Chapter 13

ALGAL FOULING IN THE NORTH SEA

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13.1 INTRODUCTION

Offshore gas extraction in the U.K. started in the mid 1960's in the southern North Sea and the first oil was produced from the central North Sea in 1975. There are now over 100 installations in the three areas of the North Sea - northern, central and southern - indicated in Figure 1. The installations in the southern North Sea extend to a maximum depth of 30m, those in the central North Sea from 45m to 142m and the deepest platforms, from 117m to 187m, are found in the northern North Sea. Throughout this paper, depths are given relative to Lowest Astronomical Tide, (L.A.T.)

All installations are rapidly colonised by fouling organisms with fouling communities extending from the splash zone to the seabed. The composition, extent and thickness of fouling in all three areas of the North Sea is broadly similar but there are differences in detail between the regions and also sometimes quite striking differences in species composition between adjacent platforms. Fouling communities have been described for several structures in the North Sea (e.g. Goldie, 1981; Goodman and Ralph, 1981; Hardy, 1981; Forteath et al., 1982; 1983; 1984; Picken et al., 1983; Picken, in press).

Licensing regulations for the U.K. sector (HMSO, 1977) require that annual surveys of fixed installations are made and that such surveys should make an assessment of the thickness of marine growth on typical members or areas of the structure. There are no detailed guidelines, however, as to how operators should make this assessment. Since 1981, AUMS (Aberdeen University Marine Studies Ltd.) has provided an analysis service to help engineers to assess the current state of marine growth and to predict its future composition and

