Nordic Marine Science Conference
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Abstracts

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ICES – providing support to the ecosystem based management

Anne Christine Brusendorff, ICES General Secretary

The effective study and management of the marine environment requires approaches that recognize the interconnectedness of the oceans, but also recognize the importance of regionalization and development of understanding at the scale of specific ecoregions, including the environmental drivers and anthropogenic affects that influence each regional ecosystem.

The management of the marine environment has also increasingly been in need of integrated approaches and assessments that focus on ecosystem processes and enable operational advice regarding possible management measures in specific eco regions. The strength of this kind of integrated approach is that it allows for the consideration of regional priorities, as well as identification of commonalities to create a framework that is consistent, but nevertheless adaptable to different ecoregions.

In this process of studying and identifying pressures on the marine environment there also needs to be an acknowledgement of the societal priorities, as part of an iterative and participatory process, where management objectives and needs must be accounted for.

ICES core competencies cover the above themes, through its coordination of monitoring and surveys, data platforms and standards, development and evaluation of indicators and targets, assessment criteria, ecosystems modelling, peer review and the application of risk based approaches in the provision of advice under the precautionary approach.

Interannual Variability in Atlantic Ocean Circulation

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Since March 2004 we have been monitoring the strength of the Atlantic circulation at 25°N as part of the Rapid programme. We combine continuous measurements of the basin-scale mid-ocean circulation using an array of moored instruments deployed across the Atlantic with electromagnetic cable measurements of Gulf Stream transport through Florida Straits and with surface Ekman transport derived from satellite-based wind observations. For the first 5 years 2004-2008 the circulation exhibited small interannual variability: for example, the yearly averaged meridional overturning circulation (MOC) varied only between 17.3 Sv and 19.3 Sv with a mean of 18.1 Sv. But during 2009-10, there was an event in which the AMOC decreased by nearly 5.5 Sv to 12.6 Sv on a year-long basis. We examine the processes involved in this reduction in the AMOC and conclude that most of the change is due to increased southward flow in the mid-ocean thermocline and reduced southward flow in the Lower North Atlantic Deep Water below 3000 m depth. This 2009-10 event is associated with reduced northward heat and salt transports across 25°N which affect ocean heat and salinity content particularly north of 26°N where colder upper ocean temperatures coincide with cold sea surface temperatures

in December 2010. These cold temperatures possibly affected the North Atlantic Oscillation and hence European wintertime conditions in late 2010 and early 2011. After the event, the circulation recovers but still appears to be weaker than during the first 5 years. We argue that there is a statistically significant trend toward reduced overturning over the full 8.5 year record to date. In terms of water mass transport, over 8.5 years there is a 50% decrease in the southward flow of Lower North Atlantic Deep Water across 25°N.

Back to the roots: Tackling ocean challenges through education

Geraldine Fauville, University of Gothenburg

The ocean provides countless goods and services for human kinds. Among other thing, it provides 50% of the oxygen we breathe, regulates the climate, and provides food and pharmaceutical compounds. In other words, the ocean is essential for the health, life and sustainability of each individual and the societies to which they belong. Unfortunately, population growth and social/technological developments have resulted in the buildup of carbon dioxide in the atmosphere and in the ocean to the extent that we now see changes in the earth's climate and ocean chemistry. The pressure on our marine ecosystems is causing unprecedented damage that is in return threatening our livelihood on this planet.

Society's handling of environmental problems typically boils down to policy; either by politicians handing over responsibility and action to the market through the use of market-based policy instruments (e.g., taxes, subsidies, trade instruments) or via legal and other regulations that steer or encourage society's actors to take on more pro-environmental behaviors.

But a bottom-up approach should also be encouraged and the citizens should be able to participate in the public debate related to marine environmental issues. To do so, a solid understanding of science behind the complex environmental changes in marine ecosystem (ocean literacy), is needed to allow citizens to make well-informed choices in their everyday life and to contribute the public debate in a participatory democracy.

The school is a key institution in paving our way into a more ocean literate society. First of all the pupils are current and tomorrow's citizens. Second, their environmental education has been shown to influences adults' knowledge and behaviors.

There is an obvious and encouraging will from scientists to communicate these marine environmental issues through education (inside and outside school). But, despite this enthusiasm there are still challenges preventing an efficient and global implementation of marine education in school.

First, the marine content is often left outside of the curricula while teachers are increasingly pressured to prevent them to cover any topic outside the curricula. Moreover, teachers often lack the marine knowledge making them confident enough to teach these topics. Finally, the education resources created by scientists are often developed without deep considerations of educational and dissemination issues, and they generally lack implementation and evaluation plans that would make it possible to assess their potentials.

In that respect, a coordinated strategy among marine education stakeholders to promote ocean literacy is key if we are to tackle these marine related issues.

The health of farmed salmon - a concern for wild salmon populations and the marine environment?

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Norway is presently the world's largest producer of farmed Atlantic salmon with an annual production of more than 1.2 million tonnes. The health status of farmed fish is crucial for the economy of the industry and disease problems have historically caused collapse in salmon-farming countries like Chile and The Faroe Islands. Farming of salmon is also highly controversial, as exemplified in e.g. British Columbia, Canada. An overview of the health situation in farmed salmon, nationally and internationally, historically and present, will be presented together with views upon future challenges and opportunities in the industry.

Climate driven changes in ecosystems and biodiversity

Key note: Nils Christian Stenseth, University of Oslo

Climate-driven changes to harvested populations in Nordic marine ecosystems

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Globally, marine ecosystems face severe pressure from both high exploitation and changes in climate. This is especially true in the Nordic region, where marine systems are particularly vulnerable to climate change and high fish stock exploitation, and where the countries are particularly dependent on their marine resources, many of which holding exceptional national, cultural, and economic significance. Thus, there is a pressing need to analyze how climate change alters marine ecosystem functioning, the fishing sector, and communities in the northern region. With such broad implications, the development of an understanding of climate-driven changes to harvested populations can only be approached in a truly interdisciplinary approach. To address this, as the chair of the National Centre for Ecological and Evolutionary Synthesis (CEES) and the Nordic Centre of Excellence *NorMER*, I strive to combine the biological and social and economic perspectives in our effort to understanding the full impact of climate variability on our marine in the Nordic region, with an emphasis on populations of Atlantic cod (*Gadus morhua*). In this lecture I will present some of the actual 'climate driven changes' we are seeing in Nordic marine ecosystems. Then, I will attempt a – preliminary – synthesis of the work we are carrying out within *NorMER*.

ORAL PRESENTATIONS

Effects of humic-rich freshwater discharge on coastal pelagic food webs.

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A common and established view is that increased inputs of nutrients to the sea, for example via river flooding, will cause eutrophication and phytoplankton blooms in coastal areas. Our studies show that this concept may be questioned in certain scenarios. Climate change has been predicted to cause increased inflow of freshwater to coastal areas in northern Europe. River waters in these areas are often brown from the presence

of high concentrations of colored allochthonous dissolved organic carbon (humic carbon), in addition to nitrogen and phosphorus. We studied the effect of riverine loads of C, N and P on marine food webs by using a combination of field, experimental and modeling studies. The northern Baltic Sea was used as model system, a semi-enclosed sea which is highly exposed to colored carbon-rich freshwater discharge. Our field studies showed that river inflow to the coastal system in general had negative effect on phytoplankton primary production, while bacterial production was promoted. Mesocosm experiments where terrestrial dissolved organic carbon was added to the seawater usually supported this conclusion; however, a negative effect on primary production did not always cause a negative effect on higher trophic, e.g. fish. A minus at lower trophic levels could actually be a plus at higher trophic levels. A modeling study, using a dynamic ecosystem model based on C, N and P, showed that dissolved organic carbon can cause drastically decreased primary production, however, the light attenuation from the colored organic carbon on the marine production may not be very high. Taken together, our results show that the CNP stoichiometry of the inflowing riverine water is a strong governing factor for coastal food webs, affecting the size structure and efficiency of the food web as well as the net ecosystem production.

Climate change impact on the seaweed Fucus serratus, a key foundational species on North Atlantic rocky shores

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Coastal ecosystems in general and intertidal systems in particular, are likely to be profoundly affected by climate change. On temperate rocky shores, the responses of foundational seaweed species to climate change can potentially profoundly change the entire intertidal ecosystem. The overall objective of our work is to identify the impact of climate change on seaweeds meadows in the North-Atlantic rocky intertidal with focus on the brown canopy-forming macroalga Fucus serratus. More specifically, we aimed to identify the impact of climate change on 1) the geographical distribution, 2) the thermal tolerance, and 3) the genetic changes, of the brown alga F. serratus. Ecological Niche Model predictions until year 2200 suggest that habitat-provisioning key species on North-Atlantic rocky shores will shift northwards as an assemblage, and while disappearing from warmtemperate regions, they may establish on Arctic shores. These predictions, however, do not take plastic and adaptive responsiveness into account. Thus, we further assessed the plastic response of F. serratus in four populations along its distribution range in West Europe in common garden heat stress experiments. The four subpopulations showed differences in photosynthetic performance and heat shock protein gene up-

regulation. Phenotypic plasticity was found to be likely insufficient to prevent the predicted extinction of F. serratus from the North-Iberian Peninsula. A temporal and spatial genome scan approach was used to assess the adaptive responsibility and revealed that the subpopulations differed in genetic diversity and that the most southerly subpopulations (i.e. in Spain) suffered a significant loss of allelic richness and an abundance decline of about 90 % during the past decade. The thesis predicts that temperate seaweeds will most likely face extinction from rocky shores in southern Europe and this will likely trigger major ecosystem changes in the entire associated ecosystem.

Behavioural responses of wild Atlantic cod to sea temperature changes

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Understanding the response of wild populations to temperature variations is essential to predict their response under future climate changes. Most ectotherms, or "cold-blooded" animals, are expected to adjust their behaviour to avoid extreme temperatures and minimize acute changes in body temperature. However, measuring such behavioural responses in wild marine fish is challenging. Using telemetry data on Atlantic cod *Gadus morhua* (N=181) in natural habitat on the Norwegian Skagerrak coast and *in situ* ocean temperature measurements, we show that increased surface temperatures tended to lead cod to deeper, colder waters and that this effect of temperature was stronger on larger fish. Diel vertical migration, which consists in a nighttime rise to shallow feeding habitats, was stronger among smaller fish, but reduced in the presence of thermal stratification. We predict the absence of cod from shallow (<5-10 m deep) habitats, such as macroalgae and eelgrass beds, under warm (>17-19 °C) summer conditions, depending on fish size. Climate change is expected to increase the number of days with such temperatures along the Skagerrak coast. In turn, cod may be critically deprived from important feeding habitats for longer periods.

Spreading of the invasive oyster *Crassostrea edulis* in the Oslofjord - increased risk due to warmer climate?

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The invasive oyster *Crassostrea edulis* was first observed in the Oslofjord in 2005. Since then, the species has been observed at low densities at several localities in the fjord, and at high densities at a few localities. Due to its large reproduction capacity (50-200 mill

eggs per individual in one spawning, maturation as 1 year old, and high longevity - they may become 30 years old), its rapid growth rate (10 cm in one year), and the likelihood of having a severe impact to native ecosystems, the species has a high risk of spreading and a high risk of being a threat to native biodiversity. By field studies, predictive distribution modeling, and by simulations of spreading of oyster larvae within the Oslofjord, we have analyzed the environmental factors that are the most important in explaining today's distribution of the species, and how future climate changes in temperature may affect the risk of achieving dense, harmful populations of the species within the fjord.

Strong seasonal effect of moderate experimental warming on plankton respiration in a temperate estuarine plankton community

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Climate change projections forecast a 1.1 to 6.4°C global increase in surface water temperature and a 3°C increase for the Baltic Sea. In this study, we examined the short-term interactive effects of a realistic future temperature increase (3°C) on pelagic respiration and bacterioplankton and phytoplankton growth in situ. This study was undertaken throughout a full seasonal cycle in the northern Baltic Sea. We found marked positive short-term effects of temperature on plankton respiration but no significant effect on bacterioplankton or phytoplankton growth. Absolute respiration rates remained similar to other comparable environments at the in situ temperature. With the 3°C temperature increase, respiration rates in situ increased up to 5-fold during the winter and 2-fold during the summer. A maximum seasonal Q_{10} value of 332 was observed for respiration during the cold winter months ($t_{water} \approx 0$°C), and summer Q_{10} values were comparatively high (9.1). Q_{10} values exhibited a significant inverse relationship to water temperature during winter. Our results thereby suggest that plankton respiration in this coastal zone is more temperature sensitive than previously reported. Additionally, field data indicated that plankton respiration switched from being temperature limited to being limited by dissolved organic carbon (DOC) after the simulated temperature increase. Assuming that our observations are relevant over longer time scales, climate change may worsen hypoxia, increase CO_2 emissions and create a more heterotrophic food web in coastal zones with a high load of riverine DOC.

POSTERS

State-dependent seasonal migrations of a high latitude copepod

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Calanus spp. copepods are keystone species in the Arctic and utilize extensive lipid storage and seasonal vertical migration to survive the long, unproductive winter. Understanding the factors influencing the timing of *Calanus* spp. migration and reproduction is important in the Arctic due to its variable, and potentially changing, seasonal regimes. Life history theory predicts state-dependent decisions and behaviors. Here we test this prediction on the timing of copepod seasonal migrations. For this we collected a high-resolution yearlong time series of *Calanus glacialis* stage composition, depth distribution and lipid content in a high-Arctic fjord in Svalbard allowing us to relate the timing of ascent and descent to individual lipid level, prosome length, and body condition. *C. glacialis* stages CIV and CV entered diapause between July and September, with the largest and most lipid-rich individuals descending first. Females and males molted and ascended in early winter: 4 and 6 months before the spring phytoplankton bloom, respectively. Large, lipid-rich CVs likely molted and ascended first. Females reproduced in April, when there was nearly no food available, thus exhibiting capital breeding fuelled by lipid stores.

Persistent Chemicals in the Baltic Sea: Investigations of Sources, Pathways and Response to Climate Change Scenarios under the EcoChange Programme

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EcoChange is a research programme of Umeå and Linnéus Universities in Sweden in close collaboration with the Swedish Museum of Natural History and Swedish University of Agricultural Sciences which strives to estimate current and future climate change responses of the Baltic Sea. The programme is hosted by Umeå University. Theme 3 addresses future changes in food web transport of legacy and emerging persistent organic pollutants (POPs), and specifically the questions:

- How do climate-induced changes influence terrestrial fluxes of pollutants and dissolved organic carbon (DOC)?

- How do temperature, DOC, nutrients, and carbon quality affect sorption and bioaccumulation of POPs in the three basins of the Baltic Sea? Do these changes lead to increased production of biogenic polybrominated *p*-dioxins?
- How can complex relations between ecosystem function and pollutant food web transfer be described and used for food web modelling?

Over the past two years we have investigated the occurrence and exchange pathways of synthetic and natural organohalogens in the Baltic Sea. Synthetic compounds include the legacy chlorinated pesticides hexachlorocyclohexanes (HCHs), hexachlorobenzene (HCBz), chlordane and dieldrin; and the currently used or recently banned pesticides endosulfan and chlorthal dimethyl (dacthal).

Measurements in air and surface water were made in Bothnian Bay (BB), the northernmost basin of the Baltic Sea (1). HCHs, HCBz and dieldrin were near vapour equilibrium between air and water, with excursions toward net volatilisation or deposition loadings depending on the water temperature and extent of binding to DOC in the water column. Consistent net volatilisation was found for chlordanes and net deposition for endosulfans. A simple scenario of future increasing temperatures and loss of ice cover predicted a 50-60% increase in deposition and volatilisation loadings to BB, largely due to a longer open-water season.

