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20. Macroalgal Mat Development and Associated Changes in Infaunal Biodiversity

Eunice Pinn and Martin Jones

School of Conservation Sciences, Bournemouth University, Talbot Campus, Fern Barrow, Poole, Dorset BH12 5BB

Blooms of macroalgal matting, comprising opportunistic species such as *Ulva lactuca*, are becoming increasingly common in Poole Harbour. A hostile environment is usually created in the sediment below a dense algal mat, influencing the invertebrate faunal assemblage. This preliminary study was conducted over a 6 month period during which a dense mat of *U. lactuca* developed and subsequently dispersed in Holes Bay. The algal mat was found to have a significant negative impact on species richness, abundance and biomass of the infauna. The results are discussed in relation to impacts on the ecosystem as a whole.

Introduction

Although blooms of ephemeral green algae are a natural component of estuarine habitats (Everett, 1991), they are becoming increasingly prevalent around the world (Morand and Briand, 1996; Pihl *et al*., 1999; Viaroli *et al*., 2001). These exceptional blooms are thought to be indicators of anthropogenically induced eutrophication at the sediment/water interface (Everett, 1991; Fletcher, 1996). The presence of these mats can lead to major changes in the biogeochemical cycles (Morand and Briand, 1996; Valiela *et al*., 1997), which can result in modification of food chains, faunal community structure and ecosystem processes (Valiela *et al*., 1997; Raffaelli *et al.*, 1998).

At the base of the mat, an anoxic gradient gradually develops due to decomposition of the algae (Bolam *et al*., 2000). In addition, the water within the mat can become super-saturated (Krause-Jensen *et al*., 1999), which leads to severe diurnal fluctuations in oxygen (D'Avanzo and Kremer, 1994). Bacterial decomposition has been demonstrated to increase dramatically within both the sediment and the water column (Nedergaard *et al*., 2002), leading to hypoxia and anoxia. This can be prolonged, resulting in the accumulation of sulphides due to the activity of sulphate-reducing bacteria (Viaroli *et a*l., 2001). It is these biochemical changes that result in modifications to the macrofaunal community and, consequently, effects higher up the food chain.

In recent years, macroalgal mats of *Ulva lactuca* have become increasingly common in Poole Harbour. Concerns have been expressed by the RSPB and English Nature regarding the impact of the annual mats on the wildfowl using the harbour. The aim of this study was to assess this impact, in part, by investigating the effect of the macroalgal bloom on the invertebrate fauna of the harbour.

Methods and materials

The study area was sited within Holes Bay, an enclosed bay of Poole Harbour with limited tidal flushing, and conducted from June to November 2002 at a permanently marked site measuring 50 m x 50 m. Due to the nature of the site, it was not possible to have a control position where no algal mat development occurred.

At monthly intervals, 30 0.25 m^2 randomly placed quadrats were used to determine the percentage coverage of the algae; 30 75 mm diameter sediment cores were also extracted on a monthly basis, to a depth of 150 mm. The sediment obtained was washed through a 0.5 mm sieve and the macrofaunal obtained recorded to species level.

Analysis of variance (ANOVA) was undertaken for species richness (i.e. number of species present per core), the infaunal abundance (i.e. total number of individuals per core) and biomass (i.e. wet weight (g) of infauna per core including shells of live molluscs) data. Prior to analysis, data were tested for homogeneity of variances using Levene's test. Data transformation, however, did not remove the heterogeneity. Underwood (1997) reported that for large balanced data sets, violations in the assumption of homogeneity and normality were unlikely to affect the F ratio. It was, therefore, decided to undertake the ANOVA using the non-transformed data, but with a more conservative probability of 0.01 (Connell, 2001).

Results

Within 2 months of the first visit in June, a dense algal mat had developed. Mean coverage increased to a maximum of 91.0% in August (Figure 1). Thereafter, mean coverage declined, reducing to 3.8% by November when the survey finished.

A total of 15 infaunal species were identified from Holes Bay (Table 1). Infaunal richness was generally very low on a monthly basis, with a maximum of 1.5 ± 0.9 per core observed in June. Species richness then declined to 0.6 ± 0.7 per core in August as the mat developed (Figure 2a). Thereafter, species richness remained at a reduced level, with the lowest value being recorded in November (0.6 ± 0.6 per core). Using ANOVA, these differences were found to be statistically significant (P<0.001, f [5, 174] = 7.212).

