

Kongsfjord Flagship Workshop 2018

20. – 21. September 2018, Fram Centre, Tromsø

Scientific Report



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Project title:

RIS number:

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Outline of the Marine Kongsfjord Flagship

The European Arctic has been identified as one of the primary region in the Arctic to be impacted by global climate change. Kongsfjorden (KF) near Ny-Ålesund is a unique study site to research these changes and draw conclusions about the future of the Arctic, as an extensive body of investigations forms a unique knowledge base nowhere else present in the Arctic. However, knowledge gaps persist about environmental changes and their impacts on different systems of the KF. The Kongsfjord Flagship Program (KFP) aims to facilitate networking among researchers, provide a structure to research and monitoring activities, and increase visibility and impacts by joint research projects. The research objectives of the KFP include impacts of changes like climate change and Atlantification on different systems and their adaptations and responses thereto, as well as modelling future outcomes.

Main hypothesis within the KF Flagship:

- Warming and acidification in Arctic coastal waters will continue
- Tidewater glaciers will diminish with consequences for seawater circulation and associated biological systems
- “Atlantification” will continue, leading to local extinction of endemic and the establishment of temperate species

Prioritized research questions:

- Is KF a suitable model system to project the future of marine ecosystems on Svalbard and beyond?
- Are contemporary changes harbingers of the future in other fjords?
- What consequences will “Atlantification” have for ecosystem processes and services such as carbon uptake and storage, sources/sinks of nutrients, or dynamics of contaminants in the food webs?
- Can effects of climate change be mitigated by acclimation and adaptation, and if so, what will those responses be?
- What is the timescale of responses towards different and interacting environmental drivers and can they help sustain ecosystem services?

Main achievements of the KF Flagship

Proposals:

Nov 2015: SSF workshop proposal: “Adaptations to the environmental changes in the Arctic”

Nov 2016: Proposal for Svalbard Strategic Grant “Studying adaptive processes in the changing Arctic”

Feb 2019: EU pre-proposal to the Horizon 2020 program

Workshops

Oct 2016: Workshop “Adaptations to environmental changes in the Arctic”. Main achievements: building of six working packages, perspective paper and recommendation letter to NySMAC.

Nov 2017: Svalbard Science Conference: flagship sessions, project brainstorming and EU call

Sep 2018: KF Flagship Workshop in Tromsø, Norway: networking within and across working packages and flagships, brainstorming for future collaborations and joint projects

Papers:

2019: Strategy paper: Bischof et al. 2019 “Kongsfjorden as harbinger of the future Arctic: knowns, unknowns and research priorities”, *Advances in Polar Ecology* (in press).

2019: Review papers from marine studies in KF (in Hop H., Wiencke C. (eds) *Advances in Polar Ecology: Ecosystem Kongsfjorden, Svalbard*. Springer Publishers, in press, DOI:)

The 2018 Kongsfjord Flagship Workshop

Outline

The aim of the 2018 KF Flagship Workshop was to give an overview of the scope of the flagship and to discuss current research and future perspectives. The workshop served as a platform for discussion within and between the working packages, for presentation of current research, and for connection between researchers towards integrated projects and collaboration.

Agenda of the Workshop 20-21 September 2018

Thursday 20 September

- 09.00: Welcome, practical information & workshop aims (Geir Wing Gabrielsen)
- 09.15: Status of KF Flagship: achievements & perspectives (Kai Bischof)
- 09.30: Short introduction from the Work Package (WP) chairs (aims & scope)
- 09.45: Introduction to the KF marine ecosystem (Haakon Hop)
- 10.15: *Coffee*
- 10.45: Introduction to marine observatories in KF (Finlo Cottier)
- 11.15: Local and long range pollution in KF (Maria Granberg)
- 11.45: *Lunch*
- 13.00: Work Package discussions (lead by the WP chairs)
- 17.00: End of day
- 18.00: *Workshop dinner at Fiskekompaniet, Killengrens gate*

Friday 21 September

- 09.00: Cross WP speed-dates
- 11.00: Presentation of discussions from the WPs (WP 1-4)
- 12.00: *Lunch*
- 13.00: Presentation of discussions from the WPs (cont. WP 5-6)
- 13.30: Existing marine infrastructure and ideas and input for further development (Christina A. Pedersen and Ingeborg Hallanger)
- 14.00: *Coffee*
- 14.15: Knowledge gaps and recommendation for future research and monitoring in Kongsfjorden. Input to further development of the flagship network
- 15.00: SIOS and SIOS marine core data (Øystein Godøy)
- 16.00: End of workshop

Presentation I: Kai Bischof “Status of the KF Flagship: achievements & perspectives”

In this talk, the aims and structure of the KF flagship were outlined and the history of the flagship and current important projects were presented (as described above). It was emphasised that the flagship has a bottom-up approach, and that collaboration with other flagships could be useful.

Slides provided by Haakon Hop

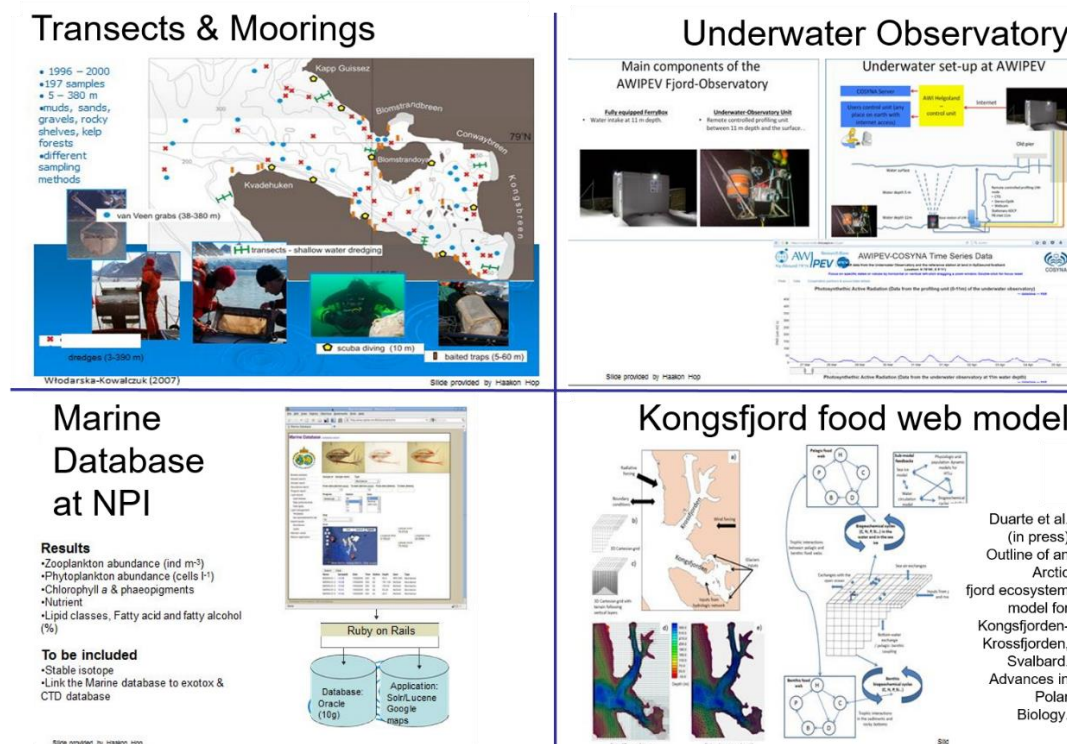


Figure 1: Overview over tools available to the marine flagship in KF. Slides provided by H. Hop to K. Bischof

Presentation II: Haakon Hop “Introduction to the KF marine ecosystem”

In this introduction to the KF marine ecosystem, a variety of changes that occurred in the last 20 years were presented and discussed. Physical changes in the KF include sea ice, temperature, and the ratio of Arctic and Atlantic water. Since 1996, the sea ice index has decreased from more than 10 to less than 3, as has the percentage of Arctic water in the fjord (from about 20% to almost 0%). In the same period, the average temperature rose about 2°C, and the percentage of Atlantic water increased from 0% before 2000 to more than 20% today (a paper by Hop et al. is in press). This has led to changes in the composition of the KF ecosystem, as Arctic species have decreased in abundance, and Atlantic species have increased¹⁻⁴. Similar trends were observed in black-legged kittiwake diet, where the proportion of Atlantic fishes has increased as opposed to Arctic fishes in the birds diet⁵. Changes have also been observed in the KF macroalgae, its biomass has moved upwards into more shallow waters due to less sea ice and warmer water temperatures⁶, and a similar trend was observed for macrobenthos⁷.