Annual loadings to BB by gas exchange were compared to "bulk" deposition (precipitation + dry particle deposition) to BB and its catchment, estimated from collections at a site near southern BB and at European Monitoring and Evaluation Programme (EMEP) stations in southern Sweden and arctic Finland (1). Loadings to the catchment and BB were comparable for HCHs and chlordanes, and four times greater to the catchment for endosulfans. Thus, atmospheric deposition to the catchment followed by river runoff could be equivalent to, or even exceed, the gas exchange pathway. A major "unknown" is the fraction of catchment-deposited substances which migrate to the rivers and subsequently enter BB.

Also under investigation are natural polybrominated *p*-dioxins (PBDDs) and bromoanisoles, transformation products of algae-produced bromophenols. PBDDs are bioaccumulating compounds which are structurally similar to the well-known polychlorinated *p*-dioxins (PCDDs) that contaminate Baltic fish. PBDDs were identified in fish and shellfish from the southern and northern Baltic (2,3) and the enzymatic coupling of precursor bromophenols to form PBDDs was confirmed (3). Recently the toxicity of PBDDs has been assessed relative to PCDDs and placed on the World Health Organisation (WHO) toxic equivalent factor (TEF) scale (4). Bromoanisoles were found in BB water and air, and showed a strong tendency for net volatilisation (1). Their contributions to the atmospheric bromine cycle are being assessed relative to lighter compounds such as bromoform and dibromomethane.

Sea ice algae – a key link mediating Arctic climate change to ecosystems

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Profound changes in the physical environment of the Arctic have been observed during the last years. Implications for ecosystem structure and functioning will be far-reaching, but are hard to predict due to the complexity of interactions. We suggest that sea ice algae represent a key link in the physical-biological coupling of climate change consequences. As primary producers, they rely on light and nutrient supply, and will hence react immediately to any changes in sea ice characteristics. At the same time, they represent in ice-covered seas a unique and important food source for herbivores, in particular during periods where no other high-quality food is available. Recent studies supported that the timing of sea ice algal blooms is crucial for the successful recruitment of key pelagic grazers such as *Calanus glacialis*. Under perfect conditions, *C. glacialis* females efficiently exploit sea ice algal blooms to fuel their reproduction, while their offspring are able to take advantage of the pelagic algal bloom, occurring several weeks later. This work discusses which environmental factors are most important for determining sea ice algal bloom phenology and how their changes will affect future ice algae bloom scenarios.

Sea urchin recruitment failure in warmer coastal water in Norway

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On the coast of mid-Norway, kelp forest (*Laminaria hyperborea*) is recovering from extensive overgrazing and nearly 40 years of sea urchin (*Strongylocentrotus* droebachiensis) dominance. At the largest extent, the overgrazed area of barren ground covered 2000 km^2 coastline (63°-71°N). Approximately 500 km^2 kelp forest has now recovered. The recovery has progressed northwards, subsequent to substantial declines in local sea urchin populations. The reduced sea urchin density might be related to climate change as *S. droebachiensis* larval development is restricted to cold water. Elevated temperatures during the sea urchin larval phase may cause development failure. Increasing sea temperatures might also facilitate northern range extensions of potential sea urchin predators.
Field sampling show low sea urchin settlement in the area were kelp forest recover, compared to sea urchin dominated barrens further north. Tethering experiments in the

field and laboratory feeding experiments showed that crab, the Edible crab *Cancer pagurus* in particular, were efficient predators of juvenile sea urchins. The stocks of *C. pagurus* have increased tremendously in mid-Norway during the last two decades. The increased abundance of crab, and collapse of the sea urchin populations, coincides in space and time with increasing sea water temperatures.

Centennial changes in water clarity of the Baltic Sea and the North Sea

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Secchi depth is a valuable proxy for detecting long term changes in the water clarity of oceanic and coastal ecosystems. We have analysed approximately 40 000 observations from Baltic Sea and the North Sea in the 20th century. Our results suggest a Secchi depth shoaling that is likely to involve ecosystem effects because of pronounced reductions in photic habitats and reduced visibility for visual predators. We suggest that the variations in colour dissolved organic matter (CDOM) on the transparency in the Baltic Sea, the North Sea and the Norwegian Coastal Water deserves future attention.

Science for ocean management

Key note Svein Sundby

Ecosystem, Fishing and Oil Exploration - competition for the same ocean areas

Institute of Marine Research

The North Sea ecosystem seems to have been relatively unaffected by the offshore oil industry that has been going on there for nearly 50 years, while fishing have had a major impact on this ecosystem during the same period of time. Over the recent years there have been scientific and political discussions in Norway on opening up the Lofoten-Vesterålen-Senja continental shelf off North Norway for oil exploration. This is another region of strong fish exploitation, but where the resources are maintained relatively unaffected. The marine science communities have expressed concern about oil activities in this region. Why is this region different from the North Sea?

ORAL PRESENTATIONS

Behaviour and habitat of the deep sea amphipod *Neohela monstrosa* in the Norwegian Sea

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There are few in situ observations of deep-sea macrofauna, due to the remoteness of this ecosystem. Visual surveys, as part of the MAREANO mapping programme, have offered unique possibilities to do such observations over large areas in the Norwegian Sea. In addition, specimens collected with hyperbenthic sleds have been used for species confirmation. One common species at depths below 700 m is the large amphipod *Neohela monstrosa* (Boeck, 1861). Dense communities of this amphipod are often found in stands of the arctic sea pen *Umbellula encrinus* at more than > 1000 meters depth.

In this study we present its bathymetric distribution and habitat requirements as well as behavioural observations. Mean density observed for larger areas is 4/100 m2, while local patches sustain a density of >20 specimens/ m^2. *N. monstrosa* digs tunnels in soft muddy bottoms; this is done primarily by using the large shovel-like gnathopods to scoop sediment out of its burrow. This behaviour has also been observed in aquaria (Enequist,1949), where it was noted that the amphipods were simultaneously reworking the sediments with its mouthparts when pushing out sediment.

We have observed *N. monstrosa* pushing and rolling sediment-balls out of its burrow. There is an upper wide burrow that seems to have a horizontal side tunnel a couple of centimeters down. This tunnel seems to be reinforced by sediment cemented in

a similar way to the mud tubes of the polychaeta *Sabella* spp. On one occasion we observed one individual "combing" a bryozoan colony (branced Anascophora). This could probably be related to feeding.

The effect of dispersed crude oil on the pumping rate, feeding rate and valve gaping behaviour of blue mussels, *Mytilus edulis*: new methods for environmental monitoring

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The Norwegian marine environment has for many years been subjected to the effects of oil and gas activities. Oil companies have a vested interest in ensuring their activities are as environmentally friendly as possible due to increasing environmental awareness in government bodies, environmental agencies and the public. A zero-emission policy is extended in the Norwegian oil industry, and as activities expand into more biologically sensitive areas such as the Barents Sea, oil companies require more documentation of policy compliance. There is a growing interest for real-time environmental monitoring (RTEM) as it gives a continuous record of environmental performance and has the potential of linking monitoring data with the acceptance criteria proposed in environmental risk assessment. A number of whole-animal biosensors were developed approximately 25 years ago, and were based on monitoring behavioural and physiological responses in real-time. These methods successfully document acute environmental changes, however, chronic exposure events are more difficult to interpret. We have used a suite of newly applied methods to measure the feeding rate, pumping rate, valve gape behaviour, growth, and oxygen metabolism of blue mussels exposed to dispersed crude oil. Mussels were exposed to nominal concentrations of crude oil (0.015 or 0.06 or 0.25 mg crude oil L-1), and behaviour in clean seawater and during exposure were compared. Preliminary results from these experiments will be presented, and reflection upon their future for use as instrumented organism biosensors for environmental change, not only in the natural resource extraction industry, will be discussed.

MyOcean: The Norwegian Monitoring and Forecasting contribution

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As part of the ongoing pan-European MyOcean project MET Norway, IMR and NERSC are collaborating to establish the ARC MFC (Arctic Monitoring and Forecasting Center). ARC MFC is one of seven such centers that covers the entire globe. The present ARC MFC forecasting system is an operational version of the TOPAZ4 Arctic Ocean system. TOPAZ4 uses the HYCOM ocean model and a 100-member EnKF assimilation scheme. It is run daily to provide 10 days of forecast (at present one single member) of the 3D physical ocean, including sea ice. Data assimilation is performed weekly to provide 7

days of analysis (ensemble average). The HYCOM physical model is further coupled to the NORWECOM biological model to provide 10 days of forecast of 3D biogeochemical variables, including nutrients and algae. Results are available daily through the MyOcean Catalogue at http://www.myocean.eu/ or at http://myocean.met.no/. The ARC MFC system will be presented together with forecasting and validation results.

POSTERS

How to make a sediment map with different multibeam systems or without backscatter?

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The Norwegian seabed mapping programme MAREANO (www.mareano.no) already covered more than 100 000 km2 of the Norwegian Sea. MAREANO has acquired multibeam bathymetry and backscatter (which gives information about the bottom type), seabed samples, video data and shallow seismic data which provide the basis for mapping geology, sedimentary processes and habitats on the seafloor. More than 1000 video lines have been recorded between 40 m and 3000 m depth, documenting a variety of structures and bottom types hosting a variety of fauna. Some of these videos have been used to make a sediment map without backscatter information. It appears that a detailed bathymetry map (10 m grid) give already a lot of information about the sediment type. Features like pockmarks, sandwaves, slide deposits on the continental slope and the deep-sea plain for example provide good indications of which kind of sediment occurs at the seabed. Indeed pockmarks occur most of the time in soft sediment like mud and sandy mud whereas sandwaves are commonly formed by sand. Moreover, combination of features like iceberg ploughmarks, largely represented in glacially continental shelves, and pockmarks allows a good estimation of sediment type. Video observations show that iceberg ploughmarks with sharp edges/berms have a high content in gravel and stones and little content in mud. When the edges/berms of the iceberg ploughmarks become smoother, the content in fine sediment increases. If pockmarks appear around the iceberg ploughmarks, the mud content becomes likely higher. Even if backscatter data exist, creating seabed sediment maps is a challenge as different frequency multibeam systems are used dependant on water depths, creating different acoustic responses for the same bottom types. Moreover, features like bedrock are better defined from the bathymetry than the backscatter as a lot of fauna and seaweeds often occur at the top of the bedrock, absorbing the backscatter signal which becomes much lower than expected.
We will show how geological features can be used to give bottom type information with or without backscatter data.

Moraines and mud - recent geological discoveries by the MAREANO programme

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MAREANO is a state funded seabed mapping programme, the main task of which is to provide knowledge to support decision-making for ecosystem based ocean management. Such management demands detailed information about the diversity of the seabed in the areas to be managed. MAREANO meets this need through the production of a series of maps, which together give a thorough documentation of the bio- and geo-diversity of the seabed. The mapping is carried out by the Norwegian Mapping Authority, The Geological Survey of Norway and the Institute of Marine Research. The main data feeding into these the maps comes from multibeam (bathymetry and backscatter) data, video imagery and physical samples. Geological maps include sediment grain size, sedimentary environment and sediment formation (genesis), while landscape type and biotope maps describe the benthic habitats while making use of geological information.
During the last seven years MAREANO cruises have been conducted on the shelf areas of northern Norway, the Norwegian Sea and the southeastern Barents Sea. Large variations in geo- and bio-diversity have been observed within and between the different areas. In the summer of 2013, MAREANO mapped an area close to the Russian border in the southern Barents Sea. Here the seabed is largely covered by mud and is characterised by countless pockmarks and iceberg ploughmarks. Furthermore, subsurface salt diapirs rise almost to the seabed at Tiddlybanken, where active gas seepage was observed.
In 2012 and 2013, MAREANO mapped areas designated to be of special value in ocean management plans (SVOs) on the Mid-Norwegian margin. This included areas on the shelf and shelf edge such as Iverryggen, Storegga and Skjoldryggen. These are all of biological interest due to their dense population of corals and sponges, and many are defined by complex geological processes such as slope failure and glacial activity. This highlights how areas that are especially interesting from a biological perspective frequently coincide with areas of high geo-diversity.

Fluxes of Cd, Cu, Pb and Zn from metal contaminated sediments capped with allochthonous and autochthonous material in Sørfjorden, Norway.

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Sediments in Sørfjorden are metal contaminated from 20th century industrial discharges. The extent to which these metals are recycled to the fjord water and biota is not well understood. Therefore, as part of the development of a remediation plan for the area, metal fluxes were determined in six selected areas between Odda and Tyssedal by use of box-core sampling and DGT-probe deployment. One of the target areas was Eitrheimsvågen, a shallow bight in which a 0.09 km2 geomembrane was placed in 1993 and covered with a 30 cm layer of sand. To avoid injury of the membrane, box-core

sampling was not recommended in Eitrheimsvågen. From the other areas, triplicate, undisturbed 0.1m2 x 0.4m
sediment sections were transported to Solbergstrand Marine Research Station by the Oslofjord and installed in a flow-through system with Outer Oslofjord deep seawater with salinity 34 PSU and temperature 8-9°C. Aeration was applied to avoid stratification of the overlying water and to maintain natural levels of bioturbation throughout the three months incubation period. Water samples were collected three times from in- and outflowing water and metal fluxes were calculated from the concentration change and water exchange rate in each box. The metal uptake on DGT-probes deployed in the mesocosm samples was found to be linearly related to the measured fluxes. Thus, the curve equations derived from the mesocosm samples could be applied to calculate metal fluxes from the metal uptake on the DGT-probes deployed by divers at five different locations in the capped area in Eitrheimsvågen.
The results showed that in Eitrheimsvågen, the fluxes of cadmium, copper, lead and zinc were reduced by factors of 7.4-9.7 compared to the fluxes determined before capping (Skei et al., 1987). However, the release of metals from the capped area was higher than the flux from uncapped areas. This might be explained either by recontamination of the cap or leakage from old deposits below the geomembrane. If the latter process was more important the DGT-profiles should show a steady increase of pore water concentrations with increasing sediment depth. Such increase was frequently observed on the probes deployed in the sand cap, but never on probes deployed in the other areas in which old, metal contaminated sediments have been covered by a natural cap consisting of a few cm of silty-clay material with a small content of organic carbon. In these areas metal minima were typically observed on the DGT-profiles 2-4 cm below the sediment surface indicating metal removal from the pore water, most likely by slow formation of metal sulphides. These results suggest that the natural silty-clay sediment provide a more efficient retention of metals than coarse sandy material with no or very low concentration of organic matter.

Initial video documentation of the seabed of formerly disputed areas of the Barent Sea: Preliminary patterns in the composition and distribution of benthic fauna and the acquisition of baseline data for future management

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After seven years of activity in the governmental mapping program MAREANO (Marine AREAl database for NOrwegian waters), and two years after the resolution of the Russian-Norwegian border conflict in the Barent Sea, the MAREANO program has started to conduct biological, geological and chemical field surveys of these newly acquired Norwegian off-shore areas, covering app. 78.000 km^2. Multibeam mapping (including bathymetry and backscatter), as well as grab, sled, beamtrawl and video sampling are to be carried out throughout the whole area over the next few years. The

area is to be fully mapped before the end of 2019, when a series of biotope maps among other data products are to be delivered, and used to assist with the spatial management of the area. The Institute of Marine Research, the Geological Survey of Norway, and the Hydrographic Service of the Norwegian Mapping Authority contribute to, and collaborate in this mapping endeavour. Of all the sampling methods used, MAREANO's own video platform, known as Campod, has yielded the first video images of the seabed along with preliminary, geo-referenced, species occurrence data. These data can be used in the interim before adequate lab-based analyses are undertaken and data more fitted to conduct biotope distribution modelling are produced. In this poster we summarize findings from exploratory analyses of data logs from 60 video transects covering 42 km of video footage. The video documentation of the seabed has revealed an epibenthic community that changes over broad scales, and a landscape characterized by pockmarks and criss-crossed by trawl marks. The distribution of some taxa, including commercial species like the King Crab and Snow Crab, or sponges like *Asbestopluma* sp., seem to respond to smaller scale processes and are patchy within the surveyed area. Taxonomic diversity might be (negatively) responding to fishing intensity as inferred from number of trawl marks. These findings are invaluable to define the spatial and ecological settings of further analyses and studies, including modelling the distribution of species, communities, and biotopes.

