IMPACTS OF CLIMATE CHANGE ON SEABED ECOLOGY

Chris Frid
School of Biological Sciences, University of Liverpool

Executive Summary

The UK marine environment comprises a major part of the European sea area (around 7.6%, the second largest share of any member state) and it delivers significant benefits to the UK and European economies (around 5% of the UK GDP is marine related). Much of this is dependent on processes and resources associated with the seafloor.

The UK lacks any national programme to assess the state of the sea floor ecosystem (benthos). Limited data are available for intertidal areas of conservation importance and the National Marine Monitoring Programme network of sites covers estuaries and a limited number of nearshore stations with data runs over around 10 years. The two offshore (6 and 12 nautical mile) stations that are part of the *Dove Time Series* (an element of the MECN) represent probably the best benthic time series anywhere in the world, however they cannot provide the spatial coverage needed for a UK perspective of factors influencing sea floor ecosystem dynamics. The assessment is based on a recent major review of data for the wider North Sea (Clark and Frid, 2001) and analyses of the Dove series (Robinson, 2004).

Climatic processes, both directly, e.g. winter mortality, and indirectly, via later hydrographic conditions, influences the abundance and species composition of sea bed communities. This will directly affect the availability of food for bottom feeding fish such as cod and haddock, impact on shellfish populations (*Nephrops* and scallops/clams) and potentially alter patterns of biodiversity and ecological functioning. This could in turn alter rates and timing of processes such as nutrient cycling, larval supply to the plankton and organic waste assimilation. These relationships are visible in the only multi-decadal UK time series of sea bed ecology and so extension to other areas is on the basis of interference. At local (although still large) spatial scales there is also evidence of effects resulting from fishing impacts and at smaller scales habitat modification and impacts from contaminants.

Level of Confidence

Low for climate effects – we only have ONE data set which extends over more than 2 decades and it only covers 1 area. Medium for other impacts – a variety of studies have covered fishing, habitat and pollution effects at appropriate temporal and spatial scales

Key sources of Information

See Supporting Evidence

Supporting Evidence

The UK lacks any national programme to assess the state of the marine benthos (Defra, 2005). Limited data are available for intertidal areas of conservation importance and the NMMP network of sites now covers estuaries and a limited number of nearshore stations with data runs over around 10 years. The two offshore (6 and 12 nautical mile) stations that are part of the *Dove Time Series* (an element of the MECN) represent probably the best benthic time series anywhere in the world, however they alone cannot provide the spatial coverage needed for a UK perspective. This assessment is based on a recent major review of data for the wider North Sea (Clark and Frid, 2001) and analyses of the Dove series (Robinson, 2004).

The North Sea has a long history of benthic ecological research. Most early records were taken from the easily accessible intertidal and inshore areas. Initial sublittoral benthic samples were taken using adapted oyster dredges, introduced in 1773 (Petersen 1918). Such devices were also used to collect data across the North Sea (Möbius and Bütschli 1875; Michaelsen 1896). The first quantitative benthic sampling gear was pioneered by Petersen, as early as 1896 (Petersen and Boysen-Jensen 1911). Blegvad was the pioneer of detailed sampling of the North Sea area during the early 20th century (Davis 1923; Davis 1925). The *Dana* expedition in the 1950s provided another snapshot, and more recently a series of research studies, e.g., the ICES North Sea Benthos Survey (Duineveld *et al.,* 1991; Heip *et al.,* 1992; Kunitzer *et al.,* 1992), and pre-drilling studies for the oil and gas industries have provided greater coverage of the seabed fauna. However, the available data do not provide a spatially continuous coverage of the whole of the North Sea and this makes it more difficult to establish the role of mechanisms which operate over large spatial scales (e.g., climate and meteorological changes).

Analysis of the available data (Clark and Frid, 2001) identify three major changes in the North Sea benthos:

- Biomass and abundance was higher during the 1980s compared with the 1970s in both littoral (Balgzand) and sublittoral (Northumberland, Skaggerak) stations.

