Benthic Algae in Polluted Estuaries

Three estuaries in north-eastern England provide a natural experiment. The Wear is relatively unpolluted, the Tyne receives a large volume of untreated sewage and the Tees mixed industrial wastes. The algal flora of these estuaries is compared to reveal the effects of different kinds of contamination.

De Falco, Jr (1967) gave a paper at a symposium on estuaries in the USA entitled 'The estuary septic tank of the megalopolis'. He pointed out that one-third of the total population of the USA is located on estuaries which are consequently fouled with domestic and industrial waste. In the United Kingdom, estuaries are again the principal pathway for the disposal of wastes to the sea. County Durham is fortunate, or unfortunate with regard to pollution, since it has three estuaries within a distance of only 40 km, the estuaries of the rivers Tyne, Wear and Tees (Fig. 1).

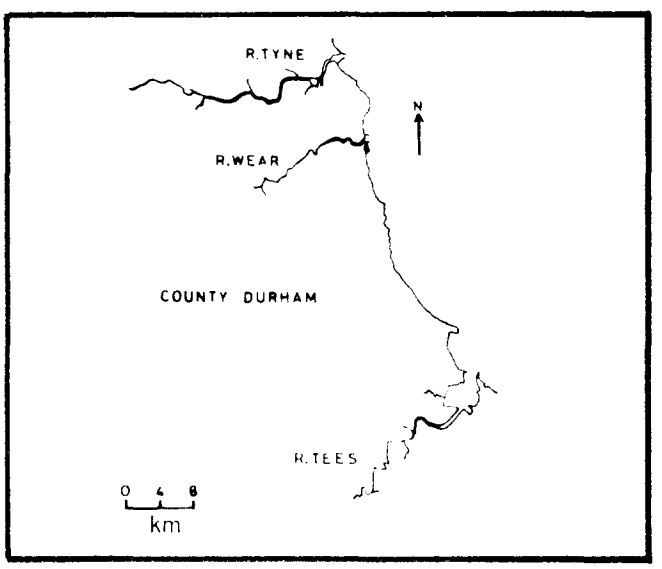

Fig. 1 Rivers of County Durham.

The Durham estuaries are of comparable size and are situated in the same geographical area, yet they are polluted in different ways (Fig. 2). The Tyne receives untreated sewage from nearly 1 million people plus a variety of mixed industrial wastes; the pollution is largely of the nutrient type. The Tees receives predominantly trade waste discharges of which over 90 per cent are from the chemical industry complex which discharges a wide variety of chemicals including sulphuric acid, metals, cyanide and phenol. The Teesside conurbation has a population of approximately 0.5×10^6 but the sewage is mainly pumped out to sea. Pollution is thus largely of the toxic chemical type. The Wear is relatively unpolluted compared to the Tyne and Tees and served as a control in these studies. The estuarine system of County Durham thus provides a huge natural experiment since the degree or type of pollution is probably the only environmental factor that varies significantly between the three estuaries. The effects of nutrient pollution in the Tyne and toxic chemical pollution in the Tees may thus be compared with the relatively unpolluted Wear.

There has been a demand recently for improved techniques to evaluate pollution and attempts have been made to discover indicator organisms. It is now

