1 Storegga og Mørebankene – istider og undersjøiske ras skapte ett av verdens største matfat

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Mørebankene og Storegga er ett av verdens rikeste matfat. Her fødes en prosent av all fisken som fanges i verden. Tallrike korallrev langs eggakanten sørger for høy biodiversitet, og områdene har status som «særlig verdifulle og sårbare områder» i forvaltningsplanen for Norskehavet.

Det er de fysiske forholdene med havbunnslandskap, bunnsedimenter og strømforhold som danner grunnlaget for dette matfatet. Siden istidene startet for ca. 2.7 millioner år siden, har Norge vært dekket av store iskapper gjentatte ganger. Langs vestkysten av Norge har store mengder løsmasser blitt «bulldozet» utover av ismassene og skapt kontinentalsokkelen slik vi kjenner den i dag – en relativt grunn (200 m – 400 m dyp) og flat sone som strekker seg 100 – 250 km ut fra kysten. Ytterst ligger eggakanten, hvor havbunnen begynner å skrå nedover mot dyphavsslettene. Noen steder finnes opptil 1500 m tykke løsmasser som er skubbet ut på denne måten. Gjentatte sykluser med isdekker som fraktet ut løsmasser i veksling med varmere perioder hvor sokkelen var isfri og avsetning av finkornede sedimenter skapte forhold for store undersjøiske ras. Særlig mange ras finnes utenfor Mørebankene, hvor det siste store raset skjedde for ca. 8200 år siden. Dette raset – Storeggaraset – skapte en tsunami som slo 15 – 20 m over datidens havnivå på Mørekysten, og skapte en gigantisk brattkant langs eggakanten. Denne kanten er ca. 300 km lang, opptil flere hundre meter og opptil 35 grader bratt. På Mørebankene som ligger innenfor skapte isdekkene store slake rygger med mye sand og grus. Disse store landskapsformene styrer i stor grad havstrømmene som kommer nordover. Kraftig strøm over ryggene på Mørebankene har vasket ut finmaterialet, og lar sand og grus ligge igjen. Dette skaper perfekte gyteforhold for norsk vårgytende sild, som foretrekker denne bunntypen. I munningen av Norskerenna, og langs hele eggakanten har kombinasjonen av hard bunn og kraftig strøm gitt gode forhold for tallrike korallrev.

Atlanterhavstrømmen (Golfstrømmen) kommer inn fra sørvest og hovedgrenen av denne strømmen kommer inn til norskekysten i Storegga-området. Her blir vannmassene presset opp og rørt om slik at næringsrikt vann kommer opp til overflaten og dermed får man en kraftig algeoppblomstring. På sin vei til Norge har Atlanterhavsstrømmen passert undersjøiske rygger og banker ved Rockall, Skottland og Færøyene og omrøringen av vannmassene starter allerede der. Det er derfor en svært næringsrik vannmasse som kommer inn til kysten ved Storegga. I Storegga blir den ytterligere omrørt og skaper ideelle næringsforhold både for alger, dyreplankton, korall, fisk og bunnfauna. Noe av vannmassene som treffer Storegga sprer seg innover kontinentalsokkelen på Møre og gir næring og gode fysiske forhold for de enorme mengdene sild, sei, torsk og hyse som har gytefelt på Mørebankene. Ute i Storegga er det særlig lange, kveite, brosme og blålange som er de dominerende artene. Disse har tradisjonelt blitt fisket med line og snøre. På 1970 tallet ble det utviklet et omfattende garnfiske etter i eggakanten etter disse artene. Oppe på eggakanten ble det også utviklet et trål og garnfiske etter sei. Trålfisket har ført til at en del korallområder har blitt ødelagt.

Det meste av vannmassen som kommer inn mot Storegga strømmer videre nordover langs eggakanten oppover mot Lofoten Barentshavet og Svalbard. På denne reisen videre tar den med seg næring, fiskeegg og larver til oppvekstområdene langs Norskekysten og i Barentshavet. Man kan dermed si at de prosessene som skjer på Storegga og Mørebankene har direkte innvirkning på fiskebestandene og andre biologiske ressurser vider nordover langs hele Norskekysten, Norskehavet og Barentshavet. De rike fiskeforekomstene fikk betydning for kystsamfunnene etter at saltet kom og fiskerne kunne ligge så langt ute i havet i flere døgn i gangen. Fisken beholdt kvaliteten og kunne selges. På andre halvdel av 1800 tallet kom dekkede fartøyer i bruk og rundt 1900 ble flåten motorisert. Dette ga et enormt økonomisk oppsving i regionen og Storegga er blitt kalt sunnmøringenes skattkammer. Banklinefisket ble grunnlaget for det rike næringslivet i Møre og Romsdal.

2 Long term shift in cod phenology linked to water clarity and delayed spring bloom onset

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Climate warming is known to advance the timing of spring activities such as plant flowering, animal migration and breeding. In high latitude ecosystems, the available window for timing life history events with resource availability is particularly narrow, and differences in response to changing phenology is hypothesised to promote trophic mismatches, such as that between food resources and early life stages of higher trophic levels. However, evidence for this is equivocal, and the role of individual plasticity to accommodate climate variability is poorly understood. Here we show that a delay in spring bloom timing of ca. 0.5 days year^{-1} between 1935 and 1990, caused by deteriorating water clarity, not temperature, is trailed by a corresponding shift in the spawning phenology of Northeast Arctic cod. Based on weekly fisheries catch and roe landing data we were able to reconstruct a time series of seasonal development in female gonad size back to 1878 (Fig 1). This suggests a delay in cod spawning time matching that of the spring bloom onset (Fig 2) – estimated based on published timeseries of water clarity and temperature-salinity profiles. Our results indicate that water clarity has until recently been overriding the effect of temperature in bloom timing, and that cod are able to trace these long-term trends and time gonadal development and spawing to maximize overlap between offspring hatch date and predicted resource availability. This finding emphasise the potential for phenotypic adaptation to climate change as well as the importance of coastal darkening on shelf-ecosystem functioning.

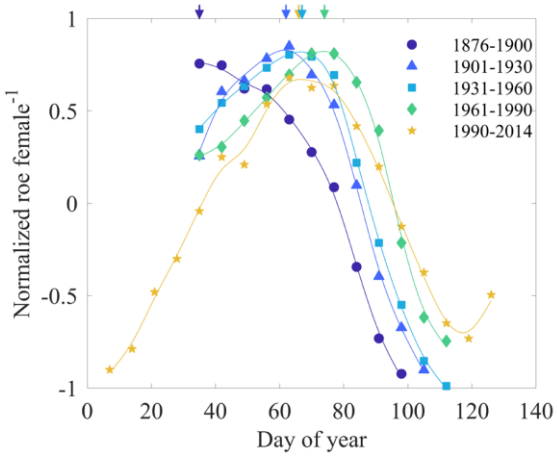

Figure 1. Mean gonad development (normalized) of Northeast Arctic cod across the spawning season for five different time-periods in Lofoten, Norway. Estimates are based on weekly commercial landings of roe volume and numbers of fish in Lofoten over the period 1878-2013. Note that timing of peak individual fecundity (marked by arrows) is delayed up until 1990, after which peak fecundity appears earlier.

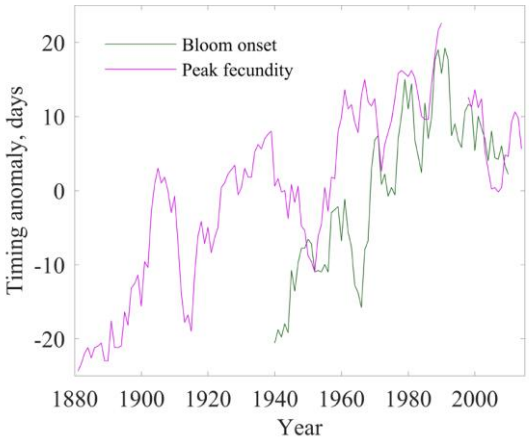

Figure 2. Estimated bloom onset anomaly (green line) based on the underwater light regime and the mixed layer depth (MLD) in Lofoten. The phytoplankton bloom onset was defined as the day where the Critical Depth exceeds the MLD, hence following the definition of Sverdrup (1953) where vertically integrated light-limited primary production equals losses due to respiration, mortality, and sinking. On top, the peak fecundity anomaly of Northeast Arctic cod (pink line) in Lofoten (see fig. 1). Sensitivity analysis suggest that the delay in bloom onset until ca 1990 is primarily driven by coastal water darkening, while the following advancement appears to increasing temperature, stabilizing the mixed layer earlier in the season.