- Changes in abundance off Northumberland (M1 and P) occurred between 1980 and 1981, coinciding with a noticeable shift in community structure at one of the stations. At the 100m-deep Skaggerak station, these changes were observed to occur a year earlier, between 1979 and 1980, while at Balgzand, the change in abundance and biomass that also occurred between 1979 and 1980 was accompanied by a shift from larger- to smaller-sized individuals.

- Between the 1920s and the 1980s, three out of five communities in the central and southern North Sea showed a definite change, whilst between the 1950s and 1980s, the Dogger Bank benthos showed a decline in long-lived taxa, although total biomass had increased, mainly because of an increase in opportunistic species.

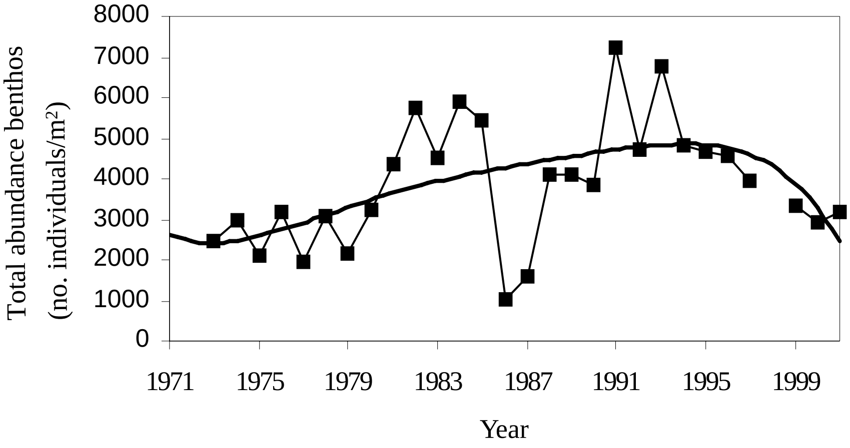
The primary mechanism governing changes in both abundance and community structure of the North Sea benthos appears to be through changes in the amount of sedimenting plankton, the main source of food for the benthos. Changes in the benthos in response to increases in organic matter reaching the sea floor would be expected to increase the productivity of the benthos (Pearson and Rosenberg 1986). Such changes were observed to occur around the late 1970s and early 1980s at a number of sites. Increases in both zooplankton and phytoplankton productivity in the North Sea also occurred at this time. Whether it is changes in climate or nutrients forcing the community depends mostly on the region concerned, as climatic effects predominate in the central and northern North Sea area, yet in the southern North Sea, the influence of climate is overridden by the magnitude of nutrient inputs into the region. The direct effect of temperature on benthic communities is also involved in forcing long-term changes, and for some communities these changes may be as important as changes in food supply. Cold winter temperatures predominantly cause increased mortality upon littoral macrobenthic communities, although they have also been recorded as affecting sublittoral communities (Beukema, 1985; 1992). Lower temperatures also exert a selective effect on the community by removing vulnerable species and allowing resilient species to thrive in the conditions of reduced competition (Kröncke *et al.,* 1998). In addition to these large-scale environmental factors, there are numerous types of anthropogenic influences (hypoxia, fly ash, sewage sludge dumping) on benthic communities. However, these effects tend to be restricted to the immediate area of the benthos affected. An exception to this is through the large-scale impact of trawling of the sediment, which suggests that trawling has been involved in shifting the benthos from long-lived to more opportunistic taxa in many areas of the North Sea. Unfortunately, this change from long-lived, slowly reproducing species to small species with a high reproductive rate (opportunists) is similar to that caused by increased food supply to the benthos, meaning that it is difficult to distinguish between changes in the benthos caused by fishing and those changes due to increased food supplies.

