Project information

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Pelagic ecosystems in ice-covered and ice-free fjords under climate change
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Project leader
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Summary of Results

WP1 (Gabrielsen, UNIS and Hegseth, UiT)

The spring bloom biomass increase started around the vernal equinox in Balsfjorden (mainland). Incubations of winter water and sediment in the laboratory yielded the same number of phytoplankton species (between 15-21 in different parts of the fjord), while only 1-4 of the species were observed in the plankton net samples. The same diatom species dominated in the winter water grown in the lab as in the bloom, while the dominating species in the net samples were dinoflagellates and small flagellates. The main diatom species during the bloom were various *Chaetoceros* species and some *Thalassiosira* species. Other important species were *Skeletonema marinoi*, *Bacterosira bathyomphala* and *Fragilariopsis oceanica*. These are the same group of species forming the spring bloom during the 1970s (Eilertsen et al. 1981), and the maximum number of cells was also comparable with data from several decades before. Hence no temporal change was observed with respect to spring bloom timing or species composition and the biomass levels in Balsfjorden. Interestingly, the inoculum for the spring bloom was present both in the sediments and in the pelagic winter community.

Cells appeared in such low abundances, however, that many of the species were not represented in the plankton net samples, nor in the samples counted under the microscope. The cells must have been mixed up from the bottom into the water column, but the hydrographical data did not tell us when, or how often the mixing had occurred. Another possibility is that a very low number of cells from the spring bloom species had survived in the water column since the previous spring, but this would have to be tested separately with long-term growth experiments. Another interesting result was a relationship between *Phaecystis* sp., a colony-forming haptophyte, and the diatom spring bloom: with the help of qPCR low quantities of *Phaeocystis* cells were detected in Balsfjorden very early in the season (early Feb), whereas population growth took off only in the last part of March. Colonies first appeared in mid-March, but were still small, and most particularly – they all were connected to diatoms cells, mainly of the genus *Chaetoceros*. It seems that *Phaeocystis* needs diatom cells to attach to in the colony-forming process and that therefore diatom and *Phaeocystis* dynamics are closely linked. *Phaeocystis* was present in the fjord as single cells in the water masses all winter, but not in the bottom sediments.

Similar to the mainland fjord, *Phaeocystis* started to become abundant in the week before the peak of the spring bloom in Isfjorden (Svalbard) in 2013, but around two months later (May 10th), and also dominated along with diatoms until early June. Another small autotroph, *Micromonas pusilla*, starts growing exponentially even earlier than *Phaeocystis*, as soon as the sun is above the horizon in mid-March. In 2014, both the spring bloom and *Phaeocystis* developed quite differently from the year before, demonstrating high interannual variability in bloom dynamics and timing in Svalbard. The abundance of Phaeocystis increased first in mid April, then in early May and finally on June 4th, a few days before the peak bloom of the diatoms (June 11th). We are currently in the process of synthesising the data from the IsA station, and to compare and contrast these to the findings from Balsfjorden.

WP2.1 (Halsband, APN)

The scanning and image classification into taxonomic groups was completed with the new ZooScan. The scanning of samples from Porsangerfjorden in different seasons was completed in November, with image analysis to be finished in December. The data set thus includes zooplankton taxa and sizes in Porsangerfjorden, the ISA station in Isfjorden (Svalbard). Samples from contrasting site off the Svalbard shelf was also scanned, together with samples from Hornsund for comparison. The learning set for automated identification of organisms was further improved as more scans became available, increasing the biodiversity covered and representative images of different taxa could be included to improve the recall (identification) of organisms. Contamination levels (false positives) improved with the refined learning set with more samples and taxonomic categories, although recognition of copepods still requires a good amount of manual validation. Size distribution comparisons between the

mainland and Svalbard fjords will be available by the end of the year and can then be combined with data on vertical distribution (WP2.2) and information on *Calanus* seasonal ecology (WP2.3). The ZooScan method and associated data collected by the flagship project will be presented at the 'Plankton Research in Svalbard' (PRiS) Workshop at UNIS 8-10 December 2015 and will also contribute to a presentation at the 6th ICES Zooplankton Production Symposium in May 2016.

WP2.2 (Norrbin, UiT)

During 2015, we have been working with data from the cruises to Porsanger the previous years. The seasonal pattern of zooplankton populations in the north-norwegian fjord Porsanger, consists of a highly depleted overwintering stock, building to maximum abundances in the fall. This is quite similar to earlier studies in Porsanger and adjacent fjords (1990-1991).