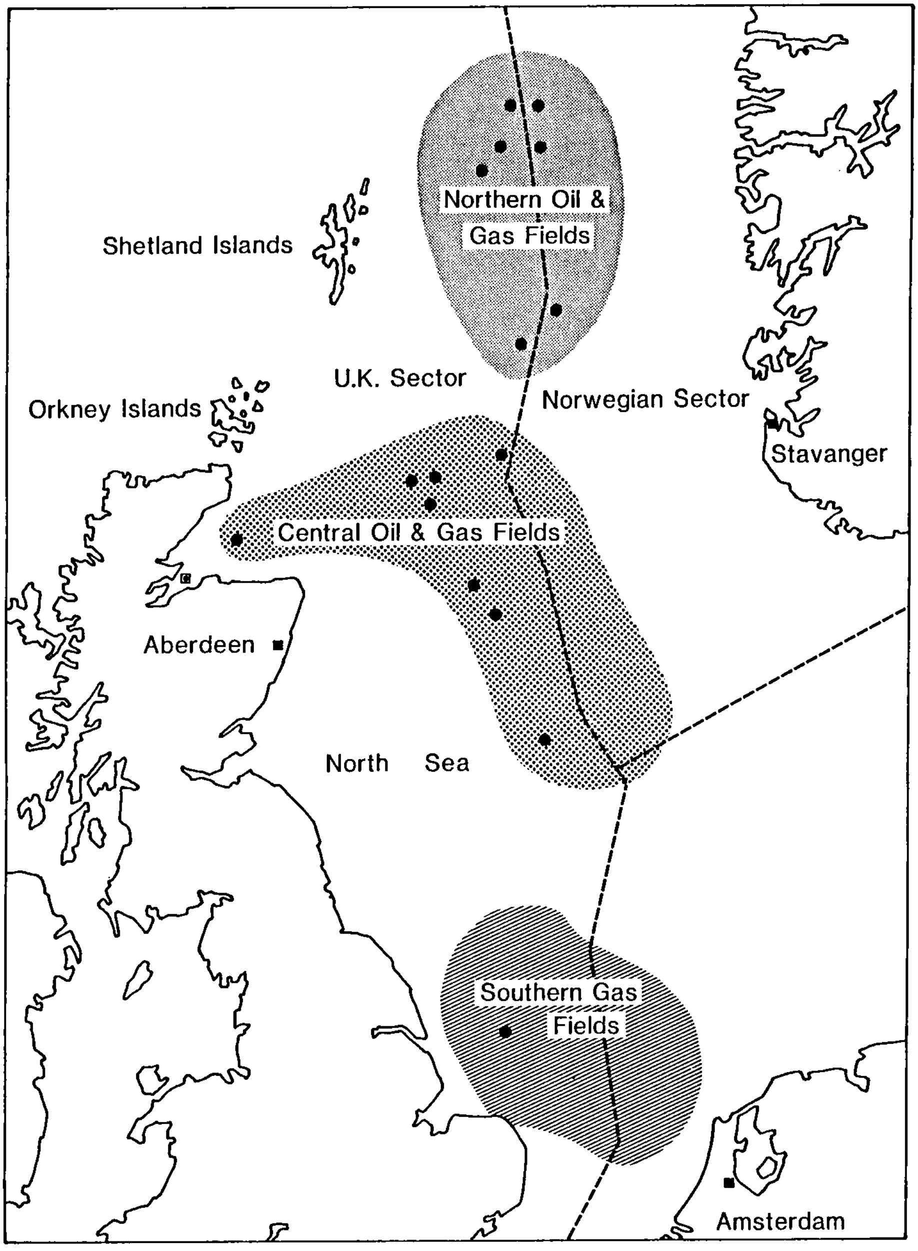

Fig. 13.1. Map of North Sea showing location of (a) offshore structures from which data on algal fouling has been obtained ● and (b) the buoys in the approach channel to the Cromarty Firth ▣ .

thickness on existing structures and on future installations. The time allocated to marine growth assessment during inspection is short and it is important to maximise the collection of relevant data (species composition, percentage cover and thickness) which will be of importance to the engineers who have to make decisions on cleaning programmes to relieve structural loading.

This paper outlines the methods of data analysis adopted to provide such information to meet engineering requirements and describes the distribution of algae on offshore structures in the North Sea. The offshore algal communities are compared with the algal fouling on navigation buoys from inshore waters in the Inner Moray Firth in north-east Scotland.

13.2 METHODS

13.2.1. Data collection from offshore structures

The locations of installations from which data on algal fouling have been obtained are shown in Figure 1. Marine growth samples were collected by commercial divers who followed a sampling programme designed in consultation with the operator. The divers located a number of pre-selected sampling points on the structure and performed the following sequence of tasks:- (1) the attachment of a site identification label; (2) the attachment of a quadrat or scale marker at each location; (3) the taking of stand-off and close-up colour photographs of the sites; (4) the measurement of the circumference of specified members using a specially designed tape measure; (5) the collection of the marine growth within the quadrat by scraping it into a labelled plastic sampling jar. Industrial methylated spirit (IMS) was added as a preservative to the samples on return to the surface.

13.2.2. Data analysis

The rationale governing the methods used by AUMS to analyse marine growth data from offshore structures has been described and discussed by Picken (1984). The information required by engineers and the source of this information from the marine growth inspection data are summarised in Table 1.

TABLE 13.1.

Sources of data for marine growth analysis

Information required	Scource of data
1. Identity of species present	Samples collected by divers Analysis of the close-up photographs
2. % cover of the major fouling types	Estimation from photographs which include a quadrat or scale
3. Average size (length or height) of each species or fouling type	Estimation from photographs which include a scale Range of size possible obtained from the literature

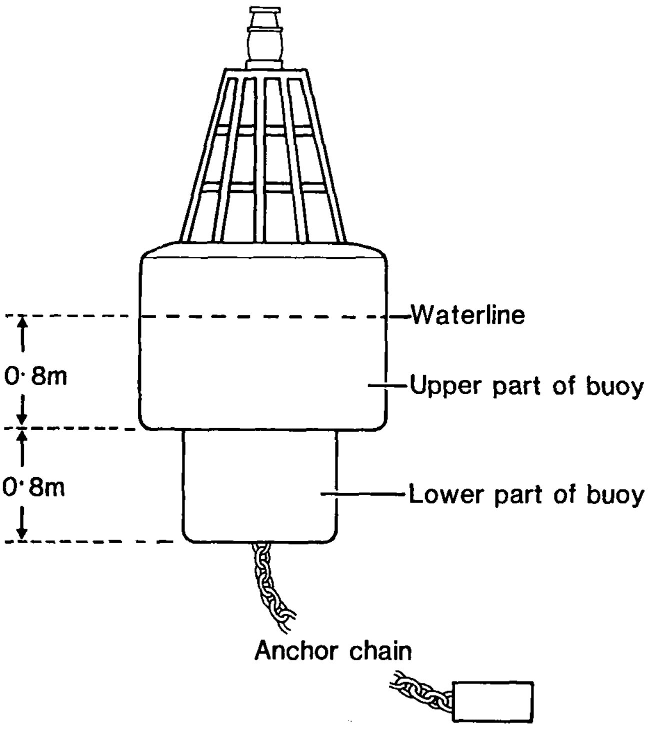

Fig. 13.2. The structure of an inshore buoy.

