workshop 19 and 20 January 2015 - participants

Sympagic	Affiliation	Country	Group	E-mail
Rolf Gradinger	IMR (UAF)	Norway (USA)	S	rolf.gradinger@imr.no
Philipp Assmy	NPI	Norway	S	Phillip.Assmy@npolar.no
Ilka Peeken	AWI	Germany	S	Ilka.Peeken@awi.de
Mar Fernández-Méndez	AWI	Germany	S	Mar.Fernandez.Mendez@awi.de
Pelagic				
Tove M. Gabrielsen	UNIS	Norway	P	Tove.Gabrielsen@unis.no
Barbara Niehoff	AWI	Germany	P	bniehoff@awi.de
Robert Campbell	URI	USA	P	rgcampbell@mail.uri.edu
Alison Cleary	URI	USA	P	alison_cleary@gso.uri.edu
Kaja Ostaszewska	IOPAS	Poland	P	kaja.ostaszewska@gmail.com
Maja Hatlebakk	UNIS	Norway	P	majah@unis.no
Anette Wold	NPI	Norway	P	Anette.Wold@npolar.no
Anna Vader	UNIS	Norway	P	Anna.vader@unis.no
Sünnje Basedow	UiN	Norway	P	Sunnje.Basedow@uin.no
Gerald Dernis,	APN	Norway (Canada)	P	gerald.darnis@akvaplan.niva.no
Cormac Booth	SMRU	UK	P	cgb@smrumarine.com
Ksenia Kosobokova		Russia	P	xkosobokova@ocean.ru
Miriam Marquardt	UNIS	Norway	P	Miriam.Marquardt@unis.no
Janne E. Søreide	UNIS	Norway	P	Janne.Soreide@unis.no
Benthic				
Bodil Bluhm	UiT/UAF	Norway/USA	B, S	Bodil.Bluhm@uit.no
Sabine Cochrane	APN	Norway	B	Sabine.Cochrane@akvaplan.niva.no
Paul Renaud	APN/UNIS	Norway		paul.renaud@akvaplan.niva.no
Barbara Gòrska	IOPAS	Poland	B	basia@iopan.gda.pl
Josephine Rapp	AWI/MPI	Germany	B	jrapp@mpi-bremen.de
From Ny Ålesund				
Jørgen Berge	UiT/UNIS	Norway		jorgen.berge@uit.no
Eva Leu	APN	Norway		eva.leu@akvaplan.niva.no
Øystein Varpe	UNIS/APN	Norway		Oystein.Varpe@unis.no
Nathalie Morata	LEMAR/UiT	France		Nathalie.Morata@gmail.com
Presenting project				
Søren Rysgaard		Canada/Denmark		Soeren.Rysgaard@umanitoba.ca
Sum	Participants*	Nations		
*early career	26 (8)	8		

References

Arndt CE, Swadling KM (2006) Crustacea in Arctic and Antarctic sea ice: Distribution, diet and life history strategies. In: Advances in Marine Biology, Vol 51, vol 51. Advances in Marine Biology. pp 197-315. doi:10.1016/s0065-2881(06)51004-1

Berge J, Renaud PE, Darnis G, Cottier F, Last K, Gabrielsen TM, Johnsen G, Seuthe L., Weslawski JM, Leu E, Lønne OJ, Moline M, Nahrgang J, Søreide JE, Varpe Ø, Falk-Petersen S (in press) In the dark: paradigms of Arctic ecosystems during polar night challenged by new understanding. Progress in Oceanography

Berge J, Varpe Ø, Moline MA, Wold A, Renaud PE, Daase M, Falk-Petersen S (2012) Retention of ice-associated amphipods: possible consequences for an ice-free Arctic Ocean. Biology Letters. doi:10.1098/rsbl.2012.0517

Bluhm BA, Gebruk AV, Gradinger R, Hopcroft RR, Huettmann F, Kosobokova KN, Sirenko BI, Weslawski JM (2011) Arctic Marine Biodiversity: An Update of Species Richness and Examples of Biodiversity Change. Oceanography 24 (3):232-248

Collins RE, Carpenter SD, Deming JW (2008) Spatial heterogeneity and temporal dynamics of particles, bacteria, and pEPS in Arctic winter sea ice. Journal of Marine Systems 74 (3-4):902-917

Collins RE, Deming J (2011a) Abundant dissolved genetic material in Arctic sea ice Part I: Extracellular DNA. Polar Biol 34 (12):1819-1830. doi:10.1007/s00300-011-1041-y

