Marine Climate Change Impacts Partnership

Topic

Seabed ecology

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Executive summary

The UK lacks any national programme to assess the state of the sea floor ecosystem (benthos). The **National Marine Monitoring Programme** network of sites covers estuaries and a limited number of nearshore stations with data runs of over 15 years. The two *Dove Time Series Stations* (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.

- The available data show that climatic processes, both directly, e.g. winter mortality, and indirectly, via **hydrographic** conditions, influence the abundance and species composition of sea bed communities.
- These variations 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.
- The alteration in the seafloor communities could alter rates and timing of processes such as nutrient cycling, larval supply to the plankton and organic waste assimilation.
- At local (although still large) spatial scales there is also evidence of effects resulting from fishing impacts and at smaller scales habitat modification e.g. wind farms, and impacts from contaminants e.g. oil and gas exploration, waste dumping.

- Changes to sea temperature and / or food supply are likely to continue to alter the ecological structure of the seabed.

Full review

What is already happening

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 15 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 & Frid, 2001) and analyses of the Dove series (Robinson, 2004; Frid *et al. in press*).

The North Sea has a long history of benthic ecological research. Petersen pioneered the first quantitative benthic sampling gear as early as 1896 (Petersen & 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 North Sea and this makes it 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 (stations 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 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 was 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). It has been possible to predict the patterns of concurrence of benthos at shallow (5-20m) sites in the southern North Sea on the basis of the hydrography (as indexed by **NAO**) the previous winter (Dippner & Kröncke, 2003).

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 vicinity of the activity. 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 identified a signal due to climatic forcing (as opposed simply to winter temperature). At Station M1, analysis of the updated time-series showed benthic abundance to be associated 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.

In addition to the direct evidence of change coming from studies of the seafloor there have also been attempts to infer change in the benthos from changes in other data series. For example, Lindley *et al.* (1995) noted changes in the abundance of larvae in the plankton and linked this to changes in the benthos, with a marked shift occurring around the 1980s. Lindley & Batten (2002) considered the possibility that this arose from an increase in the abundance of the burrowing sea urchin *Echinocardium cordatum* that does well in mild winters. Kirby & Lindley (2005) used molecular techniques to identify 94 echinoderm larvae from North Sea CPR plankton samples. Useful DNA was extracted from 24 larvae and of these 18 were larvae of burrowing sea urchins, 3 of brittlestars and 3 from spiny starfish. This suggests that the rise in echinoderm larvae noted since the 1980s is largely due to increases in urchins and thus is consistent with an effect due to milder winters. However, the authors did not comment on the apparent lack of increase of adult urchins in benthic time series (Fig. 1). This then raises the possibility that the best benthic time series we have is not representative of larger area or that the planktonic shift reflects changes in larval production/survival that are not reflected in adult numbers. Buchanan & Warwick (1974) considered, based on data collected between 1964 and 1972, that M1 was representative of the fauna and ecology of a large area of inshore sediments. Therefore this result may actually reflect changes in the timing of events in the plankton causing an altered survivorship, a phenomenon that has been evoked to explain changes in the dynamics of fish larvae (Beaugrand *et al.* 2003).

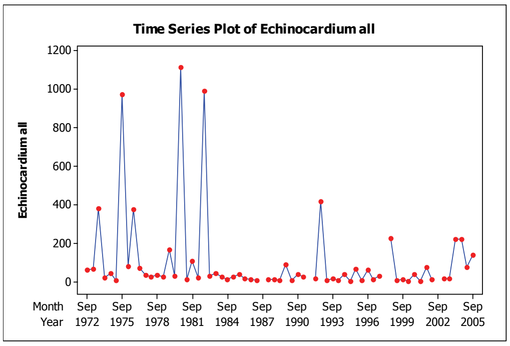

Figure 1. Mean (n=5; 0.1m^2 grabs) number of *Echinocardium* per square metre in the benthos at Dove time series station M1. The large increase in larval numbers recorded in the plankton from the 1980s is not seen in the adult

Heath (2005) indicated a long-term increase in benthic invertebrate production in the North Sea. Whilst this is attributed to a reduction in predation from fish, associated with reduced predator population abundance caused by fishing, there may well still be an environmental component underpinning the change in the benthos.

In the northern North Sea (Scottish waters) the DTI Monitoring Committee have initiated work, financed by UKOOA (now Oil & Gas UK), looking at three sites with reasonable time series data dating from the 1980s. In 2005-2006 these sites were re-surveyed using the same techniques and the same targeted strategy as in the original work. The analysis of the samples is still being undertaken and as yet nothing can be said about the results apart from the fact that they will be available towards the end of this year.

In parallel with these targeted surveys the Monitoring Committee also instigated a random stratified survey of the macrobenthos of the Fladens area based on the strategy previously employed by FRS to look at the hydrocarbon contamination of far field sediments (remote from production facilities). This demonstrated that background values, by the early part of the new century, showed a decrease when compared to the levels measured in the 1980s and

1990s. Preliminary analysis of these samples demonstrated that the fauna of the area was very homogeneous and there was little obvious impact of offshore operations. Again these data are in the process of being more deeply analysed and it is hoped they will be published in autumn, 2007.

As far as ongoing work is concerned, another random stratified survey, this time of the East Shetland Basin, will be conducted in the latter part of July this year, again under the sponsorship of Oil & Gas UK and directed by the Monitoring Committee.

What could happen in the future

There is no reason to suspect that benthic systems will stop responding both directly to environmental drivers such as sea temperature or indirectly to changes in the food supply. Both of these are strongly influenced by climatic factors and so continued climate change will be reflected by continued change in benthic systems. To date changes have been manifest in changes in species composition but not major shifts or changes in gross productivity. This is likely to remain the case in the short to medium term.

However, as the extent of the environmental change grows then so does the likelihood of a major shift. Many marine systems are known to exhibit alternative states (i.e. be susceptible to phase shifts) and there is therefore the possibility of a major shift in system dynamics. It is impossible to predict when this might occur. It may be the result of invasion through range expansion of southern species, loss through range contraction of northern species or be precipitated by a species introduced by man.

Given the broad similarity of benthic communities around the world the system is not likely to look vastly different i.e. polychaetes, molluscs and echinoderms will still dominate the macrofauna but there remains the possibility that ecological processes will be severely altered.

Confidence assessments

'What is already happening' – Medium

There is a growing body of data – direct and indirect, for change in benthic systems over the last 2-3 decades. This is based on a limited number of locations. It is less certain that climate is the main driver of the changes. It is clear that fishing has also brought about large scale, multi-decadal changes and any effects of **eutrophication** in the southern North Sea will have also contributed to benthic change via altered food inputs.

'What could happen in the future' - Low

Very limited data. The predicted changes go outside the range of current observations, the system has non-linear dynamics, and it is multi-factorial, so predictive power is limited.

Knowledge gaps

Better spatial coverage – i.e. more offshore data sets/monitoring and in more regions.

Commercial impacts

Potentially a large impact on fish stocks due to changed prey availability. Altered patterns of species abundance will impact on nutrient regeneration, waste processing and biodiversity. This could compromise delivery of other ecosystem services.

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