Otolith zone formation and change in shape during the early juvenile stage of Northeast Arctic cod

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The Northeast Arctic cod juveniles (*Gadus morhua*) experience large environmental changes during the autumn, as they settle to a demersal life in the Barents Sea. This study investigated the potential occurrence of settling checks in the otolith macro structure and how the otolith shape may be changed during settling. Cod juveniles were sampled in the Barents Sea in the period from 2005 to 2009, on trawl surveys in August-September and February-March, resulting in the following age-groups; 0-group cod in summer (0_s-group), 1-group cod in winter (1_w-group) and 1-group cod in summer (1_s-group). More than 3000 fish were measured for size, otolith size and shape were measured from 1686 otolith pairs, and macro structure was analysed in transversal sections of 77 otoliths. This study shows that otolith shape of 0-group cod change significantly from late summer to winter, which coincides with the time of settlement. In spite overlapping fish sizes, 0_s-group and 1_s-group cod caught in the same trawls were discriminated based on otolith shape. Settling checks in the otolith macro structure were not identified in the settled 1_w-group cod. Differences in otolith shape and fish condition of 0_s-group cod were observed between catches of the pelagic trawl and the bottom trawl. The results indicate the occurrence of early settlement in a proportion of the 0-group cod in August-September (when pelagic 0-group cod are registered in Ecosystem surveys conducted by Norway and Russia) and that environmental stress and changed food availability related to settlement affect both fish condition and otolith shape.

Genetic and molecular methods

Key note: Dorthe Bekkevold

Application of genomic markers in assessment of marine populations in time and space

National Institute for Aquatic Research, Technical University of Denmark

The development of high-throughput sequencing techniques in non-model species has revolutionised available tools and dramatically increased knowledge on demographic and evolutionary processes in marine organisms. Recent genomic marker based analyses in fishes thus reveal hitherto unknown insights into the demographic and evolutionary processes that affect the distributions and genetic makeup of populations in space and time. There is increasing concern for the continuing health and viability of wild populations, including awareness about conserving native fish gene pools in the face of anthropogenic changes. It is for example of great interest to assess fitness effects of hybridization and introgression by escaped farm fish on wild populations. Here, molecular quantification has proved valuable for demonstrating levels of introgression by farm fish, and increasingly, genomic analyses are applied to determine specific fitness effects and predict long-term responses of affected populations. Genomic marker analyses moreover offer a superior tool for tracing fish and fish products, e.g. in the context of supporting a shift to a more sustainable exploitation of natural marine resources under current and future fisheries management and governance schemes. Examples demonstrate value and feasibility for basic biological inference, as well as for control purposes, management and conservation.

ORAL PRESENTATIONS

Diversity and dynamics of marine haptophytes and their viruses

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Haptophytes are nano- and picoplanktonic microalgae and important primary producers in the sea. They often form blooms that may impact on global carbon balance and climate forcing, and at times cause fish kills. Viruses may terminate these blooms. Knowledge on haptophyte diversity, quantitative distribution and dynamics at species level is limited

because they are small and fragile, and species identification usually requires electron microscopy or molecular methods. In the project HAPTODIV we have developed methods to explore the diversity and dynamics of haptophytes and their viruses, using 454-pyrosequencing, environmental clone libraries, DNA-sequencing of new isolates, pulsed field gel electrophoresis, quantitative PCR, flow cytometry and microscopy. Plankton samples and environmental data were collected monthly from the Oslofjorden and Raunefjorden for two years. A high diversity of haptophytes was revealed, and a majority of the sequences represent unknown or uncultured species. Several taxa are recorded for the first time in Norwegian and North European waters and some may represent new taxonomic lineages (orders and class). In Oslofjorden and Raunefjorden, some taxa are present at all times, such as bloom-formers in the genera *Emiliania*, *Phaeocystis*, *Chrysochromulina* and *Prymnesium*, whereas the calcifying coccolithophorids were found mainly in summer-autumn, the period with highest diversity and temperature. The diversity of virus infecting algae (*Phycodnaviridae*), including haptophyte specific viruses, differed over time and with locality and was highest in spring and lowest in winter. We have isolated and characterised four new haptophyte specific viruses that differ more in genome size, DNA sequence or infection cycle than previously shown. Genetic characterisation of viruses and their haptophyte hosts have revealed their diversity, and also improved our understanding of virus-host interactions and fundamental biological processes in the ocean.

Population genetic structure in the northern shrimp (*Pandalus borealis*) in the North Atlantic

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Prosjektet POPBOREALIS har kartlagt den genetiske bestandsstrukturen til reke (*Pandalus borealis*) i hele Nord-Atlanteren ved hjelp av DNA-mikrosatelliter. Ressursen er delt opp i fjorten forvaltningsenheter, men i de fleste tilfellene har man ikke visst om denne bestandsoppdelingen var biologisk relevant. Reker ble samlet inn fra hele artens utbredelsesområde i 2009-2012, på vitenskapelige tokt eller ved hjelp av fiskere. For å sjekke for temporal stabilitet i den genetiske bestandsstrukturen ble det fra flere av lokalitetene tatt prøver i to ulike år. Resultatene viser at det er stor genetisk variasjon mellom rekene i Nord-Atlanteren. Åtte genetisk distinkte områder peker seg ut: Skagerrak/Nordsjøen og norskekysten, Barentshavet inkludert Spitsbergen, Jan Mayen, Island, Vest-Grønland, hele den canadiske østkysten fra Hudson Strait til Nova Scotia, Flemish Cap, og Gulf of Maine. Langt på vei kan denne bestandsstrukturen forklares ved fremherskende havstrømmer og larvedrift, men andre faktorer spiller også inn. Den store forskjellen mellom rekene sør og nord i Norge, og den store forskjellen mellom rekene på Canada østkyst og i Gulf of Maine er de største overraskelsene i prosjektet. Rekebestandene ved Island og særlig Jan Mayen ser ut til å være isolerte bestander med svært liten tilførsel av larver utenfra.

Same same, but different - Environmental preferences, phylogeography and demographic history of *Pseudocalanus* spp. in the North Atlantic Ocean.

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Species of the genus *Pseudocalanus* (Copepoda: Calanoida) are widespread throughout the Northern Hemisphere. Through their abundance they constitute an important prey source for a wide variety of juvenile and adult fish species. There are at least five *Pseudocalanus* species in the North Atlantic Ocean, but their ecological preferences are not well understood due to difficult identification. Through the use of the barcoding gene, mitochondrial COI, for identification, we report environmental preferences (temperature and salinity) of four species of *Pseudocalanus* along the Norwegian coast and in two Svalbard fjords. The results indicate that *Pseudocalanus* species have marked differences in temperature preference. Furthermore, we used portions of two mitochondrial (COI and CytB) and one nuclear gene (ITS-1) to investigate phylogeography, population connectivity and demographic history of five *Pseudocalanus* species across the North Atlantic Ocean. The combined results indicate that the five copepod species may represent two distinct evolutionary branches. We propose that some *Pseudocalanus* species are oceanic and easily dispersed by ocean currents while others are coastal/ shelf associated.

POSTERS

Distribution and identification of *Azadinium* species (Dinophyceae) in European coastal waters

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Azadinium is a marine dinoflagellate genus comprising cells in the nanoplankton size range. One of the *Azadinium* species, *A. spinosum* produces Azaspiracids (AZAs) and is known to cause shellfish poisoning and hence the monitoring *Azadinium* species is important for seafood safety. In this study, we report the identification and distribution of *Azadinium* species from six localities in European coastal waters. We used both culture- and 454 sequences- based methods in order to elucidate the geographical distribution and phylogeny of *Azadinium* species. First, we established a strain of *Azadinium* (UIO 296) from Oslofjorden, Norway, and made identifications based both on morphology as revealed by scanning-electron microscopy and molecular phylogenetic analysis using concatenated SSU and LSU (D1/D2) sequences. The molecular phylogeny results showed that our isolate is closely related to *A. spinosum*, but there is a slight genetic difference between them. The diagnostic morphological characters of the UIO 296 isolate resemble those of *A. spinosum*, and thus it is provisionally identified it as *A.*cf. *spinosum*. Second, we analyzed an environmental DNA dataset retrieved from 454 pyrosequencing of samples collected at six geographically widespread localities in European coastal waters to elucidate the distribution of *Azadinium* species. The results suggest that *Azadinium* is commonly and widely distributed in European coastal waters.

Effect of temperature on microRNA expression in the liver of Atlantic cod (Gadus morhua)

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Atlantic cod (*Gadus morhua*) has a wide distribution range and experiences great variation in temperature conditions on a daily and seasonal basis. Temperature induces differential expression of several hundred genes and influences many aspects of cod biology and distribution. MicroRNAs (miRNAs) constitute a class of small RNAs that regulate gene expression post-transcriptionally and are involved in many essential biological pathways. However, the role of miRNA regulation in the process of environmental adaptation is poorly understood. The objective of this study was to start unraveling this issue by investigating if and how temperature affects miRNA expression in a physiologically essential organ, the liver, of Atlantic cod. We characterized miRNA profiles from the liver of cod under normal (8°C) and experimentally induced

temperature stress conditions (12°C and 16°C) using next-generation sequencing. Expression profile analysis revealed 191 conserved miRNA from 58 miRNA families. We identified a subset of differentially expressed miRNAs upon temperature challenge. Most of the significantly altered miRNAs have functions related to suppression of cell growth and proliferation and control of apoptosis. Our results suggest that miRNAs may be involved in the response of cod to temperature challenge. Additionally, several induced miRNAs were common with those expressed under temperature stress in other organisms implying a conserved mechanism of stress response. Regulation by altered miRNAs may be essential to survive under stress conditions and provide wide temperature tolerance of cod. This work contributes a foundation for further investigations of miRNA-mediated mechanisms of environmental adaptations, and thus climate change, in local cod populations.

DNA damage in ringed seals (*Phoca hispida)* from East Greenland

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Single cell gel electrophoresis (comet assay) is a quantitative and sensitive method for measuring DNA strand breaks and is widely used for genotoxicological studies. Although there exist protocols for cryopreservation of cells, it is critical to use fresh tissue to develop the comet assay for new species and tissues, e.g. ringed seal (*Phoca hispida*). This requirement for fresh tissue has previously excluded the method for being used in studies with arctic species. Thus, current knowledge of DNA damage in animal species living in remote areas is very limited.
In the present study, we established conditions under which to perform the comet assay with minimal equipment during field sampling of ringed seals in East Greenland in February/March 2012. As with many other Arctic mammals, there is concern as to whether exposure to bioaccumulating contaminants may increase DNA damage in ringed seals. Tissues analysed were liver, spleen, brainstem and testes. As reference and internal control human whole blood was used. The results showed baseline DNA damage in all tissues, with more damage in liver compared to other tissues. DNA damage in ringed seals can be indicators of exposure to genotoxic compounds as well as to environmental stress. The higher level of DNA damage found in liver relative to other organs may be due to the role of the liver as the main detoxifying tissue.

Genome- and transcriptome-assisted development of InDel markers for solving identification challenge of calanoid copepode *Calanus finmarchicus* and *C. glacialis*

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The last years have seen the rapid development of 'Next Generation Sequencing' technologies. By sequencing DNA in a massively parallel fashion these technologies have considerably reduced the per-base sequencing cost, while dramatically increasing the number of bases sequenced. Even for non model species, large data set can be easily generated. This large amount of sequence can be mined to developed specific molecular markers for example for species identification. Despite the ecological importance of the zooplankton genus *Calanus*, identification of species is still problematic. Morphological identification of *Calanus* species is constrained by subtle morphological difference, particularly between *C. finmarchicus* and *C. glacialis. Calanus finmarchicus* and *C. glacialis* commonly used as climate indicators and beacons of climate-related changes in North Atlantic and Arctic ecosystems, and therefore require precise species identification. This study present an example of genome- and transcriptome-assisted insertion/deletion marker (InDel) development for molecular identification of two sister species *C. finmarchicus* and *C. glacialis*, utilizing massive parallel sequencing on Ion Torrent platform. Markers were developed based on blast within species assemblies and search for large species specific InDels. Search resulted in 10 genome-based and 7 transcriptome-based suitable InDels with insertion/deletion size > 7 nucleotides and ≥ 3 respectively, that could be used in a two multiplex PCR. Tests on a panel of samples from various locations have demonstrated the applicability of the markers across species distribution, as well as the easiness and robustness of genotyping.

Assessing the abundance of the ichthyotoxic *Karenia mikimotoi* by quantitative PCR and microscopy

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The dinoflagellate *Karenia mikimotoi* may form blooms causing fish kills in coastal waters of the North East Atlantic region, including Norway and Sweden. A *K. mikimotoi* specific quantitative PCR (qPCR) assay was developed, based on the use of SYBR Green 1. The abundance of *Karenia* was assessed in samples from Outer Oslofjorden (Station OF2) collected monthly from August 2011 to June 2012, and 10 stations in Skagerrak collected during a cruise in April/May 2012. According to the qPCR assay, *Karenia* was present in all samples at station OF2, with a peak in August and September and with very low signals in February, March, April and May. *Karenia* was also identified by light microscopy of net hauls (20 μm mesh) in both August and September. Cell counts were performed on the same samples and *Karenia* was only recorded in September (180 000 cells L^{-1}). At the stations of the 2012 April/May Skagerrak cruise the abundance of *Karenia* was either very low or below the detection limit of our qPCR assay and *Karenia* was not observed by microscopy in any of the corresponding cell counts or net hauls. These results demonstrate that the qPCR assay was more sensitive than traditional counting methods using light microscopy in the detection of *Karenia*. In addition to traditional microscopy based methods, qPCR assays can be a powerful tool in the identification and quantification of *Karenia* and other harmful algae and may prove especially useful if applied in early warning programs.

High diversity and seasonal patterns of protists in the Outer Oslofjorden (Skagerrak) unraveled by 454 pyrosequencing

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Studies on protist (phytoplankton and protozoa) community composition in the Skagerrak have been carried out for over a century with focus on diversity and dynamics using microscopy approaches. Introduction of molecular techniques have facilitated species identification and biodiversity analyses of natural microbial communities. The aim of the present study is to determine the diversity and seasonal distribution of small planktonic eukaryotes (3-45 μm) in Outer Oslofjorden, Skagerrak, using 454-pyrosequencing.

Nanoplankton samples were collected and abiotic data were measured monthly from September 2009 to June 2011 at OF2 station (1 m depth). Total RNA was converted

into cDNA by reverse transcription and amplified by eukaryotespecific primers targeting the hypervariable V4 region of the 18S rRNA (c. 400 bp). The QIIME pipeline was used to clean the sequence data and build clusters at 99% sequence identity level. Taxonomical assignment was performed against the Protist Ribosomal Reference database (PR2). More than 4000 unique Operational Taxonomic Units (OTUs, an estimate for species) were found. Phytoplankton groups occurred in highest numbers of OTUs. We also found taxa not yet discovered by microscopy approaches in this area. The dataset showed seasonal variability with higher OTU numbers observed during the autumn, where stramenopiles and alveolates dominated. Within stramenopiles diatoms were by far the most diverse, followed by MAST (marine stramenopile clades), and Chrysophyceae/Synurophyceae. Dinoflagellates were the most diverse group within the alveolates, followed by ciliates.