Recent analysis (Robinson 2004) of the Dove benthic series (Figures 1-4) have for the first time identified a signal due to climatic forcing (as opposed simply to winter temperature). It would be expected that the communities at the two benthic Stations, M1 and P, would respond together to regional scale extrinsic drivers and over the first 10-15 years of the Dove Time Series this did appear to be the case. At Station M1, a strong link between primary productivity and both benthic production and community structure was found over the 30-year period, agreeing with previous analyses of the shorter time-series (Buchanan, 1993). On analysing the updated time-series in this study, benthic production at M1 was also found to associate with the GSNW position of the same year and with the winter NAO Index of the previous year. This translation of climatic signal to the benthos was not obviously mediated through a mechanism involving primary production, as the associations between phytoplankton productivity and the same climatic variables did not correspond with those of the benthos at M1.

Please acknowledge this document as: Frid, C. (2006). Impacts of Climate Change on Seabed Ecology *in* Marine Climate Change Impacts Annual Report Card 2006 (Eds. Buckley, P.J, Dye, S.R. and Baxter, J.M), Online Summary Reports, MCCIP, Lowestoft, www.mccip.org.uk

Figures

a)



b)

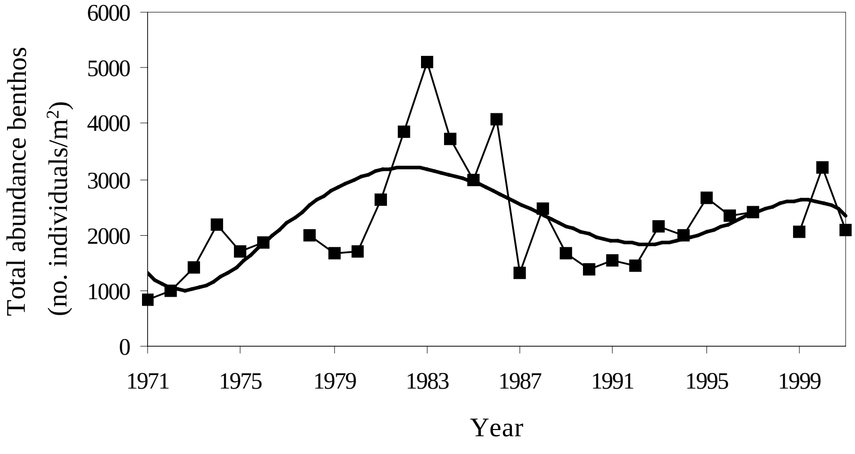
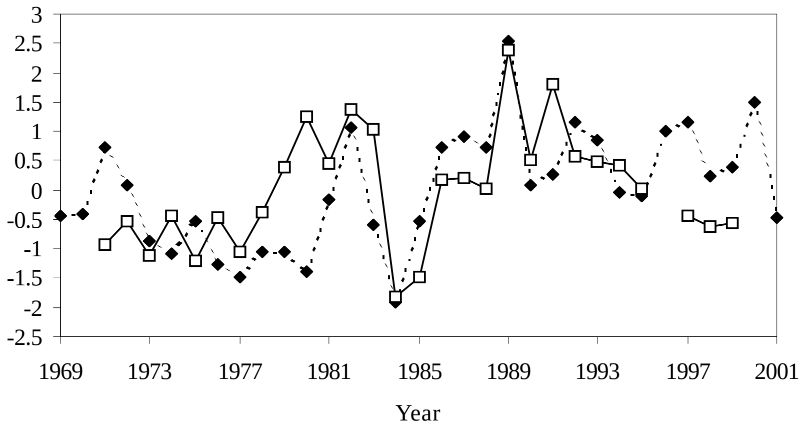


Figure 1. Annual total benthic abundance at (a) Station M1 and (b) Station P (indiv. per m^2) with a 5th order polynomial to emphasise long-term trend.

a)



b)