Infaunal abundance declined steadily from a maximum of 3.7 ± 2.2 per core in June to a minimum of 0.9 ± 1.2 per core in September, with the lowest value recorded in November (0.8 ± 0.9 per core) (Figure 2b). ANOVA revealed these differences to be significant (P<0.001, f [5, 174] = 14.229). Infaunal biomass peaked in July (0.55 ± 0.74 g per core), whilst August had the lowest biomass (0.15 ± 0.37 g per core). In October and November, infaunal biomass appeared to increase to values close to those observed

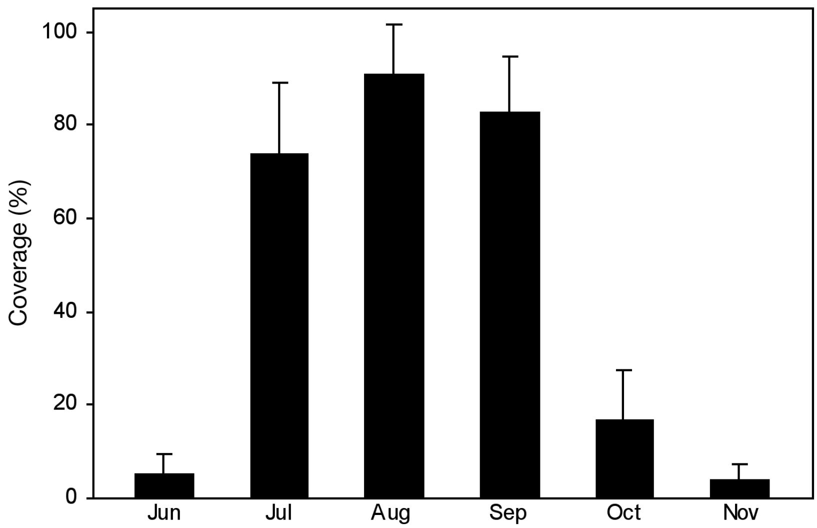

Figure 1 Development of the macroalgal mat.

at the start of the study (Figure 2c). These variations were found to be statistically significant (P <0.01, f [5, 174] = 3.143).

Discussion

In this preliminary 6 month study, marked changes were observed in the invertebrate community of Holes Bay. It should be noted that due to the lack of a suitable control site the changes observed cannot be causally linked to mat development. However, over the spring/summer period, when this study was conducted, the infaunal community would normally be expected to have the highest levels of species diversity and abundance of any time of year (Souza and Gianuca, 1995; Tuya *et al*., 2001; Rueda and Salas, 2003). It is likely, therefore, that the marked changes observed in the community are associated with the development of the macroalgal mat.

As the mat developed, there was an initial increase in infaunal diversity and abundance. However, this rapidly declined as the mat became more dense. Similar observations associated with the development of macroalgal blooms have been made by Lopes *et al*. (2000) and Bolam *et al*. (2000). The changes occurring in the benthic community in relation to macroalgal blooms are extremely complex (Hull, 1988; Raffaelli *et al*., 1998). The effects of macroalgal blooms are often similar to those resulting from organic enrichment, including an increase in opportunistic species such as *Capitella capitata* (Bolam *et al*., 2000; Lopes *et al*., 2000).

