

Project information

Keywords

Biodiversity, cod, predation, climate, fish communities, human impact, Barents Sea, Scotian Shelf, modelling

Project title

How do a dominant predator and climate shape fish biodiversity over space and time in large marine ecosystems?

Year

2015

Project leader

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Participants

National: NINA (Torkild Tveraa, Per Fauchald); Institute of Marine Research, IMR (Edda Johannesen, Randi Ingvaldsen, Mette Skern-Mauritzen); UiT The Arctic University of Norway (Nigel G. Yoccoz)

International: Polar Research Institute of Marine Fisheries and Oceanography (PINRO), the Russian Federation (Andrey V. Dolgov); Bedford Institute of Oceanography (BIO), Canada (Nancy L. Shackell, Kenneth T. Frank); Massey University, MU, New Zealand (Marti J. Anderson)

For a special focus on the waters around Svalbard, included as an additional part under the Flagship Fjord and Coast (i.e. not included in the RCN-project FISHDIV), we have included some additional researchers from IMR in 2015 (Åge Høines, Odd Aksel Bergstad, Vidar Lien)

Flagship

Fjord and Coast

Funding Source

Fram Centre, the Research Council of Norway (RCN) (HAVKYST)

Summary of Results

The scientific report covers all sources of funding (Fram Centre, RCN and own funding). In 2015 we have finalized two scientific papers, one focusing on the role of cod in shaping fish biodiversity on the Scotian Shelf (Ellingsen et al. 2015), and the other focusing on the distribution of cod in the Barents Sea (Ingvaldsen et al. 2015), see highlights 1 and 2 below.

Barents Sea: We have focused on how to handle uncertain classifications of fish taxa in the Barents Sea, particular for the arctic species, and the species list has been adjusted accordingly. We have done a number of new data analyses (using advanced statistical methods) using data on cod and sea temperature from the annual ecosystem surveys in the Barents Sea as well as satellite data for information on sea-ice cover. A challenge in our project could be to separate between the impacts of different drivers on fish biodiversity, such as cod abundance and sea temperature in the Barents Sea. However, by dividing the Barents Sea into different contrasting sub-areas based on changes in cod distribution and abundance and sea temperature, we should be able to disentangle their relative effects. In 2014 and 2015, we have therefore had a special focus on how to divide the Barents Sea into sub-areas based on changes over space and time in important drivers in the system. These analyses are essential for our focus on the patterns of fish biodiversity in space and time. Our analyses of the Barents Sea show that in some parts of the Barents Sea, the patterns of cod and/or temperature are stable, whereas in other parts there have been small or large increases or decreases. We aim to account for these dynamics, and separate between the effects of dominant predators and environmental variables on patterns of diversity. We have started with paper writing, but we need to do more analyses based on data from the Barents Sea.

Comparison of Barents Sea and Scotian Shelf: We have focused on how to compare the different situations in the Barents Sea and on the Scotian Shelf, as these areas have different geographical scales (the Scotian Shelf is about 1/10 of the Barents Sea) and different periods of sampling (1970-present vs. 2004-present). We have decided to select two decades from the Scotian Shelf and run different analyses for each decade: (A) from about 1980 and ten years; (B) the last decade (2004-2013). For the first decade (A), cod productivity was high and cod dominated in relation to biomass on the Scotian Shelf, i.e. this will be more or less comparable to the situation in the Barents Sea over the last decade. In addition, we will focus on the last decade (B) in both areas to compare the most recent situations.

Svalbard: We have had a special focus on demersal fish assemblages of the major continental shelf area surrounding the Svalbard archipelago. This is a region characterised by complex bathymetry and numerous islands, as well as steep and strong environmental gradients between the warm areas of the Norwegian Sea under the influence of Atlantic Water, and the Arctic Water to the north and northeast. We use data from the annual ecosystem surveys of the Barents Sea (2007-2014), including ca 950 bottom trawl stations with ca 60 species of demersal fish. We have processed the data, and we have divided the area into 5 sub-areas, based on

the complex bathymetry and gradients in this region. We have done a number of data analyses. We have started with paper writing, but we need to do more analyses based on data from this area.

