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The effect of green algal mats on intertidal macrobenthic communities and their predators

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Abstract

Eutrophication by sewage effluent has led to the development of extensive mats of green algae over much of the former open mudlands of Langstone Harbour on the south coast of Britain. The presence of the mat reduces the biomass and diversity of the mud-dwelling infauna but a great increase in the number and biomass of epibenthic animals (primarily *Hydrobia ulvae* Pennant) produces a total biomass almost twice that of open mudlands. Although the common invertebrates are favoured prey for many estuarine birds these algal areas are avoided by the dense aggregation of waders and wildfowl.

Introduction

Recent studies have been made of the marine invertebrates of intertidal mudflats and of the wildfowl and waders which feed over the mudlands. The intertidal muds investigated were in Langstone Harbour which forms with Portsmouth Harbour and Chichester Harbour extensive and connected tidal basins on the central south coast of England.

Langstone Harbour is an almost enclosed tidal basin of 19.4 km^2 with a shore line of 24.94 km (Fig. 1). Tidal ranges of between 2.0 m and 4.1 m occur in the harbour. The sediments exposed at low water occupy 87 % of the Harbour area and consist mainly of fine silts with small areas of saltmarsh, *Spartina* marsh and some sand in the south. Three main channels drain these flats and converge to the narrow Harbour mouth leading to the Solent. Three small streams enter the north-eastern corner of the Harbour. However, the freshwater flow is very low and the small volume of freshwater has little effect on the Harbour's 34‰ salinity.

Since the 1950's, Langstone Harbour has received increasing quantities of domestic sewage effluent from two discharge points, one in the north-east (Budd's Farm) and the other at the Harbour entrance at Fort Cumberland. Fully treated effluent from Budd's Farm sewage works is discharged at a volume of 46 million litres per day ($m \cdot l \cdot d^{-1}$) and 59 $m \cdot l \cdot d^{-1}$ of untreated effluent is discharged from Fort Cumberland. The effects of the effluent on the ecology of the Harbour have been studied by DUNN (1972) and PORTSMOUTH POLYTECHNIC (1976). These reports have shown that species of green algae, mainly *Enteromorpha* spp. and *Ulva* spp. have increased in abundance in the Harbour subsequent to the opening of Budd's Farm sewage works. Also experiments have shown that green algae respond vigorously in culture to enrichment by sewage effluent (LETTS and RICHARDS 1911, PRINCE 1974, PORTSMOUTH POLYTECHNIC 1976). A recent survey of the intertidal vegetation in Langstone Harbour was carried out in August, 1979 (COULSON and BUDD 1979). At this particular time 42% of the