Our dataset will provide new knowledge on the structure and seasonal dynamics of marine plankton in the Skagerrak and how the community is affected by environmental factors.

Microalgal diversity in a Red Sea seagrass meadow community

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Seagrass meadows are known for their high diversity of marine species and important ecological role in shallow marine and estuarine waters around the world. These habitats are experiencing a decline worldwide partly due to anthropogenic activity. Little is known about the protist/microalgal species diversity associated with this kind of habitat in the Red Sea in general, and in Saudi Arabia specifically.

We are examining the species composition in a bay north of Jedda in Saudi Arabia. We have collected samples from the water column above the meadow, scrapings from the seagrass plants, and the sediment in which the plants grow. The different algal species have been cultured, DNA has been extracted, and DNA fragments of marker regions have been amplified and sequenced, i.e. barcoded. The DNA markers of interest are the coding small subunit (SSU), the large subunit (LSU), and the non-coding spacers ITS1 and ITS2 of ribosomal DNA. The choice of markers is based both on the amount of reference sequences available, and the amount of variation found in said DNA region. The sequences will be compared with sequences from the GenBank database. Reference sequences are used to construct phylogenetic trees to unveil the taxonomic placement of the species. We will also use light- and electron microscopy along with the molecular data to determine which species are present, and characterize understudied or novel species.

This study will provide further understanding of tropical seagrass meadows's microbial species composition. It will show whether the meadow in question holds a unique microalgal community or is similar to that in other tropical regions, and possibly if there are any novel species present.

Coastal systems and multiple stressors

Key note: Daniel Conley

Managing multiple stressors in the Baltic Sea

University of Lund

Our traditional single disciplinary approach to understanding the causes and consequences of degradation of the marine environment have failed. Although we have reduced nutrients to lessen the harmful effects of eutrophication, marine ecosystems are not responding as predicted. We are attempting to manage the marine environment in the face of multiple forcing factors occurring simultaneously such as changes in fisheries, climate, urbanization, and contaminants. These stressors are affecting the quality of aquatic environments with consequences for biodiversity, recreational use and resource availability. It should be no surprise then that our efforts to reduce nutrients are not being rewarded with a healthier Baltic Sea. Understanding how ecosystems respond to these combined stressors both in the past and present is essential in order to identify the implications of future environmental changes, as well as predict the effectiveness of different management strategies. An improved understanding of the impact of these multiple stressors will not be achieved unless we engage in a multi-disciplinary effort to understand and to ultimately manage the marine environment sustainably.

ORAL PRESENTATIONS

In a squeeze? - Temperature, light, epibionts and the loss of kelp forests (*Saccharina latissima*) in Skagerrak

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Recent large-scale loss of the kelp Saccharina latissima from the south and south west coast of Norway has raised considerable concerns. Kelp forests are high-productive areas that provide ecosystem services on which many coastal communities depend. Both the ecological and economical consequences of kelp forest loss is therefore likely to be negative, - and substantial.

S. latissima is a cold temperate water species, and events of extreme high sea water temperatures in the late 1990's and early 2000's have been considered the most plausible driver of the initial losses. Small populations remained as scattered patches

along the impacted coastline, and on the west coast, these populations were able to recolonize some areas within a couple of years. Less forest recovery was observed along the south coast, and areas in Skagerrak are for the most part still devoid of kelp. Several studies show that an alternative ecological system can become permanent, even if the pressure from the driver of the ecological shift is released (e.g. when the temperature goes from extreme high and back to normal), because new mechanisms that reinforce the change may be established (e.g. competitive exclusion). In spite of several years with "normal" temperatures, the kelp forests in Skagerrak are patchy and often in poor condition. The question therefore is: What other factors affect this kelp?

In my studies, a high mortality of kelp coincided with the settlement and growth of epiphytic organisms covering the kelps' tissue. The epiphytes may reduce the light available for photosynthesis, and thereby the kelps' ability to harvest energy. We documented that the shading caused by epiphyte layers was likely to impact the kelp, especially in summer and fall. In a laboratory study, S. latissima from the south west and Skagerrak coast of Norway experienced high levels of stress and reduced photosynthesis after long term exposure to a temperature of 20 $^{\circ}$C. These results supported the notion that high temperature events harm S. latissima populations, and
suggested that extensive shading may be particularly harmful during warm periods.

Heavy loads of epiphytes on kelp plants in the depth range from 1 to 9 m in fall coincided with high mortality in Skagerrak. The probability of survival was much higher between 10 and 15 m depth where the specimens were cleaner, while most individuals at a 24 m depth died. These results suggest that a range contraction may have ocurred in Skagerrak, and indicate that this range contraction may be related to light availability.

Sex in murky waters: insights of anthropogenic disturbance on reproduction using the pipefish model system

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Due to anthropogenic disturbance, both stable as well as naturally variable environments are becoming increasingly unpredictable. In order to persist, both opportunists and specialists need to respond to these changes. A variety of animal behaviours are thus affected by human induced environmental change, which in turn may alter species interactions, population dynamics and evolutionary processes. The explosive growth of filamentous algae and phytoplankton has in recent years changed aquatic ecosystems worldwide. Increased amounts of phytoplankton alter the environment of marine organisms that have to adapt to changes in pH, oxygen, and visibility. We use pipefish as our study organism, which is a family of highly specialized fish practicing male pregnancy. Through a series of controlled laboratory experiments we show that anthropogenic disturbance alter several aspects of reproduction, including courtship behaviour, mate choice, mating propensity and reproductive success, while other processes, such as the development of sexual ornaments, seemed unaffected. We show that the way in which the environmental stressor alters reproduction may vary both

between and within sexes, populations and species. Further, different environmental stressors, such as turbidity, hypoxia and altered pH levels, elicited different responses, sometimes in opposite directions. Thus our studies emphasises the complex way in which environmental change may alter reproduction. Given the increase in human disturbance on ecosystems, answering these questions is not only important to better understand how environmental fluctuations affect evolutionary processes, but also for conservation biology and studies of the resilience of organisms to anthropogenic induced environmental change.

POSTERS

Hypoxia effects on the composition of hyperbenthos and infauna in Norwegian Skagerrak fjordic basins

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In environmental management there is a need for early warning of environmental degradation. Identification of sensitive indicator-organisms is therefore crucial. We will present the response of "hyperbenthos fauna" and macro-infauna to a gradient in eutrophication-related hypoxia represented by 11 fjord-basins. Fauna and sediment was collected with epibenthic sledge, grab and box corer. Diversity was strongly correlated with near bottom oxygen minimum during the last 5 years. For hyperbenthos, species number was clearly related to oxygen minimum (R^2 = 0.91). Species number decreased from 48-56 in the well-oxygenated basins (> 3 ml/l) dominated by Ostracoda, Isopoda and Tanaidacea, to 22-32 in intermediate hypoxia (2-3ml/l) dominated by Amphipoda and Cumacea. In the most hypoxic environment (< 2 ml/l) Cumacea dominated and species number varied from 0-7.

For infauna, diversity (H') clearly decreased with oxygen concentration (R^2 = 0.81). Species number varied from 62-123 in oxygen concentrations > 2 ml/l and was 27 below 2 ml/l. Assessment of functional attributes showed that above 2 ml/l the attributes: tube construction, shallow sediment dwelling depth, and surface deposit feeding increased with lowered oxygen condition whereas mobility and swimming activity tend to decrease.

Loss of species over time was estimated using the relation between oxygen concentration and species richness. Many fjords have lost > 50% of their species since 1980. This trend may be emphasized in the future due to climatic related changes in hydrographaphic and meteorological conditions e.g. reduced renewal of basin water and higher temperature and lower oxygen concentration of the advected water mass.

Modeling of mercury propagation in the Barents Sea

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A 3-dimensional numerical model has been used to study processes influencing the concentration of total mercury (Hg) in the Barents Sea. Processes include the transport and dispersion by ocean currents, boundary fluxes (i.e. atmospheric precipitation, rivers, oil platforms, ice connected processes) and partitioning with organic matter . A new biocgeohemistry/pollutant module, "OxyDep/PolPar", was developed and implemented into the Regional Ocean Modeling System (ROMS), a well-known primitive equation ocean model with free surface and a terrain-following vertical coordinate system. OxyDep/PolPar (Yakushev et al., 2013) was used for parameterization of processes of

seasonal formation and decay of organic matter and partitioning of Hg with dissolved and particulate organic matter.
Calculations revealed the "biological pump", the transport of contaminant from the surface to the deep waters, that were largely affected by the seasonal variability produced organic matter, with maximum in the surface water in winter, and minimum in summer. We also included processes connected with sea ice formation and melting. In winter, large regions of the Barents Sea are covered with ice and thus effectively isolated from the atmospheric precipitation. This should decrease the input of Hg, while in summer the melting ice should add this contaminant. Parameterization of the ice–related processes thus demonstrated that the seasonal cycle of the sea ice cover plays a major role. It was found that in regions covered with ice there can be higher concentrations of pollutants in summer than in winter which mask or counter or enhance the influence of the "biological pump". One effect of climate change is changes in the Arctic ice regime and hence, according to our findings, changes the fate of contaminants in this region. This issue should be considered in the future studies.

Radionuclide transport and uptake in coastal aquatic ecosystems – a comparison of a 3D dynamic model and a compartment model.

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In safety assessments of underground radioactive waste repositories, understanding the fate of radionuclides in ecosystems is necessary. Here, two mechanistic models (K- and D- model) describing the fate of radionuclides released into a Baltic Sea bay were compared. Both are based on ecosystem models that simulate the cycling of organic matter. Parallel to adsorption, transfer of radionuclides is linked to flows of organic matter (carbon) in food chains. Despite differences in temporal resolution, biological state variables and partition coefficients, the accumulation of Th-230, Cs-135 and Ni-59 in biological compartments was comparable between the models and with site measurements. Both models provided confidence limits for their modeled concentration ratios, an improvement over models that only estimate mean values. The D-model enables estimates at high spatio-temporal resolution. The K-model being coarser but faster, allows estimates centuries ahead. Future developments could integrate the two models to take full advantage of their respective strengths.

Future operational systems and products

Key note: Trine Bekkby

Distribution modelling – an overview (a talk about the history, development and the future potential for distribution modelling in research, management and planning

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Landscape ecology has a long history, and it is well-known that the distribution of species and habitats is influenced by environmental gradients and that it varies spatially. However, the tradition for spatial modelling is not very long. The development of spatial statistics and the technological development opened for a whole new field of science in the 1980s. As a consequence, an Australian group predicted the distribution of plants related to the altitude. These relationships were transferred into statistically based "rules" for the climatic tolerance limits and further into distribution maps. Since then, the availability of environmental layers has increased dramatically together with the technology, the numbers of methods for spatial analyses and the user-friendliness of software. Different data requires different methods, and all methods have pros and cons. This talk will present the history of distribution modelling, the recent development and current use (combining multibeam echosounding, laser technology, satellite imagery etc.) and the potential in future research, management and planning.

ORAL PRESENTATIONS

Developing habitat maps for coastal management within the Astafjord project, North Norway.

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The Norwegian coastal zone is very important for exploitation of marine and mineral resources, aquaculture, transport, leisure and many other activities. All these activities are of key economic interest for the local coastal communities and many also make a substantial contribution to the national economy. Despite this, Norway has no dedicated coastal mapping programme. Only some areas are fully mapped using modern methods. Without basic knowledge of the seabed and the environmental conditions management of

the coastal zone is not optimal, and coordination of the activities of the many user groups is difficult. One of the areas is Troms County, northern Norway. Under the Astafjord Project twelve local municipalities have joined forces to coordinate management of their marine areas. This is the first area to be mapped under an integrated project for geology, biology and environmental status.
Through this project The Geological Survey of Norway (NGU), developed a series of Marine Base Maps providing information on bathymetry, sediment grain size, backscatter, anchoring conditions, diggability and sedimentation basins (www.ngu.no). The maps are complemented with additional biological and environmental analysis and as a result, the project has become a showcase for integrated coastal seabed mapping in Norway. The Marine Base Maps are now the basis for a cross-municipality coastal management plan. In 2012 this map series was extended to include benthic habitat (biotope) maps, such that this important information, integrating biology and the physical environment, can also be used for management and made available to other end users.
We present the data and methods used to develop these habitat (biotope) maps and introduce the Norwegian Nature Type Classification System (NiN) version 1 (www.artsdatabanken.no), which was used as a framework for biotope identification within the Astafjord project. Biotope modelling work draws on experience in offshore mapping under the MAREANO programme (www.mareano.no) where habitat maps have been produced using multivariate analysis and modelling. Through these and several other initiatives the NGU is actively engaged in the development of a revised version of NiN which is due for publication in 2014.
With an extensive coastal and offshore area Norway need methods for habitat mapping that can be readily extended as new areas are surveyed. It is essential that all information and maps developed are effectively delivered to managers and end users of the coastal and offshore areas.

Mapping the distribution of biotopes in Inner Oslo fjord

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The fjord is frequently used by people for swimming, fishing and other outdoor activities, but is also under pressure due to coastal development. A sustainable management of the coastal zone and shallow areas requires knowledge of the biotopes found there. The present study was based on more than 2,000 benthic records from Bunnefjorden collected through NIVAs work for the National Council for Inner Oslofjord in the period 2005-2012. The records were sampled in the coastal zone using underwater drop-camera or ROV from 0-30 m depth, and biotopes were classified according to the Norwegian NiN system and the European EUNIS system. In the investigated area there was a total of 15 different NiN habitats, and the most common was “Naken løs eufotisk saltvannsbunn” (M15-2). The second most common was “Eufotisk normal svak energi saltvannsfastbunn” (M11-2). Through the EUNIS system a total of 23 different habitats were identified. Generalized additive models (GAM) were used to relate the distribution of the biotopes to environmental predictor variables. Probability maps were created from

the models for each biotope and evaluated with independent validation data, using the area under curve value (AUC).

Satellite Remote Sensing in Marine Coastal Ecosystems – Applications for Monitoring and Management

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The costal zones are the most inhabited areas of the world and are therefore strongly affected by humans, leading to undesirable environmental changes that may alter the ecosystems, such as eutrophication. In order to evaluate changes in the environment an effective water quality monitoring system for the coastal zones must be in place. Ocean colour remote sensing provides a synoptic view and therefore, when combined with field sampling, can provide the basis for more effective monitoring and management of the coastal zone and the open sea.
The chlorophyll-a concentration is commonly used as a proxy for bio-mass and as indicator for eutrophication and it can be retrieved from ocean colour remote sensing data. Several operational monitoring systems based on remote sensing are in place to monitor the open sea and, to some extent, the coastal zones. However, evaluations of coastal monitoring systems based on satellite data are scarce. Here, we compare the chlorophyll-a concentrations retrieved from an operational satellite system using MERIS (Medium Resolution Imaging Spectrophotometer) data with ship-based monitoring for the productive seasons in 2008 and 2010, in a coastal area in the Baltic Sea. The comparisons showed that the satellite-based monitoring system is reliable and that the retrieval of chlorophyll-a concentration is comparable to *in situ* measurements. Furthermore, satellite-based monitoring improves both the spatial and temporal resolution of the observations. This study shows that MERIS is better at capturing spatial dynamics and the extent of phytoplankton blooms than ship-based monitoring. A very strong and significant correlation (r= 0.90) was found between measurements from satellite-derived chlorophyll-a compared to ship measurements taken close in time (0-3 days) and the monthly means showed no significant differences. Satellite-based monitoring also increases the frequency of chlorophyll-a observations in Swedish waters by 1.5 - 13.5 times, dependant on the sampling-frequency of the respective monitoring program. Our results show that the information gained by satellite-based monitoring is comparable to the ship-based monitoring program, and furthermore, better in capturing the spatial dynamics and thus can be an important monitoring tool in areas that are less frequently monitored. These results are relevant for eutrophication assessment and status classifications of water basins and could, for example, be applied to the two EU Water Framework Directives as well as within OSPAR and HELCOM`S Baltic Sea Action Plan.