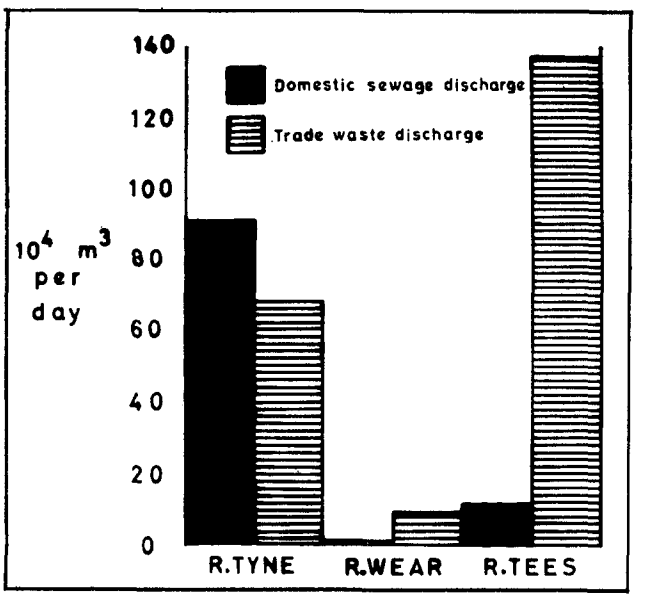

Fig. 2 Pollution characteristics of Durham estuaries drawn from data presented in ICES (1969).

recognized that biological indicators used alone are superior to chemical and physical ones used alone (Stein and Denison, 1967). Benthic marine algae comprise good potential indicators of pollution since they are attached and are thus exposed continuously to wastes over a prolonged period of time. Cotton (1911) correlated excessive growths of *Ulva lactuca* with the presence of sewage polluted seawater over half a century ago. More recently research in Norway (Sundene, 1953; Grenager, 1957), in the Netherlands (Den Hartog, 1959), in the USA (Sawyer, 1965), and in the Mediterranean (Golubic, 1970) has demonstrated the value of benthic marine algae as indicators of pollution.

Estuaries are colonized almost exclusively by euryhaline marine algae which can tolerate the wide ranges in salinity. Freshwater algae are unimportant in an estuary except near the tidal limit (Den Hartog, 1967). Thus it is valid to compare the algal vegetation of estuaries solely on the basis of the marine flora.

Methods

The species composition was determined from a total of 69 stations at approximately 1 km intervals from the mouth to the tidal limit of each estuary (Figs. 3 and 4). Benthic marine algae were collected at 27 stations on the Tyne estuary (31.4 km long), 16 stations on the Wear estuary (16.8 km long), and 26 stations on the Tees estuary (31.4 km long). The survey was conducted during September-October 1970, but in February 1971 each estuary was sampled at the mouth and at one to two stations within the estuary to investigate possible seasonal changes in the flora. The species lists