3 Food for thought: Disentangling the role of sea lice on the marine survival of Atlantic salmon

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The effects of sea lice on the marine survival of wild salmonids are widely debated. In Norway this debate has reached a crescendo as the Norwegian government has recently ratified a management system where the growth in the salmonid aquaculture industry will be conditional on regional estimated impact of salmon lice on wild fish. Sea lice have thus become the most prominent obstacle to the stated political aim of quintupling aquaculture production in Norway by 2050. Scientific documentation that salmon lice impact the marine survival of salmon is robust. However, it also evident that marine survival of salmon is strongly impacted by other factors, and that the effect of salmon lice is most likely an integral part of these other mortality factors. In this paper, our goal is to discuss and give advice on how managers and policy makers should handle this complexity, and to identify the greatest challenges in using scientific results to construct robust management rules. Inadequate extrapolation from the scale of known effects to the scale of management implementation may initially give a false impression of scientific certainty, but will eventually fuel upsetting disagreements among stakeholders as they gradually uncover the shaky foundation of the implemented policy. Thus, using a single model and parameter to determine management advice is not warranted, as no single data point reflects the natural complexity of nature. Furthermore, robust management rules should be based on unambiguous definitions of key concepts. Finally, despite the scientific consensus that salmon lice are a risk to salmon, studies on wild populations in situ that accurately quantify the impact of salmon lice are still urgently needed. We give advice on how this can be accomplished.

Key words: fish farming, *Lepeophtheirus salmonis*, management, parasite, salmon lice, salmonid,

Running title: Sea lice and marine survival of salmon

4 Mekanismer bak skifte fra kråkeboller til tareskog, som igjen fører til mer mat og mangfold langs kysten.

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Siden 1990 tallet har vi observert et regimeskift fra «kråkebolleørken» til tareskoger nordover langs kysten, først i Trøndelag og nå i 2017 opp til sør i Troms. Liknende skifte er observert noen få plasser i Øst-Finnmark siden 2011. Det romlige mønsteret i skiftet er flekkvis og til dels komplisert å forklare fordi det skyldes en miks av klimaendring og mekanismer som rekruttering, overlevelse, krabbe-predasjon og habitatkompleksitet som varierer lokalt og regionalt. Flere års data fram til og med sommeren 2017 vil belyse ulike mekanismer som fører til gjenvekst av tare langs kysten av Midt- og Nord-Norge. Gjenveksten fram til i dag har ført til en økning av mange millioner tonn tareskog og dermed en kraftig økning av primærproduksjon langs kysten. Våre undersøkelser viser en gradvis økning av biologisk mangfold, sekundærproduksjon og habitat for juvenile torskefisk. En slik storskala endring i kystsystemet fører med seg en rekke positive økosystemtjenester.

5 The characterization of the microbiota associated with the intestine of *Strongylocentrotus droebachiensis* during the digestion of *Saccharina latissima*, *Fucus serratus* and *Palmaria palmata*

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Macro algae like kelp, are known to contain high quantities of carbohydrates, and these substances are retained in though structures like alginate, which is difficult to digest. In addition, kelp contains secondary metabolites that have anti-herbivory properties, the kelp is therefore avoided by most herbivore organisms. Despite of this, sea urchins of the species *Strongylocentrotus droebachiensis*, are known to graze kelp on a great extent. This has caused a loss of large stretches of kelp forests along the Norwegian coast and Carmel Bay on the Canadian coast to mention a few. There are great numbers of organisms that live within kelp forests, and kelp forests binds 3,6 kg of CO_2 per m^2, which makes it an important ecosystem. It is suggested that symbiotic bacteria in the sea urchin gut have an important role in the digestion of kelp. By breaking down though algal structures and extracting vital nutrients, the sea urchins can survive on a kelp dominated diet. This master thesis investigates the bacterial composition in the sea urchin gut and how it varies with different types of diets. Sea urchins were collected in Drøbak, and a no-choice laboratory feeding experiment was organized. The treatments were *Saccharina latissima, Fucus serratus and Palmaria Palmata.* Pellet samples were collected directly from the intestine, and bacterial DNA was extracted.

6 *Saccharina latissima* success along an expose gradient in the southern Norwegian skerries, concerning growth, recruitment and competition

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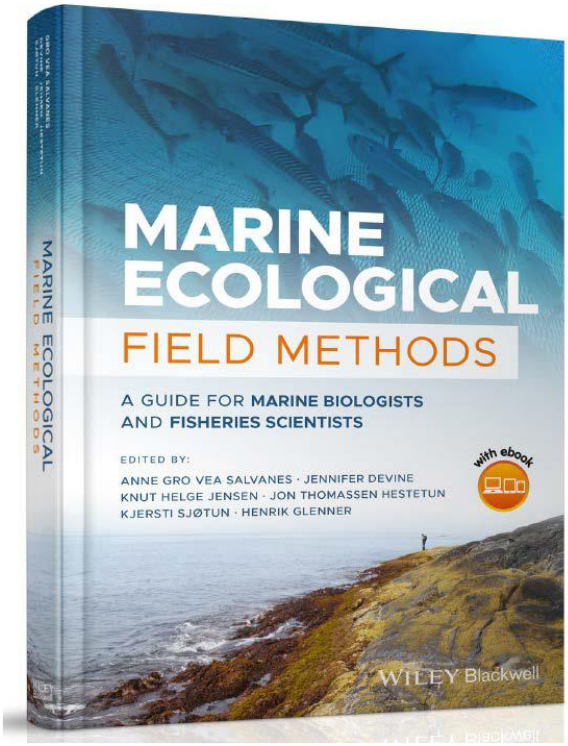
During the last 10-20 years, a major setback on the distribution of *Saccharina latissima* has been discovered along the southern coast of Norway. Once a dominating species, the climate change and other human activities has changed the terms of competition on several aspects. Higher summer temperatures and increased amounts of nutrients in the inner coast, facilitates fast growing algae. These opportunistic algae contribute little to species richness, compared to sugar kelp, and have now replaced up to 80% of the areas previously dominated by the kelp. Sugar kelp provides habitat and breeding ground for many fish and crustaceans all year around, while fast growing turf decays away in the winter.

My thesis is focusing on *S. latissima's* success along an expose gradient, from the inner skerries to the outer skerries in Grimstad. Based on six submerged stations distributed along a gradient, I have been looking into how sugar kelps are able grow and compete at each station. This has been accomplished by tagging plants and measuring their development throughout the year. Density and recruitment has also been investigated, while abiotic factors such as temperature, light attenuation, wave exposure and PAM-data, have been supplied by NIVA. These abiotic measurements have been applied as variables to explain differences in the absence of *Saccharina latissima*, along the expose gradient.

It is important to know what factors that constitute a significant difference, and to better understand the dynamics behind the decline of this important species. Sugar kelp forest maintain a rich fauna along the Norwegian south coast, and it will provide great resources for future generations.

7 Marinøkologiske feltmetodar. Handbok for Marinbiologar og Havforskarar – kjem snart i bokhandelen

Anne Gro Vea Salvanes



Ein dugnadsgjeng på Universitetet i Bergen og Havforskingsinstituttet sakna litteratur til bruk i feltundervisinga innan marine fag. Difor måtte vi vi skriva den sjølve. Boka ventast publisert i oktober/november 2017. Den kjem på engelsk og forlaget er Wiley-Blackwell i London (ISBN: 978-1-119-18430-0).

Boka er inndelt i 5 kapittel. Kap. 1 omhandlar kva type marine habitat vi har i Nord-atlanteren, og gir ei innsikt i oseanografiske prosessar, fauna og flora. Kap 2 dreier seg om korleis ein planlegg ulike typar av marine feltstudiar i littoral, pelagisk, på botn, og på døgnstasjonar. Kap. 3 går systematisk gjennom ulike typar av reiskap og kva dei blir brukt til.

Kap 4. viser korleis ein sorterer og fikserer innsamla fisk, plankton og benthos, samt korleis ein organiserer data i rekneark. Kap 5. dreier seg om dataanalyse. Dette kapitlet gir ei grundig innføring i korleis R kan brukast til å analysere feltdata. Dette kapitlet beskriv i detalj korleis ein går fram for å laga illustrasjonar, korleis ein testar enkle hypotesar, og korleis ein lagar kart over undersøkingsområde. Det er laga script til dette kapitlet, og dette er tilgjengeleg fritt på websida vår på UiB: http://filer.uib.no/mnfa/mefm/.

Dugnadsgjengen på boka har vore: Dag Aksnes, Lars Asplin, Martin Dahl, Jennifer Devine, Arill Engås, Tone Falkenhaug, Svein Rune Erga, Keno Ferter, Henrik Glenner, Jon Thomassen Hestetun, Mette Hordnes, Ragnhild Aakre Jakobsen, Knut Helge Jensen, Frank Midtøy, Leif Nøttestad, Egil Ona, Michael Pennington, David John Rees, Shale Rosen, Anne Gro Vea Salvanes, Kjersti Sjøtun og Arved Staby.

8 *Codium fragile* and *Sargassum muticum*: Non-native seaweeds in a changing environment

Caroline S. Armitage[1]

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Climate change and non-native species can both affect biodiversity and ecosystem functioning. However, how climate change will affect species invasions themselves is unclear in many cases. The aim of this PhD project was to examine factors affecting the success of two non-native seaweeds, and how they may be influenced by environmental change. The seaweeds *Codium fragile* subsp. *fragile* and *Sargassum muticum* can both form canopies in the upper sublittoral in SW Norway.

The project had three parts. First, some background work on *Codium fragile*: genetic sequences from along the Norwegian coast were checked due to frequent misidentification of native and non-native subspecies. This showed that there is another subspecies present, subsp. *atlanticum*, the morphological characters of which can overlap with those of the invasive subspecies *fragile*. However, subsp. *fragile* (hereafter *C. fragile*) is dominant in southwestern Norway.