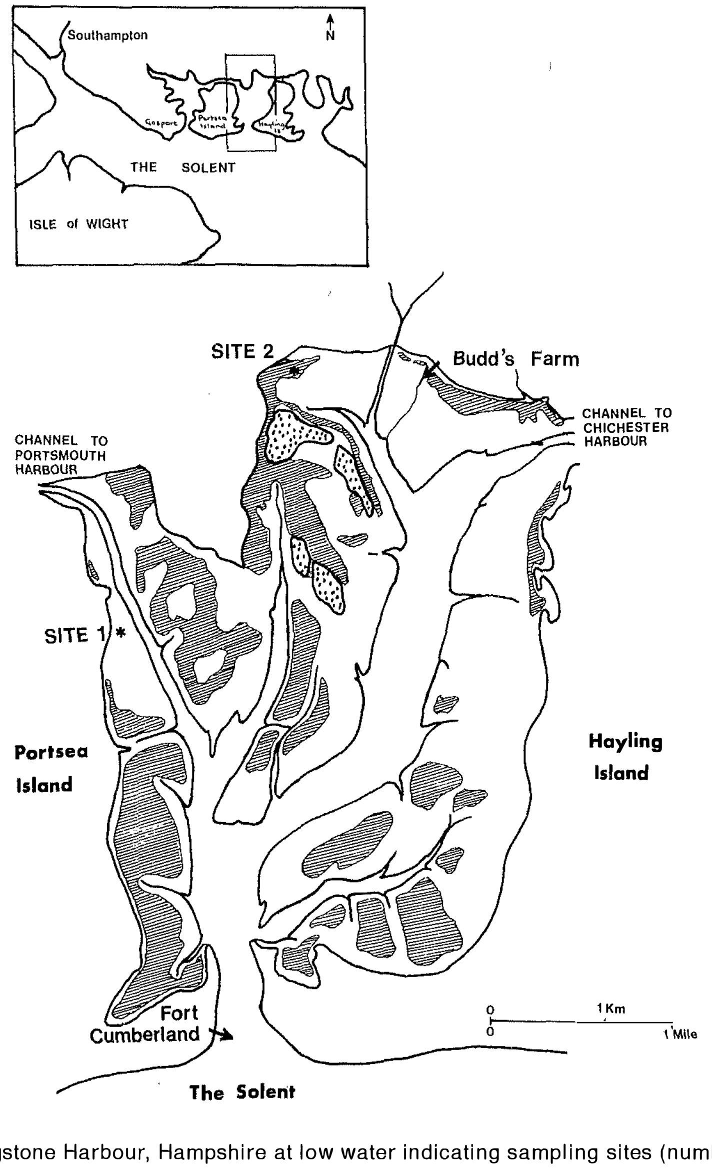

Figure 1

Map of Langstone Harbour, Hampshire at low water indicating sampling sites (numbered), four islands (stippled) and the area covered by *Enteromorpha* spp. and *Ulva* spp. (shaded), August, 1979

intertidal area was covered by green algae and only 40% lacked a vegetation cover. In more sheltered areas of the Harbour, where conditions are very favourable for growth, a continuous and dense covering of green algae can occur, with the algal mat being 10 cm to 12 cm deep. These mats are visible on the surface from May to December after which they break down and become covered with sediment. In these areas the sediment is anaerobic with high concentrations of hydrogen sulphide even in the lower layers of the algal mat. Such conditions persist throughout the whole year.

MARTIN (1973) investigated the mud fauna in Langstone Harbour using quantitative methods and demonstrated that the mud supported an abundant fauna. WITHERS and THORP (1978) have described the invertebrate macrofauna in the sandbanks. Observations from the Clyde (PERKINS and ABBOTT 1972) and Medway (WHARFE 1977) estuaries have indicated that algal mats affect mud flat fauna. The first part of this paper describes the effect of green algal mats on intertidal macrobenthic communities.

Portsmouth, Langstone and Chichester Harbours together rank as one of the eight most important British intertidal systems for wader and wildfowl populations (PRATER 1974) supporting twice the number of waders per unit area than any other intertidal system. Internationally, the Harbours are of special importance for Grey Plover (*Pluvialis squatarola*), Curlew (*Numenius arquata*), Black-tailed Godwit (*Limosa limosa*), Dunlin (*Calidris alpina*), Shelduck (*Tadorna tadorna*) and Brent Geese (*Branta bernicla*) (Table 1). TUBBS (1977) has analysed data since 1952 to identify changes in the populations of the thirteen most numerous species. Of these, nine have increased in the Harbour, one has exhibited no long-term trend and three have declined. The

Table 1

Midwinter peak counts of some waders and wildfowl in Chichester, Langstone and Portsmouth Harbours as proportions of British and European/North African populations, 1971/72 to 1974/75 (TUBBS 1977)

	Average midwinter population	% British population	% European/ N. African population
Oystercatcher *Haematopus ostralegus*	2,045	1.0	0.4
Ringed Plover *Charadrius hiaticula*	339	3.2	0.8
Grey Plover *Pluvialis squatarola*	1,518	18.9	3.5
Curlew *Numenius arquata*	2,134	2.8	1.4
Black-tailed Godwit *Limosa limosa*	1,189	8.5	1.7
Bar-tailed Godwit *L. lapponica*	1,460	2.4	0.5
Redshank *Tringa totanus*	2,007	2.0	0.8
Dunlin *Calidris alpina*	61,721	9.5	4.4
Dark-bellied Brent Goose *Branta bernicla bernicla*	9,844	28.0	16.6
Shelduck *Tadorna tadorna*	4,644	6.6	1.9

second part of the paper discusses the feeding distribution of waders and wildfowl and the possible causes for the decline of Curlew, Redshank (*Tringa totanus*) and Shelduck.

