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Spatial ecosystem dynamics in a changing environment: overview from the Barents Sea

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ABSTRACT
The arctic Barents Sea is one of the Large Marine Ecosystems that is most sensitive to changing climate, and one where relatively small externally derived environmental changes can have large impacts on the spatial structure of the ecosystem. Furthermore, the Barents Sea is home to large stocks of gadoids and forage fish, supporting extensive commercial fisheries. As a result there exists an extensive time series of fisheries and ecosystem datasets, giving a detailed knowledge base with which to examine these changes. This presentation therefore presents an overview of some of the cases where changing environmental conditions are currently, or may soon be, changing the structure (especially the spatial structure) and hence the functioning of different components of the ecosystem. Examples presented cover predators, forage fish and plankton, and their interactions. The implications of these changes for current assessment and management procedures are highlighted and discussed.

Keywords: climate change, ecosystem, assessment

INTRODUCTION
The region has a complicated bathymetry, characterized by deep (up to 500m) troughs separated by shallow (c. 50-100m) banks. Environmental conditions are dominated by the balance between warm Atlantic waters entering from the west and cold Arctic waters entering from the north. Parts of the north of the Barents Sea are typically covered in sea ice during the winter, impacting on the spatial distribution of fish and plankton populations. Recent years have seen environmental changes, with increased temperatures and reduced sea ice cover. These changes have been associated with distributional changes in many of the marine organisms in the region. There exists an extensive time series of data for this region, including several stock specific surveys, extensive annual collection of stomach contents, and an annual ecosystem survey covering all components of the ecosystem across almost the entire Barents Sea. This rich data set gives the tools to analyse the ongoing changes and assess their impacts. Three examples of these changes are presented here, together with a discussion of what implications the changes have for the assessment and management of the main fish stocks in the region.

EXAMPLES
Example 1: Cod-capelin overlap
Warming waters and reduced sea ice cover have led to cod moving further north in the Barents Sea, giving them greater overlap with capelin, a preferred food. Increased cod predation on capelin could result in greater carrying capacity for cod, greater variability in cod stock size, and reduced capelin stock (and hence catches). Capelin are surveyed in the autumn, and the proportion maturing at that time is calculated. The fish then swim south to spawn and die the following spring. Fishing is conducted on their migration with an escapement rule, requiring a 95% for the SSB to remain above a set “safe” level. It was recognized early in the development of the fishery that estimating the

significant cod predation between the time of the survey and the time of the fishery was one of the key challenges facing the assessment, and this predation has been included in the stock assessment since 1990. There is an extensive annual collection of cod stomachs, so the change in overlap is already including in the capelin assessment model.

Example 2: Jellyfish

Jellyfish numbers and distribution expanded around 2000, possibly as result of warming waters, leading to concern that the ecosystem may become increasingly jellyfish dominated. The increase was marked by expansion of jellyfish into regions that previously had only low densities. Jellyfish are a significant predator on larvae and juvenile fish, and the years with high jellyfish stocks were associated with some years of below trend recruitment for some fish stocks. However as warming continued the jellyfish levels retreated to more moderate levels, and the distribution became more concentrated in the central Barents Sea again. An extensive ecosystem survey is conducted each summer, covering all of the Barents Sea and surveying all components of the ecosystem. This survey gives sufficient data make the jellyfish biomass and distribution estimates robust.

Example 3: Mackerel

Mackerel have been moving northwards into the Barents Sea, part of a wider shift in distribution in the stock in response to high abundance of fish, and possibly of favourable climatic conditions. Mackerel are known to feed on eggs and larvae of other species. There is therefore a concern that the increasing levels of mackerel could pose a threat to the recruitment success of the main commercial stocks of the Barents Sea. However, although it is clear that there are significant levels of mackerel present in the Southern Barents Sea at some point during the summer, it is not clear what the timing of their entry into (and exit from) the Barents Sea is each year. This means that we do not currently know what the spatial and temporal overlap with drifting larvae might be, making the extent of the threat posed difficult to identify. Ongoing survey efforts are in place to full this knowledge gap.

DISCUSSION

The three examples presented here give cases where the distribution of major components of the ecosystem have shifted in recent years, arguably in response to climatic variations. In all of the cases a sustained shift in distribution has the possibility to cause major changes in the functioning of the ecosystem. The examples presented cover a range of different scenarios: one case of what seems to have been a passing phase (jellyfish expansion), one which is ongoing and to some extent accounted for in stock assessment (cod-capelin), and one which is new and is the subject of active research (mackerel). In all three cases, however, the key is to have sufficient monitoring in place to identify trends of concern and provide the data requires to assess and, where necessary, address the changes.