The second part of the project examined factors affecting success of the non-native seaweeds. For *C. fragile*, this included wave-exposure, hard substratum type, and competition with the native seaweed *Fucus serratus*. Field surveys indicated that abundance and persistence of *C. fragile* is related to substratum, both substratum and wave-exposure affect vertical distribution, and competition likely occurs between *C. fragile* and *F. serratus*. For *Sargassum muticum*, competition with *F. serratus* and *Saccharina latissima* (kelp) was assessed by field experiment - the native species did not affect growth of *Sargassum muticum*, but limited survival of its seasonal branches. For both non-native seaweeds, the effect of disturbance was assessed through a field experiment where seaweed canopies were cleared and the subsequent changes in species cover were recorded. Contrary to expectations, the non-native species did not benefit from disturbance.

The third part of the project was how environmental changes affect the seaweeds, focusing on temperature. Laboratory experiments and field surveys indicated that warmer winters increase *C. fragile* growth and abundance, but little impact of warmer summers/autumns was detected. A hot summer also had no direct benefit for *Sargassum muticum* in a field experiment, but did indirectly benefit it by negatively affecting *Saccharina latissima* competing with it. This experiment demonstrated that hot summers can change competitive relationships between canopy seaweeds. However, with regards to *Sargassum muticum* success, local factors may limit it at some sites regardless of temperature, as it developed poor condition in both hot and normal summers at some locations. N-limitation and epiphytic growth were proposed as potential local limiting factors, and examined by monitoring *S. muticum* by fish farms. Growth, condition and tissue-N were consistent with limitation by epiphytes, but did not exclude an effect of nutrient enrichment.

This thesis has been submitted, and 4 papers published (+ 1 manuscript in prep.). The work is part of the project INVASIVES, supported by the Research Council of Norway (grant no. 227780), under "Towards integrated European marine research strategy and programmes - SEAS-ERA" (ERAC-CT2009-249552) within the framework of the EU ERA-Net initiative (7th Framework Program).

9 Changes in organic carbon composition and accumulation in Norwegian fjords during the past centuries: Implications for ecological quality status and fjords as carbon sinks

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Organic carbon (OC) burial in marine sediments plays a key role in long-term carbon sequestration which controls atmospheric CO_2 concentration. Fjords, with their deep, narrow basins and high sedimentation rates, have been estimated to account for 11% of the annual marine carbon burial world-wide. Until recently, research efforts mainly focused on quantifying the OC buried in fjord sediments rather than identifying the sources contributing to OC loading. In recent decades anthropogenic OC sources increased fjord carbon loading which may have significantly changed of carbon burial patterns. Therefore, studying these OC sources could tests the paradigm that carbon burial is productivity dependent. Additionally, changes in quantities and sources of OC affect benthic ecosystem structure and function, and might alter the ecological quality status of fjord habitats.

This study will focus on the relatively scarcely studied OC sources introduced by intensive fish farming, "jelly-falls" and kelp detritus and their effect on the benthic ecosystem using benthic foraminifera assemblages. The main aim is to characterise and quantify accumulation rates of OC in fjord sediments, and describe the associated benthic foraminiferal responses during the past few hundred years. This study is divided into three sub-projects. The first will focus on the potential interaction of organic deposition from fish farms and jellyfish detritus, and how they affect the benthic ecosystem via carbon-uptake studies using ^{13}C-labelled algae in an ex-situ experiment. The second will assess present day benthic foraminiferal response to organic matter enrichment along transects from fish farms and kelp areas to un-impacted conditions. The third will attempt to characterize and quantify the temporal development (last few 100 years) of OC accumulation rates associated with fish farm waste and kelp detritus, and to assess both the implications for ecological quality status and the importance of fjords as carbon sinks.

Study material will be collected during three research cruises planned for 2017 in Øksfjorden, Kaldfjorden and Malangen, Northern Norway. Core-top samples obtained from Kaldfjorden are to be used in the ex-situ experiments in September 2017. Surface samples and down-core sediments will be obtained from all three locations to characterize and reconstruct present and past OC fluxes using $\delta^{13}C$-C_{org} and C_{org}/N_{total} ratios. Supplementary fatty acid analyses will be carried out on a selection of the samples to further characterize and potentially quantify the organic material. Additional analyses to be carried out include grain size distributions, and heavy metal concentrations in the sediment, as well as stable carbon and oxygen isotopes from 2-3 foraminiferal species. Furthermore, both live and fossil foraminiferal assemblages are to be analysed to gain information on the benthic ecosystem response, which in Øksfjorden will be compared with the macro faunal data to further develop benthic foraminiferal assemblages as a biomonitoring tool.

So far, background information regarding the fjords of interest has been collected and synthesised, and preparations have been made for the cruises and experiment. The latter includes the production of freeze dried ^{13}C labelled algae (*Dunaliella tertiolecta*). In addition, I have started to familiarize myself with the Norwegian foraminiferal taxonomy.

10 Valuation and management of marine angling in the Norwegian Arctic

Julide Ceren Ahi

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This dissertation project is part of and funded by the NFR project MarEs: changing uses and values of marine ecosystem services in the Norwegian Arctic.

Marine angling tourism has been advancing in the coastal regions of Northern Norway in recent years. This development brings considerable benefits for the coastal communities, however, it also exploits the important natural resource of coastal cod, which is used both by local recreational fishers and commercial fishers. Furthermore, while commercial fisheries are managed separately, tourism and recreational fishing are monitored very little and remain largely unregulated. Hence, this imbalance within the regulations is likely to cause conflicts between these stakeholders all after the same resource.

Recognizing the potential conflicts between the mentioned groups in the Norwegian Arctic, the goal of the project is to apply the so-called stated preferences (SP) methods from environmental economics to the case of marine angling for quantifying the values attached to the given marine ecosystem services. The welfare measures obtained from the SP data are to be further employed for informing a bio-economic model optimizing the use of the coastal cod in the region and hence generating a superior policy solution to the distribution of coastal cod between the stakeholders.

The outcome of the project will contribute to the knowledge of balancing economic aspects of marine resources, facilitating better stakeholder involvement in decision-making while providing valuable input for future trade-offs between use and conservation. Therefore, the results will be of crucial importance for planning, policy and public debate about priorities concerning the use of marine ecosystem services in the Norwegian Arctic.

Four papers are planned to be submitted to peer-reviewed journals during the run of the project. The first paper is a review of the marine angling valuation literature, which is already in progress. The second paper of the project will employ a dataset previously collected through a choice experiment by researchers at UiT. The data come from a survey investigating the preferences of locals regarding different uses of the coast and marine ecosystem services in the Norwegian Arctic. By employing this data, I intend to address some of the methodological issues and contribute to the non-market valuation frontier. The third paper is set out to measure the local population's valuation of competing uses of coastal cod by marine anglers. Analogous to the second paper of the project, the estimation will be founded upon SP method choice experiment data. However, this time a new valuation survey tool customized for marine angling will be designed and implemented online. Finally, the fourth paper of the project will focus on the optimized use of coastal cod in the Norwegian Arctic by joint application of SP methods and bio-economic modelling. The SP data gathered in the previous paper will be engaged for informing the bio-economic model which is to deliver an advanced policy solution concerning the distribution of coastal cod among the different users.

11 Population structure and dynamics of Atlantic herring

Florian Berg

Of particular interest in the Skagerrak area is a brackish water environment inside Landvikvannet, an inland lake in southern Norway connected to the open sea through an artificial canal. The very different environment inside and outside Landvikvannet, as well as the tidal effects on currents in the human made canal, makes the area interesting for studying potential environmental drivers in herring behavior. It is also an interesting area regarding potential population differences in behavior and internal drivers, such as maturation status of individual fish. Here, three putative herring populations are observed to co-occur at maturing, spawning and spent stages from March to June, where one population, 'Landvik herring', shows high fidelity to the brackish inland lake. Besides 'Landvik herring', coastal Skagerrak spring spawning herring exist in neighboring fjords, without conducting large annual migrations like those of Norwegian spring spawning herring, which are also found here. Norwegian spring spawners occur in this area mostly in March before starting their annual migration. 'Landvik herring' differs from other occurring populations, both phenotypically and genetically.

The project is separated in two parts. The aims of the first part mainly to increase the understanding of population structure in Atlantic herring with focus on Landvikvannet and adjacent waters. Therefore, different methods should be tested to discriminate the three known populations in this area, which would help to distinguish herring populations from mixed fisheries. Further, this part is supposed to increase the knowledge of the life-time history of 'Landvik herring', beginning at egg and larval stages up to mature and spawning adult herring. The second part aims to validate the distinct phenotypic characteristics for population discrimination. Thus, Atlantic purebreds and Baltic/Atlantic hybrids were co-reared under common garden conditions at two different salinities (16 or 35 psu) until their first maturity. During this time, several samples were taken and phenotypic differences between fish from different environments and/or genetics were compared. Those results, showing a clearly genetic effect on phenotypic characteristics strengthen the use of methods from the first part. Further, the results reveal new aspects in the population structure of Atlantic herring and their adaptions to given environments. The combined results may have implications in management and conservation, as local fish populations may play an important role in fisheries because they are highly vulnerable.