The Norwegian Ocean Weather Prediction system: A revisit

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The Norwegian Ocean Weather Prediction (NOWP) system is completely renewed in 2012, and was implemented in January 2013. The system uses the ROMS - Regional Ocean Modeling System - model, and consists of a triply nested grid configuration. The outermost grid covers the AtlanticOcean north of about 50 degrees north, including the Arctic Ocean, with a grid resolution of 20 km. The middle system covers essentially the Nordic Seas and the adjacent Barents and North Seas with a grid resolution of 4 km. The innermost grid covers the entire Norwegian coast with a grid resolution of 800 meters. The latter model is developed in collaboration with IMR. All three grids provides forecasts with a lead time of 66 hours to seven days of the threedimensional physical ocean, that is, tides, storm surges, sea ice, currents and temperature and salinity. The raw model results are available at http://met.no/English/Ocean_and_Ice/, and may be viewed at http://www.yr.no/ both as time series at a location of your choice, as still maps or as animations. The NOWP system and forecasting results will be presented together with some preliminary validation results from a validation system presently under development.

Acidification of the oceans

Key note: Sam Dupont

Get ready for ocean acidification

University of Gothenburg

Ocean acidification due to CO_2 uptake leads to a reduction in pH and saturation state (Ω) of seawater with respect to calcium carbonate minerals (calcite and aragonite). It is often assumed that under-saturation causes problems for calcification and marine calcifiers and Ω is used as a key geochemical threshold to link chemistry to biological and socio-economical responses. However, many species including calcifiers are able to adapt and even thrive while acutely (e.g. upwelling areas) and chronically (e.g. deep sea vents) exposed to under-saturated seawater. Identifying relevant biogeochemical threshold or species tipping point is critical but complicated by the fact that ocean acidification will operate in concert with other anthropogenic stressors (temperature, hypoxia, salinity, toxicants, oil spill, etc.) Since it is impossible to study populations of all species and take into account all interacting environmental parameters into a realistic experimental design, making any large scale projection requires understanding the mechanisms in action, how they are intertwined across levels of biological organization (molecular, cellular, systemic, ecosystem, all as a result of evolution) and their potential hierarchies. In this presentation, I will propose a new theoretical framework and a research strategy to move forward to large scale projections of the impacts of ocean acidification on marine species and ecosystems

ORAL PRESENTATIONS

Deformities in larvae and juvenile European lobster (*Homarus gammarus*) exposed to lower pH at two different temperatures

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The ongoing warming and acidification of the world's oceans are expected to influence the marine ecosystems including benthic marine resources. Ocean acidification may especially have an impact on calcifying organisms and the European lobster (*Homarus gammarus*) is among those species at risk. A project was initiated in 2011 aiming to investigate long-term effects of ocean acidification on the early life-cycle of lobster under two temperatures. Larvae were exposed to *p*CO2 levels of ambient water (water intake at 90 m depth), medium 750 (pH=7.79) and high 1200 *μ*atm *p*CO2, (pH=7.62) at temperatures 10 and 18°C. *p*CO2 values were chosen according to the levels predicted for year 2100 by the Intergovernmental Panel of Climate Change. The water quality in

ambient water did not stay stable and was unfortunately very low towards the end of the experiment in the larval phase at 10˚C, pH between 7.83 and 7.90. Ph in ambient treatment at 18˚ was even lower, between 7.76 and 7.83, i.e. close to medium *p*CO2 treatment. Long-term exposure lasted until 5 months of age. At 18°C the development from Stage 1 to 4 lasted from 14 to 16 days, as predicted under optimal water conditions. Growth was very slow at 10°C and resulted in three larvae reaching Stage 4, in ambient treatment only. There were no clear effects of *p*CO2 treatment, on neither carapace length nor dry weight. Deformities were however observed in both larvae and juveniles. The proportion of larvae with deformities increased with increasing *p*CO2 exposure, and was similar across the two temperatures. In the medium treatment, 22 and 24% were deformed at 10°C and 18°C respectively. In the high treatment as much as 42 and 45% were deformed, at 10°C and 18°C respectively. None of the larvae exposed to water of pH > 7.9 developed deformities. Curled carapace was the most common deformity found in larvae raised in medium *p*CO2 treatment, irrespectively of temperature, but also damages in the tail fan occurred as well as a bent rostrum. On the other hand, curled carapace was the only deformity found in high *p*CO2 treatment, at both temperatures. Occurrence of deformities after 5 months of exposure was 33 and 44% in juveniles raised in ambient and low *p*CO2, respectively, and 21% in juveniles exposed to high *p*CO2. Deformed claws were most often found in ambient and medium treatment (56%), followed by stiff/twisted walking legs (39%) and puffy carapace (39%). In comparison, at high *p*CO2 71% of the deformed juveniles had developed a puffy carapace. In overall, about half of the deformed juveniles from the ambient and medium *p*CO2 treatment displayed two or three different abnormalities, concurrently 70% had multiple deformities in the high *p*CO2 treatment. Some of the deformities in the juveniles may affect respiration (carapace), the ability to find food, sexual partner (walking legs, claw and antenna), and ability to swim (tail-fan damages).

Shipping Contributes to Ocean Acidification

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Studies of Ocean Acidification have focused on the acidification due to uptake of anthropogenic CO_2: since the quantities of other anthropogenic acids such as sulphuric and nitric acids resulting from anthropogenic emissions of sulphur and nitrogen oxides (SO_X and NO_X) are small in comparison. However, while the uptake of CO_2 is a global phenomenon, deposition of SO_X and NO_X occur relatively close to their sources. An examination of the potential effect on surface water pH of emissions of SO_X and NO_X from global ship routes indicates that regional pH reductions of the same order of

magnitude as the CO_2-driven acidification can occur in heavily trafficked waters. These findings have important consequences for ocean chemistry, since the sulphuric and nitric acids formed are strong acids in contrast to the weak carbonic acid formed by dissolution of CO_2. Our results also provide background for discussion of expanded controls to mitigate acidification due to these shipping emissions. This global overview will now be followed up by a regional study focusing on the Baltic Sea, where increasingly strict controls on SO_X emissions are focusing attention on developments of exhaust gas scrubbing systems as an alternative to expensive low-sulphur fuel.

Temperature, but not phosphorus limitation, changes the ratio of calcite to organic carbon in *Coccolithus pelagicus*

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The ratio of calcite (PIC) to organic carbon (POC) in coccolithophores is an important variable in ocean-atmosphere CO_2-exchange. Photosynthesis binds CO_2 into organic matter, whereas calcification releases it, so that the PIC/POC-ratio determines whether a coccolithophore bloom acts as a source or a sink of CO_2. Numerous studies have shown that this ratio can be modified by environmental parameters such as ocean pH, temperature, salinity, and nutrients, yet most studies have focused on the cosmopolitan species *Emiliania huxleyi*. Although abundant in the modern ocean, *E. huxleyi* may not be the best representative of coccolithophores' general response towards changing environmental parameters, and species-specific responses towards ocean acidification have been described. We therefore studied two subspecies of *Coccolithus pelagicus*, which produces heavily calcified coccoliths and contributes substantially to marine carbonate production, with PIC/POC-ratios generally above unity. We examined the effect of increased temperature and phosphorus limitation, a parameter predicted to change with a warming climate, on growth and calcification by growing triplicate batch cultures under phosphate limiting and nutrient replete conditions at two temperatures. Organic carbon production in the cultures was examined by growth rate and cellular POC quota. Inorganic carbon production was evaluated by cellular PIC quota, coccolith size, and coccolith malformations.
Phosphorus limitation did not influence exponential growth rates, but led to lower cell densities in stationary phase and significantly lower cellular phosphorus quota. Increased temperature on the other hand increased the phosphorus requirement of cells. Mean coccolith size was the same under both nutrient regimes and temperatures and larger cells were covered by more, rather than larger coccoliths. Although the percentage of malformed coccoliths increased slightly under phosphorus limitation, there was no overall change in PIC/POC-ratios between phosphorus limited and nutrient replete cultures. High temperature, however, reduced the PIC quota of cells by ca. 50% leading to PIC/POC-ratios below unity. High temperature also increased coccolith malformations and cultures grown at high temperature and phosphorus limitation produced up to 70%

malformed coccoliths. These interactive effects of different environmental parameters need to be taken into account when modelling the effect of a changing climate on calcifying organisms as they will likely be exposed to both increased temperature and decreased nutrient availability in the future.

Regulation of light-stimulated carbon dioxide fixation in the proteorhodopsin-containing marine flavobacterium *Dokdonia* sp. MED134

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Sunlight and carbon dioxide are the main drivers of the marine food web through their importance for phytoplankton photosynthesis. In the last decade the discovery of novel photosystems that allow also bacterioplankton to harvest energy from sunlight (making them photoheterotrophic) were discovered to be widespread and abundant in the oceans. Recent work has provided some insight into the benefit of proteorhodopsin (PR) phototrophy and carbon dioxide fixation for promoting growth and survival in different bacteria (and that over 50% of bacteria carry the PR gene). Still, little is known about how the utilization of light energy is regulated; and the metabolic pathways actually mediating the response to light remain unknown. To investigate these issues -and to uncover the role of dissolved organic matter quality for the growth of *Dokdonia* sp. MED134 in the light and darkness -we carried out experiments with artificial seawater cultures enriched with low concentrations of either a complex (yeast extract and peptone) or a simple (alanine) organic carbon source. Results showed that carbon dioxide fixation rates as well as the carbon dioxide fixation:bacterial production ratio increased in the light, implying that the central metabolism was considerably complemented by anaplerotic carbon dioxide 2 fixation (filling-in CO2 into the TCA cycle). We did quantitative PCR to assess the relative expression of 11 key genes involved in bicarbonate uptake, anaplerotic carbon dioxide fixation and alternative TCA cycle pathways. Notably, the PR gene was up-regulated nearly 40-fold in the light, together with 100-fold increases in the glyoxylate shunt genes. This reveals that the glyoxylate shunt is a previously unrecognized key metabolic feature that allow for house holding with carbon atoms for biomass synthesis in bacteria. These novel findings will be discussed in relation to how the dissolved organic carbon quality critically determines the ecosystem role of bacteria engaging in PR phototrophy in the ocean surface.

A test of evolutionary effects of ocean acidification on a copepod population

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Almost all animal studies focus on physiological responses of individuals to elevated pCO2. However, the increase in pCO2 will be slow, and major ocean acidification effects will only occur on the time scale of several generations, which leaves room for adaptation of animal populations to the changed environment through natural selection. Animals may, on the other hand, acclimatize physiologically through phenotypic plasticity, and this will counteract selection. We investigated to what extent natural selection and phenotypic plasticity drives changes in the metabolism in the copepod *Pseudocalanus acuspes*. Copepods were incubated in small mesocosms and rates of respiration and egg production were measured in two consecutive generations. To estimate the importance of selection and phenotypic plasticity we also measured these rates during reciprocal transplants of copepods between high pCO2 treatments and controls. This traditional method is an easy and powerful way to weigh the importance of selection and phenotypic plasticity for the emergence of phenotype differences among populations. The ratio between respiration and egg production was used as a proxy for metabolic stress.

POSTERS

Ocean Acidification state in Arctic outflow waters

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In 2011, the Ocean Acidification Flagship at the Fram Centre established a new time-series transect for ocean acidification studies in the Fram Strait. The study was expanded in 2012 and is part of an observational network investigating the carbonate system and ocean acidification state in the Arctic gateways. The motivation is to investigate the effect of a changing Arctic such as freshening, warming, sea-ice cover decline and changes in the Polar and Atlantic waters influence on the ocean acidification state and the carbon system. During two years, we performed extensive sampling of the water column, and determined the carbonate system parameters, nutrients, isotope tracers, and colored dissolved organic matter (CDOM). Using total alkalinity-and isotope tracer-salinity relationships we estimated the water mass composition in the water exiting the Arctic. From these data, we investigate the influence of freshwater (river runoff and sea-ice melt), Polar water, Pacific water, and Atlantic water on the ocean acidification state. Lowest pH and CaCO3 saturation state was found in a layer between 20 to 200 meters depth in the outflow water coinciding with high brine content. In this presentation we discuss the possible mechanisms for the origins of the low pH layer.

Long-term effects of ocean acidification simulations on *Calanus finmarchicus*: Developmental delay and reduced fecundity as a consequence of reduced scope for growth

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The copepod *Calanus finmarchicus*, (in Norwegian called "raudåte"), is a key player in marine food webs of the northern Atlantic, linking the transfer of energy from primary producing algae up to higher tropic levels. To investigate what the long-term impact of ocean acidification may be on this species, animals were exposed to different CO_2 scenarios, in the experimental facilities for CO2-pertrubation at NTNU Centre of Fisheries and Aquaculture (NTNU SeaLab). During two consecutive generations, effects on ontogenetic development rate, somatic growth, lipid accumulation, fecundity, hatching success and scope for growth (energy available for growth and development) were measured. At the highest CO_2 level (3080 ppm), estimates show a significant reduction of the scope for growth in second-generation sub-adult (CV) copepodites (2.9 fold reduction vs. control), which is consistent with a significant reduction of the ontogenetic development rate of several nauplii- and copepodite stages (up to 4.1 days delay vs. control), a significant reduction in lipid accumulation (50% of the control) and a significantly reduced reproductive output (33% of control). At the medium CO_2 level (2080 ppm, year 2300 scenario), estimates show a significant reduction in scope for growth among the second-generation sub-adult copepodites (3.3 fold reduction vs. control), but here, a significant delay in the ontogenetic development (up to 4.1 days delay vs. control) was only observed during the first-generation, suggesting a possible acclimation- /adaptation response in the second-generation. Interestingly, in the lowest CO_2 treatment (1080 ppm, year 2100 scenario), estimates show significantly increased scope for growth (1.9 fold increase vs. control), which corresponds with a significant increase in the lipid content (32% increase vs. control), and the absence of any negative observable effects on development and fecundity. Our findings suggest that *C. finmarchicus* may be resilient to the direct effects of long-term exposure to ocean acidification conditions that may be relevant for year 2100 CO_2-emission scenarios (e.g. ~1000 ppm CO_2). Although our results indicate that *C. finmarchicus* may also be able to adjust to CO_2 conditions that could occur within year 2300 (e.g. ~2000 ppm CO_2), further experiments, where this CO_2 scenario is combined with other forms of stress, such as rising seawater temperatures and altered food conditions, are necessary.

Effect of increased *p*CO2-level on early shell development in great scallop (*Pecten maximus* Lamarck) larvae.

