The role of apex predators and climate for biodiversity

Dr Kari Ellingsen helms a new study that is probing the effects of climate change and apex predators on biodiversity in marine ecosystems. Here, she discusses why this is relevant for national authorities

Can you explain the key objectives of your research? How has your professional background led you to this field?

My research activity has mainly focused on biodiversity, its measurement and patterns, as well as human impact and the effects of climate change on marine ecosystems. My interest in fish biodiversity and human drivers started when I visited Drs Ken Frank and Nancy Shackell at the Bedford Institute of Oceanography (BIO), Canada, during my postdoctoral studies at the University of Oslo, Norway.

The main goal of our current research is to evaluate the role of climate and dominant predators in shaping fish biodiversity in marine ecosystems. We will investigate how intensive exploitation and subsequent reduction of the top predator, cod, affects fish biodiversity. Moreover, we want to investigate the effects on fish biodiversity where cod has increased dramatically both in numbers and distribution.

How does this project adhere to the requirements of the HAVKYST Marine Ecosystems sub-programme? Why are biodiversity studies of this kind so important?

HAVKYST is the Research Council of Norway's programme for 'The Oceans and Coastal Areas'. The sub-programme aims to provide knowledge that is useful for ecosystem-based management in light of climate change. Biodiversity studies of this kind are important because, although over-exploitation and collapse of apex predators are well recognised, the impact on biodiversity remains poorly understood. Furthermore, recognition has grown over recent decades that the removal of large apex predators from nature acts

additively or synergistically with other human impacts, such as climate change, implying that different drivers should be evaluated concurrently.

What kind of influence do apex predators usually exert on ecosystems? How can climate interact with this effect?

Apex predators are known to control or structure ecosystems. At the same time, increased diversity is expected as a consequence of increasing temperature. Attention is required where climate change works in concert with overfishing. Our team aims to investigate if this might be the situation on the Scotian Shelf. In the Barents Sea, where both cod and sea temperature have increased, the drivers may work counter to one another and we aim to separate the effects of each.

At what stage is your project currently? Why are comparative studies significant and for what reason were these areas selected for your study?

The project started in January 2014 with a focus on climate and cod, and the measurement of fish biodiversity, so we are at an early stage in this research. At its conclusion, we will be able to model the role of climate and cod in shaping fish biodiversity over space and time.

The Barents Sea cod population has increased and is currently the largest in the world. At the same time, the sea-ice area in the Barents Sea is declining and the sea temperature has increased since the 1970s. On the Scotian Shelf there has been a dramatic reduction of the cod population as a consequence of heavy exploitation, with a collapse on the eastern shelf in the early 1990s, and we consider this as a 'natural experiment in time'. Our expectation is that a comparative study between these two areas with different situations and history will increase our knowledge on this topic in general.

You aim to develop a new, multivariate approach that will give earlier warning of ecosystem changes compared to traditional statistical methods. What advantages will this have?

We will focus on beta diversity, which can be defined as the variability in species composition (and abundance) among sampling units (here trawl sets) for a given area. Multivariate methods have proven sensitive to changes in faunal composition. Furthermore, the choice of biodiversity measure may have large consequences for the interpretation of the results, but this has often been overlooked in previous studies. The project is therefore relevant to both the national fishery and nature management authorities with regard to developing an ecosystem-based approach to marine resources management.

Fishing for **facts**

Vanishing due to overexploitation in some regions of the Atlantic Ocean, while very abundant in others, Atlantic cod is a valuable species both economically and ecologically. A study led by the **Norwegian Institute for Nature Research** (NINA) aims to assess the impacts of apex predators on marine fish biodiversity

ON A PLANET with a rapidly growing population, effective management of fish species is an important goal in the pursuit of food security. Ecosystem-based management has emerged as a popular approach in recent years in recognition of the important interactions between species, ecosystem components and humans. With an economy underpinned by fish-related products and activities, Norway is a country with a particularly keen interest in effective species management.

To develop strong foundations upon which to build effective ecosystem-based management approaches, the 'Marine Ecosystems' sub-programme of the Research Council of Norway (RCN)'s Oceans and Coastal Areas (HAVKYST) programme has called for the generation of new knowledge in this field. Spurring on the call is the recognition that ecosystem-based management urgently needs to address the role of climate change in northern areas. The intensive exploitation of apex predators is known to act simultaneously with other anthropogenic phenomena, such as pollution, to influence many terrestrial and aquatic food webs. Indeed, in the last few decades, the removal of top predators has led to the collapse of many commercial fish populations around the world and potentially altered major ecosystems.

KEY QUESTIONS

Marine studies often use correlations between the population size of a single species and climate parameters to focus on commercially important species but the specific role of cod (a predator at the top of the food web) and climate in shaping biodiversity of the whole fish community has not yet been analysed. Consequently, pertinent questions remain: what are the impacts on biodiversity? What happens at an ecosystem-level in a situation where predators increase? How do these impacts interact with climate change in shaping biodiversity? And which measures of biodiversity are most efficient and effective at detecting changes?

At the Norwegian Institute for Nature Research (NINA), Senior Researcher Dr Kari Ellingsen is leading a collaborative project to examine how dominant predators and climate shape fish biodiversity over space and time in large marine ecosystems. In addition to answering the RCN's call for specific research, the project is expected to generate new methods that will contribute to other sub-programmes within HAVKYST calling for novel methods, models and technology.

