A Synthesis of Results from the Norwegian ESSAS (N-ESSAS) Project

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ESSAS has several formally recognized national research projects. In Norway, it was entitled the Norwegian Component of the Ecosystem Studies of Sub-Arctic Seas (NESSAS) and was funded by the Research Council of Norway from 2005 to 2008. Its aim was to quantify the impact of climate variability on the structure and function of the marine ecosystem of the Barents Sea and adjacent waters in order to predict the ecosystem responses to possible future climate change and their possible economic impact. The scientific output during NESSAS included 39 primary publications, 13 book chapters, 4 edited volumes, 32 technical reports and 10 poster presentations. Several of the publications have been published since 2008, including earlier this year a synthesis of the NESSAS project (Drinkwater and the NESSAS Team, 2011, Progress in Oceanography 90: 47-61).

This synthesis paper highlights the project results dealing with climate forcing and its influence on the marine ecosystem, with special emphasis on the Barents Sea. New insights were provided on a number of important issues from physics to fish. Here we list only a few.

1. Arctic storms were found to be the dominate factor controlling the interannual ice extent in the Barents Sea through wind-forced advection of ice from the Arctic. On the other hand, storms travelling over the North Atlantic control sea ice variability at decadal time scales. More Atlantic storms produce reduced ice cover through induced melting because of increased inflow of warm Atlantic waters into the Barents Sea.
2. A new pathway for eastward flowing Atlantic Water to traverse the Barents Sea was identified, which flows north of Central Bank, making it 70% shorter than the well-known more southern route and potentially carries approximately 20-25% of the Atlantic Water that exits through the St. Anna Trough into the Arctic Ocean.
3. Heat budget studies using found the variability in heat content is primarily governed by fluctuations in the Atlantic Water inflow. The variability in this inflow is in part governed by centers of atmospheric sea level pressure anomalies, one located in the central and northern Nordic Seas and the other in the Mediterranean and North Africa, revealing the far field influences on the Barents Sea.

4. The biological responses to the long-term (60-80 year) Atlantic Multidecadal Oscillation
5. (AMO) showed that during the warm period from 1920s to the 1960s there was increased recruitment, growth and abundance of Atlantic cod as well as distributional shifts of this species northward and eastward in the Barents Sea. Also, there was proportionately more spawning off Northern Norway relative to spawning sites farther south along the Norwegian coast. Other species such as haddock, herring and capelin underwent similar range extensions within the Barents Sea and species that typically inhabited waters much farther south appeared in significant numbers.
6. In a follow-up study, comparison of cod responses to the early 20th century warming with responses during the recent warm period indicated similar responses, but of lower magnitude during the later period. The reduction in cod abundance and recruitment in recent years was attributed to the effects of intensive fishing reducing the spawning stock biomass.
7. Average primary production in the Barents Sea was found to be higher during the 2000s because of the reduction in sea-ice distribution.
8. Zooplankton modelling studies indicate high concentrations of Calanus finmarchicus during winter located off the shelf break in the eastern Lofoten Basin of the Norwegian Sea through a combination of deep circulation patterns and the vertical migration behavior of the zooplankton (Fig. 1).
9. Years with observed high cod recruitment are associated with higher primary production in the Barents Sea.
10. Changes in the water mass locations influence capelin distribution, although the capelin stock size determines how capelin distribute themselves within their preferred water mass. A larger stock spreads out to meet the greater food demand.
11. Modelling studies suggests that under future climate change the Barents Sea region may not experience a strong freshening during the present century despite increased melting of sea ice and enhanced river input because of the poleward transport of saline waters from the tropical Atlantic (Fig. 2).
12. The loss of summer ice in the Arctic will likely result in increased primary production, but the zooplankton, *C. finmarchicus*, while expanding farther east and north in the Barents Sea, will not be able to reside year-round in the Arctic Ocean.

13. In a warmer future, capelin are expected to likely move farther north and east in the Barents Sea and may establish new spawning grounds, e.g. on Novaya Zemlya and Svalbard.