Furthermore, important research concerning glaciers in KF was addressed. The most important conclusions are that tidal glacier plums contain high sediment loads, which reduces light transmission and thereby primary productivity; the plums also contains elevated concentrations of ammonia, urea, nutrients and oxygen. Zooplankton near the glacier plums are abundant and sustain large communities of fish near the glacier front, which constitute a feeding hotspot for

various Arctic seabird species. The retreat of tidal glaciers due to climate change will affect the estuarine circulation, production and food availability for foraging seabirds and other Arctic predators (see *e.g.* reference⁸).

Link to lecture: <https://bit.ly/2TJmYLv>

Presentation III: Finlo Cottier “Introduction to marine observatories in KF”

In this talk, different marine observatories in KF and the Arctic were presented, as well as important current research questions. Currently, there are several ongoing time series projects in the Arctic (see Figure 2), leading to more than 60 data series and more than 50 years of data from 12 different locations in fjords, basins and on shelves and shelf slopes. These pan-arctic time series are being integrated by collaboration of ARCTOS, NABOS, Arctic Net, Fisheries and Oceans Canada and the North Pole Environmental Observatory. The measurement platforms in the Arctic and in KF are various, such as moorings, ships, tagged animals, or satellites (see Fig 2b), which all have unique advantages and disadvantages.

Important current research questions include winter ecology in the Arctic, seasonal variation of various factors, Atlantification of the Arctic and the impacts thereof, and glacial dynamics (see *e.g.* references⁹⁻¹⁴). Also, the issue of data coupling was addressed. SIOS and iMOP work towards open and accessible databases to improve data coupling and collaboration.

Link to lecture: <https://bit.ly/2TJmYLv>

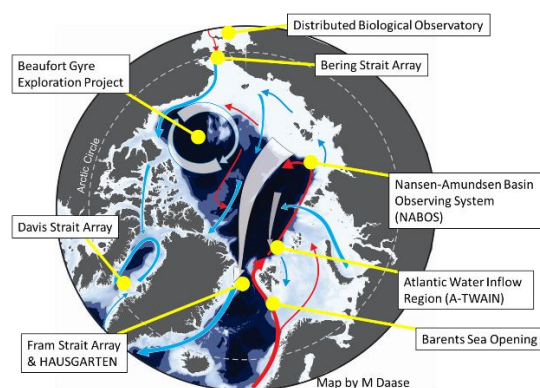


Figure 2: Arctic time series. Map by M. Daase on Haury et al. 1978

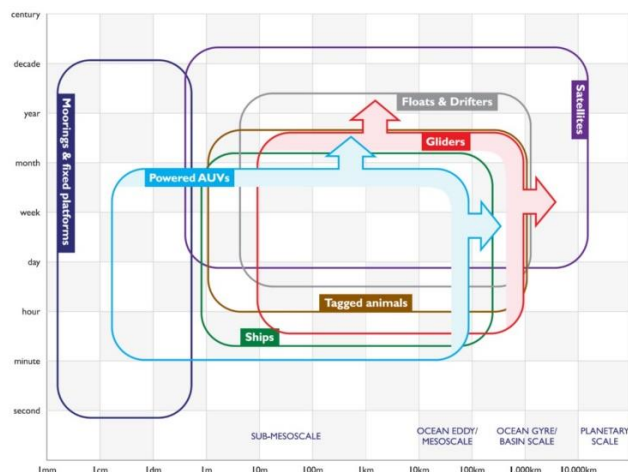


Figure 2b: Measurement platforms. After Nielsen et al. 2015 based

Presentation IV: Maria Granberg “Local and long range pollution in KF”

The global distillation theory proposed by Wania and Mackay¹⁵ is the base for the assumption that long range transport is close to the sole reason for pollutants to culminate in the Arctic. However, local pollution does exist on Svalbard, *e.g.* from mining, oil drilling, shipping, human inhabitation, lacking sewage treatment, or tourism, and one of the current research aims is to determine the proportion and composition of the local pollution on Svalbard. One concerning pollutant is plastic, and the knowledge gaps include concentrations of microplastic in the Arctic and temperate regions, sources, and effects/consequences on biota. In 2017, a cruise to KF and Rijpfjorden and the marginal ice zones attempted to address these knowledge gaps and gathered samples from the sediment, the open water column, sea ice and biota. These samples were analysed visually (microscope), and chemically to determine the polymer structure. High concentrations of microplastic were found in sea ice and water, less in sediment, but there larger

particles. Fibres dominated in biota, sea water and sediment, while particles dominated in sea ice. One hotspot in the middle of the KF with high concentrations of microplastics might be attributed to a nearby sewage outlet. In Rijpfjorden, however, the highest concentrations were close to the sea ice edge. Flame-retardants, phthalates and Bisphenol A, chemicals associated with plastic, were also measured. Brominated flame-retardants showed high levels near the sewage outlet in KF. Generally, these plastic associated chemicals have rather low concentrations compared to legacy pollutants; however, concentrations near human settlements are higher, and Bisphenol A and BFRs seem to be linked to local sources.

More information about local pollution can be found in reference¹⁶.

Another concerning local pollution in the Arctic are pharmaceuticals. As there are mostly no sewage treating facilities in the Arctic, antibiotics are directly transported into the ocean with hospital sewage, e.g. in Sisimiut, Greenland. This has led to antibiotic resistance towards β -Lactam and decreasing bacteria diversity in fish guts near the releasing pipe (Granberg et al *in prep*). This indicates, that even very low concentrations of chronic contamination can cause ecosystem change such as lower biodiversity or changed community composition. Although the Arctic species exposed to this low-level contamination might be adapted and thrive, the organisms become vectors for contaminant transfer, which may affect migrating non-adapted animals adversely.

Link to lecture: <https://bit.ly/2TJmYLv>

Presentation V: Øystein Godøy “SIOS and SIOS marine core data – Internal and external requirements”

SIOS promotes free and open access to data to everybody, and it is requested that the data is made available as soon as possible by the researcher. However, access is restricted when the release of data would affect confidentiality, international relations, public or national security, the course of justice, the confidentiality of commercial, industrial, or personal data, or the protection of the environment (more information in the INSPIRE and 2003/4/EC directives). The overall objective of SIOS is to “*develop and maintain a regional observational system for long term acquisition and proliferation of fundamental knowledge of global environmental change within an Earth System Science perspective in and around Svalbard*”, with an emphasis on long-term data collection and time series. The SIOS approach to data management is dataset oriented, metadata driven, based on open data space policy and oriented towards the connection of data centres and disciplines. The SIOS database integrates and bridges different data centres, which each have their own procedures and technical solutions. To achieve this, it is crucial to develop a common language with precise vocabulary.

The ENVironmental Research Infrastructures (ENVRI) connects SIOS with many other data base projects within the subdomains of atmosphere, marine, solid earth and biodiversity/ecosystems. The aim of EVRI-FAIR is that all participating research infrastructures have built a set of fair data services, which enhance the efficiency and productivity of researcher, support innovation, and enable data- and knowledge based decisions. Criteria for FAIR data are: findable, accessible, interoperable, and re-usable.