12 Identification and measurement of crude oil derived organic compounds bioaccumulating in early life stages of Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*)

Lisbet Sørensen

University of Bergen

As offshore oil exploration is moving further north and closer to the coast, it comes in conflict with sensitive spawning areas for several commercially important species of marine fish. An example is the areas around the Lofoten Islands of northern Norway, which is are the spawning and nursing grounds for Atlantic haddock (*Melanogrammus aeglefinus*) and cod (*Gadus morhua*). It was recently observed that haddock embryos are particularly sensitive to crude oil pollution, suffering severe malformations and cardiotoxic effects even at low doses and short-term exposures. In the current project, the aim was to develop and utilize analytical methodologies to assess accumulation of crude oil derived compounds in cod and haddock eggs. The data generated should contribute to understanding of the mechanisms that cause crude oil toxicity in fish embryos and larvae, and supply input to risk assessment models for future spill scenarios in sensitive areas.

Extraction and analysis techniques for a wide range of petrogenic compounds, that accumulate in fish eggs and larvae upon crude oil exposure, were optimized and applied. Instrumental analysis of PAHs and alkylated PAHs (including alkyl clusters) was achieved using gas chromatography tandem mass spectrometry (GC-MS/MS), while comprehensive two-dimensional GC (GCxGC) coupled to MS was used to identify previously less studied compound groups of toxicological interest.

Through this work, it was established that the adhesion of oil droplets on the chorion of haddock eggs causes an increased body burden of, particularly heavier and more toxic, PAHs in haddock embryos. Cod embryos, on the other hand, did not show the same oil adhesion or increased body burden. Furthermore, the toxicological effects were significantly less in cod compared to haddock. The conclusion is that chorion-adhered oil droplets on haddock eggs constitute a secondary exposure pathway, leading to increased internal body burden and higher toxic response compared to cod eggs. Furthermore, several groups of monoaromatic compounds were identified in cod and haddock embryos after exposure to dispersed oil or the water-soluble fraction of oil. Moreover, it was also determined that both species could rapidly eliminate both PAHs and alkyl PAHs, most likely through detoxification and metabolism mechanisms. The extent of PAH elimination was structure dependent, with increasing alkylation leading to decreasing effects of elimination on bioaccumulation under constant exposure conditions.

Finally, the use of polymer accumulated concentrations of PAHs in silicone rubber (SR) and low-density polyethylene (LDPE) passive samplers to estimate uptake of PAH and alkyl PAH in fish eggs was evaluated and showed promise.

13 Economic Efficiency and Distribution in a regional perspective: Norwegian Fisheries (RCN: 23813/E50)

Ruth Beatriz Pincinato

University of Stavanger

The project investigates the potential efficiency gains among different gear-and vessel groups from deregulations of resource allocation and technical regulations. Further, the project accounts for the institutional implications of regulatory changes, in order to operationalize potential efficiency gains at the regional level. For my thesis, three papers approaching different aspects of the main research topic are intended and, they are, currently, a work in progress. The first paper presents evidence on the benefits of the introduction of individual transferable fishing quotas. In particular, the analysis looks at the Norwegian coastal vessels between 11-15 meters using conventional gear and their response to the introduction of a transferable quota in 2008. Following the differences-in-differences approach, an unbalanced panel data of vessels costs from 2004 to 2010 was used to compare the season length, the average costs and ex-vessel prices of this group in relation to a group not under the same management policy. The second paper investigates the production risk associate to the different groups in both groundfish and pelagic fish fleets. More specific, whether inputs (such as capital, labor and fuel), that are often used on regulatory measures, increase or decrease the production risk for each group. Finally, the third paper investigates the determinants of the survival of the different landing sites in Norway, using a discrete choice model on transactions over 14 years at each landing port in mid- and northern-Norway, where approximately 90% of the whitefish landings take place.

14 Game theoretic aspects of Northeast Atlantic and Norwegian fisheries

Evangelos Toumasatos

My PhD project is part of the Modelling Eco-System Services using AGE-structures approaches (MESSAGE) project financed by the Research Council of Norway, “Marine Resources and the Environment – MARINFORSK”. Specifically, I am involved in the fourth working package (WP4) “Multispecies age-structured models” under the supervision of professor Stein Ivar Steinshamn from the Norwegian School of Economics. Professor Marko Lindroos from the University of Helsinki has also been asked and accepted to be my second supervisor. The topic of my dissertation is “Game theoretic aspects of Northeast Atlantic and Norwegian fisheries” and it is due to submission within the autumn semester of 2019. The dissertation will consist of four related scientific essays.

So far, we have used game-theoretic models to study how nations strategically interact with each other when managing shared fish stocks. In particular, we have applied the so-called partition function approach to study coalition formation in the Northeast Atlantic mackerel fishery in the presence of externalities. We have considered two different games, namely, a four-player game where the UK is still part of the EU and a five-player game where the UK is no longer a member of the EU. This project, which is titled “Coalition formation with externalities: The case of the Northeast Atlantic mackerel fishery in a pre and post Brexit context”, is the first essay towards my dissertation; and, we plan to publish it as a working paper in our institution and submit it to a related scientific journal for publication.

Regarding future projects, several ideas are being considered, but they must be investigated to see if they are feasible to implement. According to our timeline, we want to have two more projects in the finalizing stage by the end of next year.

Completion of the PhD programme also requires completing a course work consisting of a 45 ECTS credits. So far, I have gathered 34 credits, expect the results of another 8.5 and plan to take the last 2.5 this semester.

15 Et tiår for havforskning for bærekraftig utvikling 2021-2030

Peter M Haugan[1]

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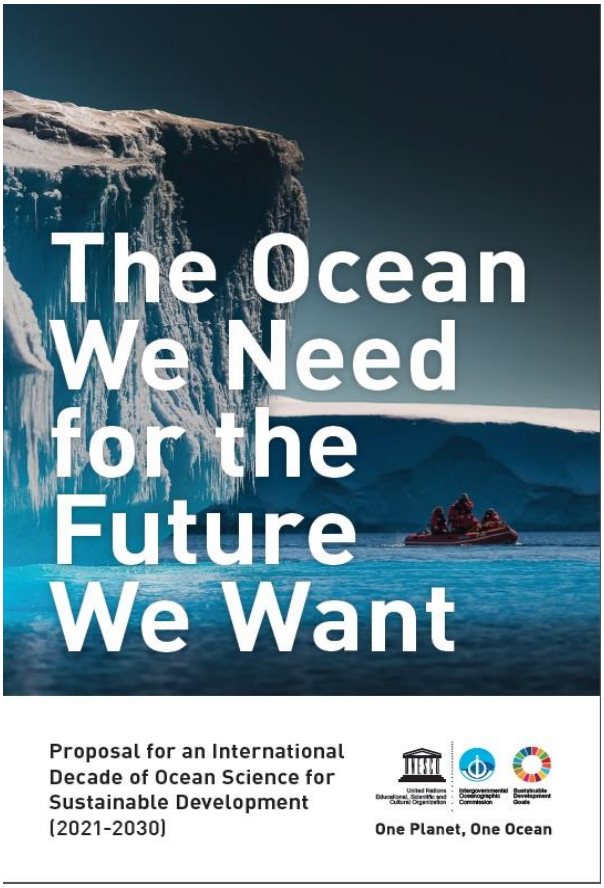
Den mellomstatlige havkommisjonen (Intergovernmental Oceanographic Commission, IOC), som er en del av UNESCO, har foreslått at 2021-2030 gjøres til et internasjonalt tiår for havforskning for bærekraftig utvikling. Initiativet har fått støtte fra en rekke land og fra mellomstatlige og internasjonale organisasjoner inkludert FAO, WMO, UNEP, IMO, IHO, CBD, ICSU, ICES, PICES, m.fl. Forslaget ble fremmet og anbefalt på konferansen om bærekraftsmål 14 i New York i juni 2017 og skal taes opp på FNs generalforsamling i høst med sikte på offisiell FN-status.

Som aktiv medforslagsstiller og valgt leder av IOC 2015-2019 ser jeg gjerne at havforskere i Norge er bevisst på de muligheter dette kan gi for bedre forskning, mer fokusert og relevant forskning, styrket internasjonal data og informasjonsdeling, kapasitetsbygging m.m. Prosessen hittil har vært og er top-down med utgangspunkt i bærekraftsagendaen og politisk prioriterte spørsmål. Det skal nå utvikles en handlingsplan med aktiviteter der forskningsledere og forskere kan og bør spille en mer aktiv rolle.



Tiåret kan bli en unik mulighet til å vise nytteverdien av moderne observasjons og analysemetoder og dermed legge grunnlaget for god havforvaltning. Dette gjelder ikke minst internasjonale havområder der havretten ennå er mangelfull bl.a. når det gjelder biologisk mangfold. Nye mellomstatlige mekanismer som må utvikles må få en god vitenskapelig basis. Tiåret er et globalt initiativ som dekker verdenshavet inkludert havbunnen og vekselvirkning med land og atmosfære. Havforskere inviteres med til å definere og utvikle dette initiativet.