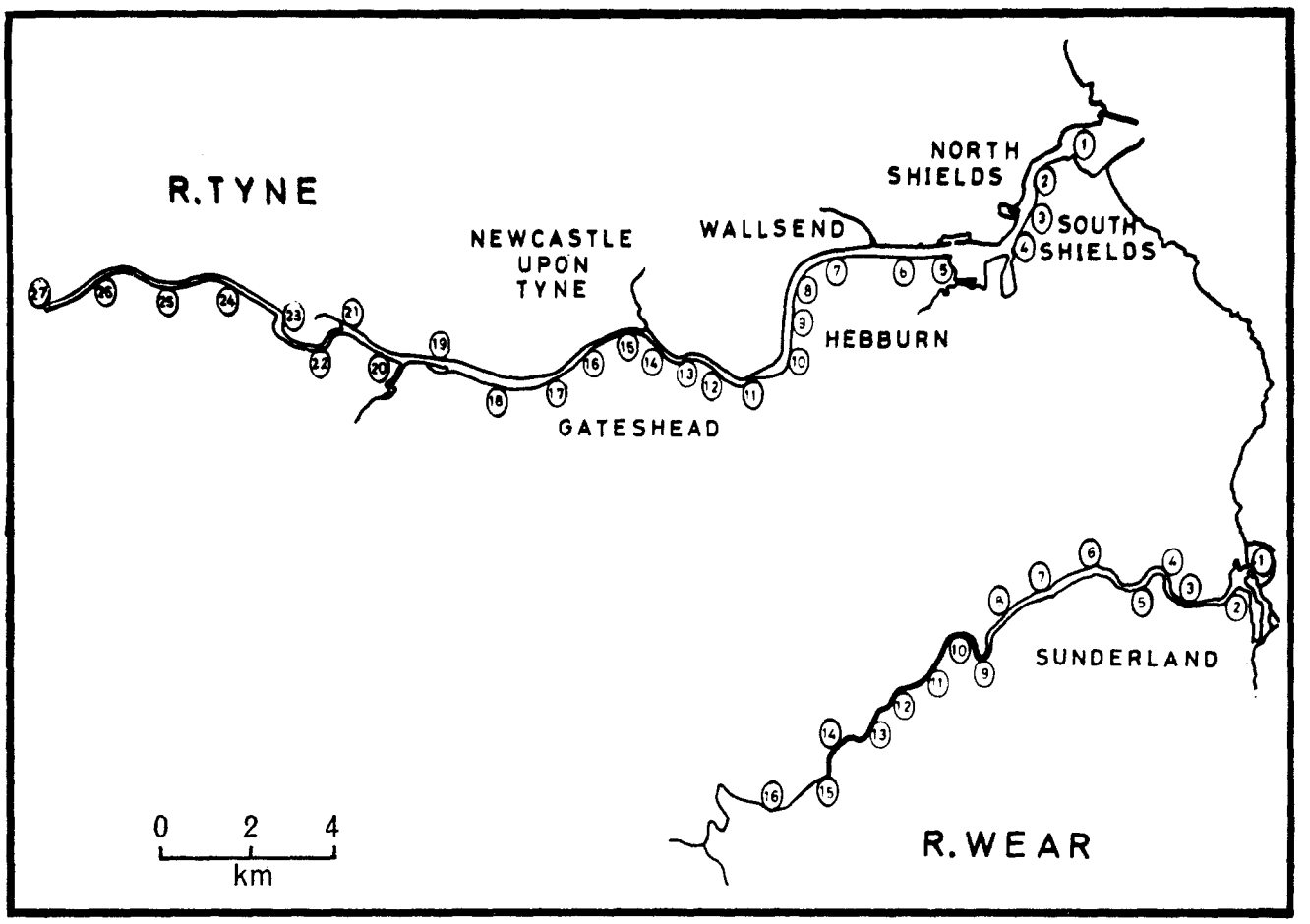

Fig. 3 Sampling stations on the Tyne and Wear estuaries.