14. Under climate change fish productivity in the Barents Sea is expected to increase and their distributions expand northward and eastward meaning more fish entering Russian waters.

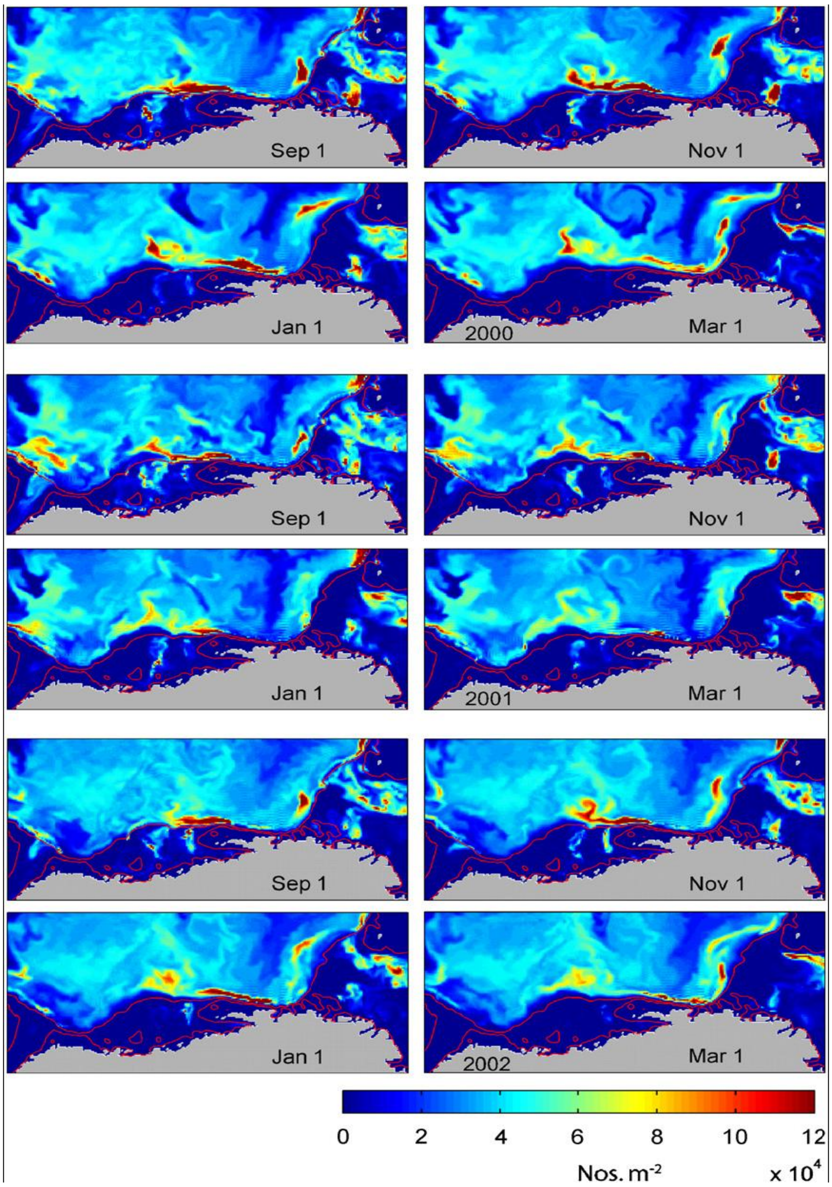

Fig. 1. The modeled concentrations of zooplankton (*Calanus finmarchicus*) in the eastern Norwegian Sea from September 1999 to March 2002. Note the high concentrations along the shelf slope especially off the northern coast and at the western entrance to the Barents Sea (right hand side of figures). These are held there by eddies and the mean circulation. (From Slagstad and Tande, 2007) .