We found a clear seasonal migration of all zooplankton groups, including herbivores (e.g. *Calanus finmarchicus*, *Pseudocalanus* spp), omnivores (e.g. *Oithona* spp) and carnivores (e.g. chaetognaths). Before and at the start of the bloom, zooplankton were spread out in the water column. During the phytoplankton bloom, most of the zooplankton could be found around the chlorophyll *a* peak. In August, they concentrated a little lower than the chlorophyll peak, and in November, the zooplankton community was located deep in the water column.

When we compared the fine-scale depth distributions for different zooplankton taxa, including predator species, we obtained the following results (Varela, 2015):

Similar depth distributions were observed for invertebrate predators and copepods over the season. Thus, there was no avoidance of predator-rich strata by prey species. Larger copepods had different distributions than small copepods during the periods of time when the abundance of predators was higher (summer/fall). Omnivorous species had a significantly different distribution than herbivorous species. All zooplankton with large lipid reserves (copepods, euphausids and chaetognaths) avoided the surface layers during day in summer and fall. These were all species vulnerable to visual predation.

Reproduction of *C. finmarchicus* began earlier at the outer stations, influenced by the Norwegian coastal current, then in Østerbotn, as evidenced by an earlier occurrence of adult females (early March vs early April) and nauplii (early April vs May). This reflects the situation found in Isfjorden/Billefjorden in WP2.3. However, in the case of the innermost basin of Porsangerfjord, Østerbotn, the low temperatures in Porsanger is likely responsible for delayed development in the zooplankton.

In May 2014, we had a post-bloom situation, with large aggregates of diatoms dominating the phytoplankton community in Østerbotn, and Phaeocystis colonies

dominating at the outermost stations. (Priou, 2015)). Further analysis of depths distributions and VPR images reveal that the small copepod *Microsetella* sp is associated with the diatom aggregates, but not the *Phaeocystis* colonies. The phytoplankton composition from cell counts and the zooplankton occurrence at adjacent depths analyzed in VPR data also suggested associations between certain species (Fig XXXX). This analysis is only based on May and November, but will be expanded using more cell counts from May, August and October.

P2.3 (Søreide, UNIS)

In 2014-2015, we focused on data analyses and writing, and presentations of results on conferences and meetings. Additional funding from F&C Flagship has allowed us to analyse more samples from our long-term plankton data series in Isfjorden which has been the basis for one new master thesis in 2015 and also a more detailed study on meroplankton which so far has resulted in one submitted manuscript. This Isfjorden long-term data series is also the basis for one new project funded by the NRC (see below), and a new proposal to Flagship Fjord and Coast (see below).
High resolution meroplankton data (bi-weekly sampling year-round in 2012) showed that the timing of meroplankton coincided with the productive algal season from May through September with a burst of cirripedia at the onset of the spring bloom with a peak in bivalve larvae later in the bloom phase when smaller algal cells dominated. Interestingly, meroplankton comprised 50-80% of the zooplankton abundance and biomass during spring-summer which thus makes this component a very important one in coastal areas and fjords in Svalbard. This study is no under revision in Journal of Plankton Research (see below). From the monthly samples collected in Billefjorden in 2012-2013 we sorted out copepods of the genus *Calanus* (*Calanus* spp. CV and adults) in 2014-2015 which were stained so gonad status could be investigated in more detail. Preliminary results show that gonads of CV were largest in January and at that time moulting to adults started. The results of this specific study were presented at the ASLO Aquatic Science Meeting, in Granada, Spain, 23 - 28 February 2015 (Niehoff, B., Freese, D., Graeve, M., Søreide, J. E., Gonad development in juvenile *Calanus glacialis* during overwintering in a high Arctic fjord).
In 2013-2014, microscopic analyses of zooplankton samples collected in Isfjorden was done. Zooplankton (60 µm and 200 µm) from Billefjorden (Stn. BAB) from June 2012 to July 2013 were analysed as well as seasonal zooplankton (60 µm) data from Adventfjorden (Stn. ISA) from 2013. These high-resolution zooplankton data (Fig. 1) are important for several papers which now are either submitted or in their final preparation (see 6. below). Comparisons to earlier data in Billefjorden and Isfjorden show that there are considerable variations between years when it comes to total abundance, *Calanus* population development and dominant overwintering stage. In 2012-2013 the total zooplankton and *Calanus* spp. abundance was an order of magnitude higher than in 2008-2009. Main overwintering stage in 2012-13 was *C. glacialis* CIV, while in 2008-2009 it was CV. When it comes to *Calanus* reproduction this

was intensively studied from January to June 2013 in Billefjorden (Hatlebakk 2014). Females had immature gonads until early April (Fig. 2). In April sea ice algal food become more abundant and at the onset of the phytoplankton bloom in early May the majority of the females had ripe gonads and peak egg production rates were measured.