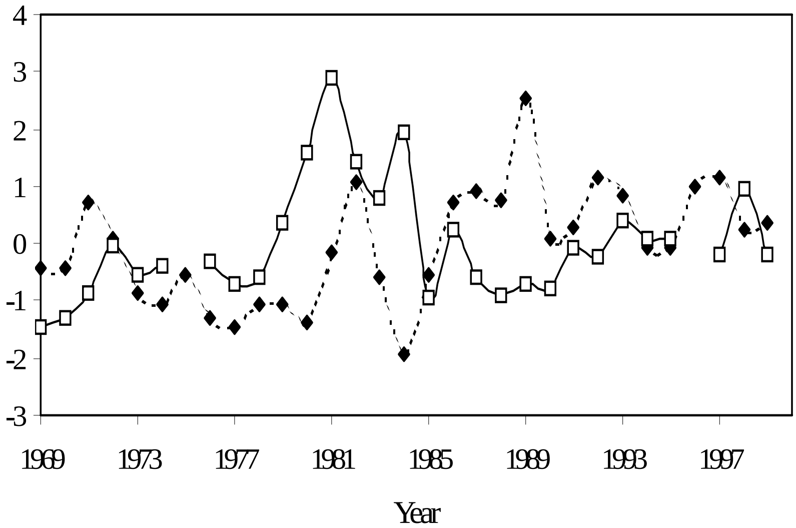
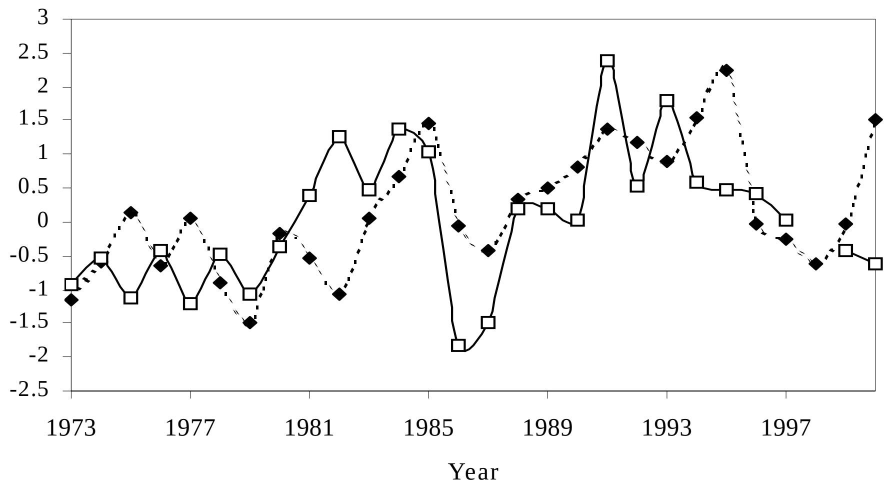


Figure 2. Standardised time-series plot of Phytoplankton Index (dotted line) with (a) M1 and (b) P benthos at a 2-year lag (solid line),

(a) r^2=22.5%, p=0.037



(b) r^2=17.3%, p=0.033

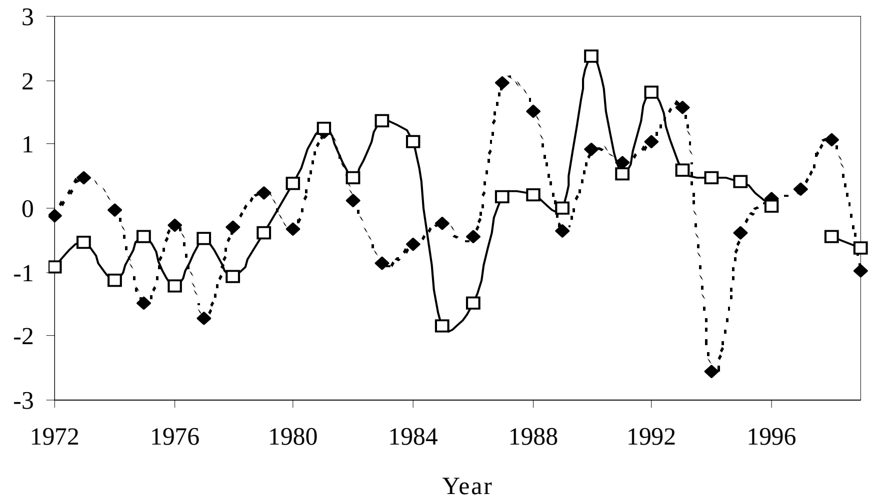


Figure 3. Standardised time-series plot of (a) GSNW position (dotted line) with M1 benthos (solid line), and (b) NAO Winter Index with (dotted line) M1 benthos at a 1-year lag (solid line).