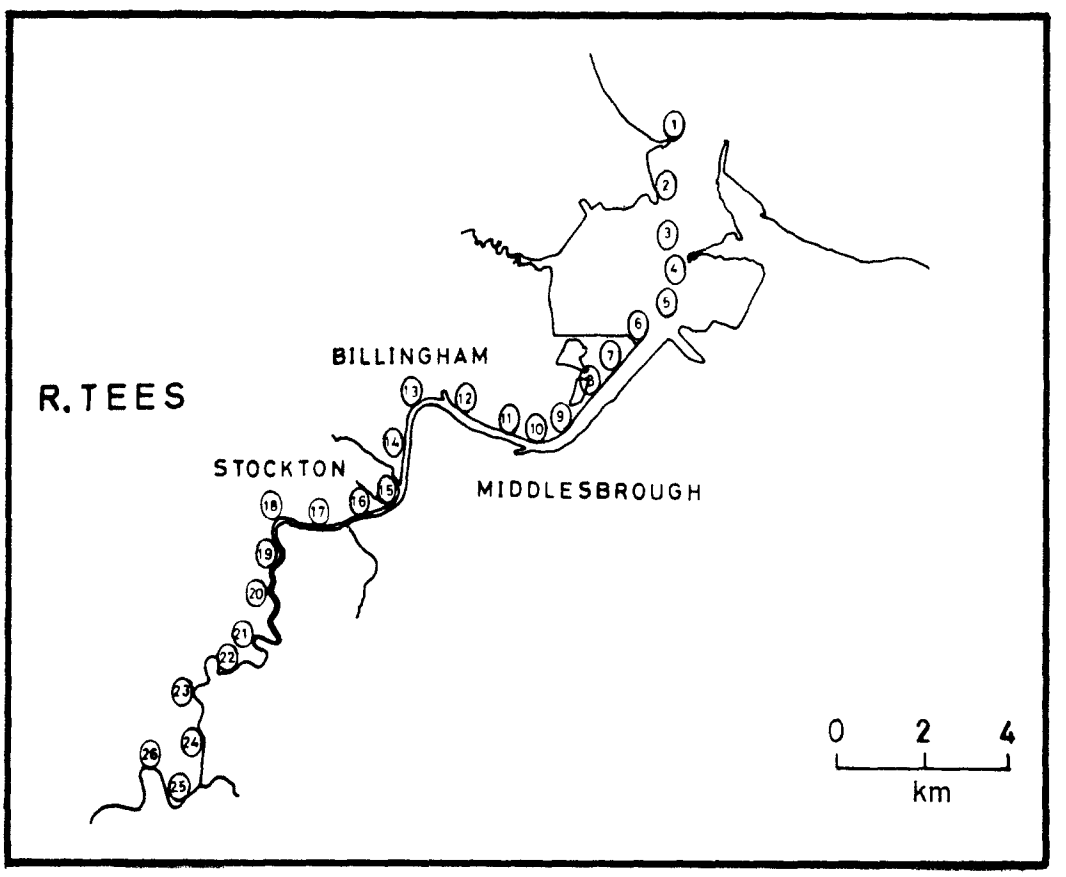

Fig. 4 Sampling stations on the Tees estuary.

MARINE POLLUTION BULLETIN QUESTIONNAIRE

MARINE POLLUTION BULLETIN has now been published by Macmillan Journals Limited for two years and the point has come at which we must plan its future development. It is intended that we shall increase the topicality and comprehensiveness of the news section in the front, chiefly by the use of correspondents in the United States. The publishers would, however, be glad of your replies to the following questions:

1. Do you find the leading articles

   ☐ stimulating ?

   ☐ of passing interest ?

   ☐ irrelevant to the main purpose of the journal ?

2. Which items do you read first

   ☐ leading article ?

   ☐ news?

   ☐ research papers ?

3. Do you think the scope of the journal should be

   ☐ broader ?

   ☐ narrower (or more technical) ?

   ☐ as at present ?

4. If you wish to see the scope of the journal extended, please indicate which of the following topics should be included:

   ☐ rivers and inland lakes

   ☐ water pollution in general

   ☐ air pollution

   ☐ heavy metal contamination of the environment

5. Any other comments

Please return to: Marine Pollution Bulletin (Q), Macmillan Journals Ltd, 711 National Press Building, Washington DC 20004, in envelope provided.

from the same station at different seasons were almost identical indicating little or no seasonal change in the estuarine flora. Alexander *et al.* (1935) did not observe any seasonal changes during their survey of the Tees.

Vegetation of the Estuaries

A total of 54 species of benthic marine algae were recorded from the three estuaries. The species composition of the Wear estuary, the relatively unpolluted estuary which served as the control, is presented in Table 1. The largest number of species occurred at the estuary mouth but as the estuary was penetrated, stenohaline species rapidly disappeared. Several species reached the mid-estuarine section but only a few euryhaline green algae and *Vaucheria* occurred as far as the upper estuary. *Fucus* spp. penetrated into the middle of the estuary and *Enteromorpha* spp. occurred almost to fresh water. The pattern for the nutrient-polluted Tyne estuary (Table 2) was similar with *Fucus* spp. reaching to the middle of the estuary and *Enteromorpha* spp. almost to fresh water. The total number of species recorded from the two estuaries was similar with 42 species from the Wear and 45 species from the Tyne. However the green alga *Prasiola stipitata* occurred in vast amounts at stations 7 to 9 in the Tyne and at the other stations where it was recorded it was much more abundant than in the Wear or the Tees. The species is generally reported to be abundant on rocks covered with bird droppings (Taylor 1937) and Lewin (1955) demonstrated that the growth of the plant in culture is markedly stimulated by organic nitrogen. The occurrence of *Prasiola stipitata* in abundance in certain parts of the Tyne estuary may possibly reflect the high nutrient content of the waters and the species may possibly be an indicator of nutrient pollution. The similarity in species composition and distribution between the nutrient polluted Tyne estuary and the relatively unpolluted estuary of the Wear is surprising. Non-polluted environments generally possess more species than polluted ones; in the latter environment pollutant intolerant species die and more tolerant forms increase in abundance because of a decrease in competition (Stein and Denison, 1967). However estuarine organisms are subjected to a rigorous environment and

