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Observing change in a North Sea benthic system: A 33 year time series

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ABSTRACT

Since 1972 the macro-benthic infauna at station M1, 10.5 km off the Northumberland coast (central western North Sea), have been sampled by grabbing each March and September. The data series now includes over 500 taxa from 327 genera. During the 1970s the system showed a regular alternation of high and low abundance years and this was interpreted as evidence of density dependence, when this broke down in the 1980s winter temperature appeared to be involved. After 20 years of data collection analysis of the time series, showed that variability had increased and that there was a very strong link to phytoplankton production in the overlying water. The latest analyses show that this relationship has now also disappeared. The number of genera represented in the system has increased over time while total productivity has not altered significantly. Multivariate ordinations also show changes through time with breakpoints occurring in the early 1980s and early 1990s. The coastal benthos of this region shows decadal scale and longer term changes in biological composition and ecological function. The system is certainly influenced by climatic variation, environmental conditions (winter temperature) and carbon flux to the benthos. Over the 33 year time series none of these appears to have a dominant effect, rather different factors seem to dominate at different times. The extent to which this is due to a biological 'system memory' imposed by good recruitments of long lived taxa would warrant further study.

1. Introduction

With the adoption of the Convention on Biological Diversity (CBD) (United Nations, 1992), managing the impact of human activities on the environment to ecologically sustainable levels has shifted from being an option to a legal necessity: sustainability is now the over arching goal of environmental management policy. Ecosystems have a natural resilience. This means that the real challenge for managing how humans impact on the system is understanding the key drivers and determining the sustainable limits (Frid et al., 2006). That is to say, what are the natural drivers on the system and how does the system vary over time in response to these factors and what are the types and levels of human activities that can be sustained without compromising the functioning of the ecosystem? Or to put it another way, it is a case of determining limiting factors when multiple factors may impinge upon a system at any one time (see Hiddink and Kaiser, 2005). Those resulting from human actions might be subject to management while knowing the role of natural drivers may influence how human activities are managed.

A key policy tool for delivering sustainable use of ecosystems and conservation of ecological functioning is the application of management measures developed using the 'ecosystem approach' (Frid et al., 2005). European countries are required to develop and implement ecosystem-based management in the marine environment to fulfil their obligations to the Rio Convention on Biological Diversity (United Nations, 1992), the Jakarta Mandate on Marine and Coastal Biological Diversity (United Nations, 1995), the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem (FAO, 2001), the EC Common Fisheries Policy (EC, 2002), the World Summit on Sustainable Development (United Nations, 2002) and the Convention for the Protection of the Marine Environment of the North–East Atlantic (OSPAR, 2003).

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The recognition that future management must be informed by better understanding of ecosystem dynamics has prompted a resurgence of interest in long-term ecological studies. This is seen as essential to understand and manage environmental change caused by factors such as changing climate and broad-scale human impacts on marine ecosystems (e.g. eutrophication and fishing) (Frost et al., 2005). There exist only a few long term (>25 year) marine ecological studies and a similar number of studies have used historic data to make comparisons with contemporary data sets (for review see Frost et al., 2005).

Three multi-decadal time-series are collected off the northeast coast of England in the central-west North Sea (Clark and Frid, 2001) (Fig. 1). Originally established by staff from the University of Newcastle's Dove Marine Laboratory, data collection continues using the same methods as when the series commenced (Clark and Frid, 2001). One series considers mesozooplankton and is not considered further. The other series are of benthic macrofauna at two offshore stations away from local river discharges.

Studies undertaken at a number of scales across the North Sea have identified a role for climatic forcing in the structuring of both zooplankton and benthic invertebrate communities (Taylor and Stephens, 1980; Colebrook, 1986; Aebischer et al., 1990; Fransz et al., 1991; Taylor et al., 1992; Beukema, 1992a,b; Kroncke et al., 1998; Taylor, 1995; Reid et al., 2001; Warwick et al., 2002). Previous analyses of the Dove time-series datasets have revealed some trends that parallel the pattern of variation in the climatic indices (Evans and Edwards, 1993; Frid and Huliselan, 1996), but the high resolution of the series also suggests the operation of smaller scale complex mechanisms of community control, involving extrinsic drivers, intrinsic biotic feedback and anthropogenic forcing (Buchanan and Moore, 1986a,b; Buchanan, 1993; Frid et al., 1996, 1999; Frid and Huliselan, 1996; Nicholas and Frid, 1999; Clark and Frid, 2001; Clark et al., 2003).