(a)

(b)

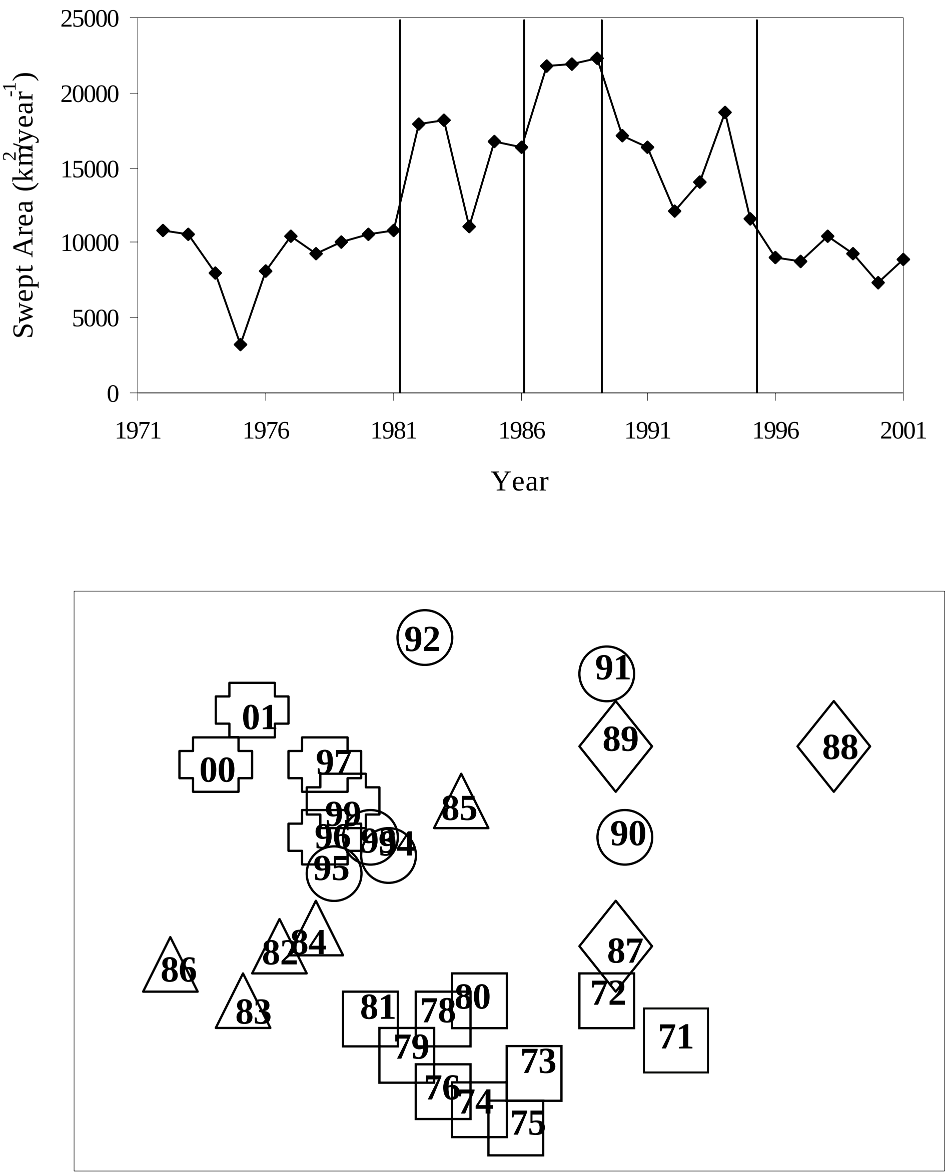


Figure 4. (a) Time-series plot for the average swept area ($km^2.y^{-1}$) of ICES rectangle 39E8 and, (b) MDS ordination of the Bray-Curtis similarity in genera composition of P benthos, with superimposed phases of fishing effort;

Low effort , medium effort , high effort , post-high medium effort and post-high low effort .