Type	Purpose	Description	Examples
Discovery metadata	Used to find relevant data	Discovery metadata are also called index metadata and are a digital version of the library index card. It describes who did what, where and when, how to access data and potential constraints on the data. It shall also link to further information on the data like site metadata. GCW is required to expose this information through WMO Information System as well. Discovery metadata are thus WIS metadata, although the GCW portal can translate to WIS for those not using WMO standards directly.	ISO19115 GCMD DIF
Use metadata	Used to understand data found	Use metadata are describing the actual content of a dataset and how it is encoded. The purpose is to enable the user to understand the data without any further communication. It describes content of variables using standardised vocabularies, units of variable, encoding of missing values, map projections etc.	Climate and Forecast Convention BUFR GRIB GBIF/DwCA
Configuration metadata	Used to tune portal services for datasets for users.	Configuration metadata are used to improve the services offered through a portal to the user community. This can be e.g. how to best visualise a product. This information is maintained by the GCW portal and is not covered by discovery or use metadata standards.	
Site metadata	Used to understand data found	Site metadata are used to describe the context of observational data. It describes the location of an observation, the instrumentation, procedures etc. To a certain extent it overlaps with discovery metadata, but more so it really extends discovery metadata. Site metadata can be used for observation network design.	WIGOS OGC O&M



www.sios-svalbard.org

Figure 3: SIOS types of metadata. Figure provided by Øystein Godøy



Figure 4: SDMS basic principles. Figure provided by Ø. Godøy

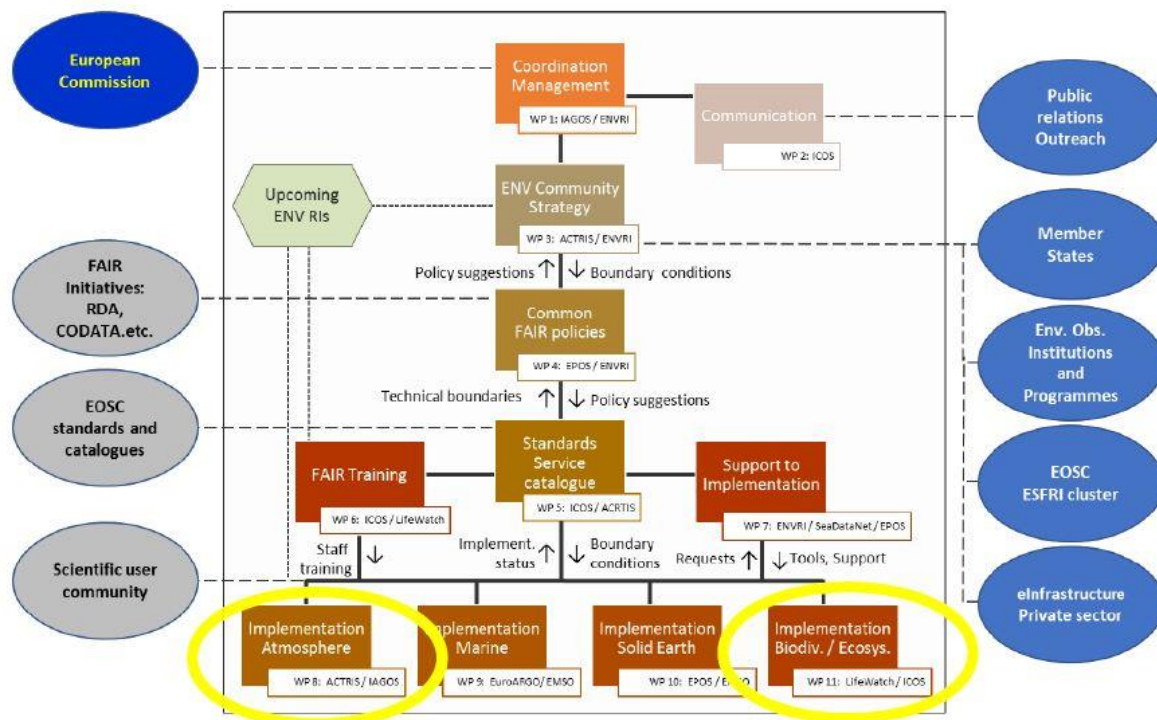


Figure 5: The ENVRI-FAIR structure. Source: Ø. Godøy slides; sios.svalbard.org

Links:

<https://sios-svalbard.org/>

<http://envri.eu/>

Within workgroup meetings September 20, 2018

WP1 Physical, chemical and ecological observations (F. Cottier, SAMS, UK)

Current research

Haakon Hop: Ecology and bioenergetics of pelagic, sympagic (ice-associated) and hard-bottom fishes and invertebrates in Arctic waters

Arild Sundfjord: Upper-ocean vertical mixing processes; effects of turbulence on stratification and ice melt and formations; horizontal density gradients and large scale oceanic circulation

Sebastian Gerland: Sea ice and climate research with focus on the Arctic, especially Fram Strait, Svalbard and Barents Sea – sea ice thickness investigations, sea ice growth, melt and drift; remote sensing, glaciology

Sarat Tripathy: Primary productivity and bio-optical studies for understanding dynamics of KF and Krossfjorden during summer (monitoring primary productivity through FRRF, chlorophyll, phytoplankton taxonomy, pigments, as well as chemical, physical and bio-optical parameters).

Philipp Fischer: Fish behaviour; fish acoustic; underwater observatories; scientific diving;

Manuel Bensi: Large-scale Mediterranean Sea circulation, Arctic and Antarctic oceans, dense water formation, bottom-arrested currents, eddies, thermohaline variability. Research areas of interest are the Mediterranean Sea and the Polar Regions.

Leonardo Langone: Oceanography, paleoclimatology and geochemistry

Finlo Cottier: Long term, multi-parameter marine observatories to investigate coupled processes in Arctic waters and now utilising robotic platforms that will transform marine research in the coming decades

Discussion of WPI

Text by Finlo Cottier

The main focus of the discussion throughout the day was on the role that sustained marine observations in the form of instrumented moorings can support and inform on other scientific areas of the flagship. There was recognition of the historic value of the observations and the additional observational capacity that new moorings bring to the site. However, the primary direction of the WG discussions was on aspects of coordination, harmonisation and data access.

In terms of coordination, there are two elements to this. One is coordination locally, and future discussions on optimising (if necessary) the placement of moorings to best represent the spatially varying conditions in a dynamic environment (e.g. inflow, outflow, inner basin, etc.). The other is coordinating with other mooring operations around Svalbard (e.g. Isfjorden, Rijpfjorden and moorings offshore on the western shelf/slope). The full value of the KF moorings is only realised when taken as part of a larger picture of observation in the region. This can be further expanded so that the observations are a node in a network of pan-Arctic observations. Here we should be making links with, for example, SAON [www.arcticobserving.org].

Additional coordination of mooring activities might include harmonisation on the instrumentation that is used, agreements on calibration and operation of the instruments, disposition of available instrumentation on each mooring in KF. This is much longer term and is likely to be dependent on resources from the operator of each mooring. Further, the lifespan of moorings is often uncertain as it can depend on the particular blend of funding available. One mooring in KF is implemented in the Norwegian SIOS Infrastructure programme SION InfraNOR, which in effect will ensure that it will be in operation until 2026.

The addition of new instruments to moorings requires careful communication between the research groups and the mooring operators. Often the instruments are very particular in their function/calibration and need a level of skill and/or experience to be able to generate the highest quality data. An example of that is the addition and use of pH meters to moorings to monitor Ocean Acidification. This requires very careful understanding of how the instrument behaves long term and how data is then subsequently processed. This could form the basis of a small research project in itself.

Data in particular was an area of intense discussion. There needs to be a level of communication and coordination between institutional/national data archiving and the accessibility through, for example, SIOS. The later presentation on SIOS data systems was helpful in this respect. However, the onus is still on the owners of the instrumentation to get their data into accessible formats and internationally recognised data centres. One proposition for kick-starting the data coordination activity would be to work towards a common paper that required data to be prepared and available for the group; effectively drive data delivery through a scientific exercise rather than an administrative one. Even focussing on a single year – for example, 2018, would be an important start in this respect.

Although the WG only considered mooring data, there was a discussion around the curation and availability of data from other aspects of the WG, e.g. related to the chemical and ecological measurements. There was a recognition that whilst some participants have these data well

organised and accessible, there is great inconsistency across all groups working in KF. It is likely that there are considerable amounts of data that are not available to the community for a variety of reasons.