The team responsible for delivering the project results is spread internationally, including participants from the Institute of Marine Research (IMR), UiT The Arctic University of Norway, Bjerknes Centre for Climate Research, the Polar Research Institute of Marine Fisheries and Oceanography of the Russian Federation (PINRO), the Bedford Institute of Oceanography, Canada, and Massey University in New Zealand. With their combined expertise in biodiversity, ecology, fishery biology, statistics, climate and physical oceanography, the consortium is well positioned to probe deeper than more common small-scale studies of alpha diversity. Where these projects tend to investigate the species diversity in a single unit or habitat, the project focuses on multivariate methods, and, in particular, patterns of beta diversity (between-habitat diversity), and takes into account the variation in faunal composition (and abundance). The aim is to capture changes in ecosystems early and generate a fuller picture of the balance of aquatic life.

A CONTRAST IN COD

The researchers are focusing on two marine ecosystems where in the last decades it has

TRAWL SAMPLE © CECILIE KVAMME, IMR

been reported that cod has a strong structuring role. The Scotian Shelf – a section of the continental shelf off the coast of Nova Scotia covering 171,000 km^2 – has been subject to research bottom trawl surveys conducted by the Canadian Department of Fisheries and Oceans (DFO) every year since 1970. The cod population on the Scotian Shelf has been dramatically reduced because of overfishing, with a collapse in the early 1990s on the eastern shelf. Since then, the recovery of cod in the region has been unexpectedly slow despite the cessation of fishing in 1993. Conversely, the Barents Sea is an area of 1.6 million km^2 and home to the largest cod population on the planet.

In the Barents Sea, cod is dominating the biomass of commercial demersal fish, and is an economically and ecologically important species. An increase in the fish diversity is expected when water temperatures rise and the area of sea-ice declines, as it has in the Barents Sea. Currently, the impact of cod on biodiversity is not proven, but Ellingsen expects it to be considerable given that the cod population has changed.

Based on data gathered from the DFO's annual surveys, Ellingsen foresees a very different picture of biodiversity in the Barents Sea compared to the Scotian Shelf: "Our predictions are for a more homogeneous bottom fish community with an increasing

cod population". It is proposed that several processes may be acting simultaneously to bring about this scenario, such as specialist species giving way to generalists (such as cod), and species with large ranges may replace species with small ranges.

FROM ALPHA TO BETA

Most studies on diversity have been conducted at small (local or alpha-level) scales. Differences among stations/areas or years (beta diversity) has been far less studied. The project's focus on beta diversity, here defined as the variability in species composition (and abundance) among sampling units for a given area, requires the division of the Scotian Shelf and the Barents Sea into geographical sub-areas. Basing these divisions on climate variables and topography, the team hopes they will help to make more detailed comparisons of fish biodiversity over space and time.

While alpha diversity can be determined as the average number of species in a single trawl set, more rigorous methods are implemented for the analysis of beta diversity. Beta diversity is measured as the average distance from individual sampling observations (trawl sets) to their group centroid in multivariate space (ie. within each sub-area) as defined by a chosen resemblance measure. A focus on beta diversity measures based on both presence/absence and abundance can yield useful insights into the nature of changes in the communities. Accordingly, analyses of beta diversity will be performed on the basis of different resemblance measures.

Since 2004, IMR and PINRO have been jointly running the Barents Sea Ecosystem Survey between August and September when sea-ice coverage is at a minimum. With over 7,300 trawl sets available from the DFO, the Barents Sea survey (which annually produces 350-600 trawl sets and climate data) and additional satellite data recording the varying coverage of sea-ice, the project will provide new knowledge on the picture of fish biodiversity in these regions.

ECOSYSTEM-BASED MARINE MANAGEMENT

To evaluate the importance of different factors in predicting alpha and beta diversity (separately for each resemblance measure), Ellingsen and her collaborators will generate different models called for by the RCN's Marine Ecosystems sub-programme to understand how both climate and cod can affect fish biodiversity in the Barents Sea and the Scotian Shelf.

Moreover, although the original call from the RCN is focused on northern areas, it is likely that an extensive comparative study such as this will be useful for shedding light on the effects of trophic downgrading in general. In helping to answer questions regarding both the loss and dominance of the apex predator cod and how this augments climate change impacts, the methodologies developed by Ellingsen and her collaborators will provide the relevant authorities with invaluable early warnings on changes and help them develop an ecosystem-based approach to marine resources management.

Ecosystem-based management urgently needs to address the role of climate change in northern areas

INTELLIGENCE

ROLE OF A TOP PREDATOR AND CLIMATE IN SHAPING MARINE FISH BIODIVERSITY

OBJECTIVE

To evaluate the role of climate and dominant predators (notably cod) in shaping fish biodiversity in marine ecosystems.

Secondary objectives:

- To investigate how intensive exploitation and subsequent reduction of the apex predator cod affects fish biodiversity
- To investigate the effects on fish biodiversity where cod has increased dramatically both in numbers and distribution
- To examine how the impacts described above interact with climate change in shaping fish biodiversity

KEY COLLABORATORS

Norwegian Institute for Nature Research (NINA) • **Institute of Marine Research (IMR)**, Norway • **UiT The Arctic University of Norway** • **Polar Research Institute of Marine Fisheries and Oceanography** (PINRO), Russian Federation • **Bedford Institute of Oceanography** (BIO), Canada • **Massey University**, New Zealand

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KARI ELLINGSEN earned her PhD in Biology from the University of Oslo, Norway, where she then also completed her postdoctoral degree before becoming a research scientist from 2003-05. She is now Senior Researcher at NINA. Her research activities focus on the measurement and patterns of biodiversity, and the impact of humans and climate change on marine ecosystems.

NINA
Norwegian Institute for Nature Research