Highlight 1:

We have published a paper in *Journal of Animal Ecology*, a recognized general ecological scientific journal (impact factor 4.5):

Ellingsen, K.E., Anderson, M.J., Shackell, N.L., Tveraa, T., Yoccoz, N.G. & Frank, K.T. (2015) The role of a dominant predator in shaping biodiversity over space and time in a marine ecosystem. *Journal of Animal Ecology*, 84: 1242-1252. doi: 10.1111/1365-2656.12396.

The paper is an examination of annual bottom trawl survey data (1970-2010) over a broad area on the Scotian Shelf, north-west Atlantic. Populations of the Atlantic cod (*Gadus morhua*) were overfished and several collapsed in the early 1990s across Atlantic Canada, providing a unique opportunity to study potential ecosystem-level effects of the reduction of a dominant predator on fish biodiversity, and to identify how such effects might interact with other environmental factors, such as changes in climate, over time. Although, it is well known that exploitation of living marine resources has resulted in major changes to populations of targeted species and functional groups of large-bodied species in the ocean, the effects of overfishing and collapse of large top predators on the broad-scale biodiversity of oceanic ecosystems remains largely unexplored. Our aim was therefore to quantify the ecosystem-level effects of overfishing and climate variation on the biodiversity of fishes on the Scotian Shelf. Using advanced multivariate analyses and causal modelling, we found that the dramatic decline in cod populations caused by overfishing has resulted in large changes in the diversity of the fish community. We found that both alpha and beta diversity increased with decreases in cod occurrence, and fish communities were less homogenous and more variable in systems where cod no longer dominated. The effects were most pronounced in the colder north-eastern parts of the Scotian Shelf. Our results provide strong evidence that intensive harvesting (and collapse) of marine apex predators can have large impacts on biodiversity, with far-reaching consequences for ecological stability across an entire ecosystem.

Highlight 2:

We have published a paper in *Nature Climate Change*, a highly recognized scientific journal (impact factor 14.5):

Ingvaldsen, R.B., Bogstad, B., Dolgov, A.V., Ellingsen, K.E., Gjørseter, H., Gradinger, R., Johannesen, E., Tveraa, T. & Yoccoz, N.G. (2015) Sources of uncertainties in cod distribution models. *Nature Climate Change*, 5: 788-789. doi:10.1038/nclimate2761.

Our paper is a reply to another paper published in the same journal earlier this year (Wisz et al. 2015. *Nature Climate Change* 5, 261-265.2015), where climate researchers from Denmark and Switzerland simulated that Atlantic cod would find suitable environmental conditions in the southern and central Barents Sea by around 2060-2100. The northern Barents Sea would, according to these simulations, not be suitable even by 2100. The problem is that cod are already present in these areas. In recent warm years, the northern border of the cod summer feeding distribution in the Barents Sea has expanded to 80-82° N, north of Svalbard. We suggest that the use of a robust ensemble of climate models will provide more reliable projections and predictions of future fish distributions in the Arctic. Furthermore, we suggest that a thorough validation of the environmental models to properly match the present situation, both in terms of environment and fish distribution, should be the next step before any further predictions of the future distributions of commercially important species.

For the Management

Prosjekttittel: Hvordan påvirker predasjon og klima biodiversitet i marine fiskesamfunn?