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As a result of high anthropogenic CO2 emissions, the concentration of CO2 in the oceans has increased causing a decrease in pH, known as ocean acidification (OA). Numerous studies have shown negative effects on marine invertebrates, and that the early life stages are the most sensitive to OA. We studied the effects of OA on embryo and unfed larvae of the great scallop (*Pecten maximus* L.), at *p*CO2-levels of 469 (ambient), 807, 1164, and 1599 µatm until seven days after fertlization. To our knowledge, this is the first study on OA effects on larvae of this species. A drop in *p*CO2-level the first 12 hours was observed in the elevated *p*CO2-groups due to a discontinuation in water flow to avoid escape of embryos. When flow was re-started, *p*CO2-level stabilized and was significantly different between all groups. OA affected both survival and shell growth negatively after seven days. Survival was reduced from 45 % in the ambient group to 12 % in the highest *p*CO2-group. Shell length and height were reduced with 8 and 15 %, respectively, when *p*CO2 increased from ambient to 1599 µatm. Development of normal hinges was negatively affected by elevated *p*CO2-levels in both trochophore larvae after two days and veliger larvae after seven days. After seven days, deformities in the shell hinge were more connected to elevated *p*CO2-levels than deformities in the shell edge. Embryos stained with calcein showed fluorescence in the newly formed shell area, indicating calcification of the shell at the early trochophore stage between one and two days after fertilization. Our results show that *P. maximus* embryos and early larvae may be negatively affected by elevated *p*CO2-levels within the range of what is projected towards year 2250, although the initial drop in *p*CO2-level may have overestimated the effect of the highest *p*CO2-levels. Future work should focus on long term effects on this species from hatching, throughout the larval stages and further into the juvenile and adult stages

The Oslofjord - ecosystems under pressure

Key note: Ketil Hylland

The inner Oslofjord: a field laboratory for studying urban environmental impacts

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The inner Oslofjord is recipient to wastes from more than one million humans, as well as inputs from shipping, recreational boating, some industrial and agricultural activities, local and long-range atmospheric inputs, hospital effluents and runoff. The inputs of nutrients, personal care products, pharmaceuticals and contaminants are typical for coastal areas in Europe and elsewhere in the world, but the hydrography of the fjord results in a longer residence time of water, and hence pollutants, than in open-coast areas.

The Oslofjord has been subject to marine ecological and oceanographical studies for over a century and it has been possible to follow changes in eutrophication status and fish recruitment for many decades. In addition to stored data, the community composition of foraminifera in sediment cores have been used retrospectively to elucidate pressures to the inner Oslofjord ecosystem over the past century. Over the past few decades there has been an increasing focus on environmental contaminants and possible effects on inner Oslofjord ecosystems. As mentioned above, contaminant inputs to the fjord range from pharmaceuticals, personal care products and illicit drugs released in sewage, through metals in rivers and rain to polycyclic aromatic hydrocarbons (PAHs) that are present in nearly all conceivable contexts, including oil, surface runoff, sewage and atmospheric deposition. Annual studies on the consequences of contaminant inputs on the health of Atlantic cod populations in the inner Oslofjord have shown that the cod population is exposed to higher levels of PAHs than in reference populations and a link to changes in biotransformation processes. There are also indications that lead (Pb) may still be affecting fish in the inner Oslofjord. Recent results indicate that cod in the inner Oslofjord have higher levels of DNA damage than in reference populations, but they also have higher capacity for protection against such damage than fish in other areas. Putative knock-on effects on fish condition and growth have not been consistent, but data for most years show a cod population with somewhat lower condition and slower growth than similar populations in the outer Oslofjord.

Nutrient inputs have generally been decreasing over the past few decades, but levels of most contaminants remain at a similar level as previously and some have been increasing in the tissues of e.g. cod over the past decade. Although not at concentrations likely to cause harm to marine organisms, emerging contaminants such as sweeteners, personal care products, pharmaceuticals and flame retardants are commonly detected in Oslofjord waters or biota; the inner Oslofjord will remain a laboratory for environmental studies for decades to come.

ORAL PRESENTATIONS

Historical changes in the seaweed vegetation in inner Oslofjord

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The seaweed vegetation in inner Oslofjord has been studied numerous times and there are records dating as far back as 1893-94 (Gran 1897). The algae vegetation was described in detail in the 1940-60s by e.g. Sundene (1953), Grenager (1957), Rueness (1973) and Klavestad (1966, 1978). In 1974 a monitoring programme was started in the inner Oslo fjord, including registration of seaweeds in order to monitor possible effects of eutrophication (Bokn & Lein 1978).

The five most common canopy forming seaweed species (*Ascophyllum nodosum*, *Fucus spiralis*, *F. vesiculosus*, *F. serratus* and *F. evanescens*) have regularly been recorded at 123 different localities in the Inner Oslofjord, located from Filtvet south of Drøbak to the inner part of Bunnefjorden. In addition, detailed quantitative analyses of the vegetation and lowest water depth for observing selected macroalgae have been studied at selected localities (Berge et al. 2012).

The algae vegetation has been subjected to major changes the last 120 years. In the 1890s the knotted wrack (*Ascophyllum nodosum)* was described as growing in littoral, sheltered locations and was common in the inner parts of the Oslofjord (Gran 1897). A few years later, *Fucus evanescens* was accidentally introduced to the Oslofjord, probably from northern Norway. In the 1940s the knotted wrack was still common in sheltered locations and *F. evanescens* grew rather scattered and was not found over wide areas in spite of extended examinations (Sundene 1953). But in the 1950-60s the amount of *Fucus evanescens* increased substantially as pollution increased, and by the 1970s it had become the most abundant wrack in the Oslofjord. In 1974-80 it was found in 94% of all examined localities and had dense populations in the majority of stations. At the same time *Ascophyllum* had disappeared from the inner parts of the fjord and was only common in the southern part of Vestfjorden (Bokn & Lein 1978).

In the late 1980s/1990s the amount of *Fucus evanescens* started decreasing (Bokn et al.1992) and new records from 2011-2013 have shown that the amount of *F. evanescens* has decreased substantially the last 10 years (Berge et al. 2012). It is still present at 89% of the localities but it grows scattered and is only abundant in 10 % of the localities (mainly in the harbour area near the city of Oslo). *Ascophyllum* has further decreased since the 1970s and is found in 13% of all examined localities (compared to 36% in 1974-80). For the other species the changes are more subtle and diverse.

Quantitative analysis of the littoral algae vegetation have shown an increase in species diversity from 1974 to 2001/2002, but only smaller changes from 2001/2002 to 2011.

The lowest water depth for observing selected macroalgae is regarded as a good environmental quality element related to eutrophication. This parameter has been attempted used in the inner Oslofjord, but has in most localities proven to be an unsuitable parameter due to urchin grazing and scarce alga vegetation.

Turbulence caused by a combination of tides and baroclinic mean pressure gradients over a fjord sill.

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Fjord entrances with sills are typical locations of strong flow-topography interactions due to strong barotropic and baroclinic currents caused by tides and exchange processes between the fjord and the coastal water. Here we investigate the conditions at the Drøbak Sill of the Oslofjord with respect to mixing. The area was transected 13 times with a free falling microstructure shear probe during 4 days in June 2011, at the same time an ADCP was deployed inside the sill. During most tidal cycles, internal hydraulic jumps with high dissipation rates were found on the downstream side of the sill. However, the internal response differed strongly between different tidal cycles with similar barotropic forcing. In one transect dissipation rates of more than 10^{-3} W/kg was observed in a hydraulic jump downstream the sill, while in another transect no hydraulic jump was observed. Both transects had the similar barotropic forcing, but during the first transect a strong baroclinic flow was observed inside the sill in the depth range 10-25 m. This baroclinic flow was absent during the second transect. It can be seen from the salinity profiles 500 m inside and outside the sill that the horizontal gradients over the sill was different during the two transects.

A reasonable explanation for the missing hydraulic jumps therefore is that the mean baroclinic exchange pushes the flow below the limit of a controlled situation during those occasions where hydraulic jumps are not present. We conclude that the conditions at the sill is on the edge of forming hydraulic jumps, and that, e.g., the mean baroclinic exchange may push the flow above or below the limit of a hydraulic jump depending on the situation.

Monitoring in the Inner Oslo fjord – Results from 2012 and a historical overview.

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The Inner Oslo Fjord is an enclosed water body with a total surface area of 190 km^2 and consists of 2 main basins and several sub basins. Water exchange with the Outer Oslo fjord and Skagerrak is through a 1 km wide strait at Drøbak with a sill depth of 20 m. Investigations in the fjord started just before 1900 and monitoring has been performed regularly through "Fagrådet" since 1973? The inner Oslo fjord monitoring programme was originally designed to cover the pollution status of the fjord due to eutrophication but has later also included aspects related to contaminant. The monitoring includes physical, chemical and biological conditions in the fjord.

The pollution load of nutrients to the fjord is dominated by discharges from treatment plants for municipal sewage. Sewage from near 1 million persons are treated by the 3 plants. Between 1910 and 1996, the anthropogenic discharges of nutrients (mainly from municipal sewage) increased by a factor 1-2 for phosphorus and by up to a factor 6 for nitrogen. The difference between phosphorus and nitrogen load is related to the establishment of sewage treatment plants (chemical treatment) between 1970 and 1990. Removal of nitrogen started in 1995/96 and was completed in 2001, when the latest sewage treatment plant became operative.

The total load from industry and municipal sewage in 2012 is estimated to be 75 tons phosphorous and about 2338 tons nitrogen. Compared to 1985, the anthropogenic reductions up to 2007 were 60 % for phosphorous and nitrogen. The discharges was at a minimum in 2003-2004 but has since increased slightly since.The local input of nutrients to the Inner Oslofjord has thus been significantly reduced since 1985.

Until the early 1980s, most of the wastewater was discharged to the fjord's surface, while it after the 1980s has been discharged to the intermediate water layers (30-50 m depth) of the fjord and thus to a lesser extent than previously come in contact with the part of the water column where photosynthesis can take place. This has contributed to a reduced eutrophication effect.

The yearly water exchange (water between 20 m depth and bottom) in the Inner Oslofjord varied between 20 and 140 % during the years 1973-2012 and was very low in 2012 (25 %). Long periods of winds from the North during the winter increase the probability of deep water renewal in the fjord. In the innermost basin deep water renewal usually takes place at 3-4 years interval resulting in periods with low concentrations of oxygen in the bottom water in years with little water exchange. In the outer basin deep water renewal takes place every year and low oxygen conditions are more seldom observed.

In the inner basin (the Bunnefjord) there was no deep water renewal during the winter 2012 and the oxygen concentration decreased steadily throughout the spring and summer, with some hydrogen sulfide development at 150 m depth until August. The winter of 2012 did however result in relatively good deep water renewal in the outer basin (the

Vestfjord) and oxygen concentrations in the deep water reached almost 5 ml/l in April, but with elements of older water with less than 4 ml/l at medium-depth.

The concentrations of Tot-N and Tot-P in surface water during the winter show a long term reduction. Data for 2012 showed a relatively low value for Tot-P in relation to the preceding 7 years and the conditions could be classified as very good. Data on Tot-N shows a steady upward trend over the last 4 years, but environmental conditions could still be classified as good.

A new sewage treatment plant was established at Bekkelaget in 2001. Before this, hydrogen sulphide and low oxygen conditions were regularly observed in the basin receiving the discharges (Bekkelagsbassenget). After the establishment of the new treatment facility with a discharge of fresh water at 50 m depth, oxygen concentrations have significantly improved. Oxygen conditions in the Bekkelagsbassenget were in 2012 well within what has been observed since 2001.

Water quality has improved substantially in the fjord surface layer during the last four decades. The improvement was greatest between the first two periods, and the percentage improvement has been greatest in the areas with poorest water quality. Although the environmental conditions in the Inner Oslofjord have improved since the 1970 ties, there are however still challenges. These are related to future discharges from an increasing population, lack of capacity for sewage treatment, possible climatic changes and presence of contaminated matrixes.

POSTERS

Benthic communities at the opera in Bjørvika, Inner Oslofjord

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In 2008 the new opera building was opened in Bjørvika in the innermost part of the Oslofjord. The declining (approx 15°) northern part of the building is entering the water, and below the surface there are 7 horizontal steps down to a depth of approx 3 m before it drops down to approx 8 m depth. During spring and fall 2012 we investigated the organisms growing at these steps. In the surf zone there is a dense population of *Littorina littorea*, keeping the upper surface clean from green algae. On the 5 uppermost steps *Fucus vesiculosus* dominates on the horizontal surfaces, while the vertical walls are covered by barnacles (*Semibalanus balanoides* and *Balanus improvisus*). Deeper down the horizontal steps are covered by blue mussels. There is also a small patch with eelgrass (*Zostera marina*) on one of the steps. In total 19 species of animals and 27 species of algae were recorded. The result from this study demonstrates that the water quality in the innermost part of the Oslofjord can house a diverse community.

Deep water discharge of treated sewage water helps improving deep water oxygen conditions in Bekkelaget basin in the Inner Oslofjord.

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The most clearly observable change in the Inner Oslofjord during the last decades is the sudden and lasting improvement in oxygen conditions in the semi-enclosed basin outside Bekkelaget from 2001. During the monitoring period from 1973 to 2001, hydrogen sulphide and low oxygen conditions were regularly observed almost each year in this basin. The first treatment plant at Bekkelaget was built in 1963. Until 2001, treated sewage water from the plant was discharged by a tunnel at 25 m depth with no diffusor arrangement, and was mixed into the upper layers of the basin. Although the discharges of nutrients to the fjord as whole was substantially reduced in this period, and conditions in surface layers of the fjord improved, the oxygen conditions in the deeper layers (40-70 m) did not improve.

When a new treatment plant at Bekkelaget was planned in 1998-2000, a fjord model developed at NIVA was used to predict the effect of relocating the discharge to a diffusor at 50 m depth. The results indicated substantial improved deep water oxygen conditions. Subsequent monitoring has confirmed the predictions. After 2001, the Bekkelaget basin has had mostly permanent oxic conditions down to 50-60 m depth, with regular deep water renewal each year. The change occurred quite suddenly from the year when the new plant was put into operation.

The improvement is clearly caused by the discharge of treated sewage freshwater through the diffusor. Turbulent freshwater jets from the diffusor will mix with surrounding water and rize to a depth where the increasing jet density exceeds the density of surrounding stratified water. The entrapped diluted runoff will then spread horisontally by gravitation. Depending on the entrapment depth, the result is an enhanced direct water exchange with the rest of fjord and/or a reduction in deepwater density in the basin which increases the frequency of episodic deep water exchanges.

The data shows corresponding effects around 40 m depth in Bunnefjorden, with larger and more regular seasonal variations in hydrography, and oxygen conditions may also have been improved by the Bekkelaget discharge; with consistently higher yearly minimum concentrations at depths 20-50 m since 2001, and reduced development of hydrogen sulphide at >70 m depth.

Recent modelling with the NIVA fjord model indicates that a similar discharge of treated sewage water to 100 m depth or more in Bunnefjorden will have a major impact in improving further the deep water oxygen conditions there. Comparison with hypothetical model scenarios with no municipal sewage water release indicates that with the present degree of treatment, the discharge of treated sewage water to deep basins seems to have a net positive effect on oxygen conditions, helping to overcome the topographical limitations to deep water renewal in the Inner Oslofjord.

First reef of Crassostrea Gigas in the Oslo fjord – a warning for future developments?

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Base on financing from The Norwegian Environment Agency, Institute of Marine Research has since 2010 had a surveillance program for the pacific oyster on 5 localities, 2 in the county of Aust-Agder and 3 in the county of Vestfold in the outer part of the Oslo fjord. In addition, registrations of *C. Gigas* in the Oslo fjord has been done through several projects in the area.

