MCCIP Marine Climate Change Impacts Partnership

Topic

Plankton

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Executive summary

Major changes have taken place in both the plant (**phyto-**) and animal (**zoo-**) plankton of the seas around the British Isles over the last few decades. They include:

- The important decadal climate indicator for the North Atlantic, the NAO, has been rising along with Northern Hemisphere Temperatures over the past 30 years and the surface waters of the European Continental shelf have been warming. This has caused extensive changes in the planktonic ecosystem in terms of plankton production, biodiversity and species distribution which has had effects on fisheries production and other marine life (e.g. seabirds) (Reid & Edwards, 2001; Edwards *et al*, 2001, 2002; Beaugrand *et al*, 2003, 2004; Richardson & Schoeman, 2004; Southward *et al*, 2004; Alheit *et al*, 2005; Heath, 2005) .

- In the North Sea the population of the previously dominant and important zooplankton species, (the cold water species *Calanus finmarchicus*) has declined in biomass by 70% since the 1960s. Species with warmer-water affinities are moving northward to replace the species but are not numerically as abundant (Beaugrand *et al*, 2004; Edwards *et al*, 2007).

- There has been a northward shift in the distribution of many plankton and fish species by more than 10° latitude (over 1000km) over the past fifty years. This shift is particularly associated with the shelf edge current running north along the European continental margin (Beaugrand *et al*, 2002; Brander *et al*, 2003; Genner *et al*, 2004).

- The seasonal timing of plankton production also altered in response to recent climate changes. Some species are occurring up to four to six weeks earlier than 20 years ago. This has consequences for plankton predator species, including fish, whose life cycles are timed in order to make use of seasonal production of particular prey species (Edwards & Richardson, 2004).

- The decline of the European cod stocks due to overfishing has been exacerbated by climate induced changes in plankton production. The survival of young cod in the North Sea appears to depend on the abundance, seasonal timing and size composition of their planktonic prey. As the stocks declined they have become more sensitive to the effects of regional climate warming due to shrinkage of the age distribution and geographic extent (Brander, 2005).

- Future warming is likely to alter the geographical distribution of primary and secondary **pelagic** production, affecting ecosystem services such as oxygen production, **carbon sequestration** and **biogeochemical cycling**. These changes may place additional stress on already-depleted fish stocks as well as have consequences for mammal and seabird populations.

Full review

Overview

In Northern European Seas and waters surrounding the British Isles changes in both plant (**phyto-**) and animal (**zoo-**) plankton species and communities have been associated with Northern Hemisphere Temperature (NHT) trends and variations in the North Atlantic Oscillation (NAO) index (Edwards *et al*, 2001; Beaugrand & Reid, 2003). These have included changes in species distributions and abundance (Beaugrand *et al* 2002), the occurrence of sub-tropical species in temperate waters, changes in overall phytoplankton biomass and seasonal length (Edwards *et al*, 2001), changes in the North Sea ecosystem (Reid & Edwards, 2001; Edwards *et al*, 2002; Beaugrand 2004), community shifts, **phenological** changes and changes in species interactions (Edwards & Richardson, 2004). These major changes in the plankton primarily caused by regional climate warming have had important impacts on other higher **trophic levels** (e.g. fish, seabirds). Future warming is likely to alter the geographical distribution of primary and secondary plankton production (0-5 yrs), affecting ecosystem services such as oxygen production, **carbon sequestration** and biogeochemical cycling (20-50yrs). Ocean acidification may become a problem in the future (100yrs).

Introduction

Plankton are at the base of the food chain and are the source of food for all other marine organisms. The carrying capacity of ecosystems in terms of the size of fish resources and recruitment to individual stocks is highly dependent on variations in the abundance, timing and composition of the plankton. These organisms also play a crucial role in climate change through the export of the important greenhouse gas CO_2 to the deep ocean by carbon sequestration in what is known as the 'biological pump'. Without this process concentrations of CO_2 would be much higher in the atmosphere and the climate of the world would be much warmer.