13.2.3. Fouling communities on inshore buoys

During May 1984 AUMS was able to examine the fouling on six navigation buoys, situated in the Inner Moray Firth in the approach channel to the Cromarty Firth (see Figure 1.), when they were taken aboard a lighthouse ship for annual maintenance work. The structure and dimensions of these buoys are shown in Figure 2. When each buoy was lifted clear of the water onto the vessel photographs were taken of the fouling and samples of the filamentous and micro-algae were taken for laboratory identification. During this annual maintenance the fouling on the upper and lower parts of the buoys was removed using scrapers, the upper parts cleaned with cloths and coated with an antifouling paint. The lower part was not antifouled and the fouling on the chain was not removed.

13.3. RESULTS

An example of typical results from the analysis of marine growth on a structure in the central North Sea standing in 130m of water is shown in Figure 3. This type of presentation has been adopted to summarise information on marine growth composition and thickness for engineering purposes. The identity of individual species is not particularly important in this context but division into the major fouling groups is useful. In the example illustrated, algae were found in the depth range L.A.T. to -15m where the competitors for space were mussels and hydroids. Both algae and hydroids were frequently found overgrowing the mussels. Mussel beds formed the dominant hard growths from L.A.T. to -45m but at greater depths the dominant hard fouling consisted of solitary tubeworms. Hydroids were present throughout the depth range with other soft growths, including soft corals and anemones, present from -15m to a depth of approximately 100m.

The depth range of algae on offshore structures in the North Sea is determined by the clarity of the water and the geometry of the structure. There are many regions in the photic zone on steel platforms which are so shaded that algae are absent; on steel structures algae are predominantly found on the outer faces of legs and on the upper surfaces of horizontal and vertical diagonal members. In the shallow turbid waters of the southern North Sea algae are therefore confined to areas shallower than -5m whereas in the central and northern sectors plants have been found as deep as -40m.

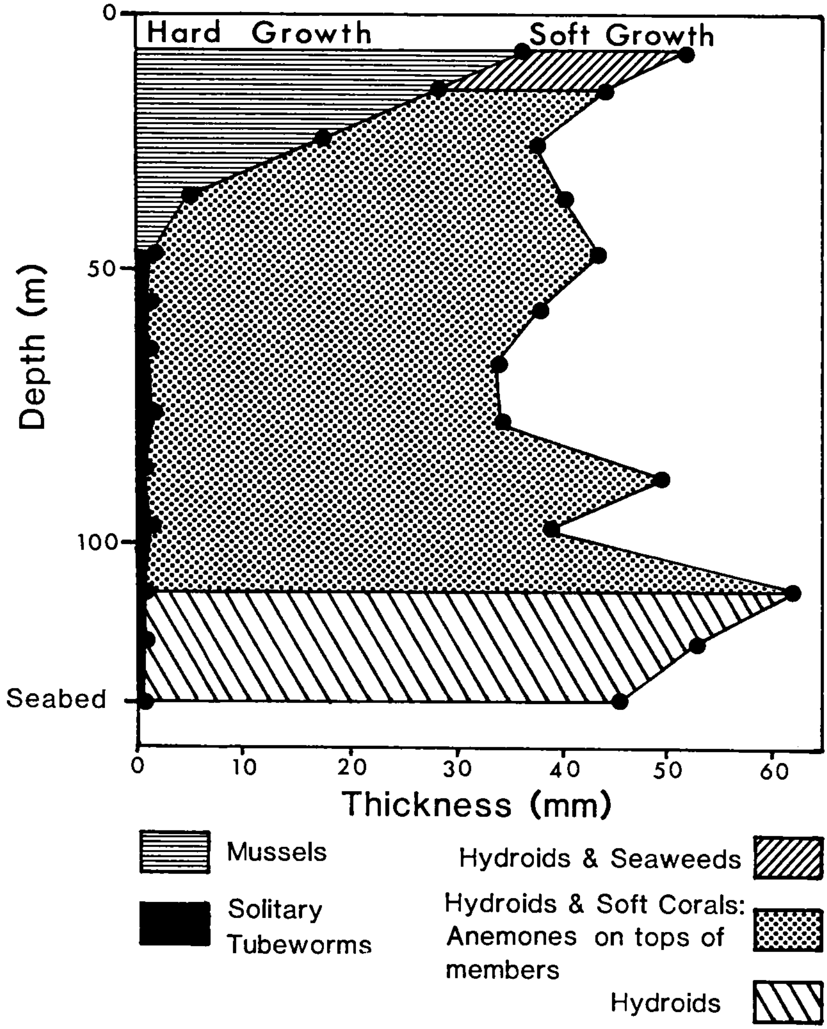

Fig. 13.3. Depth zonation and average thickness of the major components of the fouling community on a steel structure 5 years after placement in the central North Sea.