Sebastian Gerland gave a comprehensive description of the time series of sea ice observations (extent, thickness and snow cover) from KF. Many of these data are summarised or published in journals. These are supplemented by additional metrics of sea ice cover derived either from remote sensing products or acoustic measures of ice presence/absence. It is important that these metrics are made more widely known and available. A review paper on sea ice in KF will be published in the Kongsfjord volume of *Advances in Polar Ecology*.

There was a short discussion on the utility of KF locality to be an ideal place for testing, developing and operating robotic platforms. Future infrastructure plans need to take this into account both for marine and airborne platforms.

Key Action Points

- Collate and publicise the variety of sea ice observations that are available.
- Try and arrange an annual meeting of mooring operators (perhaps by video conference)
- Prepare a 1-page annual summary of mooring operations and a look ahead a plan for future deployments.
- Create a consistent data product from the moorings against which to validate models
- Investigate if sediment trap material can be used for investigating distribution of marine plastics.

WP2 Contaminant flow and deposition (G. W. Gabrielsen, NPI, Norway)

Current research

Geir W. Gabrielsen: Screening of new contaminants in the Arctic; food web studies, plastic studies in seawater, sediments, sea-ice and biota; POP effect studies on Arctic sea birds; effect of climate change on POP and mercury levels

Zhiyong Xie: levels, seasonal trends and dry and wet deposition of emerging POPs in the Arctic and the role of climate change on long-range transport (LRT) and geochemical cycling of emerging POPs in the Arctic

Nicoletta Ademollo/Luisa Patrolecco: Distribution, fate and trends of legacy and emerging POPs in Mediterranean and Polar ecosystems; water quality; effects of POPs in biota and on structural and functional characteristics of ecosystems

Stefano Aliani: Floating microplastic in the Mediterranean, Arctic and Southern oceans. Projects: BASEMAN, ESA Space plastic, SCOR WG153

Ingjerd Krogseth: Mechanistic environmental fate and bioaccumulation models to understand and predict emissions of organic contaminants and exposure to ecosystems and humans

Anita Evenset: Effect of climate change on contaminant composition in KF; local pollution on Svalbard; effect of climate change on mercury methylation; effect of runoff on nutrient composition; Bjørnøya: POP trend studies, POP effects on fish; NOR-RUS: marine litter project between Norway, Russia, Japan and France

Maria Granberg: Interaction between eutrophication and contaminants; oil and pharmaceutical pollution on Greenland; effects of pollution from shipping; method developing for plastic research

Yubo Li: Working on sampling devices for microplastics, because the nets material might interfere with the samples, and the water volume determination is not accurate

Ingeborg G. Hallanger: Uptake and transfer of contaminants in Arctic marine food webs; transport and levels of contaminants in the abiotic environment; microplastic contamination of the Arctic marine and terrestrial environment

Discussion of WP2

1. Project ideas related to contaminants in the Arctic

Chemical contaminants:

- interactions between chemicals (especially new contaminants) and climate change in food webs
- comparison between local and LTR pollution
- emerging POPs in different compartments of the ecosystem
- contaminants in glacial runoff
- analysis of old samples with new technology

Plastic pollution:

- finding improved methods for sampling and analyses
- effects of plastic on biota and human health
- analysis of biofilms on plastic particles and their effect on uptake
- biogeography of plastics
- microplastics in sea ice – composition of biofilm, effect on sea ice species, physics between plastic and sea ice
- studies on nanoplastics, additives and degradation in the Arctic

Other pollution:

- effect of pollution from shipping on Arctic ecosystems/species (noise, turbulence, contaminants, oil spills)

effect of tourism on the environment and limits of tourism in the Arctic

2. Current data/results

Currently, work is being done on ocean currents and plastic transport, and models are being developed to predict where the plastic could end up. The Governor of Svalbard has a lot of important information on plastic pollution on Svalbard.

In 2020, a NPI cruise is planned to investigate plastic pollution around Svalbard.

3. Current applications or projects

- Aliani and Ademollo: proposals pending for contaminant research in Greenland
- NILU: combined effect studies of climate change and contaminants; non-target screenings of emerging contaminants
- Li: Shangai contaminant and plastic samples will be compared to data from KF
- Granberg: trying to establish collaboration with meteorologists to work on fate of plastics

4. Possible partners for interdisciplinary contaminant studies

Possible partners could come from a background of snow and sea ice research or oceanography to investigate the fate and behaviour of different contaminants in the physical environment, especially with regard to climate change. Collaboration with modellers would be useful to understand current contaminant behaviour in e.g. the physical environment or food webs, and predict future outcomes. Analytical researchers could help establish better methods for emerging chemicals and plastic analyses.

5. Key action points

- Develop methods for plastic sampling and analysis
- Assessing the origin of plastic particles
- Studying the effect of climate change on contaminants (e.g. distribution, behaviour, fate, chemistry)
- Compare KF with other Arctic fjords (e.g. Rjppfjorden)
- Assess the role of adaptation to climate change and rising contaminants
- Study emerging compounds: metabolites and their effects on biota

WP3 Land-sea-atmosphere interactions (K. Bischof, Univ. Bremen, Germany)

Current research

Peter Convey: Biodiversity and biogeography of polar terrestrial invertebrates, plants and microbes; life history and ecophysiological strategies of polar terrestrial biota; polar ecosystems as models to identify the past and future global consequences of climate change; palaeobiogeographical reconstruction; and human impacts, conservation and management

Kai Bischof: Ecophysiology of seaweed; acclimation strategies towards abiotic stress; stress physiology of zooxanthellae; physiological protection mechanisms against high light stress; generation and scavenging of reactive oxygen species; competition; bioinvasions; comparative research on related algae from different climate regions

Agneta Fransson: Polar Ocean carbonate system, CO₂ fluxes and biogeochemical processes in sea ice and seawater in the Arctic and Antarctica. Focus is on the effect of increased CO₂ in the oceans (ocean acidification), and the related processes for the understanding of seasonal and inter-annual variability. Main studies on the effect of ice formation and ice melt from sea ice and glacier on surface water CO₂ and calcium carbonate saturation state, which is a measure on chemical stability of calcium carbonate, and processes within the sea ice and the exchange at air-ice-water.

Maria Jensen: Modern coastal sedimentology in the Arctic, reconstruction of climate and sea level from the sedimentological record, sand body geometrics in fluvial to nearshore environments, and evolution of Arctic coastlines

Discussion of WP3

Text by Peter Convey

The group shortly discussed the scope of WP3 – inputs into fjord system; climate/glacial influences on ecosystem functioning; change and black carbon; sediment and freshwater input; radiation and salinity influence on primary production; modulation of trophic interactions (transfers) between marine and terrestrial systems; use existing data to make initial predictions.

Given largely interdisciplinary expertise present in a rather small group, a somewhat pragmatic approach was taken to identify ‘what would be possible/practicable to do in a reasonable timescale?’

Some driving interests/ideas provided the focus of most of the discussions:

- A need to avoid ‘parochialism’ which is a danger focusing on a single fjord system, i.e. the need to provide foundation for larger scale polar/bipolar relevance and generalisation
- Land-sea exchanges (both directions), involving nutrients, sediments, invasive or native species movements. Elements of this include: terrestrial runoff/freshwater determining seawater chemistry; sediments directly affecting organisms; effects through light on primary producers; interaction with less ice; ‘negative’ effects of increased sediment on

certain biota (but also positive on others?); increased kelp biomass in shallow water (temperature effect?); lower distributional limits shifting upwards; shifts in biodiversity/biomass/trophic functions represented; new trophic systems establishing (e.g. reindeer grazing on seaweed). Also methodological issues of differing uses of sediment traps by biologists and sedimentologists – more interaction/mutual comprehension needed.