TABLE 1. BENTHIC MARINE ALGAE IN THE RIVER WEAR ESTUARY

Species	*Station*															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Prasiola stipitata Suhr in Jessen	*	*	*			*	*	*			*			*		
Rosenvingiella polyrhiza (Rosenv.) Silva	*			*	*	*	*	*			*		*	*		
Ulothrix flacca (Dillw.) Thur. in Le Jol.	*	*		*	*	*	*	*	*		*		*			
U. subflaccida Wille	*			*	*			*				*		*	*	*
Monostroma oxyspermum (Kütz.) Doty				*	*	*	*	*								
Blidingia minima (Näg. ex Kütz.) Kylin	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
Enteromorpha compressa (L.) Grev.	*		*													
E. intestinalis (L.) Link	*		*	*	*	*		*	*	*	*	*	*			
E. linza (L.) J. Ag.	*															
E. prolifera (O. F. Müll.) J. Ag.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Ulva lactuca L.	*															
Acrosiphonia arcta (Dillw.) J. Ag.	*															
Urospora penicilliformis (Roth) Aresch.	*															
Chaetomorpha litorea (Harv.) Harv.	*															
Rhizoclonium riparium (Roth) Harv.	*	*	*	*	*		*	*	*	*	*	*	*	*		*
Vaucheria piloboloides Thur.			*		*	*	*	*	*	*	*	*	*	*	*	
Ectocarpus fasciculatus Harv.	*															
Pilayella littoralis (L.) Kjellm.	*	*	*	*	*		*									
Spongonema tomentosum (Huds.) Kütz.	*															
Ralfsia verrucosa (Aresch.) J. Ag.	*															
Elachista fucicola (Vell.) Aresch.	*	*	*	*	*	*	*									
Laminaria digitata (Huds.) Lamour.	*															
L. saccharina (L.) Lamour.	*															
Alaria esculenta (L.) Grev.	*															
Fucus ceranoides L.							*	*	*							
F. serratus L.	*															
F. spiralis L.	*															
F. vesiculosus L.	*	*	*	*	*	*	*									
Acrochaetium virgatulum (Harv.) J. Ag.	*															
Rhodochorton floridulum (Dillw.) Näg.	*															
R. purpureum (Lightf.) Rosenv.	*			*	*											
Gigartina stellata (Stackh.) Batt.	*															
Hildenbrandia prototypus Nardo	*															
Antithamnion cruciatum (C. Ag.) Näg.	*															
Callithamnion arbuscula (Dillw.) Lyngb.	*															
C. hookeri (Dillw.) S. F. Gray	*															
C. sp.	*															
Ceramium rubrum (Huds.) C. Ag.	*															
C. shuttleworthianum (Kütz.) Silva	*															
C. strictum Harv.	*															
Polysiphonia nigrescens (Huds.) Grev.	*															
P. urceolata (Lightf. ex Dillw.) Grev.	*															
Porphya umbilicalis (L.) J. Ag.	*		*		*											

a possible correlation between their wide ecological resistance to the natural environment and a tolerance to high concentrations of nutrients would explain the similarity between the floras of the two estuaries.

13 and 14 in the mid-estuarine section between the Transporter and Newport Bridges. These data indicate the possible detrimental effect of toxic chemical pollution on the benthic marine algal flora.