Prosjektleder: Kari E. Ellingsen, Norsk institutt for naturforskning (NINA)

Prosjektdeltakere: *Nasjonale:* NINA; Havforskningsinstituttet (HI); UiT Norges arktiske universitet. *Internasjonale:* Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Russland; Bedford Institute of Oceanography (BIO), Canada; Massey University (MU), New Zealand

Prosjektsammendrag: Intensiv høsting med påfølgende kollaps av toppredatorer i marine økosystemer er velkjent. Effekten av dette på biodiversiteten på økosystemnivå har man derimot begrenset kunnskap om. På kontinentalsokkelen i det nordvestlige Atlanterhavet (Scotian Shelf) har torskpopulasjonen blitt dramatisk redusert og kollapset på den østlige delen tidlig på 1990-tallet. Våre analyser viser

at dette har resultert i store endringer i fiskebiodiversiteten med økt variabilitet i bunnfisksamfunnet. Det betyr at fiskesamfunnet var mer homogent da torsken var mer dominerende i systemet. I Barentshavet har torskepopulasjonen derimot økt dramatisk både i antall og utbredelse over stor skala. Torskebestanden i Barentshavet er nå den største i verden. Samtidig har klimaet i Barentshavet endret seg i løpet av de siste tiårene, med økt (og varierende) havtemperatur og redusert havis. Vår forventning er at bunnfisksamfunnet blir mer homogent etterhvert som torskepopulasjon øker i Barentshavet. Samtidig forventer vi at fiskediversiteten øker som en konsekvens av økt havtemperatur. Disse to forholdene virker altså i hver sin retning på systemet. Vi studerer betydningen av torsk og klima for fiskebiodiversiteten i rom og tid på økosystemnivå. Et komparativt studie, der vi fokuserer på de to svært ulike situasjonene på Scotian Shelf og i Barentshavet med hensyn til klima og torsk, vil bidra til at vi bedre kan forstå totalbildet og dermed øke kunnskapen på et internasjonalt nivå. Gjennom disse studiene vil vi utvikle nye metodiske tilnæringer som forventes å gi et tidligere varsel om endringer i økosystemer enn de metodene som tradisjonelt brukes. Slike tidlige varsler er viktig for forvaltningen.

Prosjektet har støtte fra Norges Forskningsråd (NFR, HAVKYST) for perioden 2014-2016. I 2014-2015 har prosjektet blitt knyttet opp mot Flaggskipet Fjord og kyst, der vi i tillegg har et spesielt fokus på områdene rundt Svalbard. Fokuset på områdene rundt Svalbard er ikke opprinnelig inkludert i NFR-prosjektet.

Published Results/Planned Publications

1. Ellingsen, K.E., Anderson, M.J., Shackell, N.L., Tveraa, T., Yoccoz, N.G. & Frank, K.T. (2015) The role of a dominant predator in shaping biodiversity over space and time in a marine ecosystem. *Journal of Animal Ecology*, 84: 1242-1252. doi: 10.1111/1365-2656.12396.

2. Ingvaldsen, R.B., Bogstad, B., Dolgov, A.V., Ellingsen, K.E., Gjørseter, H., Gradinger, R., Johannesen, E., Tveraa, T. & Yoccoz, N.G. (2015) Sources of uncertainties in cod distribution models. *Nature Climate Change*, 5: 788-789. doi:10.1038/nclimate2761.

Planned publications:

We are currently working on a manuscript where we focus on demersal fish assemblages of the continental shelf area surrounding Svalbard (Bergstad and Høines are lead authors; working title: 'Demersal fish assemblages in the boreo-arctic shelf waters around Svalbard: baseline analysis of identity and distributions in relation to hydrography and substrate').

We are currently working on a manuscript focusing on fish biodiversity in the Barents Sea (Johannesen et al.; working title: 'Climate change and the rise of an apex predator: consequences for biodiversity patterns').

We are currently focusing on a manuscript where we compare the situations in the Barents Sea and on the Scotian Shelf (Ellingsen et al.; working title: 'The fall and rise of an apex predator: interactions with climate and consequences for patterns of biodiversity').