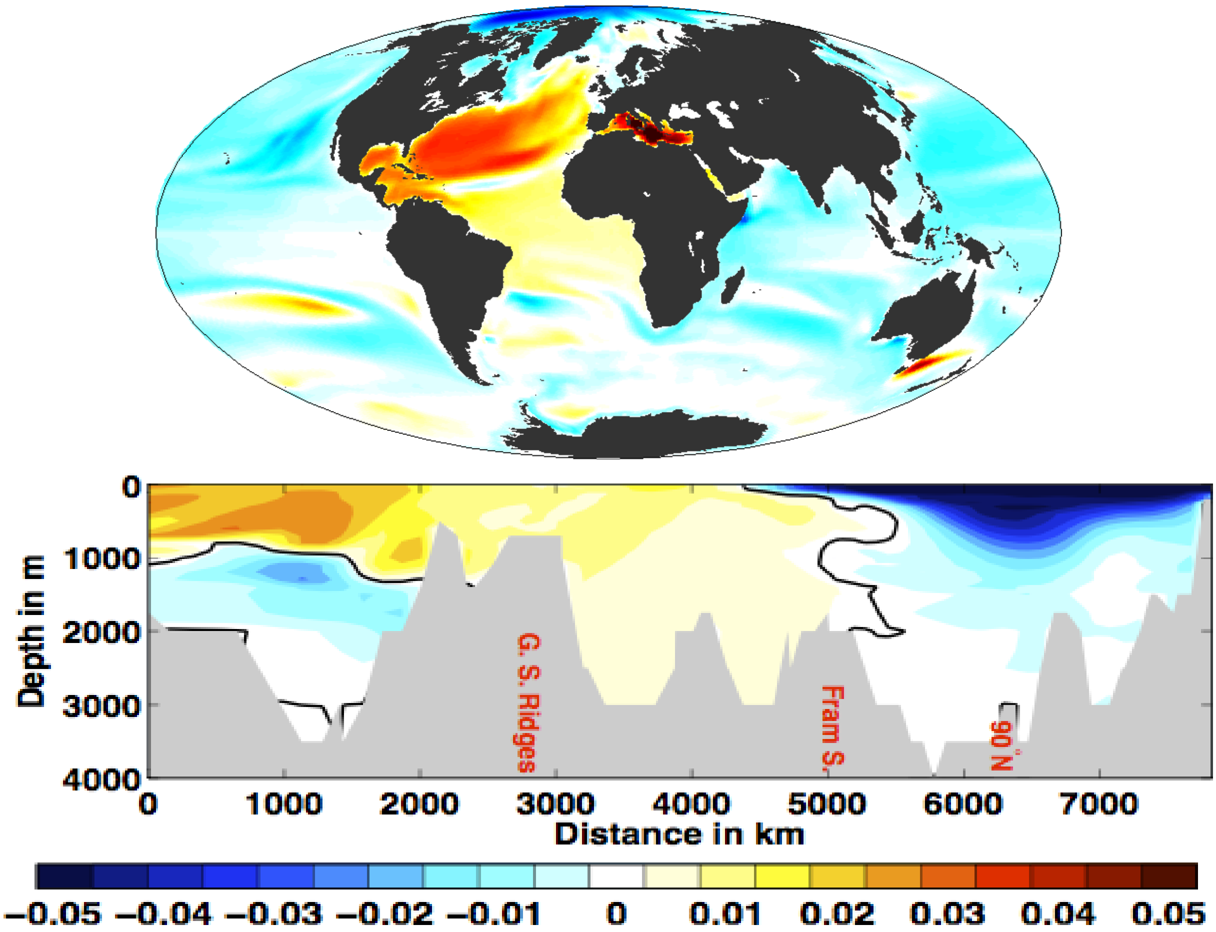

Fig. 2. The modeled surface salinity anomalies for the globe (top) and throughout the water column along an Atlantic-Arctic transect (bottom) under climate change. (Taken from Bethke et al., 2008).