TABLE 13.2.

Species list of algae recorded on offshore installations in the North Sea. Taxonomic nomenclature follows that of Parke and Dixon (1976).

Chlorophyceae		Rhodophyceae	
Enteromorpha spp. (includes E. intestinalis, E. linza, E. torta and Enteromorpha sp.)	(S,C,N)	Erythrotrichia carnea	(C)
Ulva lactuca and Ulva sp.	(S,C,N)	Bangia atropupurea	(S)
Chaetomorpha sp.	(C)	Porphyra sp.	(C,N)
Cladophora sp.	(C,N)	Audouinella concrescens	(S)
Spongomorpha sp.	(C)	Audouinella sp.	(S,C,N)
		Gelidium latifolium and Gelidium sp.	(N)
Xanthophyceae		Bonnemaisonia hamifera "Trailliella" phase	(N)
Vaucheria sp.	(N)	Palmaria palmata	(C,N)
		Lomentaria clavellosa	(C,N)
Phaeophyceae		Lomentaria orcadensis	(C,N)
Ectocarpus sp.	(C,N)	Antithamnion floccosum	(C,N)
Spongonema tomentosum	(N)	Ceramium rubrum	(C,N)
Giffordia sp.	(N)	Plumaria elegans	(N)
Pilayella littoralis	(C)	Delessaria sanguinea	(N)
Desmarestia ligulata	(C,N)	Hypoglossum woodwardii	(N)
Desmarestia viridis	(S,C,N)	Polysiphonia brodiaei	(C,N)
Alaria esculenta	(C,N)	Polysiphonia macrocarpa	(C,N)
Laminaria digitata	(C,N)	Polysiphonia nigrescens	(N)
Laminaria hyperborea	(C)	Polysiphonia ureolata	(S,C,N)
		Rhodomela confervoides	(N)

S = Southern North Sea
C = Central North Sea
N = Northern North Sea

Data from Goldie, 1981; Hardy, 1981, Forteath et al., 1982; 1983; 1984; and unpublished sources.

A species list of the algae which have been identified from offshore situations in the North Sea is given in Table 2. Few recognisable trends in algal distribution have been observed between different structures or regions of the North Sea. Kelps, however, are not widespread in the southern North Sea and although they occur on many platforms in the other two sectors they are a serious problem on only two of the installations. The upper regions of some structures, particularly those in the southern sector, can be totally dominated by the mussel *Mytilus edulis*, but algae may overgrow such a cover if light levels are sufficient.

A common fouling pattern was found on all six navigation buoys in the Moray Firth. The upper part was fouled from the waterline region to its junction with the lower part - a depth of 0.8m. Three zones were distinguished on this upper part; a splash zone approximately 15cm deep above the waterline, a large mid zone and a low zone covering the basal 10 to 15cm of the upper part of the buoy. The algae in the splash zone were *Ulothrix* sp., *Enteromorpha* sp., *Chaetomorpha linum*, unidentified small stages of green algae, and blue-green algae. The mid zone was dominated by *Ectocarpus* sp., with *Scytosiphon lomentaria*, *Polysiphonia fibrata* and *Ulva* sp. also present. On some of the buoys the cover of *Ectocarpus* extended above the waterline. Laminarians, principally *Laminaria saccharina*, were present in the low zone, with some *Ectocarpus* sp. The mussel, *Mytilus edulis*, dominated the lower part of the buoy with some *Laminaria digitata* and, to a lesser extent, *L.saccharina* also present.

13.4 DISCUSSION

The fouling on offshore installations in the North Sea has necessitated a regular monitoring of the species composition, extent of cover and marine growth thickness. The thickness measurements are particularly important for estimating the effects of marine growth on hydrodynamic loading. Although the sampling methods carried out offshore fall short of an ideal biological programme, they have enabled data on these offshore communities to be obtained while providing operators with information to answer engineering problems.