Future change

Regional climate warming has had and is continuing to have a major effect on the plankton in Northern European seas. Future warming is likely to alter the geographical distribution of primary and secondary plankton production (0-5 yrs), affecting ecosystem services such as oxygen production, carbon sequestration and biogeochemical cycling (20-50 yrs). These changes may place additional stress on already-depleted fish stocks as well as have consequences for mammal and seabird populations. Ocean acidification may become a problem in the future (100yrs) and has the potential to affect the process of calcification, therefore certain organisms such as molluscs and components of the plankton may be particularly vulnerable to future CO_2 emissions (Feely *et al*, 2004). Potentially, chemical changes to the oceans and its effect on the biology of the oceans could reduce the ocean's ability to absorb additional CO_2 from the atmosphere which in turn could affect the rate and scale of global warming.

Natural variability vs human induced climate change

The observed changes have been significantly linked to regional hydro-climatic variability (sea surface temperature, salinity, oceanic inflow, wind strength and direction, nutrients and water column stability) that is associated with regional climate warming, the **NAO** and NHT. It is the significant statistical association with the latter index of hemispheric warming that suggests that the changes are a regional response to global warming. The observations summarised in the executive summary primarily come from the 75 year old **Continuous Plankton Recorder (CPR)** survey, but are confirmed by other single point time series such as that collected at Helgoland and through intercomparison with satellite measurements.

Relative importance of climate change to other human pressures

Other factors such as eutrophication, fisheries and future acidification may also contribute to plankton variability, but they are believed at present, by general consensus, to be less important than hydro-climatic forcing at large regional scales. However, eutrophication may be a problem at local-scales

(Edwards *et al*, 2006) in certain areas and acidification may be a serious problem in the future if planktonic organisms are unable to adapt fast enough to the changing environment. Little is known of the adaptive capacities of plankton organisms, however, due to their fast regeneration times they may be able to adapt faster than higher organisms; There is some evidence from the southern North Sea that climate change might exacerbate eutrophication effects. In summary, at the ecoregional scale climate change is the dominant driver of long-term plankton trends.

Regional Variations

At the provincial (Northern European Seas) and ecoregional scale (i.e. North Sea, Celtic Sea) there are no major significant differences to general trends. Climate change impacts, however, are more exacerbated in the southern North Sea due to this region warming faster than other Northern European sea areas. There is smaller-scale variability in the patterns of change seen in the plankton, but the general trends described in the executive summary are characteristic of all waters around the UK.

Confidence assessments

'What is already happening' – Medium

'What could happen in the future' - Low

There is a medium to high level of confidence in what is happening to the plankton now based on information from the **CPR** survey and corroborated through smaller-scale surveys and satellite observations. For example, changes in the biogeography and phenology of plankton are highly significantly correlated with Northern Hemisphere Temperature changes. We are less (medium to low) confident of future scenarios.

Knowledge gaps

- Understanding and predicting rapid and abrupt ecosystem shifts.
- Mechanistic links between climate warming, plankton and fisheries to form a predictive capacity.
- Understanding the rate of genetic adaptation to climate change impacts.
- Identifying species or communities particularly vulnerable to climate change impacts.
- Understanding the processes involved in the biological pump and quantifying its global spatial and temporal variability.
- Determining the mechanisms behind observed temperature increases off the continental margins of Europe including **advective** processes and their effect on Northern European Seas.
- **Filling major gaps in the coverage of pelagic and biochemical measurements in the global oceans in particular the Arctic Oceans and Nordic Seas.**

Commercial impacts

The changes in the plankton have had a major impact on commercial fish stocks and the general carrying capacity and health of marine ecosystems. For example, the decline in gadoid biomass, especially cod has been linked with plankton, and can also explain the marked reduction in returns of salmon to home waters (Beaugrand *et al,* 2003; Beaugrand & Reid, 2003). A climate link has also been established between plankton, sandeels and seabirds (Frederiksen *et al*, 2006).

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