- Coastal parts of fjord systems like KF are very dynamic, while across Svalbard different fjord systems are under differing glacial and local geological (chemistry) influence, again emphasising value of comparative approach, and possibility of using fjords at different stages of development as past/future analogies – e.g. Dicksonfjorden as a future KF. Potential (actual) work on sedimentary microbiology and other features (both across and along fjords) across gradients away from outlet sources. Quite good physical descriptions of different systems exist. While coastal dynamics (accretion/erosion) are very active they are largely unquantified (specific project in Isfjorden), while mapping and remote sensing increasingly powerful. Potential for more detailed (labour intensive) local scale studies on sediment changes and retention timescales. May be possible to estimate timescale of transition from marine – intertidal – true terrestrial habitat formation as sediments extend out into fjord, and whether this is changing (and with it succession processes) in a more rapidly warming world.
- Detailed study of glacial deltas could provide mass balance information, and link with sediment concentrations in discharge water and seawater; also be looked at over varying timescales (practical logistics), and in relation with weather and marine conditions. Caution that deeper marine sediment grabs in KF are not easy to relate directly to terrestrial environment. Organic material is present in deep sediments. Potential for examining human influence (coal, pollutants) on sediments spatially, or over time.
- Mass and chemical/biological contribution of ‘sandstorms’ – transfer from land to sea by wind! More widely, long distance transfer of dust, pollutants, biological propagules (clear links with other WP groups).
- Yearly sea ice cores for chemistry analysis; influence of freshwater (glacial) in sea ice formation.
- Quantification of freshwater release (isotope measurements) (how accurately can we do it? Calculations from pH/salinity changes, precipitation, river flows, precision 3D mapping of glacial mass loss (same for accurate quantification of sediment input).
- Potential for much more accurate estimating/modelling of nutrient transfers land-sea and v.v. Dissolved nutrients could be from biological sources (bird colonies) and could be differentiated from mineral (rock) sources using stable isotopes or organic chemistry. Polish group at Hornsund is using isotopes to trace vertebrate input into both local terrestrial and adjacent marine ecosystems, also near LYR. Potential of KF for representative studies of this sort.
- We note that our expertise could not really address ‘atmosphere’ connections (despite the overall WP title being ocean-land-atmosphere interactions!), but this also includes changing CO₂ and warming.

We discussed what sort of work might actually be achievable on different timescales, over and above what individuals or separate institutions are already doing. Small parts of additional work can be funded/added to existing plans for existing staff through normal core institutional funds, where specific future fieldwork is already planned, and taking advantage of different investigators coinciding in the field. Potential, where collaborations involve UNIS/Norwegian

investigators, for planned use of UNIS Masters students to create Master's projects using existing collected material and/or data. In terms of greater ambition in new proposals, we felt that the only plausible opportunities are with funding calls whose deadlines are from next fall onwards. Mechanisms exist to apply for PhDs in Norwegian and German systems (also UK), but the overall driving need is to be able to fund salary costs in larger calls. The use of imaginative Fellowship opportunities – Carlsberg, L'Oreal, Total, National Geographic, and charitable/philanthropic foundations should also be explored, as these can be 'attracted' by polar work.

Key action points:

The group came up with two larger scale potential new project titles that might be suitable for developing international collaborative groupings directed at future larger funding calls:

'Does terrestrial runoff and contained nutrients control the distribution of biodiversity in the marine fjord environment in the same way as it does on land on Svalbard?'

How are runoff processes changing in the KF environment, as a paradigm for the physical and chemical impacts of land-sea interactions?'

Against this background, the group plans for a pilot study on downstream effects of terrestrial run-off (sediments and freshwater) in front of the Midtre Lovénbreen discharge delta. Related changes in light and nutrient availability, consequences to the coastal carbonate system and potential feed-back loops from sea to land should be addressed. Initial activities will be conducted during the summer season of 2019 and are supposed to yield preliminary data as foundation of upcoming interdisciplinary research proposals.

WP4 Seasonal control of the nutrient regime (C. Jimenez, Univ. Malaga, Spain)

Current research

Carlos Jimenez: Influences of environmental factors (e.g. temperature, CO₂, UV radiation, light/dark cycles, nutrient loads) on photosynthesis, carbon uptake, growth, composition and response to stress in selected species of macroalgae in KF

Benjamin Viñegla: Soil ecology (soil functionality associated with microbial activity), biogeochemical cycles in terrestrial ecosystems, plant-soil relationships with emphasis on Mediterranean forests. Arctic research: the role of microbial communities in soil nutrient mineralization and its influence on the marine ecosystem

Børge Damsgård: Marine and freshwater behavioral ecology; ecological interactions; predation and anti-predator behavior; competition and aggression; behavioral trade-off mechanisms; fish biology; environmental adaptation and acclimation; physiological and behavioral stress responses; growth and maturation; underwater acoustics in whales; experimental ecology; animal ethics; tourism; citizen science

Discussion of WP4

Text by Carlos Jimenez

In the summer months, continuous solar irradiation coincides with a nutrient-depleted and strongly stratified environment. Due to the combination of these factors, Arctic algae in summer are prone to regular or even chronic photoinhibition. However, increasing global temperatures may lead to the release of different forms of organic and inorganic N and P from terrestrial sources. Increased contribution to the N and P pools in the fjord in summer may affect growth

and metabolic performances of phytoplankton as well as benthic micro- and macrophytes. Given the strong interactive effects of nutrient limitation and other environmental drivers (e.g. temperature, CO₂) on the competition between photosynthetic organisms, such knowledge is indispensable when assessing the potential for climate change adaptation of the KF system. Important gaps of knowledge include remobilisation of nutrients from the permafrost, the seasonality of nutrients, atlantification and runoff, the future of phytoplankton blooms as well as macrophytic and nitrophylic species. Furthermore, the changes in the community structure and the possible mismatch between primary producers and consumers need to be addressed.

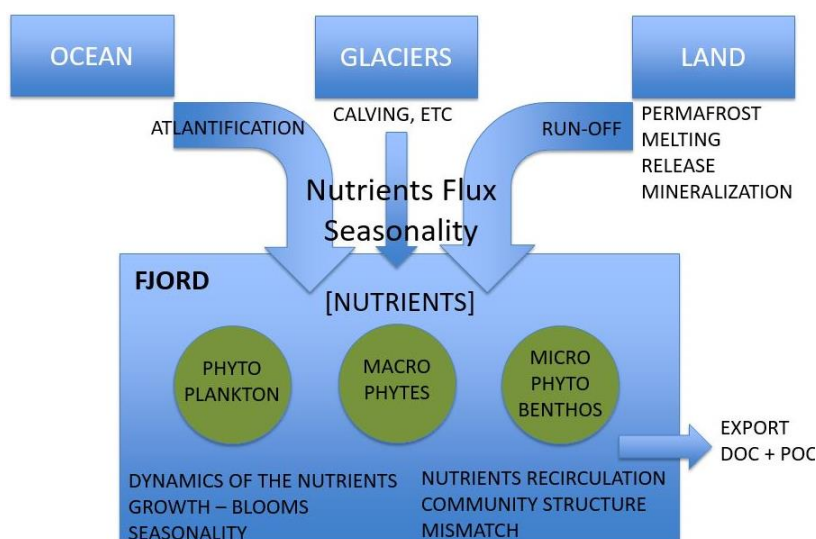


Figure 6: Possible influences on the KF systems. Figure made by WP4 led by Carlos Jimenez.

Current data

Our knowledge on the effects of increased nutrient loads on Arctic photosynthetic organisms in the summer period is very scarce. Gordillo et al. (2006) indicated that external Carbonic Anhydrase activity was present in all 21 species of macrophytes analyzed, and showed a general decrease after nutrient enrichment. Inversely, Nitrate Reductase activity increased in most of the species examined. Changes in pigment ratios pointed to the implication of light harvesting system in the acclimation strategy to increased nutrient concentration. Despite enzymatic and pigmentary response, the Arctic seaweeds can be regarded as not being N-limited even in summer, as shown by the slight effect of nutrient enrichment on biochemical composition. The exception being the nitrophilic species *Monostroma arcticum* and, to a lesser extent, *Acrosiphonia sp.* For the rest of the species studied, no general pattern was shown. Acclimation to unexpected nutrient input seemed to ensure the maintenance of a stable biomass composition, rather than an optimized use of the newly available resource (except for the nitrophilic species). This indicates a high degree of resilience of the algal community to a disruption in the natural nutrient availability pattern.