16 Why do Bluefin tuna spawn so early, and in cold water?

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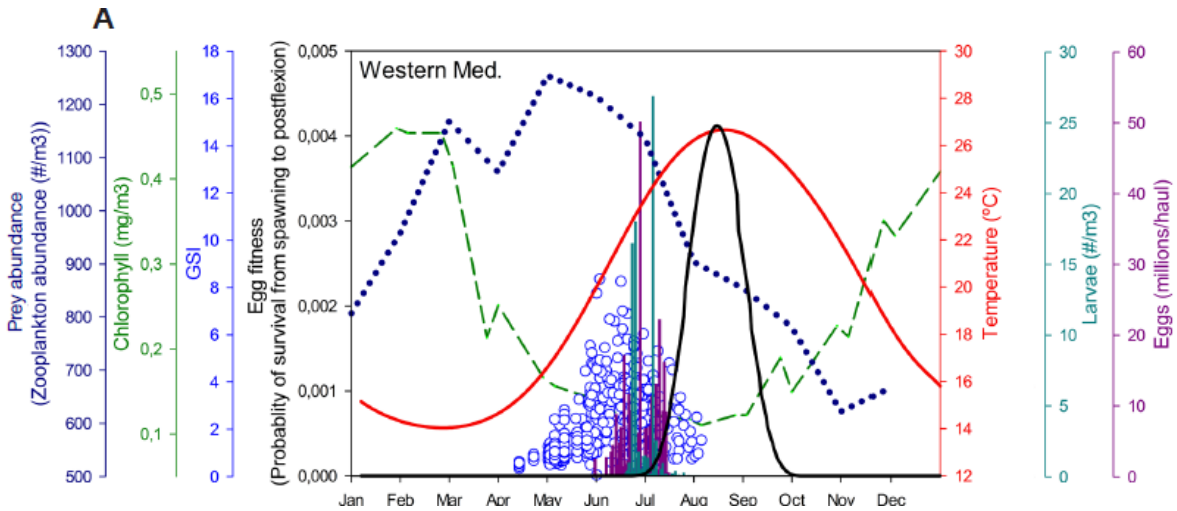
Life-history traits such as spawning migrations and timing of reproduction are adaptations to specific environmental constraints and seasonal cycles in many organisms' annual routines. In this study we analyze how offspring fitness constrains spawning phenology in a large migratory apex predator, the Atlantic bluefin tuna. The reproductive schedule of Atlantic bluefin tuna varies between spawning sites suggesting plasticity to local environmental conditions. Generally, temperature is considered to be the main constraint on tuna spawning phenology. We combine evidence from long-term field data, temperature controlled rearing experiments on eggs and larvae and a model of egg fitness, and show that Atlantic bluefin tuna do not spawn to optimize egg and larval temperature exposure. The timing of spawning leads to temperature exposure considerably lower than optimal at all spawning grounds across the Atlantic. Spawning phenology is constrained by thermal inhibition of egg hatching, but matching the larval prey peak may be a more important driver for bluefin tuna spawning phenology than currently realized. Our findings illustrate how the timing of spawning has evolved as an intricate trade-off in seasonal patterns of temperature and ocean productivity across all spawning areas. This finding is important for predictions of reproductive timing in future climate warming scenarios for bluefin tuna: they need to include the ocean productivity cycle and not just temperature.



17 Viral-host interactions: from strain to natural planktonic communities

Eliana Ruiz Martínez[1], Anne-Claire Baudoux[2], Nathalie Simon[2], Mathilde Lindivat[3], Monique Oosterhof[1, 4], António Pagarete[1], Ruth-Anne Sandaa[1], Aud Larsen[5],

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Being the most abundant and diverse entities in planet Earth, viruses are thought to play a relevant role in controlling the composition and diversity in phytoplanktonic microbial communities. Microbial communities sustain life in the oceans and even in terrestrial environments if we account for half of the oxygen in the atmosphere, which is produced by their photosynthetic members. Thus, understanding how viruses and their hosts interact at the vast oceanic scale, and the potential impact viruses might have on the development of marine microbial communities, remain of primary relevance.

To what extent do viruses exert a significant pressure on the microbial communities they infect? To what extent does that interaction lead to the existence of a variety of "virus-driven" trade-offs between host traits, such as resistance and growth capacity? Despite the progress that has been in this area, especially with prokaryotes, we still lack assertive answers to these questions. This work aims to increase the current knowledge on marine viral role and their potential action in shaping marine microbial communities.

To do so, cross-infectivity experiments were conducted and parameters such as growth rate (μ), resistance (R), and viral production (Vp), were investigated for two relevant eukaryotic phytoplankton systems: *Micromonas* / *Micromonas* Virus (MicV) and *Emiliania huxleyi* / *Emiliania huxleyi* Virus (EhV), respectively. Competition experiments between *Micromonas* strains with different resistance capacities and similar growth rate were also performed. Viral impact was also measured at the broad level of complex natural marine microbial communities with six viral depletion microcosm experiments.

The significant trends observed on single virus-host interactions demonstrated strong co-interactions at different levels between the tested phytoplankton strains and their viruses; however, a potential viral role as major drivers behind a growth-rate/resistance trade-off was not consistently observed in any of the studied systems. In 4 out of 7 competition experiments was such trade-off possibly present, but even then not in an explicit manner. Surprisingly, higher viral production capacities were measured in generalist viral strains from both systems. For the viral depletion experiments, the incubation period itself was sufficient to provoke significant changes in the composition of the microbial communities under study; however, viral impact was significant in half of the experiments, mostly in the prokaryotic community.

Overall, this work challenges the conception of viruses as main drivers of marine microbial diversity, emphasizing the need for more knowledge about virus-host interactions in the oceans.

18 Fish versus meat: Consumer perspectives on Cod and other meat sources

Jonas Torrissen

University of Stavanger

This doctoral thesis is part of a multidisciplinary NFR research project (Project No: 233709), Qualifish, which aims to examine the value chain of Norwegian whitefish and develop innovations to improve the profitability of the industry. The project involves multiple academic institutions, as well as several industry partners. As part of Qualifish, this projects responsibility lies with examining market strategies and economic perspectives to contribute to the development of innovations at the product and processing stage. The main objective will be evaluating the demand for whitefish products in local and international markets.

The goal of this project is to understand the requirements of end-consumers and their food involvement. This is accomplished through an online survey targeting 2,000 consumers in each of the 4 countries: United Kingdom, France, Germany and Norway. The questionnaire explores the consumer's consumption and perception of cod and compares this with their perception of other competing protein sources (chicken, beef, pork and salmon). The questionnaire responses have been gathered, but the analysis is still a work in progress. The aim is that the information collected regarding product preferences, quality thresholds, and willingness to pay (WOT) for certain product criteria can be of use to develop products and processes where the growth and profit potential are highest.

19 Mesozooplankton in the Barents Sea: key drivers, predation effects and impacts on fish stock productivity

Johanna Myrseth Aarflot

PhD candidate 2016-2019, Institute of Marine Research/University of Bergen

Zooplankton serve as a primary food source for numerous species during their larval and/or adult stages, and is important for energy transfer from primary production to higher trophic levels in marine pelagic ecosystems. My PhD project focuses on mesozooplankton in the Barents Sea, with special attention to the lipid-rich *Calanus* spp. In my first project, I quantified the contribution of *Calanus* to the mesozooplankton biomass in the Barents Sea, and evaluated changes concurrent with the recent warming in the area. My current project focuses on disentangling predation effects on the mesozooplankton community, and finally I aim to determine whether zooplankton availability is limiting for fish production in the Barents Sea.

Calanus spp. are key drivers of the mesozooplankton biomass in the Barents Sea (submitted)

In this project, I analysed an extensive dataset of *Calanus finmarchicus*, *C. glacialis* and *C. hyperboreus*, collected at various research surveys by the Institute of Marine Research (IMR) over a 30-year period. My results demonstrated that *Calanus* species are main drivers of variation in the mesozooplankton biomass in the Barents Sea. While *Calanus* constituted nearly 90 % of the total at high biomass levels, the proportion of *Calanus* decreased below 50 % at low zooplankton biomass, possibly due to a combination of advective processes and size selective foraging. In the western area of the Barents Sea, we observed indications of an ongoing borealization of the zooplankton community, with a decreasing proportion of the Arctic *C. glacialis* over the past 20 years. Atlantic *C. finmarchicus* increased during the same period.

Disentangling predation effects on mesozooplankton in the Barents Sea (ongoing)

The optimal depth habitat for zooplankton involves a trade-off between food availability and predation risk, and studies have demonstrated increased diel vertical migration (or less light exposure) at high predator abundance. The Barents Sea has large stocks of capelin, herring and other small pelagic fishes that constantly consume zooplankton as their main prey. How does this predator-prey interaction impact the size-structure and vertical distribution of zooplankton in the Barents Sea? I will use long-term survey data from the Barents Sea with vertical distribution of mesozooplankton in three size classes, to study this question. Combining the data with modelled surface irradiance and measurements of chlorophyll a in the water column, I can estimate the light intensity at the depth of the zooplankton samples. A mechanistic model for fish foraging can provide estimates of zooplankton mortality in the water column at different light regimes.

Is mesozooplankton limiting the production of planktivore fish in the Barents Sea? (future)

Particulate visual feeding is the most common foraging mode in planktivore fish, and fish visual capacity, prey size and –depth distribution are important factors in the encounter process. With a planktivore foraging model, survey data of mesozooplankton depth distribution, fish abundance, stomach content and modelled light, I will assess the food availability for fish over spatial and temporal scales, and identify food limitation and carrying capacities for planktivore fish stocks in the Barents Sea.