Collins RE, Deming J (2011b) Abundant dissolved genetic material in Arctic sea ice Part II: Viral dynamics during autumn freeze-up. Polar Biol 34 (12):1831-1841. doi:10.1007/s00300-011-1008-z

Conover RJ, Huntley M (1991) Copepods in ice-covered seas--Distribution, adaptations to seasonally limited food, metabolism, growth patterns and life cycle strategies in polar seas. Journal of Marine Systems 2 (1-2):1-41. doi:Doi: 10.1016/0924-7963(91)90011-i

Conover RJ, Siferd TD (1993) Dark-Season Survival Strategies of Coastal Zone Zooplankton in the Canadian Arctic. Arctic 46 (4):303-311

Daase M, Varpe O, Falk-Petersen S (2014) Non-consumptive mortality in copepods: occurrence of Calanus spp. carcasses in the Arctic Ocean during winter. Journal of Plankton Research 36 (1):129-144. doi:10.1093/plankt/fbt079

Dunton KH, Reimnitz E, Schonberg S (1982) An Arctic kelp community in the Alaskan Beaufort Sea. Arctic 35 (4):465-484

Forest A, Sampei M, Makabe R, Sasaki H, Barber DG, Gratton Y, Wassmann P, Fortier L (2008) The annual cycle of particulate organic carbon export in Franklin Bay (Canadian Arctic): Environmental control and food web implications. Journal of Geophysical Research-Oceans 113 (C3). doi:10.1029/2007jc004262

Glover AG, Smith CR, Mincks SL, Sumida PYG, Thurber AR (2008) Macrofaunal abundance and composition on the West Antarctic Peninsula continental shelf: Evidence for a sediment 'food bank' and similarities to deep-sea habitats. Deep-Sea Research Part Ii-Topical Studies in Oceanography 55 (22-23):2491-2501. doi:10.1016/j.dsr2.2008.06.008

Hagen W (1999) Reproductive Strategies and Energetic Adaptations of Polar Zooplankton. Invertebrate Reproduction & Development 36 (1-3):25-34

Hagen W, Auel H Seasonal adaptations and the role of lipids in oceanic zooplankton. In, 2001. pp 313-326

Hirche HJ, Kosobokova KN (2011) Winter studies on zooplankton in Arctic seas: the Storfjord (Svalbard) and adjacent ice-covered Barents Sea. Marine Biology 158 (10):2359-2376. doi:10.1007/s00227-011-1740-5

Hopcroft RR, Clarke C, Nelson RJ, Raskoff KA (2005) Zooplankton communities of the Arctic's Canada Basin: the contribution by smaller taxa. Polar Biol 28 (3):198-206. doi:10.1007/s00300-004-0680-7

Kosobokova KN, Pertsova NM (2005) Zooplankton of the deep-water part of the White Sea at the end of the hydrological winter. Oceanology 45 (6):819-831

Kraft A, Berge J, Varpe Ø, Falk-Petersen S (2013) Feeding in Arctic darkness: Mid-winter diet of the pelagic amphipods Themisto abyssorum and T. libellula. Marine Biology 160 (1):241-248

Lalande C, Forest A, Barber DG, Gratton Y, Fortier L (2009) Variability in the annual cycle of vertical particulate organic carbon export on Arctic shelves: Contrasting the Laptev Sea, Northern Baffin Bay and the Beaufort Sea. Continental Shelf Research 29 (17):2157-2165. doi:10.1016/j.csr.2009.08.009

Leu E, Mundy CJ, Assmy P, Campbell K, Gabrielsen TM, Gosselin M, Juul-Pedersen T, Gradinger R (in press) Arctic spring awakening – steering principles behind the phenology of vernal ice algae blooms. Progress in Oceanography

Lonne OJ, Gulliksen B (1991) On the Distribution of Sympagic Macro-Fauna in the Seasonally Ice Covered Barents Sea. Polar Biol 11 (7):457-469

Melnikov IA (1997) The Arctic Sea ice ecosystem. The Arctic Sea ice ecosystem.

Melnikov IA, Zhitina L. S., G. KH (2001) The Arctic sea ice biological communities in recent environmental changes. vol 54.