Materials and methods

Invertebrate macrofauna

Sampling intertidal soft sediments presents problems which have been discussed by COULSON et al. (1980). In this present survey two study areas were chosen, one on the west shore of the Harbour (site 1, Fig. 1) which had no previous record of algal cover, the other on the north shore (site 2, Fig. 1) where a continuous and deep cover of algae occurred from year to year. Both these areas were on the mid-tide level and had similar substrate types (Md. ∅ 4.9). Each area was divided into strips of 2 m x 24 m across the tidal contour. One strip was sampled each month from November 1976 to April 1978. To avoid the effect of disturbance new strips were sampled each month. Twelve cores of mud were taken on each sampling occasion to a depth of 15 cm using a polythene tube with a cross-sectional area of 0.017 m^2. In the area with algal cover, small quadrats of algae (0.04 m^2) were taken off the mud surface before a core was taken and preserved and sorted at a later date. The mud cores were taken to the laboratory, placed in a bucket of water and gently broken down by hand to form a slurry. This was passed through a 0.5 mm mesh aperture sieve. All material remaining in the sieve was preserved in 4 % seawater formalin and Rose Bengal (0.5 g l^{-1}). The animals were identified, counted, washed free of formalin and dried in a vacuum oven at 60 °C. They were then ignited in a muffle furnace at 550 °C for 4 hours so that the ash-free dry weight could be determined and this was used as a measure of biomass.

Estuarine birds

Counts of waders and wildfowl have been carried out in Langstone Harbour at monthly or shorter intervals since 1952 and the data have been used to identify changes in the populations of the thirteen most numerous species (TUBBS 1977). From 1977 to 1978 the feeding distributions of Shelduck and eight waders were mapped. The waders were Oystercatcher (*Haematopus ostralegus*), Grey plover, Dunlin, Knot (*Calidris canutus*), Redshank, Black-tailed Godwit and Curlew. In addition, observations on feeding behaviour were made during August and September 1978. The methods for this have been explained in more detail by TUBBS and TUBBS (1981).

Results

Invertebrate macrofauna

The results are presented in Tables 2 and 3 and Figures 2, 3 and 4. The more noteworthy features can be summarised as follows: The species composition of the two sites is very similar (Table 2, columns 1 and 2; Fig. 2) but the relative abundance of individual species differs considerably (Fig. 2).

At site 1 a typical fauna of open mudflats is present with many species each well represented in number. In contrast the algal covered site has only a few species with high numbers, with molluscs comprising 70% of the total (Table 2, column 4).

The polychaete data reveal these site differences very clearly. Characteristic estuarine species e.g. *Nereis diversicolor* Müller, *Ampharete acutifrons* Grube, *Tharyx marioni* Saint-Joseph and *Manayunkia aestuarina* Bourne are abundant in the open conditions at site 1, but occur only in low numbers at site 2 where the dominant species are *Capitella capitata* Fabricus and *Scolelepis fuliginosa* Claparède (Fig. 2). However the oligochaete, *Peloscolex benedeni* Udekem, was abundant at both sites.

Table 2

Representation of the various taxa in terms of numbers and species found at site 1, no algal cover (i) and site 2, dense algal cover (ii) (Nov. 1976 to Nov. 1977)

	Numbers of species		Mean number of species month^{-1}		Mean number of individuals		% of total number of individuals month^{-1}	
	i	ii	i	ii	i	ii	i	ii
Oligochaeta	2	2	2	2	11,413	10,480	37.5	17.2
Polychaeta	15	14	11	6	9,474	7,444	31.2	12.3
Crustacea	6	5	2	2	89	130	0.3	0.2
Mollusca	4	6	4	6	9,370	42,533	30.8	70.0
Others	4	5	3	3	65	156	0.2	0.3