This PhD is part of the NMR funded TIBIA project (Trophic interactions in the Barents Sea – steps towards an integrated assessment) at the Institute of Marine Research, which aims to improve our understanding of trophic interactions, food web structure and function, and energy flow in the Barents Sea ecosystem. Supervisors are Hein Rune Skjoldal (IMR), Øyvind Fiksen (UoB) and Padmini Dalpadado (IMR).

20 Diatom Rubisco – abundant or not?

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Ribulose-bisphosphate carboxylase/oxygenase (RuBisCO) is a fundamental enzyme for CO_2 sequestration and cell growth in all photoautotrophs (plants, algae). The competing oxygenase reaction results in a loss of carbon from the cell as dissolved organic matter. Diatoms, silicifying microalgae, have RuBisCO with high specificity for the carboxylase reaction (Haslam et al., 2005). Although RuBisCO can account for >50% of total soluble protein in leaf extracts (Ellis, 1979), a recent study claims that RuBisCO makes up only a minor percentage of total protein in phytoplankton (Losh et al., 2013).

In this study, we measured the RuBisCO content of several northern/Arctic diatom species, spanning a range of cell sizes. Enzymes from cold-water species tend to have high catalytic efficiency. Therefore, diatoms isolated from Arctic regions are prime candidates for discovering efficient RuBisCO enzymes. First, we attempted to develop and adapt an ELISA method with a commercially obtained anti-RuBisCO antibody (Agrisera) to rapid screening of numerous samples. As this proved unsuccessful, we went back to the classical method of Western Blotting using the same antibody.

The RuBisCO content of some of the analysed diatom species was comparable to that previously reported in the literature (Raven, 1991), i.e. between 4-11% of total soluble protein. However, two species stood out with regard to high RuBisCO content, i.e. 32 and 43%. However the variability of these values was high. Further research must be aimed at clarifying the reason behind this high variability and to determine whether it is methodological or biological. Interestingly, one of our species grows rapidly even at low temperature. High RuBisCO amounts in the cell pose high requirements on the cell's nitrogen budget. It is therefore surprising and worth further investigation that high RuBisCO content apparently pairs with high growth rate in this species. Here, it would also be beneficial to include molecular methods to e.g. examine at which level RuBisCO expression is regulated.

Diatoms represent a renewable biomass resource to be used as e.g. aquaculture feed, biofuels essential fatty acids or secondary metabolites. Our group is currently involved in a pilot project to mass cultivate selected diatom species on industrial fumes to be used as aquaculture feed. Knowledge about RuBisCO content and growth efficiency of different species can help to select productive strains for mass cultivation, as well as to optimize cultivation conditions. One immediate goal is to analyse the role of CO_2-addition e.g. in the form of industrial fumes on RuBisCO content in our rapidly growing - high RuBisCO diatom species.

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21 Spatial and temporal dynamics of the cod-capelin interaction in the Barents Sea

Norwegian Research Council project CODFUN (The cod-capelin interaction in the Barents Sea: spatial dynamics in predator prey overlap and functional response)

Project participants: Edda Johannesen[1] (project leader, main supervisor), **Johanna Fall[1,2]** (PhD student), Geir Odd Johansen[1] (co-supervisor), Øyvind Fiksen[2] (co-supervisor), Georg Skaret[1], Espen Johnsen[1], Samuel Subbey[1], Per Fauchald[3], Lorenzo Ciannelli[4], and Göran Englund[5].

[1]Institute of Marine Research, Bergen. [2]University of Bergen. [3]Norwegian Institute for Nature Research, Tromsø. [4]Oregon State University, Corvallis, U.S.A. [5]Umeå University, Sweden.

Background

Cod (*Gadus morhua*) and capelin (*Mallotus villosus*) are commercially and ecologically important species in the Barents Sea, and their predator-prey interaction has been central to the survival and recruitment of both species. In recent years, the effect of low capelin abundance on the cod population has been small, which was not the case during capelin stock collapses in previous decades. We are also in the middle of a new situation with a cod stock that has grown almost as large as before the onset of industrialized fishery, while the capelin stock once again has collapsed. This novel state may result in changes of overlap and trophic interaction between the two species. The stock assessment of capelin was one of the first assessments extending beyond single-stock evaluation, attempting to quantify effects of the cod and herring stocks on capelin mortality and recruitment. In the capelin stock projection model, the natural mortality of capelin varies with the abundance of cod and the observed feeding intensity inferred from cod stomach contents. However, recent changes in cod distribution and feeding have not been incorporated in the model, and including spatially explicit information about the cod-capelin interaction has since long been a main objective in future improvement of the capelin assessment. A main objective of the CODFUN project is therefore to quantify, explain and account for spatial and temporal variation in the cod-capelin interaction at different spatial scales in the Barents Sea.

PhD project

I am about to start the final year of my PhD project. In the first part, I built a theoretical model of cod's prey selection based on optimal foraging theory. With the model, I explored the profitability of different cod prey, and considered their catchability and digestibility as factors in prey choice. This was a first step towards a mechanistic understanding of the dichotomy that is cod's apparent preference for capelin while having a largely generalist feeding behaviour, and an exploration of a potential role for foraging theory in fisheries management. Here, capelin stood out as a prey that can be digested relatively quickly, a favourable property in cold waters where digestion is slow. The second part was a quantitative analysis of a 12-year time series on cod and capelin distributions from winter and late summer. Here I used spatially explicit statistical methods (GAM) to explore the distribution patterns in relation to the environment and changes in stock size. I then predicted the spatial overlap of cod and capelin during the study period, and related the changes we saw to species-specific responses to the physical and biological environment. Here, we found an overall higher overlap in autumn than in winter, and the previously important feeding connection between immature cod and mature capelin in winter appears to have become less important in recent years. In the final part, I will tie the individual and population scales together by analysing the spatial and seasonal pattern of capelin consumption by cod based on stomach contents data. With knowledge about how an individual cod can maximise energy intake in an idealised environment, and an understanding of the spatial and seasonal variation in cod-capelin overlap, we will be better equipped to understand the spatial patterns of consumption.

22 Energy allocation and fishing-induced changes in growth, condition, and reproduction of the Norwegian spring-spawning herring

Marion Claireaux

Human harvesting is among the most potent drivers of rapid and contemporary evolution (Darimont et al., 2009). This is particularly relevant for marine species, as fishing mortality is typically four to five times higher than natural mortality in many commercially exploited stocks (Mertz & Myers, 1998). Over the last decade, attention has been drawn to fisheries-induced evolution of life-history traits (reviewed in Heino and Godø, 2002; Jørgensen *et al*., 2007; Kuparinen and Merilä, 2007; Allendorf *et al*., 2008; Heino and Dieckmann, 2009), and there is now a whole body of evidence that fishing pressure is driving changes in maturation age at decadal timescales (Kjesbu & Witthames, 2007; Sharpe & Hendry, 2009). However, similar changes have not been reported for pelagic species such as the Norwegian spring Spawning herring (NSSH) which have been harvested intensively for many decades. This could come from the precautionary management regime put in place since the infamous collapse of the stock in the 1960s. Herring also differs from the demersal species usually studied by having schooling anti-predator behaviour, a swimming and nomadic life-style, and a diet consisting mostly of zooplankton. Finally, the herring fishery primarily target mature fish: in this case, selection on timing of maturation is weak and may even favor delayed reproduction (Law & Grey 1989). How this situation affects other traits is unexplored. Our goal is to investigate traits linked to behaviour, reproduction, growth and energy allocation in the NSSH and attempt to shed light on the mechanisms explaining the impact of fishing on this stock.

We are now about to submit a first paper about how fishing on a specific behaviour could lead to evolution of other life-history traits. Because the NSSH is fished while forming dense schools, it is possible that a certain behavioral trait is unintentionally targeted by the fishery and plays a role in the seemingly lack of fisheries induced evolution for this stock. The goal was then to develop theoretical expectations for how fishing gear may lead to changes in behavioral and life-history traits. Using a dynamic optimization model, we simulated a fishery targeting “hiding” (e.g. bottom trawls, purse seins) or actively foraging individuals (e.g. gillnets, traps). Our model predicted that behaviour-selective fishing changes not only the behavioral trait directly targeted by the fishing, but also other life-history traits and emergent natural mortality. Further investigation is needed to make strong conclusions for the NSSH case.

The work on investigating changes in energy allocation is in progress. By using the non-linear mixed effectmodel framework to fit an energy allocation model, we estimate (i) rates of energy acquisition, (ii) maintenance, (iii) reproductive investment and (iv) the onset of maturation (Brunel et al. 2013). The model is now running and we are waiting for the end of the calculations. Once the parameters will be estimated for every cohort, we will use the GLM/GAM framework to estimate potential changes in them, using spawning stock biomass (SSB), climate, fishing, time (accounting for evolution), competitor abundance, and year class strength.

The work on the traits linked to reproduction is ongoing. As a proxy for reproductive output, we used the ratio of the weight after spawning and the weight before spawning. We used the GLM/GAM framework to estimate potential changes in it for four length classes (31 to 34 cm), using the same covariates as above. We are now refining the models and are about to start writing the publication.