Mapping of existing mesozooplankton samples in storage at UNIS finished in early 2014 and in total 1200 samples were registered and of these ca 400 samples were from Isfjorden. In September-October, more video plankton recordings were conducted in Billefjorden (with F. Norrbin, WP 2.2 and her two MSc students) and elsewhere in Svalbard to map high resolution vertical distribution of zooplankton. No strong Diel Vertical Migration (DVM) patterns were detected by *Calanus* spp. (Fig. 3). Ontogentic migration (seasonal vertical migration) was by far much more pronounced (Fig. 3). Zooplankton high-resolution distribution patterns, particularly prey-predator distribution patterns, will be identified from these recordings and compared to those identified in Porsangerfjorden.

For the Management

There is large interannual and site variability in the development of spring blooms, with consequences for zooplankton population development and ecosystem functioning in high latitude fjords. Mechanistic understanding of what drives these differences needs to be developed.

Published Results/Planned Publications

Stübner E, Søreide JE, Reigstad M, Marquardt M, Blachowiak-Samolyk K (in review) Year-round meroplankton dynamics in Isfjorden (78°N), Svalbard. Journal of Plankton Research.

Priou, PD (2015) *Associations between herbivorous zooplankton, phytoplankton, and hydrography in Porsangerfjord, northern Norway.* MSc thesis, UiT. 57 pp.

Varela, AP (2015) *Vertical distributions of zooplankton using the Video Plankton Recorder in two high-latitude fjords.* MSc thesis, UiT. 66 pp

de Vries, C. (2015) Disentangling mortality and development rates in an Arctic copepod population. MSc thesis, 32 pp. University of Amsterdam, Netherland and The University Centre in Svalbard (UNIS), Longyearbyen, Norway.

Nordgård IK (2014) Microbial winter and spring bloom dynamics in a high Arctic fjord. Master thesis, University of Bergen/UNIS. 54 pp.

Thomson S (2014) Seasonal abundance of parasitic Marine Alveolate Group II (MALV II) in an Arctic fjord, Svalbard. UiT The Arctic University of Norway/UNIS. 84 pp.

Kristiansen HB (2014). Characterization of marine fungal communities using next

generation sequencing techniques. University of Oslo/UNIS. 52 pp.

Terwagne E (2014) Seasonality of the haptophyte *Phaeocystis pouchetii* in Adventfjorden, western Spitsbergen and Balsfjorden, northern Norway. Master thesis, POLYTECH Clermont-Ferrand/UNIS. 76 pp.

Hatlebakk MK (2014) Capital or Income Breeder: The Role of Lipids and Fatty Acid Composition for Successful Reproduction in *Calanus glacialis*. MsC thesis, NTNU/UNIS. 56 pp.

Planned presentations:

Priou, PD, Varela, AP & Norrbin, MF (in prep) Association between plankton and hydrography in Porsangerfjord, northern Norway. *Abstract for Workshop on northern fjords, Tromsø, 25-27 November 2015* (There will be a special volume with publications from the workshop)

Norrbin, MF, JE Søreide, C Halsband, TM Gabrielsen, EN Hegseth (in prep). Plankton phenology and community structure in ice covered and open high-latitude fjords; a comparison between Isfjord, Svalbard and Porsangerfjord, northern Norway. *Abstract for ICES 6th Zooplankton Production Symposium, Bergen 9-13 May 2016*. (There will be a special volume with publications from the symposium)

Norrbin, MF, PD Priou, AP Varela (in prep). Fine-scale distribution of zooplankton is linked to phytoplankton species composition and abundance. *Abstract for ASLO/AGU Ocean Sciences Meeting, New Orleans, 21-26 February 2016.*

Previous presentations:

Stübner E, Søreide JE. Timing of meroplankton in Arctic waters. ARCTIC FRONTIERS Science Conference, Tromsø, Norway, January 2015. Oral presentation.

Niehoff B, Freese D, Graeve M, Søreide JE. Gonad development in juvenile Calanus glacialis during overwintering in a high Arctic fjord. ASLO Aquatic Sciences Meeting, Granada, Spain, February 2015 (poster).