Middelboe M, Glud RN, Sejr MK (2012) Bacterial carbon cycling in a subarctic fjord: A seasonal study on microbial activity, growth efficiency, and virus-induced mortality in Kobbefjord, Greenland. Limnology and Oceanography 57 (6):1732-1742. doi:10.4319/lo.2012.57.6.1732

Miller LA, Papakyriakou TN, Collins RE, Deming JW, Ehn JK, Macdonald RW, Mucci A, Owens O, Raudsepp M, Sutherland N (2011) Carbon dynamics in sea ice: A winter flux time series. Journal of Geophysical Research: Oceans 116 (C2):C02028. doi:10.1029/2009JC006058

Morata N, Michaud E, Wlodarska-Kowalczuk M (2015) Impact of early food input on the Arctic benthos activities during the polar night. Polar Biol 38 (1):99-114. doi:10.1007/s00300-013-1414-5

Morata N, Søreide J (2013) Effect of light and food on the metabolism of the Arctic copepod Calanus glacialis. Polar Biol:1-7. doi:10.1007/s00300-013-1417-2

Niemi A, Michel C, Hille K, Poulin M (2011) Protist assemblages in winter sea ice: setting the stage for the spring ice algal bloom. Polar Biol 34 (12):1803-1817. doi:10.1007/s00300-011-1059-1

Nygard H, Berge J, Soreide JE, Vihtakari M, Falk-Petersen S (2012) The amphipod scavenging guild in two Arctic fjords: seasonal variations, abundance and trophic interactions. Aquatic Biology 14 (3):247-264. doi:10.3354/ab00394

Nygard H, Wallenschus J, Camus L, Varpe O, Berge J (2010) Annual routines and life history of the amphipod Onisimus litoralis: seasonal growth, body composition and energy budget. Marine Ecology-Progress Series 417:115-U135. doi:10.3354/meps08798

Piepenburg D (2005) Recent research on Arctic benthos: common notions need to be revised. Polar Biol 28 (10):733-755. doi:10.1007/s00300-005-0013-5

Rozanska M, Poulin M, Gosselin M (2008) Protist entrapment in newly formed sea ice in the Coastal Arctic Ocean. Journal of Marine Systems 74 (3-4):887-901. doi:10.1016/j.jmarsys.2007.11.009

Seuthe L, Topper B, Reigstad M, Thyrhaug R, Vaquer-Sunyer R (2011) Microbial communities and processes in ice-covered Arctic waters of the northwestern Fram Strait (75 to 80 degrees N) during the vernal pre-bloom phase. Aquatic Microbial Ecology 64 (3):253-266. doi:10.3354/ame01525

Sorensen N, Daugbjerg N, Gabrielsen TM (2012) Molecular diversity and temporal variation of picoeukaryotes in two Arctic fjords, Svalbard. Polar Biol 35 (4):519-533. doi:10.1007/s00300-011-1097-8

Svensen C, Seuthe L, Vasilyeva Y, Pasternak A, Hansen E (2011) Zooplankton distribution across Fram Strait in autumn: Are small copepods and protozooplankton important? Progress in Oceanography 91 (4):534-544. doi:http://dx.doi.org/10.1016/j.pocean.2011.08.001

Vader A, Marquardt M, Meshram AR, Gabrielsen TM (2015) Key Arctic phototrophs are widespread in the polar night. Polar Biol 38 (1):13-21. doi:10.1007/s00300-014-1570-2

Varpe O (2012) Fitness and phenology: annual routines and zooplankton adaptations to seasonal cycles. Journal of Plankton Research 34 (4):267-276. doi:10.1093/plankt/fbr108

Varpe O, Jorgensen C, Tarling GA, Fiksen O (2009) The adaptive value of energy storage and capital breeding in seasonal environments. Oikos 118 (3):363-370. doi:10.1111/j.1600-0706.2008.17036.x
Webster CN, Varpe O, Falk-Petersen S, Berge J, Stubner E, Brierley AS (2015) Moonlit swimming: vertical distributions of macrozooplankton and nekton during the polar night. Polar Biol 38 (1):75-85. doi:10.1007/s00300-013-1422-5
Weydmann A, Søreide JE, Kwaśniewski S, Leu E, Falk-Petersen S, Berge J (2013) Ice-related seasonality in zooplankton community composition in a high Arctic fjord. Journal of Plankton Research 35 (4):831-842. doi:10.1093/plankt/fbt031
Zhang Q, Gradinger R, Zhou QS (2003) Competition within the marine microalgae over the polar dark period in the Greenland Sea of high Arctic. Acta Oceanologica Sinica 22 (2):233-242