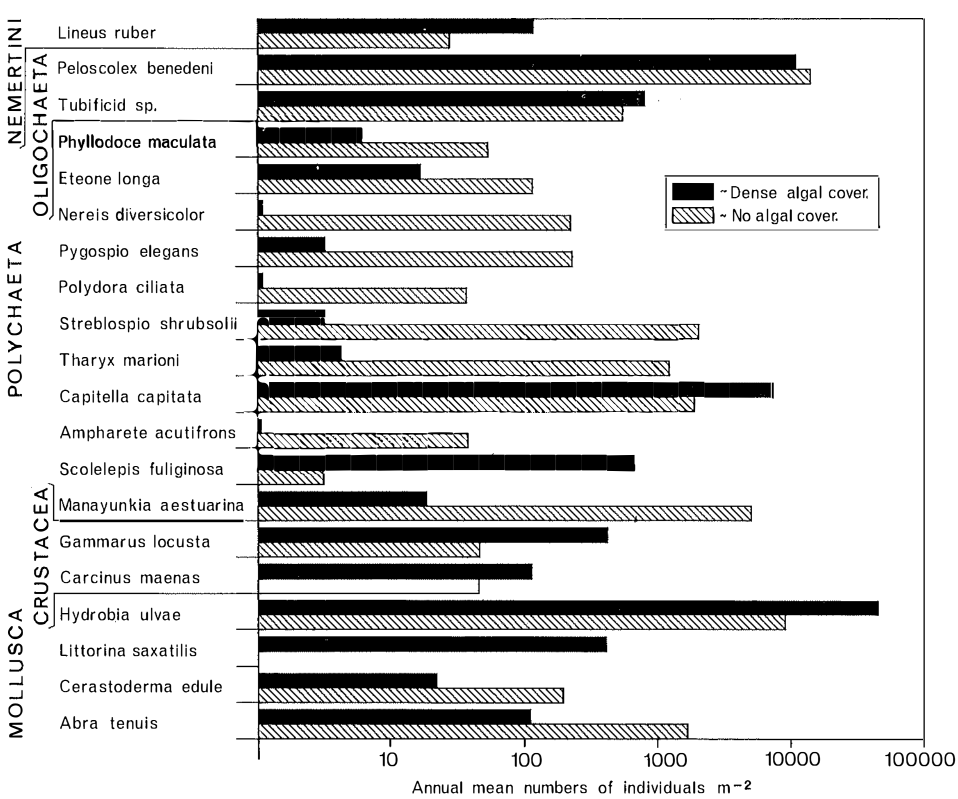

Figure 2

Annual mean numbers of the main species of invertebrates at site 1, no algal cover and site 2, dense algal cover

Molluscs contribute most of the biomass at both sites (Fig. 4). The bivalves (Lamellibranchia) are the major contributors in open muds but the gastropoda predominate in the algal site. Although these epibenthic gastropods are well represented at both sites, they dominate the algal site both in number and biomass and this dominance is almost entirely the product of one species, *H. ulvae*.

Table 3

Annual mean biomass of the macrofauna from areas with dense algal cover and no algal cover

	Biomass(g m^{-2})	
	Area with dense algal cover	Area with no algal cover
Epifauna	27.420	5.420
Infauna	3.326	13.245
Total	30.746	18.665

The predominant role the epifauna play in the greater biomass of the algal site is well illustrated in Table 3. By the end of March when the algal cover has almost disappeared, biomass is greatly reduced and does not recover until the algal mat is reestablished (Fig. 3).

Estuarine birds

TUBBS (1977) indicated that two waders (Curlew and Redshank) and Shelduck had declined since the 1960's. The numbers of the two waders are highest between June

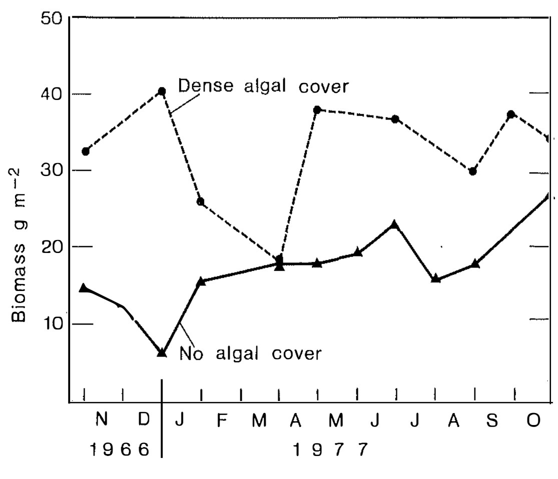

Figure 3

Monthly mean biomass of invertebrate macrofauna from site 1, no algal cover and site 2, dense algal cover