The work on growth is about to start. We will investigate changes in juvenile and adult growth (i.e. length-at-age) using the GLM/GAM framework. We will also try to separate environmental and evolutionary effects by applying a model from Swain et al. (2007) to our data.

Poster

23 Molluscan sclerochronological-derived paleo proxy records and their potential to obtain better understanding of the variability of the Faroe Current

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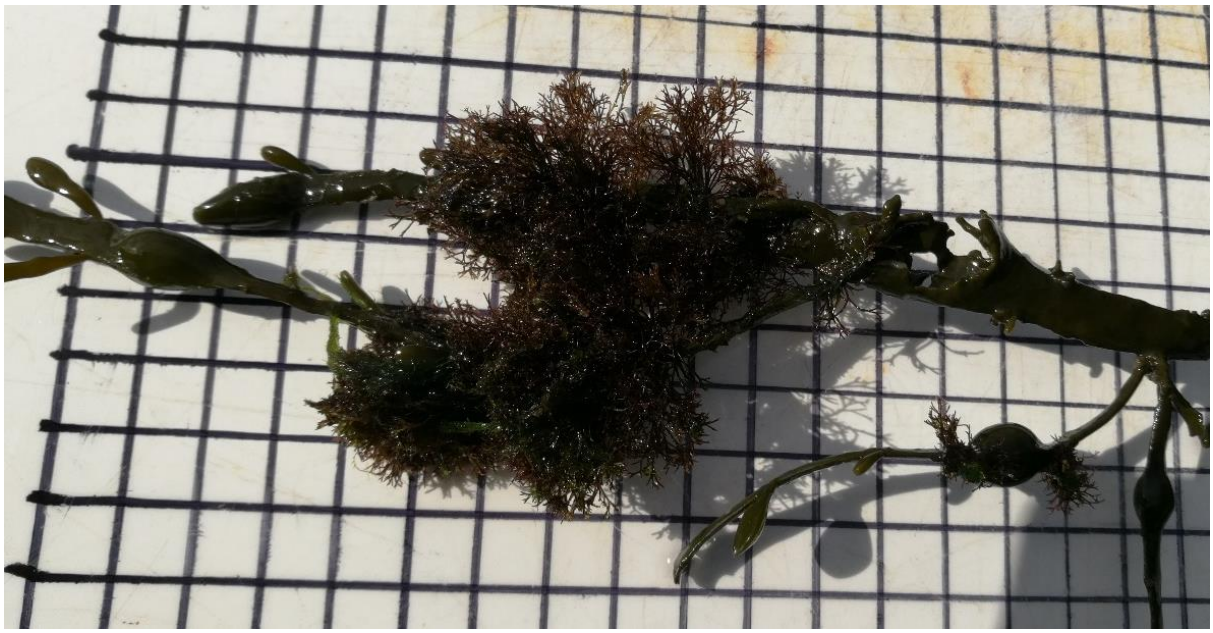
In this study we apply sclerochronological techniques to obtain closer insights into climatic and paleoceanographic conditions of the Faroe Current. The Faroe Current is one of the main inflow branches of warmer water masses into Northern Europe and is therefore of great importance for the climate development in this region. The shells of the bivalve species *Arctica islandica* provide annually resolved paleo proxy records because it forms annual growth increments, which can be analyzed similarly to tree rings and their geochemical compositions can be used for temperature reconstructions. Here we present the first multi-centennial absolutely dated chronology (AD 1642-2013) from the Faroe Shelf. The growth increment variability seems to be strongly influenced by more local year-to-year phytoplankton dynamics and to a lesser extent by air and sea surface temperatures. $\delta^{18}O$ values from several samples per increment reveal a seasonal temperature signal, which can be translated to a main growing season from around March – September. $\delta^{18}O$-based temperature reconstructions from all single growth increments of the chronology suggest an overall warming trend from the end of the Little Ice Age towards present times with several fluctuations on decadal time scales. Correlations of the RBAR, which is an indicator for the signal strength throughout the chronology, with reconstructions of the Atlantic Multidecadal Oscillation (AMO) suggest an inverse relationship between these time series indicating that periods of higher AMO-index result in weakened signal strengths. In conclusion, our results suggest that the growth increment variability in shells of *A. islandica* from the Faroe Shelf reflects local environmental and ecological on-shelf dynamics and the $\delta^{18}O$ measurements of the growth increments can serve as a tool for temperature estimations on multi-decadal time scales. Furthermore, the variability of the signal strength throughout the chronology may provide information about the variability of the AMO on multi-decadal time scales.

24 Grisetangdokke (*Vertebrata lanosa*) – The new truffle in town?



Mari Vold Bjørdal

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Alger er fundamentet i mange marine næringskjeder som primærprodusenter og finnes i store mengder langs norskekysten. I likhet med grønnsaker inneholder de essensielle vitaminer og mineraler, og rødalger kan også inneholde store mengder protein.

Den vesle rødalgen grisetangdokke er en vanlig epifytt på brunalgen grisetang, og finnes langs norskekysten nord for Sørlandskysten. Den har vekket interesse hos nordiske gourmetkjøkken på grunn av sin trøffellignende smak og kalles også trøffeltang. I år er den en råvare i den prestisjefylte kokkekonkurransen Bocuse d'Or.

Det er ingen tvil om at grisetangdokken har potensiale til å bli populær som matalge, men vi vet fortsatt relativt lite om den. Under hvilke forhold trives den best? Hvor lett sprer den seg? Og ikke minst; hvor fort vokser den tilbake etter høsting? Dette er spørsmål denne studien skal prøve å finne svar på.

Gjennom et master-prosjekt skal 30 fjærestasjoner med grisetang undersøkes, og dekningsgrad av grisetangdokke registreres. Videre blir fysiske faktorer som helninggrad, eksponeringsgrad, type substrat og mengde grisetang på stasjonene registrert. Salinitet og temperatur i sjøen måles regelmessig. Resultatene vil bli analyserte for å finne miljøfaktorer som påvirker forekomsten av grisetangdokke. Det er også planlagt å ta prøver til genetiske analyser for å undersøke hvor stor den genetiske variasjonen er i et område. Gjenvekst av grisetangdokke vil bli undersøkt ved å systematisk rense greiner for å simulere plukking, og deretter måle hvor mye som vokser tilbake over tid.

Målet er at prosjektet kan belyse spørsmål rundt høsting av grisetangdokken som matalge og eventuell senere forvaltning.

Poster

25 Kelp detritus effect on the growth of key filter feeding species in the littoral zone

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Mytilus edulis and *Semibalanus balanoides* were fed different diets to determine the significance of detritus from *Laminaria hyperborea* on their growth. These animals were collected from the Oslofjord at Drøbak. Control groups were set up with running seawater from the fjord at the university's biological station there. The test groups were placed in aquaria receiving artificial seawater at Kristine Bonnevies hus in Oslo. One test group consisting of 30 individuals *M. edulis* received a diet of ground up kelp while the other test group received a cocktail of phytoplankton cultures (*Skeletonema pseudocostatum, Protoceratium reticulatum, Prorocentrum minimum*). The shell length of *M. edulis* was recorded once a month for three months. After settlement on small plates the diameter of *S. balanoides* is being measured and photographed with the same timeframe and the same culture conditions as for *M. edulis*. A fatty acid analysis will be performed at the end of the feeding experiment. This master project is one of the tasks of work package 2 in the KELPEX project (NIVA). Kelp forests could play a significant role in the growth of these key filter feeder species. It is important to understand this relationship if kelp forests in Norway continue to experience regime shifts.

26 Fangst av krill og torsk (*Gadus morhua)* ved bruk av lysfelle; effekt av lyskildens egenskaper.

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Syn er en viktig sans for de fleste akvatiske organismer. De responderer på lys og lysintensitet, for eksempel i form av vandring, stiming og fødesøk, men også i forbindelse med predatorer og unnvikelse. Slike egenskaper åpner for at en kan manipulere atferd hos marine organismer ved bruk av kunstig lys, noe som har lange tradisjoner innen pelagisk fiskeri, men også i oppdrettsnæringen. Hvordan og hvorfor effekten av lys fungerer har blitt lite studert, og med en bedre forståelse av hvordan akvatiske organismer responderer på lys kan det bidra til utvikling av mer miljøvennlige fiskemetoder. Hvordan arter og organismer responderer på lysstimuli, som for eksempel tiltrekning eller unnvikelse, kan utnyttes i fiskeriteknologi.

Det er et mål og minske miljøpåvirkningen av fiskeriaktivitet, og utvikling av LIFE-redskap (miljøvennlige fangstmetoder) er viktig. Teiner er eksempel på et LIFE-redskap, men teiner har vist seg å være lite effektive ved fangst av fisk. Utfordringen er ikke å tiltrekke seg fisk, men å motivere fisken til å trekke inn i teina. Tilstedeværelsen av et visuelt og levende bytte inne i teina vil kunne være motiverende, noe det er gjort flere forsøk på både i Norge og i Sverige. Havforskningsinstituttet gjorde høsten 2016 et forsøk med lys i torsketeiner, noe som viste seg å gi mye større fangst enn i teiner uten lys (200kg i teiner med lys, 5kg i teiner uten lys). Undersøkelser viste at fisk fanget i teiner med lys hadde magesekker fulle av krill.