Appendix 1. Work shop agenda 19 and 20 January 2015

Monday 19 January

09:00 Welcome and a short introduction of all present
09:30 Big Black Box background and work shop tasks (Tove M. Gabrielsen & Janne E. Søreide)
10:00 The MOSAiC – initiative (Ilka Peken, AWI)
10:30 Coffee-break
11:00 Discussion and division into groups (3 topics: sympagic [1], pelagic [2] and benthic [3])
12:00 LUNCH
13:00 Work in groups (white paper writing)
14:30 Coffee-break
14:50 Work in groups (white paper writing)
16:00 We all meet and summarize the work progress so far
17:00 End of Day 1

(17:30-19:30 USA-NOR BBB-project meeting)

Tuesday 20 January 2015

09:00 Short update of the status after workshop day 1 and a brief intro to Day 2 program
09:30 Tromsø -Ny Ålesund video-conference: presentation of 3 new large NRC 'Økosystem' projects:

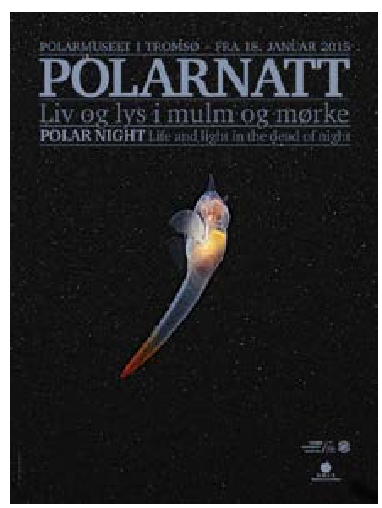
Jørgen Berge: *Arctic Ocean ecosystems - Applied technology, Biological interactions and Consequences in an era of abrupt climate change*
Eva Leu: *Future Arctic Algae Blooms - and their role in the context of climate change*
Phillip Assmy: *Ice-algal and under-ice phytoplankton bloom dynamics in a changing Arctic icescape*
Discussion – how to coordinate activities the coming years
Discussion – should we plan for a future EU project

12:00 Lunch
12:30 ASP-ICE consortium, presented by Prof. Søren Rysgaard
13:00 Continue the 'white paper work' in groups (2 rooms available)
14:30 Coffee break
15:00 Synthesis work, white paper
16:30 Summary and what is the next step?
17:00 End of workshop

20:00 Science ice breaker, Arctic Frontiers Conference

Wednesday 21 January

18:30 Polar Night Exhibition Reception, Polarmuseet, Tromsø
http://www.mare-incognitum.no/index.php/66-outreach-in-the-aftermath-of-marine-night-2015/



Appendix. 2 Tentative outline White Paper

Big Black Box: Marine ecological processes during the polar night

Abstract

1. Introduction

1.1. Why study the winter?

1.2. Historical background

1.3. Recent discoveries

1.4. Aim of this "white paper"

2. Physical and biological constraints in winter

Short intro defining "winter"

2.1. Light

2.2. Temperature

2.3. Food availability

3. Overwintering strategies of functional groups

Current knowledge on overwintering strategies for functional groups from the three habitats

3.1. Viruses and bacteria

3.2. Autotrophs

3.3. Heterotrophs

3.4. Herbivores/omnivores

3.5. Omnivores/Carnivores/scavengers

3.6. Invasive species (boreal species "advected "to the Arctic)

4. Food sources and energy fluxes in winter

4.1 Trophic importance of boundary layers

4.1.1. Sea floor

4.1.2. Sea ice –water interface

4.1.3. Halocline

4.2 Biological pump

4.2.2 Fluxes

4.2.3. Advection

4.2.4. Role of DVM

5. Seasonal constraints in a climate change perspective

5.1. Internal vs. external triggers

5.2. Organisms plasticity

5.3. Evolutionary context

6. Key research questions (mirroring most critical knowledge gaps)

Examples:

1) Overwintering strategies of key Arctic herbivores, omnivores and carnivores in sympagic, pelagic and benthic realms (behaviour, energy investment/reproduction, feeding?)
2) Metabolic costs and overall energy budgets in winter
3) Fate of advected boreal species in winter
4) Identify boundary layers where food concentrate and these “biotopes” trophic importance in winter.
5) Importance of marine snow and stored “food” in sediments
6) Directions and magnitude of carbon and nitrogen flows in winter (the biological pump)

7. Action plan

7.1. Ongoing research

7.1.1. Arctic ABC

7.1.2. FAAbolous

7.1.3 Marine Night

7.2. Tentative research platforms in future

7.2.1. Ice breakers

7.2.2. Land based field station

7.2.3. Sea ice drift stations

7.2.4. Moorings/autonomous observatories

7.2.5. MOSAiC?