Possible partners

Prof. Carlos Jiménez, from the University of Málaga, Spain, will be responsible of the coordination of the group, as well as will participate on the macrophytobenthos research.

Prof. Angela Wulff, from the University of Gothenburg, Sweden, will participate in the analysis of the effects of increased nutrient loads on microphytobenthos communities.

Prof. Benjamín Viñeola, from the University of Jaén, Spain, will be responsible of the study of the contribution of soils to increased nutrients in KF.

Prof. Børge Damsgård, from The University centre in Svalbard (UNIS), will participate with contribution to the analysis of nutrients and flux in the littoral zone.

Key action points

- How much of the organic N and P from the permafrost is mobilized and mineralized and enters the fjord?
- How much N and P are mobilized through soil erosion?
- Influence of Atlantification
- Seasonality of the nutrients
- Phytoplankton blooms (time of the year and composition)
- Macrophytes. Possible blooming of nitrophylic species
- Role of microphytobenthos in nutrients cycling
- Changes in the structure of the communities (phytoplankton, microphytobenthos and macrophytes)
- Mismatch between primary producers and consumers

WP5 Response to key environmental drivers and adaptive potential (J. P. Gattuso, CNRS, France)

Current research

Jean Pierre Gattuso: Cycling of carbon and carbonate in marine ecosystems

Clara Hoppe: Arctic primary production; phytoplankton ecology; ocean acidification effects on polar phytoplankton communities; multiple stressors; photophysiology & carbon acquisition in phytoplankton; biogeochemistry; marine carbonate chemistry

Jozef Wiktor: Arctic phytoplankton and ice-algae taxonomy and ecology

Anette Wold: Long term monitoring of pelagic ecosystems including nutrients, phytoplankton and zooplankton

Discussion of WP5

Text after Jean Pierre Gattuso

1. Overall goals and research approach

The understanding of the response of biological communities to on-going and future changes in the Arctic is very poor, especially the capabilities for acclimation and adaptation. To tackle these knowledge gaps, a two-pronged approach should be taken. First, time-series observations of physical, chemical and ecological parameters need to be analysed in terms of bioclimatic envelopes and responses to continuous and abrupt events. While the KF ecosystem may serve as a harbinger of changes to be observed elsewhere, field observations often do not allow to identify causal driver-response relationships because of natural variability and co-occurring of multiple environmental change (e.g. simultaneous change in temperature, nutrients, pH etc.). Thus, hypothesis-driven experimental studies are necessary to develop process-based understanding, which can then be fed into parametrizations of ecological and biogeochemical modelling approaches that aim at predicting future ecosystem services. Therefore, perturbation experiments with three objectives should be undertaken:

- Investigate communities and several trophic levels rather than isolated species
- Manipulate more than one driver to understand the combined response to multiple drivers

2. Ongoing projects

- **AMUST** (AWI): Arctic under multiple stressors (phytoplankton) in KF and Baffin Bay (experimental)
- **FAABULOUS** (Akvaplan-niva, AWI, UNIS, SAMS, UiT, IOPAS): comparing van Mijenfjorden and KF in terms of chemistry, physics, microalgae for 5 times per year over 2 years
- **MOSJ** (NPI, IOPAN): pelagic long term survey of KJ (nutrients, phyto- and zooplankton)
- **AREX** (IOPAN): fjord and west Spitsbergen current
- **Benthic** (IOPAN): Macrobenthos in KF and Hornsund; mapping macroalgae in Isfjorden
- **COPPY** (IOPAN): phytoplankton changes along the west coast of Svalbard
- **GAME** (IOPAN): Comparison between KF and Hornsund, investigation of all pelagic trophic levels
- **Fram Center Flagship Ocean Acidification** (NPI – Allison Baley, Haakon Hop)

3. Submitted proposals

- Pelagic mesocosm (AWI, NPI, Rimouskii): simplified community; manipulating nutrients and carbonate chemistry in spring and summer
- ERC (CNRS-SU, AWI, Århus, Akvaplan-niva, Bremen): Coastal Arctic and Blue carbon in a changing climate. Comparing Isfjorden, KF, Rijpfjorden and Young Sound (Greenland).

4. Key action points:

- Get more researchers involved into experimental work in Ny-Ålesund and this WP
- Build strong collaborations between researchers studying phytoplankton and zooplankton to study climate change effects on grazing
- Measure grazing rates of key species pairs under natural conditions to be able to design sensible experiments
- Seek for third-party funding for large international consortia (as experimental work is logistically challenging, particularly expensive, and needs many people)

WP6 Modelling the KF/Krossfjorden ecosystem (P. Duarte, NPI, Norway)

Current research

Pedro Duarte: The effects of “borealization” on the structure and functioning of Arctic marine ecosystems; the future of primary productivity related to higher trophic levels; the impact of tidal glacier retreat onto land on primary and secondary production.

Tomas Torsvik: Oceans and sea ice

Alexey Pavlov: In situ bio-optical observations (inherent and apparent optical properties, suspended particulate matter, colored dissolved organic matter); effects of changing light climate on ecosystem of KF; using optical methods (proxies) to study biogeochemical and ecosystem processes in KF; improving light parameterizations in coupled physical-biological models; ocean color remote sensing

Arild Sundfjord: see WP1

Mikko Vihtakari: Effects of climate change on Svalbard marine ecosystems; ecosystem modeling; effects of tidewater glaciers on nutrient dynamics in glaciated fjords; Greenland halibut otolith geochemistry; Greenland halibut population genetics; pan-Arctic sea ice algae synthesis; use of Logarithm Ratio Analysis in geochemistry

Discussion of WP6

Text by Pedro Duarte

1. Overall goals and research approach

The overall goal of WP6 is to study the effects of environmental change on the structure and function of the marine ecosystem. To achieve this, coupled physical-biogeochemical models, species distribution models, dynamic energy budget models and food web models are used. Some of these models are e.g. ModOIE, A4, S800 and K160. The last one is also implemented specifically for the KF system, whereas A4 and S800 are larger scale models that may be used to generate boundary conditions for K160.

2. Notes from the discussion

- There was consensus about the idea of including a sediment sub-model in K160 due to the importance of suspended matter in KF
- The availability of field and satellite data is a major asset to validate a sediment sub-model (links with WP2 (contaminants), WP4 (Nutrient regime))
- Implementing such sub-model would be a first step, towards the implementation of a benthic diagenesis sub-model, responding to the belief about the importance of benthic processes (links with WP4, microphytobenthos and macroalgae)
- Furthermore, the effects of sediments on the quality and the quantity of absorbed light may be used to investigate further the effect of different parameterizations of the effects of light on pelagic and benthic primary production
- The accumulated knowledge about KF and the availability of data present a unique opportunity to develop a modelling environment of the whole ecosystem
- The development of such a tool should incorporate the best available knowledge about the KF ecosystem and it could be achieved through a project with wide participation of experimental scientists on model conceptualization

3. Ongoing projects/studies

1) Investigating the changes in non-linear dynamics within the KF marine food web

The objective of this study is to identify non-linear and emergent (novel) changes in predator-prey interactions and energetics. The reason for this study is to overcome the limits of conventional modelling approaches to consider non-linear interactions. A new approach is applied combining observational data, food web theory and statistical physics. Observed time series (physical and biological) are used to reconstruct the system dynamics using a physics approach based on multi-variate attractor manifolds and combining results in a food-web model of changes in abundance and also changes in energetics. The new methodological approach including software in R and model are developed and results available from 1998 to 2016 for 10 species and some environmental changes. There are plans to extend the concept to more species and other physical changes and to place results in risk assessment analysis for management.

2) TIGRIF: Tidewater Glacier Retreat Impact on Fjord circulation and ecosystems

This is project funded by the Norwegian Research Council. Its main goal is to evaluate the effects of the retreat of tidewater glaciers onto land on Kongsfjorden water circulation and ecosystems. This project is mostly based on the S800 and K160 models mentioned above. The effects of glacier retreat on circulation were already evaluated and now simulations are being carried on to evaluate the effects on some ecosystem properties.