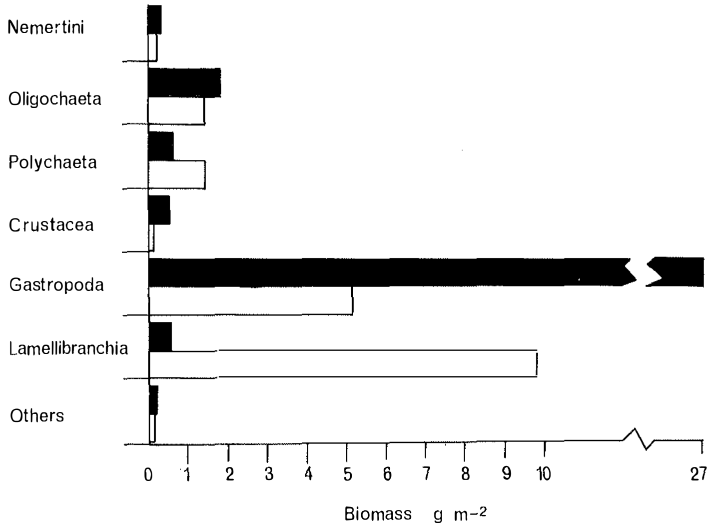

Figure 4

Annual mean biomass of the various taxa from site 1, no algal cover (clear) and site 2, dense algal cover (shaded)

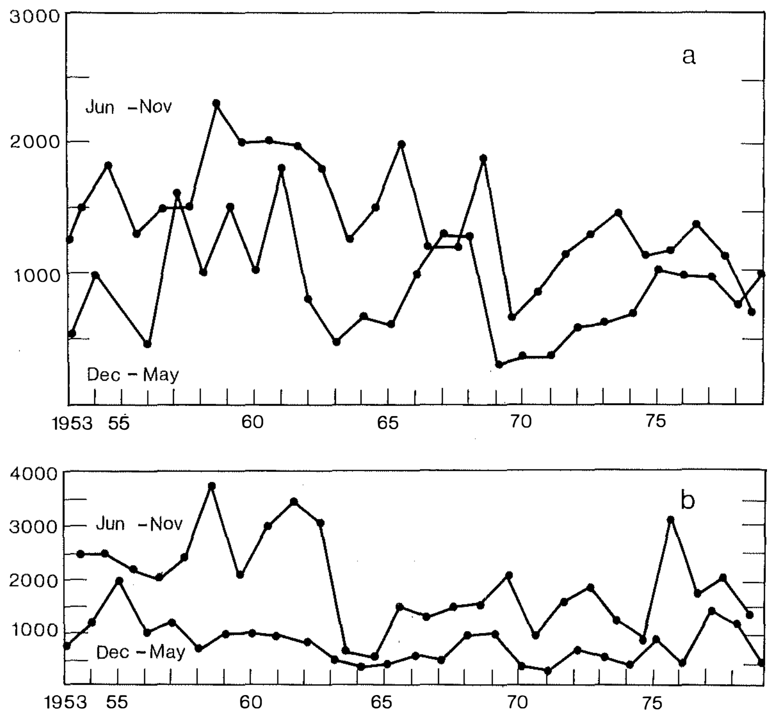

Figure 5

Annual peak counts of Curlew in Langstone Harbour, 1953 to 1978 (a)
Annual peak counts of Redshank in Longstone Harbour, 1953 to 1978 (b)

and November with smaller overwintering and spring numbers (Fig. 5). Curlew, Redshank, Grey Plover and Dunlin exploited most of the intertidal area for feeding, though at varying densities. In winter the first three species tended to avoid areas which had carried a dense crop of algae the previous summer but the Dunlin, although avoiding the areas with algae in the summer, fed freely over formerly covered areas during the winter. Most Shelduck (Fig. 6), which are primarily winter visitors, arrive after the mats have gone, but their feeding correlated closely with areas which were free of algae in summer and autumn. The remaining birds studied fed within relatively discrete areas presumably dictated by the distribution of their preferred prey. For instance, Oystercatchers fed on areas known to support large populations of *Cerastoderma edule* L. Few such areas were covered with dense algae in summer.