References

Beukema, J. J. (1985). In Marine biology of polar regions and effects of severe winters on high and low tidal flats in the Dutch Wadden Sea (ed. Christiansen, J. S. G. a. M. E.) 351-361 (John Wiley and Sons, London, 1985).

Beukema, J. J. (1992). Expected changes in the Wadden Sea benthos in a warmer world: Lessons from periods with milder winters. *Netherlands Journal of Sea Research* **30**, 73-79.

Clark, R. A. and Frid, C. L. J. (2001). Long-term changes in the North Sea ecosystem. *Environmental Reviews* **9**, 131-187.

Davis, F. M. (1923). Quantitative studies on the fauna of the sea bottom. No. 1 Preliminary investigations of the Dogger Bank. Fishery Investigations. Ministry of Agriculture, *Fisheries and Food Series* **2** 6, 1-54 (1923).

Davis, F. M. (1925). Quantitative studies on the fauna of the sea bottom. No. 2 Results of the invesigations into the southern North Sea 1921-1924. Fishery Investigations. Ministry of Agriculture, *Fisheries and Food Series* **2** 8, 1-50.

DEFRA (2005). Charting Progress: An Integrated Assessment of the State of UK Seas. Department of Environment, Food and Rural Affairs, London.

Duineveld, G. C. A., Kunitzer, A., Niermann, U., Dewilde, P. and Gray, J. S. (1991). The Macrobenthos of the North-Sea. *Netherlands Journal of Sea Research* **28**, 53-65.

Heip, C., Basford, D., Craeymeersch, J.A., Dewarumez, J.M., Dorjes, J., de Wilde, P., Duineveld, G., Eleftheriou, A., Herman, P.M.J., Niermann, U., Kingston, P., Kunitzer, A., Rachor, E., Rumohr, H., Soetaert, K. and Soltwedel, T. (1992). Trends in Biomass, Density and Diversity of North-Sea Macrofauna. *Ices Journal of Marine Science* **49**, 13-22.

Kröncke, I., Dippner, J. W., Heyen, H. and Zeiss, B. (1998). Long-term changes in macrofaunal communities off Norderney (East Frisia, Germany) in relation to climate variability. *Marine Ecology Progress Series* **167**, 25-36.

Kunitzer, A., Basford, D., Craeymeersch, J.A., Dewarumez, J.M., Dorges, J., Duineveld, G.C.A., Eleftheriou, A., Heip, C., Herman, P., Kingston, P., Niermann, U., Rachor, E., Rumohr, H. and Wilde P.A.J. (1992). The Benthic Infauna of the North-Sea - Species Distribution and Assemblages. *Ices Journal of Marine Science* **49**, 127-143.

Michaelsen, W. (1896). Die polychaetenfauna der deutschen Meere, eischlisslich der benachbarten und verbindenden gebiete. Wissenschaftliche Meeresuntersuchugen Kiel 1872-73, 229-268.

Möbius, K. and Bütschli, O. (1875). Zoologische ergebnisse de Nordseefahrt IV Echindermata. Jahresberichte der Kommission Wissenschaftliche Untersuchugen Deutschen Meere Kiel Fur 1872-73 2-3, 143-152.

Pearson, T. H. and Rosenberg, R. (1986). In Organization of communities: past and present (eds. Gee, J. H. R. and Giller, P. S.) 373-398 (Blackwell Scientific, 1986).

Petersen, C. G. J. and Boysen-Jensen, P. (1911). Valuation of the sea. Animal life of the sea bottom, its food and quantity. *Report of the Danish Biological Station* **10**, 1-76 (1911).

Petersen, C. G. J. (1918). A survey of work done in connection with the valuation of the Danish waters from 1883-1917. *Report of the Danish Biological Station* **25**, 1-62.

Robinson, L. A. (2004). The Scientific Basis for an Ecosystem Approach to Managing Benthic Systems. PhD Thesis, University of Newcastle, Newcastle upon Tyne.