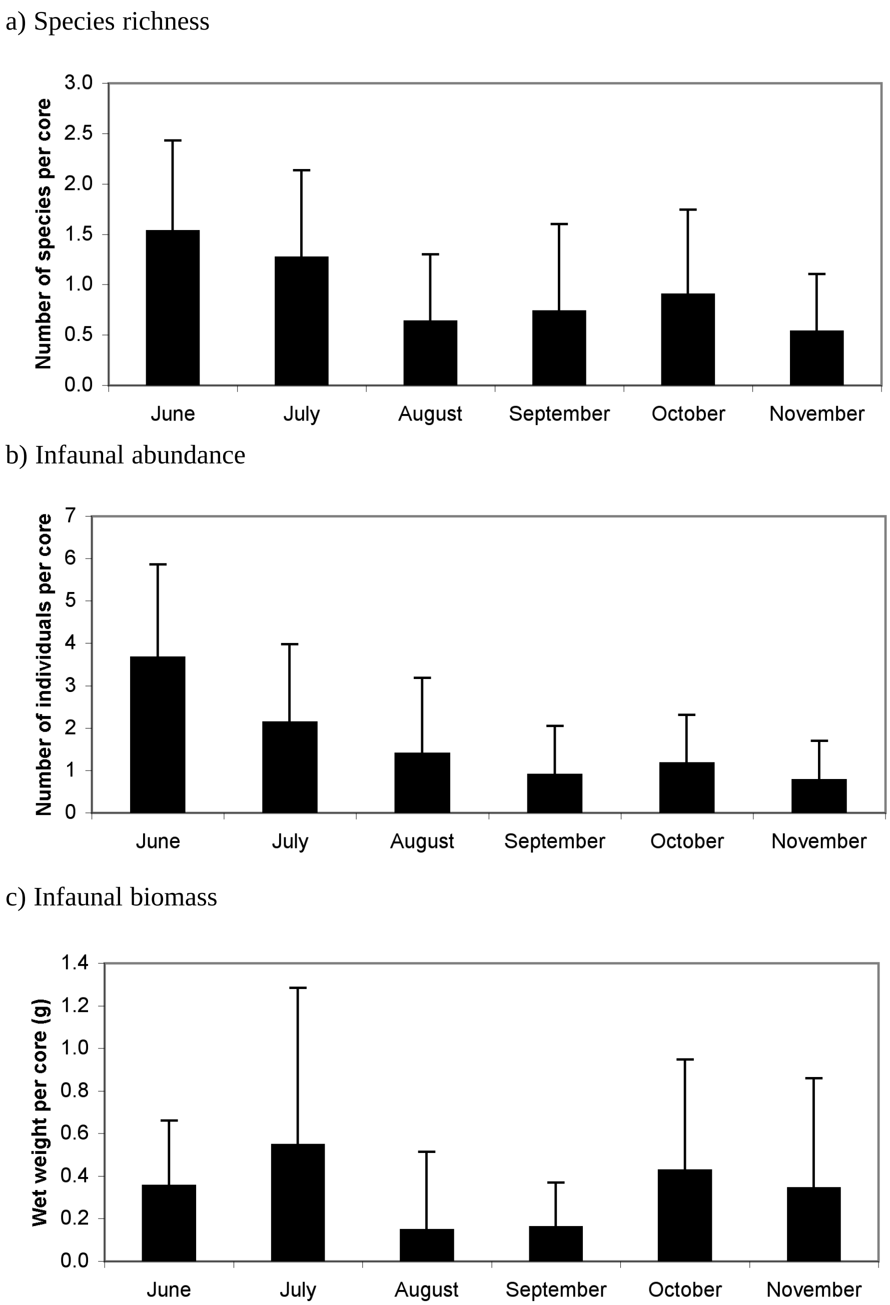

Figure 2 Variation in infaunal community.

Table 1 The infaunal community

	June	July	August	September	October	November
Hediste diversicolor	C	C	C	C	C	C
Nereis zonata	C					
Nereis pelagica	C	C		C		
Perineris cultifera	C			C		
Arenicola marina						C
Nephtys caeca					C	
Capitella capitata					C	
Hydrobia ulvae	C	C	C	C		
Tapes descussatus	C		C	C	C	
Lutraria lutraria	C	C				
Cerastoderma edule		C				
Gari costulata		C				
Venerupis senegalensis						C
Carcinus maenus		C				
Peachia cylindrica	C	C	C	C	C	

C = present in cores.

Hediste diversicolor is a typical estuarine species and the dominant member of the infauna observed in the current study. Conflicting reports on the impact of algal mats on this species have been published, ranging from increasing abundance (Norkko and Bonsdorff, 1996; Österling and Pihl, 2001), through initial increases then declines (Lopes *et al*., 2000), to steady declines (Lewis *et al*., 2003). In the current study, the abundance of this polychaete declined steadily, whilst biomass measurements did not decline initially. This may indicate that initially *H. diversicolor* gained from the impact of the mat on other species, but subsequently succumbed itself to the environmental impacts of the algal bloom.

Bivalve molluscs are another important component of estuarine communities. Everett (1994) and Österling and Pihl (2001) found that bivalves such as *Macoma balthica* and *Cerastoderma* spp. decreased in abundance under macroalgal mats. In contrast, Hull (1988) and Bolam *et al*. (2000) reported greater numbers of bivalves. In the current study, although mollusc abundance initially increased, latterly it declined with almost all bivalve species being lost from the system by November. Bolam *et al*. (2000) proposed that these differences relate to algal biomass, with bivalve numbers only declining at higher algal densities.

Any long-term altering of the benthic community could have a cascading effect on ecosystem function (Franz and Friedman, 2002). A shift to ephemeral green algae from other habitat types will result in dramatic alterations in the invertebrate community and complexity of the ecosystem. In some areas, this has already had an effect higher up the food chain (e.g. Raffaelli, 1999; Lewis *et al*., 2003). It will be necessary to undertake further, more detailed surveys in Holes Bay before the effect of the annual macroalgal bloom can be assessed. It is likely, however, that the bloom will impact on the important wildfowl populations of the area.

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