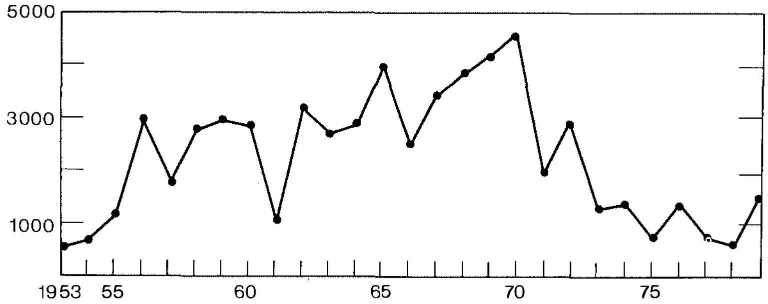

Figure 6

Annual peak counts of Shelduck in Langstone Harbour, 1953 to 1978

Although small numbers of Grey Plover, Dunlin, Redshank, Black-tailed Godwit and Curlew were seen feeding in areas with dense algal mats, close observation showed that most individuals were following intricate paths over mud either lightly covered or totally free from algae. Nonetheless many individual Grey Plover and Ringed Plover (*Charadrius hiaticula*), small flocks of Dunlin and occasional Redshank were watched taking prey items from the algal surface. The only wader which frequently exploited the interior of the algal mats was the Turnstone (*Arenaria interpres*) but individual Redshank and some small groups of Herring Gulls (*Larus argentatus*) and Common Gulls (*L. canus*) were seen to move the algae aside with their bills.

Observations of the prey preferences of Curlew have shown that they mainly take large polychaetes, especially *N. diversicolor*, but the crab, *Carcinus maenas* L., is important during the summer and early autumn. Redshank generally fed on a relatively wide range of smaller polychaetes and crustaceans but apparently take few molluscs. The main food item for Shelduck in Langstone Harbour is not known.

Discussion

The open mudflat of site 1, with its diverse biomass of estuarine infauna and more restricted epifauna can be envisaged as the typical habitat to which the birds' feeding behaviour was adapted. With the gradual increase in inorganic nutrients derived from the sewage effluent a community has arisen which in its present extent and importance is unique to modern times. What was initially an annual summer growth of algae of very restricted distribution has become a widespread carpet persisting most of the year and producing a perennial change in the substrate. This totally anaerobic mud supports a much reduced biomass with high numbers restricted to three species, the oligochaete, *P. benedeni* and the polychaetes, *C. capitata* and *S. fuliginosa*. A similar change has been recorded in the Medway (WHARFE 1977). These three species have been widely regarded as characterising polluted conditions (READ and RENSHAW 1977, HALCROW et al. 1974, PEARSON and ROSENBERG 1976). Above this mud the algal mat supports an abundant epifauna whose very high biomass is mainly due to the one species *H. ulvae*. The successful exploitation of this altered habitat by a few species has increased the invertebrate biomass to nearly twice that of the normal mudflat.

The food potential of the algal areas does not seem to be exploited by the avifauna, for most birds avoid the dense mats in summer and in winter only Dunlin fed regularly on areas formerly covered by algal mats. Such avoidance by the birds might have suggested that the invertebrates present formed an unacceptable diet but both this study and the work of GOSS-CUSTARD et al. (1977) have shown that *H. ulvae*, *C. maenas* and small polychaetes, all of which are abundant, are the main prey of the waders. This suggests that it is either the algal mat or the associated high levels of hydrogen sulphide that are acting as a deterrent.

Most of the bird species studied have presumably had no difficulty in obtaining sufficient food from the reduced area of open muds, for TUBBS (1977) has shown that their numbers have increased during the period of excessive algal growth. Furthermore, TUBBS and TUBBS (1981) showed that many species did not make maximum use of available feeding time. However, the three species Curlew, Redshank and Shelduck have declined over the same period. This may indicate that the almost perennial influence of green algae in the Harbour has begun to exclude certain estuarine birds which were once more abundant.

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