4. Current applications

BOREAL - BOREalization at Arctic Ocean Latitudes around Svalbard (Researcher Project - MARINFORSK) – submitted to the Research Council of Norway in September 2018.

Ecological Footprint of Tidewater Glaciers in Svalbard (EcoTide) – to be submitted to the Fram Centre, Fjord and Coast flagship, until 1 November 2018.

5. Key action points

- Validate the coupled version of K160 with observational data from KF
- Implement a sediment sub-model in K160
- Include benthos in the biogeochemical sub-model of K160 in close connection with WP4
- Improve the land-sea forcing in close connection with WP3 and, possibly, the Terrestrial flagship
- Analyse possible synergies with WP2 considering the biogeochemical variables already simulated and their role as possible pollution vectors

“Speed dating” - Cross WP discussions September 21, 2018

Aim: update the respective WPs about ongoing research and find links between the groups to establish possible future joint projects.

WP1 and WP2

How are POPs affected by climate change via water temperature, salinity, etc? Also, a possible collaboration on plastic pollution is discussed: passive samplers for plastic, moorings for plastic monitoring, and physical characteristics like turbulence and the behaviour of sea ice around plastic to understand the fate of plastic.

Possible studies: Sources and fate of microplastics; NPI plastic cruise 2020

WP1 and WP3

Focus on the availability of data from the moored instruments to support the proposed focussed research project that WP3 had conceived

WP1 and WP4

Focus on the provision of seasonally resolved data to the nutrient team (WP4).

WP1 and WP5

Observations are essential to plan experiments and analyse changes in communities

WP1 and WP6

The large availability of data from KF can be used for hypotheses testing with models based on hind-cast simulations. However, the data need to be formatted for modellers and stored in a place with easy access.

WP2 and WP3

How does sea ice form around plastic? How does plastic behave in the sea ice, and how are the concentrations on sea ice compared to other compartments? Where are the hotspots of plastics? What are the effects of very small particles? What role do atmospheric currents play in the distribution of microplastics?

Another discussion topic were brines in sea ice – those show higher contaminant concentrations as well as higher salinity than open sea water, what are the implications for organisms living in or on brines? Furthermore, run/off dynamics of pollutants from land to sea should be quantified.

WP2 and WP4

How are contaminants affecting primary production? Many dumping sites in the Arctic are on permafrost, and contaminants might be washed into soil or water when the permafrost melts. Through contamination, the quality and biomass of primary producers might change.

Possible studies: investigation into local contaminant sources; mesocosm experiments to understand the effects of contaminants on aquatic photosynthetic organisms, as well as in the structure of communities, including the fates of contaminants.

WP2 and WP5

Does atlantification change the resistance/resilience to contaminants? How does pH affect contaminants?

WP2 and WP6

Possible studies: 1) Model to understand the fate of (micro)plastic, incorporating physical properties of environmental factors and plastic. 2) Flow of contaminants and nutrients to and through sea bird colonies. 3) Seasonal variation of contaminants and the role of light in degradation.

WP3 and WP4

The contribution of terrestrial and glacial run-off to the nutrient regime, as well as the bidirectional flow of biomass and nutrients from land to sea and vice versa (i.e. fertilisation of terrestrial systems by seabird droppings) should be quantified. WP3 activities are mainly centered in the study of interactions and fluxes between the land, the sea and the atmosphere. Collaboration will permit to calculate the inputs of nutrients to the fjord, allowing WP4 colleagues to simulate conditions of increased nutrient availability and primary productivity. Also, light profiles will give information about irradiance (quantity and quality) reaching the macroalgal and microphytobenthos communities.

WP3 and WP5

Terrestrial discharge of freshwater, sediment, carbon and nutrients and their contribution to the known (and yet unknown) key drivers of biological changes (alterations in light, temperature, pH and nutrient regimes).

WP3 and WP6

A link with the terrestrial flagship could be useful for the implementation of a land-drainage model to handle data about the input from land into the marine ecosystem. Furthermore modelling of run-off and sedimental discharge as modulator of light availability and primary production.

WP 4 and WP5

Nutrients are a key driver for the development of macro and microalgae, but are difficult to manipulate experimentally. It was proposed to use mesocosms and bethocosms for manipulation of the nutrient concentration in order to understand the future scenario in a warmer summer with higher nutrient loads.

WP4 and WP6

WP4 emphasised the importance of benthic primary producers and suggested that they should be included in attempt to simulate the KF system, especially since changes in the distribution of macroalgae in KF have been observed. This emphasises the need to include the benthic ecosystem in ongoing coupled physical-biogeochemical model developments.

WP5 and WP6

Providing essential variables for coupled and biogeographic modelling and set-up of perturbation experiments

Infrastructure on Ny-Ålesund research facilities

Edits by Ingeborg Hallanger

In May 2018 a “Strategy for research and higher education in Svalbard” was released by the Norwegian Ministries. This strategy is a long-term platform that determines the frameworks and principles for research and higher education in Svalbard. The general frameworks and principles include using Svalbard’s natural advantages, high scientific ambition and consideration for the environment. Already established communities and research stations should be used continuously, field activity has to undergo application first. Other principles include good logistic support, security management and training. To save resources and achieve best possible research quality, project information and research results should be shared, and field activity as well as access to infrastructure should be well coordinated among researchers. Frameworks specifically concerning the research stations in Ny-Ålesund emphasize, that the unique character of the region should be exploited in the best way possible while preserving its features as a natural clean science laboratory. The operation and development of services and infrastructure in Ny-Ålesund must be in accordance with the research needs and priorities identified in the Strategy. Buildings, infrastructure and services in Ny-Ålesund shall be developed and managed to support the comprehensive thematic priorities of the place. The Government will continue development towards more thematically based centres with shared-use infrastructure.

Current infrastructure for marine research includes the marine laboratory, MS Teisten, the Old Pier, diving facilities and other marine platforms like underwater observatories and moorings.

Listed below are the KF System Flagship Programs scientific recommendations and questions regarding the existing infrastructure in Ny-Ålesund.

Research in KF:

- There is a scientific wish for KF to be a focus for winter time studies. This implies access to boat and open water also in wintertime, which is by now not available.
- A movable hut for scientist conducting 24h study circles in a research hotspot area within KF
- Is it possible for Kings Bay, through the marine lab staff, to provide a regular monthly sampling day for long-term marine monitoring?

Marine laboratory

- Unfortunately, the marine laboratory, as it stands today, is not sufficiently maintained compared to the description and costs given by Kings Bay. There are several issues regarding malfunction of cold rooms, filter systems, water systems, MilliQ-water, lacking equipment, malfunctioning equipment, and equipment that has not been serviced, and lacking spare parts for broken equipment.
- The marine lab is a highly technical building to maintain and run. This cannot be done without committed and dedicated personnel. The turnover of the marine laboratory staff has a too short overlap for the new person to learn the management of the marine laboratory sufficiently. The staff is not well enough educated in lab management and instrument maintenance. A longer overlap between new and old staff would ensure proper instruction of new employees. There are several occurrences where visiting scientists have repaired the instruments provided by Kings Bay because the person in charge have not had the competence on the lab nor the instruments.
- Maybe Kings Bay should/could visit other relevant marine laboratories to observe how other institutions run and manage their marine laboratories, maybe Christineberg Marine Centre in Lysekil.

- There is also a question of why there are no toilets on the lab floor.
- Reliable access and space to use is more important than special equipment, which can be brought by scientists
- With the standard of today the marine laboratory is too expensive, and it is questioned why the cost is established per person and not for the actual space used.
- There is a need for better communication from Kings Bay on how the rented time/rooms in the marine lab will be organised. As it stands now, one can come to Ny-Ålesund and have to share laboratory rooms and cold rooms with other scientists. This is not always possible depending on the research carried out by the different scientists.
- There is a need for proper handling of radioactive waste and chemicals. AWIPEV is making a manual for radioactive work/waste handling and we hope that Kings Bay with the marine laboratory also implement such manuals.