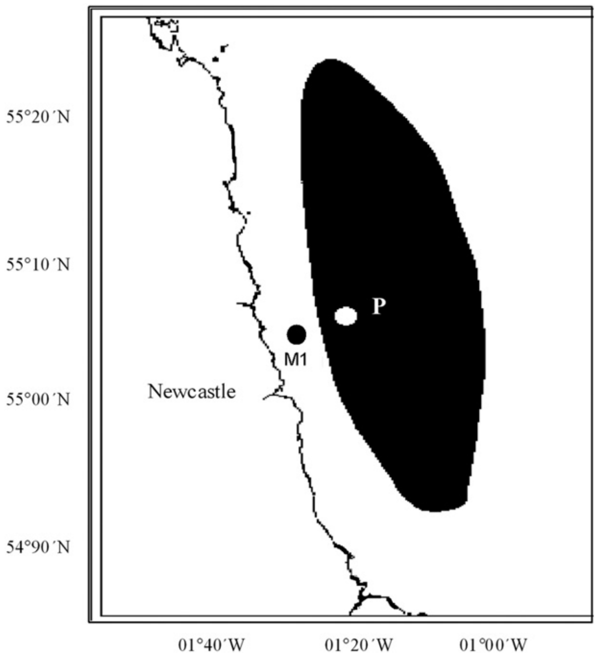

Fig. 1. Location of the benthic stations, M1 and P, in the western central North Sea and the CPR area C2 from which the phytoplankton data were derived.

Ideally, the level of understanding of the relationships between particular drivers and the associated response in ecosystem components should allow the forecasting of trends given particular scenarios. Over recent years, close links between proxies of oceanic scale climate phenomena and weather and hydrography patterns in the North Sea have been identified (Dickson et al., 1988; Taylor, 1996; Reid et al., 2001). For example, the North Atlantic Oscillation accounts for a third of the total variance in sea-surface air pressure over the North Sea. Therefore, there may be the possibility to make predictions about regional scale weather and hydrographic patterns in the North Sea using oceanic scale climatic proxies. However, utilising these for bioresource management, nature conservation protection or simply predicting the variability in key ecosystem components is unlikely to be straightforward. The drivers are likely to operate in both a nested fashion, biotic interactions will occur within an envelope of environmental conditions set by the meteorology, but also may involve non-linear interactions, for example the strength of settlement being influenced by the match of planktonic larvae to their food supply.

The Dove benthic time series include two stations M1 and P. In the initial period of study both stations showed similar dynamics however from around 1980 the behaviour diverged (Buchanan and Warwick, 1974; Buchanan et al., 1978). Analysis of the series in the 1970s suggested a clear role of winter temperature in controlling dynamics (Buchanan et al., 1978) but with the change in behaviour attention switched to the role of organic flux at station M1, a factor that did not seem to be important at the deeper station P (Buchanan et al., 1986; Buchanan and Moore, 1986a,b). Subsequent analyses focussed on M1 and the role of organic flux and benthic–pelagic coupling in benthic dynamics (Austen et al., 1991; Buchanan, 1993; Frid et al., 1996). More recent analyses of the benthos at Station P have suggested that local fishing activity may have a major influence on the variability in community structure (Frid et al., 1999; Bremner et al., 2005). In this paper we focus on the dynamics over the last 33 years of the infaunal benthos at station M1, 10.5 km off the coast of Northumberland.

2. Methods

2.1. Dove Benthic series—M1, 1972–2005

Station M1 lies some 10.5 km off the Northumberland coast (Fig. 1). It has predominantly sandy sediment, with a 20% silt–clay content and lies in 55 m of water (Frid et al., 1996, 1999). Sampling commenced in September 1972 and the dataset analysed here covers samples taken in March and September of each year between September 1972 and 2005. No samples were taken, due to weather or operational constraints, in September 1987, 1991 and 2002 and March 1998.

On each sampling at least 5 0.1 m^2 grab samples were collected (5 replicates has been the standard since 1978 but in some of the early years as many as 20 were taken). Each was gently sieved over a 0.5 mm mesh and the residue fixed in 4% buffered formalin. All organisms were identified to species, where possible and enumerated. Buchanan and Warwick (1974) and Buchanan and Moore (1986a) describe the