Daase M, Renaud PE, Berge J, Heggland K, Søreide JE, Vogedes D, Gabrielsen T, Varpe Ø, Cottier F, Wassman P, Falk-Petersen S, Halsband C. Size Matters- Impact of climate change at the base of the Arctic food chain. Gordon Research Conference on Polar Marine Science, Tuscany, Italy 16-20 March 2015 (poster)

Søreide JE, Daase M, Hatlebakk M, Boissonnot L, Freese D, Graeve M, Niehoff B. Fate of the key Arctic copepod Calanus glacialis in a changing Arctic. Fram Science Days, Nov. 2015

Blachowiak-Samolyk K, Trudnowska E, Dmoch K, Boehnke R, Daase M, Søreide JE (2014) Year-round patterns in mesozooplankton community structure in the Arctic fjord ecosystem (Isfjorden, Svalbard). The World Conference on Marine Biodiversity 2014 (WCMB2014), 12-16 October 2014, Qingdao, China.

Søreide JE, Daase M, Hatlebakk MK, Boissonnot L, Freese D, Niehoff B, Graeve M. Energetic costs for the Arctic copepod *Calanus glacialis* during overwintering. IMBER Open Science Conference. 23-27 June 2014, Bergen, Norway.

Boissonnot L, Søreide JE, Graeve M (2014) Effect of food and light on the development of the Arctic copepod *Calanus glacialis* during the winter-spring transition. ASLO science meeting, Hawaii, 2014.

Søreide JE, Boissonnot L, Freese D, Daase M, Hatlebakk M, Graeve M, Niehoff B (2013) Ecological effects of earlier sea ice retreat on overwintering Arctic zooplankton. University of Alaska Fairbanks, Marine biology seminar series, Oct. 2013

Communicated Results

Workshops:

Ecology of Northern Fjords, UiT The Arctic University of Norway, 25-27 November 2015, co-organized by F. Norrbin

Plankton research in Svalbard (PRiS). UNIS, 8-10 December 2015, co-organized by J. Søreide

Interdisciplinary Cooperation

Through integration with other funded projects (e.g. CLEOPATRA II, MicroFun, etc.) close cooperations are in place with physical oceanographers at SAMS, UK and Jørgen Berge (UiT/UNIS) for maintaining and processing continuous hydrography data collections on moorings at sampling locations in Billefjorden and Isfjorden. The project further benefits from a co-operation with the Shirshov Institute Moscow, Russia (NFR/NOR-RUSS, 'Fate of COPePod secondarY production in a changing Arctic' COPPY, 2013-2016).

Budget in accordance to results

Flagship funding has financed salaries, equipment, sampling efforts in Svalbard and mainland fjords, ZooScan analyses and conference presentations. Additional personnel was supported to perform the weekly sampling in Adventfjorden and to run Zooscan analyses. Regular sampling efforts are costly, and would not have been possible without funding from the Flagship. Some funds were used to purchase field equipment (Niskin bottles) and part of a Microscope PAM.

Could results from the project be subject for any commercial utilization

No

Conclusions

During the project, we have optimized and established the use of qPCR (quantitative PCR) to quantify the abundance of microbial eukaryotes such as *P. pouchetii* in sea water samples, a tool to allow us to study the seasonality of these microbial organisms. In addition to the fact that the bloom forming species are present in the water column throughout winter, a close relationship between the colony-forming flagellate *Phaeocyctis* and diatoms was found in Balsfjorden, potentially with wider significance. The differences and similarities found in the timing and dynamics of phytoplankton blooms in Balsfjorden and Isfjorden present opportunities for further research on bloom dynamics, composition and diversity in a changing Arctic and the implications for zooplankton grazers and their own spatial and temporal dynamics.

Seasonal data sets of zooplankton abundance, size, taxonomic structure and vertical distribution are now available for the ISA station in Isfjorden and for Porsangerfjorden from several years. Size structure will be compared between the mainland and the Svalbard fjord, together with further sample analysis from other fjords (Billefjorden, Svalbard shelf). We have obtained a seasonal overview of vertical zooplankton structure in Porsanger and now also have some data from Billefjorden (January and October). Interannual variability in *Calanus* ontogeny and overwintering strategies, as well as detailed reproduction cycles were recorded. Two workshops in Tromsø and in Svalbard in late 2015 bring together international experts in fjord physics, geology and plankton ecology to discuss recent research results and integrate both current knowledge and available methodologies.