The Old Pier

- There is a common wish from KFP that the old pier is maintained. The Old Pier is a good place to have seawater access without the use of boats, which could greatly help in winter time. However, safe access is vital and to provide a good working platform in the future it is essential that the Old Pier is maintained sufficiently.

RV Teisten

- There is a pressing need for a new winch on Teisten.
- It is important to us as scientists to also on Teisten be met by service minded, dedicated and competent staff that are good at handling the instrumentation, winch and scientific equipment brought by scientists.
- All instruments on Teisten need proper maintenance and upgrade to meet the standard described on Kings Bay webpage.
- It is important to secure and upload data, such as CTD from Teisen, today these are uploaded, however, they are not saved in a standardized format where position and time is identified with the load up.

Feedback system after use of Kings Bay facilities

- Today there are no standardised ways to give constructive feedback after using Kings Bays facilities. To have either a written sheet or a webpage to fill in feedback would in our opinion make maintenance and daily routines at the Marine Laboratory, and elsewhere, easier.

Marine robotics

- KF is an ideal place for testing, developing and operating robotic platforms. Future infrastructure plans need to take this into account both for marine and airborne platforms.

Preparation of EU Horizon 2020 proposal

As an outcome of the previous discussion within the flagship the two chairs of the flagship together with a group of colleagues from the Norwegian Polar Institute, Sorbonne University, UNIS and Noord University started the initiative to write a proposal in response to the H2020 call **LC-CLA-07-2019**: “The changing cryosphere: uncertainties, risks and opportunities”. The steering group has decided to prepare a proposal with a focus on the ecological and socio-ecological transitions in response to climate related changes in sea-ice and glacial fjord systems. In accordance to the call text, the social and the natural sciences will equally contribute to the research envisaged. The steering team has identified six major work packages in which the

overall project should be organised. Currently the consortium is being built and will likely include 12 institutions from 9 different nations. The proposal will be submitted in a two-step evaluation procedure with a deadline for the pre-proposal in February 2019 and the deadline for the full proposal in September 2019. Funding of this proposal would certainly mean a tremendous boost of research activities within the Kongsfjord flagship.

Anticipated work and activities for the working groups

WP1: The long established marine observations and marine observatories (moorings) in KF and adjacent shelf have led to a wealth of data series covering the physical, chemical and ecological elements of the KF system. The priority activities of WG1 are to (i) consolidate the data availability (ii) provide oversight on future data collection and (iii) initiate cooperative analyses of the time series to establish the rate of change in the region and the coupled interactions between the component parts. In particular, the operation of long-term marine observatories is seen as providing essential supporting data for the variety of research projects identified in the 2018 workshop. Further, robotic systems become more prevalent in their application to science questions; there is considerable expectation to see their utilisation within KF.

WP2: The overall objective of WG2 is to understand the scope of pollution: (i) its distribution globally, within different departments of ecosystems, and through food webs. (ii) Its effects on biota and (iii) the effect of climate change on pollution (e.g. runoff from melting glaciers, changes in distribution routes and deposition, ecological changes).

The Arctic and especially Svalbard is exposed to both long-range transported and local pollution such as chemical contaminants, plastic, petroleum or pharmaceuticals. The distribution and fate of these pollutants is highly influenced by ecological factors and consequently climate change. Elevated temperature in the Arctic are expected to change the transport and deposition of contaminants to the Arctic. Furthermore, elevated temperatures might lead to secondary emissions of stored contaminants from melting sea ice, glaciers, and permafrost. Svalbard is more affected by climate change than most other places in the Arctic, and shows some of the highest levels of both legacy and emerging pollutants within the Arctic. Considering the large body of research on KF, it is vital to continue contaminant research in this area also in cooperation with other flagship programs, such as the atmospheric and the terrestrial flagship.

WP3: Climate change will exert considerable changes in the continuum of interactions between atmosphere-land-sea. Coastal parts of fjord systems like KF are very dynamic, while across Svalbard different fjord systems are under differing glacial and local geological influence, emphasising the value of comparative approaches, and possibility of using fjords at different stages of development as past/future analogies (e.g. Dicksonfjord as a future KF). Consequently, the following overarching questions have been formulated as guidelines for upcoming activities in this research field: (1.) “Does terrestrial runoff and contained nutrients control the distribution of biodiversity in the marine fjord environment in the same way as it does on land on Svalbard?” and (2.) “How are runoff processes changing in the KF environment, as a paradigm for the physical and chemical impacts of land-sea interactions?”

Upcoming activities within WG3 will include a pilot study on downstream effects of terrestrial run-off (sediments and freshwater) in front of the Midtre Lovenbreen discharge delta. Related changes in light and nutrient availability, consequences to the coastal carbonate system and potential feed-back loops from sea to land are addressed. Members of the WG3 have agreed to prepare for this pilot study to be conducted during the summer season of 2019.

WP4: Our understanding on the effects of increased CO₂, temperature and UV radiation on Arctic marine primary producers is mainly restricted to the summer months. During this time, continuous solar irradiation coincides with a nutrient-depleted and strongly stratified environment. Due to the combination of these factors, Arctic algae in summer are prone to regular or even chronic photoinhibition, which only disappears as the darkness progressively increases towards the autumn. However, increasing global temperature may lead to the release of different forms of inorganic nitrogen (N) and phosphorus (P), mainly from terrestrial sources and through Atlantic waters entering KF. We hypothesize that increased contribution to the N and P pools in the fjord in summer may affect growth and metabolic performances of phytoplankton as well as benthic micro- and macrophytes.

Key topics of WG 4: 1. How much of the organic N and P from the permafrost, and/or soil erosion is mobilized and mineralized and enters the fjord? 2. Influence of Atlantification. 3. Seasonality of the nutrients. 4. Phytoplankton blooms (time of the year and composition). 5. Macrophytes, possible blooming of nitrophylic species. 6. Role of microphytobenthos in nutrients cycling. 7. Changes in the structure of the communities (phytoplankton, microphytobenthos and macrophytes), and 8. Mismatch between primary producers and consumers.

WP5: The Arctic is one of the regions being most affected by global change, with rates of warming and ocean acidification occurring faster than anywhere else on the planet. The responses of biological communities to these on-going and futures changes in the Arctic are, however, very poorly understood. Thus, hypothesis-driven experimental studies are necessary to develop process-based understanding, which can then be fed into parametrizations of ecological and biogeochemical modelling approaches that aim at predicting future ecosystem services.

We aim at conducting experimental studies that will allow us to elucidate if, how and why Arctic coastal pelagic and benthic ecosystems will respond to multiple environmental drivers such as ocean acidification, warming and changes in light regimes. Experimental treatments will be partially determined by the environmental history experienced by organisms in KF as determined in WG 1-3, as well as projected future conditions (WG 6).

WG6: Today there are models for KF, such as the 3D oceanographic model, which is now being coupled with a sea-ice and a biogeochemical sub-model within the scope of the project TIGRIF, financed by the Research Council of Norway. This model may be used as a framework to integrate more processes in close interaction with the remaining WGs.

Therefore, (i) implementing a sediment sub-model is one of the most urgent modelling tasks. Furthermore, (ii) it will be necessary to improve the land-sea model forcing. Whereas tidewater glacier forcing has been assessed in detail within the scope of the TIGRIF project, (iii) there is not so much knowledge about the forcing associated with the ephemeral drainage basins discharging water, nutrients and suspended matter to the fjord during summer. Improving the way this forcing may be incorporated in the mentioned model framework implies synergies with WG 3 and, possibly, with the Terrestrial flagship. Another line of work is related with (iv) the pollutants and their integration in ongoing model efforts and here we emphasize synergies with WG 2. Furthermore, the large concentrations of microplastic in sea ice is a matter of great debate that goes beyond the boundaries of KF. Available model tools at the Fram Centre in Tromsø, Norway, covering a large marine domain around Svalbard may be useful to get insight about how plastic may disperse within this area and become associated with the sea-ice.

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