15. Comparative studies between the Barents and Norwegian seas with Canadian ecosystems revealed a major change in the atmospheric forcing since the mid-1990s. Prior to this time the temperature in the Labrador and Barents Seas were out of phase and were linked to the NAO, however, after this time the temperature variability in the two regions have been similar with both showing signs of warming.

16. The level of primary production between the Barents and Bering seas and Georges Bank appears to be related to the available nutrient supply in the deep waters.

17. With the rise in temperatures, primary production in the seasonally ice covered Bering and Barents Seas has increased due to reduced ice cover. Increased production in the Gulf of Maine/Georges Bank region was also detected and may be related to increased nutrient supply (Fig. 3).

A more extensive list of results from NESSAS and further details about the above can be found in the synthesis paper and the references therein.

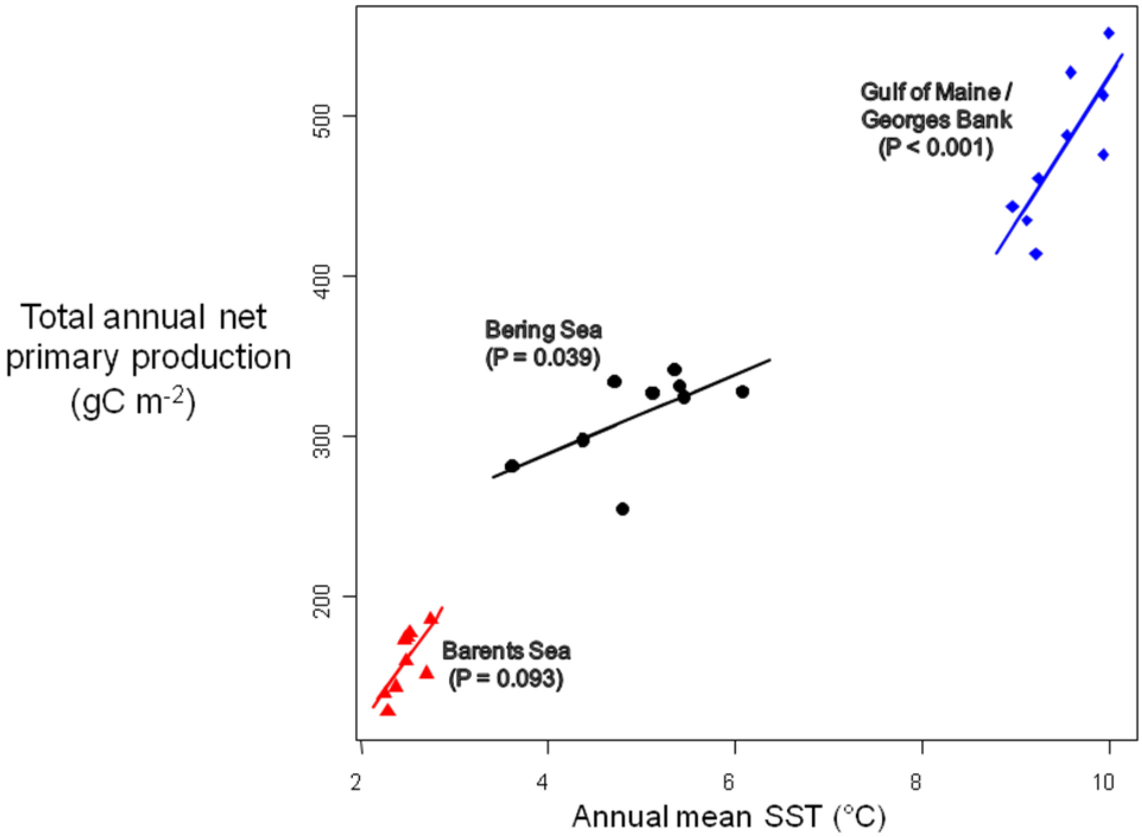

Fig. 3. The total annual net primary production for the Barents Sea, the Bering SE and the Gulf of Maine. The data represent the years 1998 to 2006. The linear fit to the data are provide along with the significance levels.

References

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