Registration on these localities started in 2008 with the first registration of a major population of C. Gigas at the island of Stor-Hui in the municipality of Tjøme. The densities of oysters in 2008 were about 5 oysters/m² increasing to 40 oysters/m² in 2009. During the cold winters in 2009/2010 and 2010/2011, a mortality up to 95% were registrated. Probably due to a mild winter in 2011/2012, minor increases in max density were found at 2 localities in 2012 (max 8 oyster/m²). Then, in 2013 there were a slight reduction on one locality, no change at 2 localities, a minor increase at one locality and a dramatic increase to a maximum density of more than 100 oyster/m² at one locality.

The results from 2013 shows a major difference in population development even over very short distances. This could indicate that recrutation might have a major local component with some kind of retention mechanisms of eggs/larvae. Under optimal conditions, an oyster reef could be established in 2-3 years.

With financial support from The Nordic Council, a **S**candinavian **N**etwork on **O**yster **K**nowledge and management (**SNOK**) were established in 2011. This network plays now a major role in giving a coordinated and updated advice of how to handle the invasive species Crassostrea gigas.

Temporal and spatial differences in soft bottom communities in the Inner Oslofjord

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The benthic macrofauna of the Inner Oslofjord was sampled at 51 stations in 1993. In 2009 35 of the same stations was resampled using the same method and equipment, as a part of the Inner Oslofjord monitoring program. The aim of the survey was to classify the benthic quality status of the fjord by applying several indices for use in fjords and coastal waters, to compare the performance of the different indices, and to compare with the 1993 results in order to assess any changes in the species composition, species diversity or quality status. The results show that the aim of good ecological status is not achieved at most localities on the Inner Oslofjord. The abundance and number of species have increased markedly from 1993 to 2009 and are seen as an environmental improvement. However, the overall species diversity did not increase significantly from 1993 to 2009, and the quality index NQI1 implies that the ecological quality of the fjord has not improved.

Diversity and dynamics of dinoflagellates in outer Oslofjorden as revealed by molecular methods

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Dinoflagellates are amongst the most dominant and diverse taxa in marine phytoplankton. The phylum contains many potentially toxic species that raises concerns to various human aspects such as health, economy and tourism. Diversity, community dynamics and the role of environmental factors affecting this are not fully understood. In this project we explore how diversity and species composition changes through the season and in relation to environmental factors, with special focus on toxic species. We analyzed 454-pyrosequencing data obtained from September 2009 to June 2011 in the outer Oslofjorden in the projects HAPTODIV and BioMarks. We observed 879 unique OTUs (Operational Taxonomic Units) representing dinoflagellate species throughout the two years sampling period. Highest numbers of OTUs were found in autumn. Taxonomic composition will be studied in more detail with the aim of detecting temporal occurrence of dinoflagellate species with emphasis on the toxic ones.

Mapping of introduced marine species in inner and outer Oslofjord

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During summer 2010 a mapping project of marine introduced species along the Norwegian coast was started up. The method Rapid Coastal Survey was applied in 70 marinas in the outer and inner Oslofjord during five days in august 2012. 32 introduced species were targeted in this investigation and nine target species were registered. One new record for Norway was made, the invasive red algae *Gracilaria vermiculophylla* was found at three sites at Nøtterøy and Tjøme. The largest population of slipper limpet (*Crepidula fornicata*) ever recorded in Norway was registered at Ula close to Larvik. The bivalve *Petricolaria pholadiformis* was recorded for the first time in 50 years at Ula. The ascidian *Styela clava*, which has spread at the west coast, where not recorded in the Oslofjord area. The Japanese wire weed *Sargassum muticum* was the most widespread species in the area and was recorded on 25 of 70 sites, and was quite abundant on many of them particularly in the Larvik/Sandefjord area.

Open session

ORAL PRESENTATIONS

Amount of epiphytic algae on kelp (*Laminaria hyperborea*) stipes according to sea urchin (*Echinus esculentus)* densities in Nordland.

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Kelp (*Laminaria hyperborea)* forests are diverse ecosystems. In healthy kelp forest the kelp stipes are often covered with epiphytic algae. The epiphytic algae are important habitats to a rich community of associated mobile fauna by providing a diverse three-dimensional habitat. The amount of algae depends on light conditions, wave exposure level, and other geophysical factors. The red sea urchin (*Echinus esculentus*) grazes on the epiphytic algae. Grazing by the red sea urchin impacts the kelp forest community by removing the epiphytic community from the stipes and thereby the associated community of fauna.

This study focuses on the importance of red sea urchins for the amount of epiphytic algae on kelp stipes in the kelp forests, and it is based on spatial analysis of the distribution of red sea urchins and epiphytic algae along important geophysical gradients (such as depth, terrain variability, wave exposure and ocean current speed). Semi-quantitative (ordinal) data of epiphytic algae densities were sampled by use of submersible camera in the field in the autumn of 2012 and used as response data. These data was analyzed using layer data on important geophysical variables in GIS (geographical information system) and semi-quantitative data on red sea urchin densities. We used cumulative linked models (CLMs) and Akaike Information Criterion (AIC) for model selection.

Survival and growth of herring (*Clupea harengus* L.) eggs and larvae at different salinities

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Herring, *Clupea harengus*, is widely distributed in the North Atlantic and exhibits great plasticity in time of reproduction and tolerance to a wide range of environmental conditions during its early life stages. In order to clarify phenotypic responses to salinity conditions, a laboratory experiment was initiated to follow offspring subjected to controlled salinity levels at fertilization and subsequent two months. Full-sibling

offspring of spring spawning herring from two sites in western Norway were incubated and reared at three nominal salinities: 6, 16 and 35 psu. After hatching larvae were fed live natural and cultured plankton in excess over a 7 week period to determine growth and survival at respective salinity levels. Viable offspring were produced in all salinities, but survival was lower and more variable at 6 ppt than 35 ppt, both during incubation and subsequent rearing. Further, initial larval growth was inhibited at 6 ppt, but this was partly due to reduced survival and availability of natural zooplankton in the experimental tanks at this salinity. The final survival of larvae was also lower in the 6 ppt treatment than in the 16 and 35 ppt treatments. Average final size ranged between 21 and 27 mm and was largest among larvae reared at 35 ppt, the salinity level closest resembling the conditions from where the offspring originated. These experiments constitute preliminary trials of multi-generational studies of genotypic responses to ambient salinity conditions in herring early life stages.

Diel vertical migration and individual behavior beyond the mesopelagic zone

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Diel vertical migration is normally restricted to the upper 500-1000 m. While there are some acoustic reports on deeper migrations, little is known about the identity of migrators, the behavior at depth and details of migration patterns. In the Red Sea, data from ship-borne echosounders show consistent formation of daytime patches of backscatter deeper than 1000 m, the patches dissolving at night. We submerged echosounders at depths down to 1460 m to unveil details on the behavior of these individuals in the bathypelagic zone, as well as details on their vertical migration patterns. In contrast to what is known for most deep-living fish, the acoustic targets were very active, swimming rapidly up and down, particularly in the morning when they possibly searched for conspecifics. Swimming subsided as swarms were established, yet individuals might leave a swarm throughout the day, joining other assemblages of apparent conspecifics. The entire population carried out diel vertical migration. However, there was no synchronized descent in the morning or coherent population response to onset of darkness in the evening, when the period for ascent spanned 4-5 hours. The acoustic target strength TS (a proxy for size) at 38 kHz was close to -50 dB and very constant regardless of strongly varying swimming direction (vertical orientation). We did not succeed in sampling the acoustic targets. Based on the behavioral and acoustic evidence, as well as jig fishing in shallow waters at night, the squid *Sthenoteuthis* sp. is a likely candidate.

Convection on a shallow bank: benthic cyclones

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An earlier laboratory model of the Barents Sea (www.sintef.no/coriolis) was placed in SINTEF's 5-m diameter rotating basin to study, among other things, the production and transport routes of dense water at Central Bank and the Novaya Zemlya shelf. A large laboratory experiment was later performed to observe fine details of brine-induced ocean convection on shallow shelves or banks. A 3-m diameter, uniform, axisymmetric, surface source of brine was used to force convection in a 5 cm or 10 cm thick layer of fresh water in the 13 m diameter rotating facility at IMG/LEGI in Grenoble. The inflow of fresh water to the convective mixing created cyclonic swirl and an intense cyclonic vorticity near the rim of the source. The induced flow established a pressure gradient that reduced the inflow below the non-rotating, overmixing limit. Most of the inflow occurred in an interfacial Ekman layer, suggesting a viscous overturning instability.

In many cases the flow was baroclinically unstable, and in some cases with slow rotation, it also became barotropically unstable in time. At large enough rotation rates corresponding to large banks like the Central Bank in the Barents Sea, intense cyclones formed in the upper layer near the source and migrated anticyclonically into large meanders in the external annulus. The cyclones were much more intense than mesoscale features in nature. This, and friction, were found to be the most significant scale effects in the experimental setup.

Once the flow went unstable, there was a large horizontal exchange which broke down the cyclostrophic inhibition of the inflow of surface water to the convective mixing region. This increased the production of bottom water and reduced its density. The surface cyclones induced cyclones in the bottom outflow, apparently resulting from a combination of Ekman pumping and vortex stretching. The coupled cyclones transported large volumes of bottom water away from the source region. This causes a large variability in the benthic outflow.

Behavioral adjustments of a pipefish to bacterial challenge

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Animals can profit from increasing temperatures by prolonged breeding seasons and faster growth rates. However, these fitness benefits are traded off against higher parasite load and increased virulence of temperaturesensitive pathogens. In thermally stratified habitats, behavioral plasticity can allow hosts to choose the optimal temperature to enhance individual fitness and to escape parasite pressure. To test this idea, we performed a temperature choice experiment with the host–parasite system of the sex-role reversed broad-nosed pipefish (Syngnathus typhle) and its bacterial pathogen Vibrio spp. In this species, pregnant males are expected to face a trade-off between shortening their brooding period in warm water and decreasing the effect of the infection in cold water. We found that exposure to Vibrio changed the temperature preference for both pregnant and nonpregnant males, as well as females compared to nonchallenged fish that tended to prefer warm water. We also tested for change in mate choice between infected and non infected males when given a choice between infected and non infected females. This

study shows that behavioral plasticity is one option for avoidance of higher bacterial prevalence, as expected due to rising ocean temperatures.

Are sea ducks suitable as biodiversity indicators for the Baltic Sea?

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Using surrogacy in ecology as a means to monitor or assess biodiversity has occurred for decades. Biodiversity indicators can be used as biological surrogates to predict biological habitats or communities and are of special interest for decision-makers. However, currently these are lacking in the Baltic Sea. This study focused on identifying possible relationships, to be used in developing biodiversity indicators, between sea ducks, in particular the long-tailed duck *Clangula hyemalis*, and blue mussel *Mytilus edulis* communities in the Hanö Bight (southern Baltic Sea). These blue mussel communities have in previous studies been shown to sustain patches of high biological diversity. Sea duck abundance data were related to blue mussel cover, hard substrate cover and water depth using linear regression methods. A grid cell system was implemented to deal with spatial discrepancies between the variables as data were used from different surveys and years. Results showed that in general there were significant positive relationships between the abundance of sea ducks and blue mussel cover, albeit fairly weak. A common finding was also that a lower spatial resolution (i.e. larger grid cell size) tended to show stronger relationships compared to a higher spatial resolution. In conclusion, there was insufficient evidence to suggest that the long-tailed duck could be suitable as a biodiversity indicator in the Baltic Sea. Nonetheless, with further research in this area the long-tailed duck may be a suitable indicator of benthic biodiversity and aid in conservation-policy decisions for the Baltic Sea region.

Intra-site variability and sampling effort necessary to recover the gradient structure in marine benthic surveys

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Marine benthic surveys aiming to properly reveal and describe the underlying gradient structure (i.e., the existence and composition of gradients in species composition) should aim for a good coverage of the environmental variation within the study area. Due to the time-consuming and resource demanding nature of such surveys, there will always be a cost-benefit trade-off involved. The standard solution to this trade-off is to sample each visited site by collecting four or five grab samples. We tested the impact reduced sampling effort had on the recovery of the gradient structure, using a data set of marine

sedimentary macrofauna from 28 sites, each sampled four times. The gradient structure remained to a large extent unchanged when comparing the full data set of four samples to the reduced data sets of three, two or one samples. Even one grab per sample confidently recovered the structure of the data set, as revealed by Procrustes analysis and Kendall's rank correlations. Marine benthic surveys for general-purpose, ecological studies are likely to benefit from reduced local sampling effort and increased number of visited sites because the variation of the fauna is likely to be better described. Monitoring programmes may also benefit from adopting a one-sample, many-visited-sites strategy, especially if increasing sampling sites leads to better coverage of both vital natural and anthropogenic processes can be achieved, which again can help disentangle their effects from each other.

Widely distributed species versus species complexes in the oceans: where to go towards management of species-rich resources and habitats?

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Considerable challenges and needs, but also important gains, arise when ecological research aims at species-rich resources and habitats. Especially in insufficiently explored, highly diverse regions, taxonomy needs to be enhanced to provide an adequate baseline for ecosystem monitoring and management. A good example are recently initiated taxonomic revisions of goatfishes (family Mullidae), a group of coastal and upper-slope dwelling, sand-, reef-, or seagrass-associated marine vertebrates, with dramatic implications for local and regional resource management. Comparative studies of 34+ species of the genus *Upeneus*, involving a large set of over 55.000 data gathered mostly from museum specimens deriving from tropical and subtropical areas of Indo-Pacific and Atlantic, provide evidence for several previously undiscovered species complexes deeply embedded within this genus. During the course of discovery and description of new, closely related species it became also evident, however, that two species which formerly appeared to be geographically well separated and distinct represent only a single, widely distributed species. Accordingly, the finstripe goatfish *Upeneus taeniopterus* extends now from Mozambique, Western Indian Ocean (WIO) to Hawaii. It occurs mostly around oceanic islands and is targeted there by localized fisheries. Within the last four years and for the genus *Upeneus* alone, a total of ten new species have been described, two species have been revalidated, and at least four additional yet undescribed species have been discovered. As exemplified for the WIO Region and the three genera of goatfishes occurring in this area, enhanced taxonomic exploration results in novel species diversity and distribution information, prompting a thorough updating of local and regional monitoring and management plans.

POSTERS

The relationship between the native fucoid *Fucus serratus* and the introduced chlorophyte *Codium fragile* subsp. *fragile.*

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Invasive seaweeds can have impacts on native competitors and on the fauna which they support. The distribution of *Codium fragile* subsp. *fragile* (hereafter *Codium*) was recorded on the southwest coast of Norway, and investigated along with the vertical distribution of the native canopy-forming alga, *Fucus serratus*, to see if these species are potentially competing. Associated fauna on these seaweeds were compared to see impacts of the invader on the community. *Codium* was patchily distributed, a pattern which appears to have sustained over time since introduction in this area. It grew predominantly in the upper subtidal, but often formed large dominating patches to greater depths on stony substrate at sheltered sites. Its vertical range of growth overlapped with *F. serratus*, and when *Codium* was abundant *F. serratus* tended to grow shallower and at lower abundances. This suggests that *Codium* is affecting *F. serratus* through competition, but only in the lower portion of *F. serratus*' vertical range and at sites favourable for its own growth with regards to shelter and substrate. The fauna community was different on *Codium*, but no less diverse or abundant than on *F. serratus*, suggesting no overwhelmingly negative impact. However certain taxa such as Bryozoans were severely affected. Observations over the last century suggest that the abundance of *Codium* is variable over time, being more common during periods with elevated sea surface temperatures. With projected climate changes, this may have important consequences for the interactions studied here.