Communicated Results

We had a workshop in Tromsø with national participants from NINA, UiT and IMR and international participants from Canada and Russia in April 2015, covering all aspects of the project. In addition, we had a working meeting in Bergen with participants from NINA and IMR in October 2015, with a special focus on the Svalbard-paper.

The paper by Ellingsen et al. (2015) is in the top 5% of all articles scored by Altmetric, Wiley Online Library, based on the number of times mentioned by tweeters, Facebook pages, Google+ users and news outlets. We have paid for 'online open' for this paper, in order to reach a broader audience. Based on this paper, we made a news story published at forskning.no, nina.no and framsenteret.no, and it has later been published by Nationen (newspaper), Bladet Vesterålen (internet and newspaper), Kyst og Fjord (internet), Alt om Fiske (magazine) and Jakt & Fiske (magazine).

NTB made a news story based on the paper by Ingvaldsen et al. (2015), and this has later also been published by forskning.no, nrk.no/troms and E24.no.

Interdisciplinary Cooperation

The participants have an interdisciplinary composition and the project brings together the disciplines of biodiversity, ecology, fishery biology, statistics/modelling and climate/physical oceanography. Indeed, our project benefit in a positive way from this inter-disciplinary cooperation. In addition, the high-level international competence increase the impact of the project at an international scale.

Budget in accordance to results

Funding in KNOK:

'Incentivmidler', Fram Centre for 2013: 250

Fjord and Coast, Fram Centre for 2014: 255

Fjord and Coast, Fram Centre for 2015: 300

RCN, HAVKYST for 2014-2016: 4 669

Own funding NINA and IMR for 2014-2016: 655

In addition, own funding, but not specified in KNOK, are provided by the following institutions:

- Own funding from IMR and PINRO for the annual ecosystem surveys in the Barents Sea (2004-2013)
- Own funding from UiT The Arctic University of Norway for the work done by Nigel G. Yoccoz
- Own funding from Bedford Institute of Oceanography, Canada for the work done by Nancy L. Shackell and Kenneth T. Frank

The funding from the Fram Centre has been important in several ways. The funding from 2013 (incentive money) made it possible to write the research project proposal to the RCN (HAVKYST). The funding for 2014 and 2015 (Fjord and Coast) has given us the opportunity to have a special focus on the shelf waters around Svalbard, including the western and northern parts. This special focus was not originally included in the RCN-project, and therefore not included in the RCN-budget. This funding has also made it possible for some additional fishery people and a physical oceanographer at IMR to work more closely with some core project participants in the RCN-project, with regard to the special focus on the waters around Svalbard. Funding from the Fjord and Coast Flagship has also contributed to strengthening of the core activity in the RCN-project. Furthermore, the funding for 2015 also made it possible to publish a scientific paper 'online open' at Journal of Animal Ecology (23 046 NOK). The funding for 2015 has also been used for the popular dissemination of the results (i.e., based on the paper by Ellingsen et al. 2015). These expenses were not included in the RCN-budget. The budget for travelling with regard to the meeting in Bergen at IMR with participants from NINA and IMR in October 2015, for a special focus on the Svalbard-paper, was covered by own funding from NINA.

Could results from the project be subject for any commercial utilization

No

Conclusions

- a) The project has so far given an important contribution to the understanding of dominant predators for shaping biodiversity. We found that fish alpha and beta diversity increased with decreases in cod occurrence on the Scotian Shelf. Fish communities were less homogeneous and more variable in systems where cod no longer dominated.
- b) We expect that multivariate measures will capture changes in ecosystems at an earlier stage and give additional information compared to more traditional methods. We found that the changes in the fish diversity on the Scotian Shelf started earlier than when the collapse of cod and other groundfish were reported.
- c) The northern border of the Atlantic cod summer feeding distribution in the Barents Sea has expanded to 80-82° N. This means that cod are already present far north of the areas Wisz et al. (2015. Nature Climate Change 5, 261-265.2015) predicted to become suitable with regard to the environmental conditions by 2060-2100.