Det er altså mulig å bruke lys for å tiltrekke seg krill og annet makroplankton i teinene og motivere torsk til å trekke inn i teina. Men en burde se på hvilket lys (intensitet og bølgelengde) som er mest effektivt, som gir mest krill og da sannsynligvis gir mer torsk. Dette er det jeg ser på i min masteroppgave; sammenligner ulike bølgelengder og intensiteter for å se hva som tiltrekker seg mest krill. Videre skal dette lyset testes ut i torsketeiner for å se om en kan få større fangst av torsk enn tidligere. Målet er å finne et lys som kan bidra til en utvikling av teinefisket da det er potensiale for å gjøre dette kommersielt lønnsomt.

Poster

27 Introducing a new hypothesis – Southward shifts of species distributions under climate change?

Gabriella Ljungström, **Tom Langbehn**, Christian Jørgensen, Øyvind Fiksen

The distributions of a wide range of taxonomic groups are shifting or expanding poleward due to global warming. This is thought to be the result of organisms tracking their thermal preference. At higher latitudes daylight becomes increasingly seasonal, with month-long periods of winter darkness or midnight sun at the Arctic extremes. In visual predators, such as most fish, foraging and hence energy acquisition critically depends on light availability. With higher water temperatures metabolic demands of fish will increase and therefore the need to forage. In summer, mid-night sun limits safe foraging close to the surface for non-schooling diel-vertically migrating fish. More frequent foraging forays into the photic zone may therefore increase predation risk. To avoid starvation during the long and dark winter, many boreal and Arctic species rely on energy reserves built up during the light summer. When metabolic demands rise, the only way to make these reserves last over the winter may be to move towards latitudes where the dark period is shorter. Based on this logic, we suggest that there are limits to poleward migration under global warming and that equatorward shifts may also be likely. Using a conceptual model we outline a summer and a winter scenario based on this hypothesis.

28 Bentiske makroalger og dyr fra fjæresonen i Ytre Hvaler Nasjonalpark

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For å få et øyeblikksbilde av artsmangfoldet av bentiske makroalger og dyr i Ytre Hvaler nasjonalpark, har det blitt besøkt 14 fjærestasjoner med tilhørende fjærepytter. Til hver stasjon har de blitt laget en soneringsprofil og artsliste. Innsamlingen ble gjort på våren og om sommer, ved hjelp av snorkling og håndplukking. Alger og dyr er identifisert til art eller lavest mulig takson. Salinitet og temperatur ble målt, og det planlegges å bruke en kartografisk metode for å klassifisere stasjonene etter eksponeringsgrad. Hittil er det observert at mange av artene som ble funnet på våren, som *Bangia fuscopurpurea*, *Porphyra linearis*, *Ulothrix spp*. og *Urospora penicilliformis*, ikke er å finne på sommeren, men er erstattet av bart fjell. Masterprosjektet er en kvalitativ undersøkelse av bentiske makroalger og dyr i nasjonalparken, og skrives som en del av lektorutdanningen i biologi og kjemi ved Universitetet i Oslo. Dette vil gi kunnskaper som senere er nyttige i undervisningssituasjoner. Både å ha kjennskaper til arbeid i felt og laboratorium, og å kunne klassifisere og identifisere arter er nyttig som lærere i biologi. Dette er en stor del av læreplanen i faget, hvor formålet blant annet er å kunne bruke naturen som læringsarena.

29 Oppdrettsavfall som gjødsel i ope hav?

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«Observe, at all times, the Law of Return. All crop and animal residues should be returned to the soil. If you sell something off the holding, then you should import something of equal manurial value back onto it" skreiv John Seymour i den klassiske boka frå 1976 om sjølvberging. Det ein tek ut må vere i balanse med det ein gir tilbake – i jordbruket har dette vore kjent i tusenvis av år. Men korleis greier vi det i havet? Mennesket «haustar» vill- og oppdrettsfisk, nærme land og i det opne hav, men det vi «gir tilbake» er for det meste i form av punktkjelder nærme land. Det skjer ikkje nødvendigvis der det er mest gunstig for det marine økosystemet.

Vi lét oss inspirere av rolla til kvalen – som gjødslar havet med avføringa si og bidreg til oppblomstring av planteplankton – og kjennskapen at produksjonen i havet skjer flekkevis. Difor ville vi undersøke om avfall frå oppdrettsannlegg kan brukast strategisk til å gjødsla ope hav, auke produksjonen lokalt, for å så hauste den auka avkastninga. Denne kanskje noko naive ideen vekte mange spørsmål, som vi har prøvt å svare på fyrst og fremst gjennom eit litteraturstudie. På denne posteren presenterer vi nokre av svara – og fleire spørsmål.

Poster

30 Hormone strategies as a key for understanding life history trade-offs in growth and survival: Insight from a juvenile fish growth model

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Animal behaviour is affected by stimuli from both the internal and external environment. Hormones controlling metabolism and growth have the potential to directly and indirectly affect how individuals solve the trade-offs between active foraging and predation risk as well as allocation to growth, reserves and reproduction. By adjusting their hormone levels animals can adjust their activity levels, overall energy use, regulate feeding behaviour and energy allocation. We have developed a dynamic optimisation model where levels of growth hormone and thyroid hormone determine energy allocation and growth. The model also includes the neuropeptide orexin, which controls foraging behaviour as a mediator for the satiety hormone leptin, and the hunger hormone ghrelin. In the general model a juvenile fish must find food, grow, reach maturation and avoid predation in a stochastic environment by optimising its hormone profile. We find that observed correlations between hormones emerge from evolutionary optimisation. This model can later be used to study hormonal adaptations in animals depending on factors like food availability, predation pressure, seasonality and climate change.

Poster

31 Norwegian fjords contain sub-populations of roundnose grenadier, *Coryphaenoides rupestris*, a deep-water fish

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The roundnose grenadier (*Coryphaenoides rupestris*) is a benthopelagic fish distributed along the continental, island, and seamount slopes of the North Atlantic and Mid-Atlantic Ridge. Currently, we know little about *C. rupestris* biology and its role in deep-sea ecosystems, particularly in fjords where it has yet to be studied. Previous studies have indicated that *C. rupestris* is divided into sub-populations across the North Atlantic, but these have yet to address small-scale population structuring at the scale of fjords. We investigated the population genetic structure of *C. rupestris* in southwestern Norway to get an understanding of the evolution of the species along the Norwegian coast and to identify biological sub-populations. We incorporated samples from three Norwegian fjords (Lustrafjord, Masfjord, Korsfjord) and two coastal sites (Trondheimsleia, Skagerrak). Using microsatellite DNA markers, we observed significant genetic heterogeneity across the study area, suggesting that *C. rupestris* occur in biological sub-populations at each of the sites studied, and possibly at a finer scale within the Lustrafjord. We also contrasted genetic data with environmental variables and fish condition indices to identify some potential drivers of evolution in the species. Our analysis suggests that population structuring in *C. rupestris* along the Norwegian coast is influenced by geographic distance and Norway's complex bathymetry. Fjord sills, for instance, appear to limit its dispersal and migration between fjords and the ocean. *C. rupestris* is an overfished species that has been red-listed as critically endangered. Our findings therefore have important management implications for the species.

32 Fish assemblages in coastal vegetation

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KELPFISH will provide important new knowledge about fish use of coastal vegetation and effects from kelp trawling. Fish assemblages and behavior is difficult to study in dense vegetation with low visibility. Kelp forests and seagrass meadows have been suggested to be important for coastal fish stocks as nursery and feeding grounds, by providing habitats and food by rich faunal communities associated to these benthic plants. Complementary methods of imaging, acoustics, and fishing are used to overcome the difficulties of different visibility inside and outside vegetation when comparing trawled and untrawled areas.

Poster

33 Exploring the practical applications of balanced harvesting by using an Atlantis ecosystem model for the Nordic and Barents seas

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To meet the objective of the Ecosystem Approach to Fisheries, "Balanced Harvesting" (BH) has been suggested as one possible strategy to ensure a high sustainable yield while maintaining ecosystem structure and function. BH proposes a moderate fishing mortality in proportion to productivity spread across the widest possible range of species, stocks, and sizes in an ecosystem. The intent is a sustainable and overall unselective harvest that reduces alterations to the ecosystem structure by maintaining the relative size and species composition. Although the impacts of BH on ecosystems and yields has been well studied within theoretical simulations, the models have mostly used simplified abstract fishing pressure to model removals. There is little work to evaluate the feasibility of achieving (some approximation to) BH using actual realistic fishing fleets, nor the impacts of "achievable fishing patterns" on the ecosystem and yields. We take the Barents Sea as a case study, where there has been moderate fishing pressure and elements of ecosystem based approach to management for many years. We will investigate the extent to which BH can be achieved by realistically modelled fishing fleets in an Atlantis end-to-end model for the area ("NoBa Atlantis"), and compare the results to a control run where the historical fisheries were applied. By running scenarios with varying mortality rates and fishing pressure, we investigate interaction effects of components harvested and fishing mortality rate relative to production and identify to what extent a balanced harvest is feasible with the existing fleet components.

Keywords: Balanced harvesting, end-to-end modeling, management strategy evaluation, Atlantis