Algekultursamlingen ved Universitetet i Oslo

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Algekultursamlingen ved Universitetet i Oslo ble startet på 1950-tallet ved avdeling for Marin botanikk til bruk i eksperimentelle og taksonomiske studier. Samlingen har gjennomgått stadige forandringer og vært preget av pågående forskningsprosjekter. I dag består samlingen av mer enn 200 stammer av eukaryote og prokaryote marine mikroalger innen algedivisjonene Haptophyta, Dinophyta, Chlorophyta, Ochrophyta, Cryptophyta, Cyanophyta, Euglenozoa og Chloraracniophyta. De fleste stammene er isolert fra norske kystfarvann og ved fortynningsserier eller kapillærisolering av ansatte ved instituttet. De dyrkes i ulike sjøvannsmedier med saltholdighet fra 10 til 40 PSU, i 7 klimarom med temperaturer fra 3 til 25 °C. Nåværende samling har blitt utviklet blandt annet for forskning relatert til alger innen divisjonen Haptophyta, og inkluderer 85 stammer av denne gruppen. Samlingen inneholder flere "type-kulturer" som representerer en ny art beskrevet av UiO-forskere, og flere toksiske stammer. Algekulturene er en sentral del av forskningen og undervisningen om mikroalgers taksonomi, fylogeni, økologi, fysiologi,

kjemi, genomikk og evolusjon ved instituttet. Kulturer sendes også til andre forskere i inn- og utland. Algekultursamlingen er en verdifull ressurs som også kan utnyttes innen bioprospektering og bioteknologi.

Er reproduksjonsstrategien hos Calanus glacialis *bestemt av individenes lagrede fettressurser?*

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Reproduksjonssuksess hos den arktiske hoppekrepsen *Calanus glacialis* påvirkes av stor variasjon i mattilgang. Hoppekrepsens lagrede fettressurser i polarnatten er viktig for overlevelse mot våroppblomstringen av planktonalger. Konsekvenser av klimainduserte endringer av tidspunkt for våroppblomstringen av planktonalger i arktiske farvann kan være viktig for overlevelse og utbredelse av denne hoppekrepsarten.

Det eksperimentelle arbeidet har blitt utført ved på vestkysten av Spitsbergen etterfulgt av laboratoriestudier på UNIS fra januar til mai 2013. Både hanner og hunner ble inkubert individuelt for å følge utviklingen av lipidsekken. Hannene ble inkubert for å se om det er en korrelasjon mellom totalt lipid innhold, estimert ut fra arealet av lipidsekken, og tidspunkt når de døde. Hunnene ble inkubert for å se om det er en sammenheng mellom totalt lipidinnhold og reproduksjonssuksess. Dette ble målt ved å telle hvor mange egg som ble lagt og beregne klekkesuksessen. Det har blitt samlet inn prøver av voksne, egg og nauplier fra både lab og felt for senere lipidanalyser.

Selv om den generelle trenden er at eggproduksjonen er lavere i den sultede gruppen enn i den fôrede, er det variasjoner innad i gruppene med individer som legger mange egg til tross for at de ikke får mat, og andre som legger få egg til tross for ubegrenset tilgang til mat. Det samme skjedde med klekkesuksessen.

Ved å supplere målingene med lipidanalyser av voksne, egg og nauplier vil vi prøve å se om variasjonene i eggproduksjon og klekkesuksess kan forklares av variasjoner i lipidinnholdet hos hunnene, og om de lagrede fettressursene er signifikant for eggproduksjon.

Genotoxic Effects of Emerging Contaminants on Blue Mussels (*mytilus edulis)*

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PFOA and fluoranthene are persistent organic pollutants with a widespread environmental occurrence. They are both found at high concentration in the environment, and are known to concentrate and bioaccumulate in organisms. There are several studies showing toxic effects in marine organisms exposed to PFOA and Fluoranthene. However, no studies have investigated the genotoxic effects of these two. In this project, DNA damage and alteration in gene expression were investigated in blue mussels (Mytilus edulis) exposed in vivo to Fluoranthene and PFOA. DNA strand breaks were analyzed in haemocytes by the comet assay. The sensitivity of the assay was further improved by implementing the lesion specific enzyme FPG, to detect oxidative DNA damage. Only some increase in DNA damage was observed in M. edulis compared to vehicle control and with increasing exposure time. RT-qPCR was used to study the alteration of gene expression. Target genes were selected on the basis of their potential involvement in mechanisms of pollutant and xenobiotic response, including genes involved in oxidative DNA damage and DNA repair response.

Towards understanding the impact of climatic factors, trophic relationships and cross-habitat linkages in shallow coastal waters using a scale-dependent landscape ecology approach

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The influence of seascape configurations on fish communities via species migration between habitats is an important factor in management of marine environments and resources. The current study aims to examine the effects of seascape configuration and climatic factors on fish communities in common eelgrass, *Zostera marina,* meadows on the Swedish west coast. Thirty seascapes (300 m radius) were selected based on the quality of the central eelgrass meadow. Within each seascape fish surveys were conducted in the central eelgrass meadow using both remote underwater video cameras and a beach seine net to determine species abundance, diversity and total length. Additionally, eelgrass structural complexity data were collected and the habitat mapped using a drop video camera. Using multivariate statistics, the influence of habitat complexity and different climatic factors on fish communities within the shallow-water seascape will be analyzed. Climate data will later be combined with historical offshore fisheries data to create predictive models for evaluating the effects of climate change on the relationship between coastal and deep-sea fisheries. A more complete understanding of seascape connectivity and its influence on fish communities may contribute to improved marine conservation and resource management.

Moon jellyfish, *Aurelia aurita*, feeding on adult fish

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The moon jellyfish, *Aurelia aurita*, was observed and photographed feeding on adult three-spined sticklebacks (*Gasterosteus aculeatus*) up to a size of approximately 5 cm. Stable isotope analysis showed clear evidence for predatory behaviour, indicating sticklebacks and black gobies (*Gobius niger*) as putative prey. The study was conducted in an enclosed fjord "Kertinge Nor" in Kerteminde, Denmark, characterized by eelgrass beds (*Zostera marina*) with high densities of jellyfish, sticklebacks and gobies. To our knowledge, the ability of *A. aurita* to feed on adult fish has not been reported previously. Their predation on fish larvae of e.g. cod, herring and flatfish is well documented, but predation decrease with larval ontogeny, as escape speed, reactivity and detection of predator improves. The largest fish previously reported as prey are herring larvae up to 18mm and gobies with a length of 2-3 cm in lab experiments. Our observation is the first in-situ confirmation of adult fish as a food source of *Aurelia aurita*. However, since none of the fish were alive when observed, we cannot evaluate whether the single jellyfish were the cause of death.

Influence of anthropogenic and natural factors on the activity of lysosomal glycosidases of the blue mussels *Mytilus edulis L.*

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Mussels represent the typical mariculture both in Russia and many European countries and can be used to release biochemically active compounds for the purpose of applying them in different economic sectors. Due to its high sensitivity to the toxicants they are widely used for biotesting and biomonitoring of water objects. Furthermore, the bivalves are used as objects to study adaptive responses of water organisms because they are inhabitants of the intertidal zone and adapted to sudden changes in external conditions. Carbohydrates perform many different functions in the organism. Particularly, they determine the energy exchange in mussels. Lysosomal glycosidases are the enzymes which catalyzes the hydrolysis and transglycosylation of carbohydrates. So it's suggested that they can participate in adaptive responses of these water invertebrates. So, the aim of the present study is to investigate the influence of heavy metals and varying conditions of the environment on the activity of two lysosomal glycosidases (β-glucosidase, β-galactosidase) in different tissues of the blue mussels. Molluscs for the present study were collected from sublittoral zone of Chupa inlet, Kandalaksha Bay of the White Sea at the facility of biological station "Kartesh" of Zoological Institute of RAS. Then, they were placed in aquaria with sea water, natural light and temperature conditions and compulsory aeration. After the mussels had been acclimated to laboratory conditions for a week, two different experiments were done. The first group of the mussels was exposed

to the short-term influence of temperature. Molluscs were transplanted from aquarium with 0°C into aquaria with -5 and +10°C (low tide simulation in the air and in the sun). Exposure time was 6 hours. The second group was exposed to different concentrations of Cu^{2+} and Cd^{2+} salts (chlorides). Exposure last for 24 and 72 hours. The activity of enzymes studied and protein content were measured spectrophotometrically by methods used in our laboratory. During the low tide simulation in the air, the activity of β-galactosidase significantly decreased in gills and digestive gland. It can be the evidence of metabolism reduction under these conditions. During the low tide simulation in the sun, the significant increase of the activity of both enzymes in digestive gland was determined. Digestive gland is the organ which realizes the basic synthesis, including the synthesis of enzymes whose activity is manifested during the adaptation. Temperature increase activates the metabolism, including carbohydrate metabolism which is a determining factor in the power supply of the mussels. The protein content increased by 10-15% both in gills and digestive gland. Perhaps this is due to the activation of the protein synthesis, including regulatory proteins, enzymes involved in adaptive responses, heat shock proteins etc. It was shown that the content of Cd^{2+} in mussels has increased 25-29 times and Cu^{2+} – 3-4 times during three-day exposure. The accumulation of heavy metals caused increase of total protein. The high concentration of Cu^{2+} and Cd^{2+} caused decrease of the activity of enzymes studied in digestive gland while increase of their activity in gills. The data obtained allow to conclude that the lysosomal glycosidases are actively involved in adaptive metabolic reconstructions and changes in the enzymes' activity depended on specificity of organs' functions and nature of effecting factor.

Dinoflagellates in the Arctic marine summer ecosystems

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Dinoflagellates are common in the Arctic marine ecosystems in summer. The dominating groups, however, are small athecate species (< 20 µm), and the majority of these are probably undescribed. Armoured, unknown species are also present, and of the more well-known genera a high number are found, even far north of Svalbard: *Gymnodinium, Gyrodinium, Ceratium, Dinophysis, Protoperidinium, Heterocapsa, Peridiniella, Karenia, Prorocentrum, Pronoctiluca, Oxytocum*. Cells of all sizes up to > 80 µm are found, but the biggest only in low numbers.
For two stations north of Svalbard dinoflagellates contributed from 0.5 to 12 % of total cell numbers, but the carbon content varied from 20 to 85 % (average 45-67 %) of the total cell carbon in the water column down to 50 m. Dinoflagellates as food organisms in the ecosystems may then be much more important than evaluated from cell numbers only, since the majority of the organic carbon may be found in these organisms, and not in the numerous, but small flagellates.
CHEMTAX analyses are commonly used to identify different algal groups based on pigment content, and for dinoflagellates the pigment peridinin is treated as a marker. The dinoflagellates pigment fraction in the northern Barents Sea in summer revealed a strong relationship with dinoflagellate cell numbers, indicating that the dominating group in

most areas consisted of autotroph species. Comparing the dinoflagellate carbon fraction in the samples with the peridinin fraction revealed less accessory pigments in the upper layers, and more deeper down in low light. CHEMTAX analyses may provide additional ecological information of these undescribed plankton groups

A New Method for the Determination of Water-Dissolved Organic Carbon (DOC) Distribution Constants of Legacy and Emerging Organic Pollutants

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Dissolved organic carbon (DOC) is a collective denomination used to describe a wide and diverse array of organic substances dissolved in the natural waters. DOC plays a very important role in changing of solubility, transport, volatilization and the bioavailability of small organic molecules such as environmental pollutants. The environmental fate of pollutants is largely affected by their affinity towards sorption to DOC. The magnitude of interaction (sorption) between DOC and small organic molecules can be quantified through the determination of DOC-water distribution constants (K_{DOC}). In this study a novel method will be described that has been developed utilizing the non-invasive sampling mechanism of Solid Phase Microextraction (SPME). The freely dissolved concentration of pollutants is determined before and after the addition of fulvic acid (used to model natural DOC) and through the change of these concentration values the distribution constants are then calculated using the following equation:

$$K_{DOC} = \frac{C_{DOC-bound}}{C_{free}}$$

The target compounds used in this study cover a wide range of physical-chemical properties from legacy persistent organic pollutants (POPs) to currently used pesticides and organophosphates. The interaction is studied using Nordic Reference Fulvic Acid as a representative DOC extract for the Baltic Sea.

Impact of sea-cage fish farms: short-term recovery of benthic communities

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Farming of Atlantic salmon (*Salmo salar*) is the major aquaculture activity in Norway that can result in changes of the surrounding benthic environment by organic pollution. The fallowing practice, where fish production is shortly paused, is commonly used as a management tool for reducing benthic impacts by allowing time for recovery. At present, the dynamic processes occurring during the fallowing time is poorly understood. However, in order to use the fallowing practice, knowledge on the short term recovery is essential. The present study was undertaken (1) to investigate macrofauna community changes along a gradient of fish farm impact and (2) to assess the short term recovery dynamics in response to different fallowing timing at two fish farms that have been fallowed for 2 and 6 months. Macrofauna and sediment characteristics were sampled in spring, summer and autumn 2012 at the Norwegian coast. Samples were taken at two stations near the cages (20 m from cages), at an intermediate station (500 m from cages), and at a control station (>1 km from cages). The results showed no differences in the sediment characteristics (such as TOC, pH, Eh) among the stations. In contrast, analyses of macrofauna communities revealed clear effects of fish farming at the cage stations with high abundances of opportunistic Capitellidae, low diversity measures and significantly different community structure compared to the reference stations. As a result of the fallowing period, initiation of recovery was observed at both cage stations with different successional stages at the end of the study. At the cage station with fallowing time of 2 months, macrofauna community showed a very early stage of succession, with a significant decline of Capitellidae only. At the cage station with fallowing time of 6 months macrofauna community showed general increase in diversity and changes in taxa composition, resulting in a higher similarity of community structure with the reference stations. The observed changes in the macrofauna community indicate a specific short-term response to the fallowing periods, but the communities still showed clear indications of disturbance after the fallowing time of up to 6 month.
Keywords: Aquaculture; Fallowing; Recovery; Macrofauna community

FAUNAL COLONIZATION OF SUBMARINE MINE TAILINGS: an intertidal experiment to investigate the influence of sediment organic carbon content

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We present the initial results from a study focussing on to which extent increased organic carbon has influenced colonisation of so-called 'submarine tailing placements' (STPs). The possible mechanisms for colonsation alongside implications for increased biological recovery of STPs are also discussed.

Current financial estimates of mineral mining in Norway are about 12 billion NOK per year. Most of the industry is located close to the coast and the inert waste produced ('tailings', granulometrically similar to sand) is currently deposited in adjacent fjords as STPs. STP deposits in Norway range from 300,000 to 4 million tons/ year and may be 10s of metres thick. Active STPs smother the local resident biological assemblages and subsequent recovery is dependent upon subsequent colonisation by larval, juvenile or adult stages of the various species. However, observations of current sites indicate that colonisation and subsequent ecosystem recovery is slow and this is hypothesised to result from the lack of organic carbon within such deposits. To test this, we conducted an experiment in the Crouch Estuary, Essex (UK) during April 2012 to assess whether increased organic matter content of mine tailings leads to an enhancement in faunal colonisation. The project was part of the Norwegian Research Council funded project, IMPTAIL (IMProved submarine TAILings placements in Norwegian fjords). The experiment, based on a randomized block design, comprised tailings treatments containing different concentrations of organic carbon (0, 0.5, 1, 2.5 & 5% organic carbon) Samples for fauna, sediment grain size, and carbon and nitrogen content were collected at T = 0, 45, 115, 180 and 365d. REDOX potentials (1, 2 and 4 cm sediment depth) were also measured for each plot on each occasion.