TABLE 2. BENTHIC MARINE ALGAE IN THE RIVER TYNE ESTUARY

Species	*Station*																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Prasiola stipitata Suhr in Jessen	*	*	*		*	*	*	*	*	*	*	*	*	*	*												
Rosenvingiella polyrhiza (Rosenv.) Silva	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*			
Ulothrix flacca (Dillw.) Thur. in Le Jol	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
U. subflaccida Wille	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Monostroma oxyspermum (Kütz.) Doty		*	*	*	*	*	*	*	*	*	*	*			*	*		*	*	*	*		*	*	*		
Blidingia minima (Näg. ex Kütz.) Kylin	*	*	*	*	*	*	*	*	*	*	*	*	*	*					*	*	*		*	*	*	*	
Capsosiphon fulvescens (C. Ag.) Setch. et Gardn.																			*	*	*			*			
Enteromorpha intestinalis (L.) Link																				*							
E. linza (L.) J. Ag.	*	*																									
E. prolifera (O. F. Müll.) J. Ag.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Percursaria percursa (C. Ag.) Rosenv.						*																					
Ulva lactuca L.	*				*																						
Acrosiphonia arcta (Dillw.) J. Ag.	*																										
Urospora penicilliformis (Roth) Aresch.	*	*							*																		
Cladophora rupestris (L.) Kütz.	*																										
Rhizoclonium riparium (Roth) Harv.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*		*	*	*	
Vaucheria piloboloides Thur.		*	*			*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	
Ectocarpus siliculosus (Dillw.) Lyngb.					*	*	*	*	*	*		*	*	*	*	*	*					*					
Mikrosyphar polysiphoniae Kuck.	*																										
Pilayella littoralis (L.) Kjellm.	*	*	*	*	*			*	*		*	*	*														
Spongonema tomentosum (Huds.) Kütz.	*																										
Ralfsia verrucosa (Aresch.) J. Ag.	*																										
Elachista fucicola (Vell.) Aresch.	*	*	*	*	*	*	*	*		*	*	*	*														
Laminaria digitata (Huds.) Lamour.	*																										
Sphacelaria radicans (Dillw.) C. Ag.	*					*						*															
Cladostephus spongiosus (Huds.) C. Ag.	*																										
Ascophyllum nodosum (L.) Le Jol.	*																										
Fucus serratus L.	*																										
F. spiralis L.	*																										
F. vesiculosus L.	*	*	*	*	*	*	*	*	*	*	*	*	*														
Acrochaetium virgatulum (Harv.) J. Ag.	*																										
Rhodochorton floridulum (Dillw.) Näg.	*																										
R. purpureum (Lightf.) Rosenv.	*	*	*	*		*		*			*	*		*													
Gigartina stellata (Stackh.) Batt.	*																										
Hildenbrandia prototypus Nardo	*																										
Callithamnion arbuscula (Dillw.) Lyngb.	*																										
C. hookeri (Dillw.) S. F. Gray	*	*																									
C. sp.	*																										
Ceramium flabelligerum J. Ag.	*																										
C. shuttleworthianum (Kütz.) Silva	*																										
C. strictum Harv.	*	*																									
Polysiphonia nigrescens (Huds.) Grev.	*																										
P. urceolata (Lightf. ex Dillw.) Grev.	*	*																									
Bangia fuscopurpurea (Dillw.) Lyngb.	*		*																								
Porphyra umbilicalis (L.) J. Ag.	*	*			*			*		*																	

The species composition of the Tees estuary is presented in Table 3. Thirty-three species only were found in the estuary as opposed to 45 and 42 species for the Tyne and Wear respectively. *Fucus* spp. were collected only at the first three stations, that is only 3.4 km up the estuary, and *Enteromorpha* spp. only up to station 12, 11.7 km up the estuary. Thus there was a drastic reduction in the distribution of both genera in the Tees compared to their distribution in the Tyne and Wear. No benthic marine algae were observed at stations

Comparison with Previous Data

The data obtained during the study were compared with those of the 1929-1933 Tees survey (Table 4). The latter survey considered only the larger benthic marine algae and consequently only 24 species were recorded compared to 33 in the present survey. However a comparison is revealing. Several conspicuous species have apparently disappeared recently, e.g. *Plumaria elegans* and *Membranoptera alata*. Furthermore *Fucus* spp. then penetrated into the mid-estuarine section and