Algal fouling can affect offshore installations in a number of ways:- (1) it obscures the underlying substratum and impairs the inspection of a structure. Some non-destructive testing requires the pre-removal of fouling; (2) it increases dynamic and hydrodynamic loading; (3) it can provide environments for bacterial activity (see, for example, Terry and Edyvean, 1986). Sulphate reducing bacteria (SRB) are active in anaerobic pockets under macrofouling and they can enhance corrosion of structural steels. Sulphur oxidising bacteria, which can promote dissolution and spalling of concrete, can be active in aerobic pockets under macrofouling; (4) it can affect corrosion and corrosion protection offshore (see, for example, Terry and Edyvean, 1986).

The most significant effect of algal fouling is its contribution to hydrodynamic loading, and it now appears that the contribution of soft growth to hydrodynamic loading has been underestimated. Recent laboratory investigations have shown that the effect of kelps on drag and inertia coefficients may be nearly twice the generally assumed value and therefore greater than those for hard growths (Wolfram and Theophanatos, 1985).

There has been much debate about which measure of size, particularly for soft frond growths, is appropriate for use in hydrodynamic loading calculations. Although the average thickness of hard growths can be reasonably accurately determined from photographic analysis, circumferential tape measurements or probe readings, such measurements may not accurately reflect the roughness factor (Wolfram and Theophanatos, 1985) and measurement procedures may have to be modified in the future. It is even more difficult to determine what is an appropriate thickness measurement for soft compressible growths such as algae. To date, the maximum length of the algal fronds as determined by photographic analysis has been used. This gives the "worst possible case" for engineers to consider in their calculations but the use of this measurement may also have to be reviewed in the light of any further experimental data on the effects of soft growth on loading.

Collating data from a number of sources, we have recorded a total of 35 species and/or genera of algae on offshore structures over the period 1977 to 1984 (Table 2). This appears appears low when compared with values of 120 algal species and/or major groups in permanent intertidal monitoring quadrats on rocky shores in the north-east of Scotland (Terry and Sell, in press) and 55 algal fouling species on floating structures in Sullom Voe (Tittley and Fletcher, 1984).

Although this list is probably an underestimate of the total species present, it is possible that offshore algal communities are in fact less diverse than those nearshore. The relative paucity of the offshore flora may be due to a combination of factors:- (1) the difficulties encountered in obtaining samples from offshore and in particular from the depth range L.A.T. to -15m. Wave action is most pronounced here and working conditions are difficult; divers may loose or overlook small species; even when divers can work in this region most intertidal and splash zone species will be excluded as surveys concentrate on sublittoral regions below L.A.T.; (2) the poor quality of many algae which are returned from offshore. It is rare to obtain an entire plant in a reasonable condition and the use of IMS as a preservative further hinders identification to species. In the absence of specimens, identification from photographs is usually only to group or genus level; (3) the difficulties which algae have in reaching offshore sites. It is not clear by which method or methods algae are able to seed particular platforms. Spores may arrive at a site through natural dispersal in currents, they may attach to the installation if it has been partially submerged inshore during construction, they may colonise during tow-out or they may even reach the offshore site on ships' hulls.

Competition for space on offshore fixed structures which are not cleaned regularly often results in the algae overgrowing hard organisms, usually mussels, as the results in Figure 3 from the central North Sea installation show. Such algal communities are often dominated by red algae, particularly species of Polysiphonia. Although Enteromorpha sp. and Ulva sp. have been recorded frequently on offshore structures in the North Sea, records for other green algae have been less common. This is probably because the upper splash zone is rarely sampled on offshore structures; the highest samples are obtained from L.A.T. and, because of the difficulties of working at 0m, samples from even this depth may be lacking. A splash zone community dominated by filamentous green algae probably exists offshore but, unlike the navigation buoys, it is never adequately sampled.

Given the difficulties in sampling the algal dominated regions of offshore structures it is perhaps not surprising that few generalisations can be made about algal distribution, both verticaly on individual platforms or between different structures in the North Sea. Different faces of a structure may be sampled in successive years and these faces may receive different patterns of wave action; samples may also be obtained from different depths on different occasions. It is rare to adequately sample the entire algal-covered region on any one visit. It is still not clear, for example, how precise algal zonation is offshore. Although photographs of entire structures frequently show an Enteromorpha-dominated splash zone, this genus has also been found well below the L.A.T. mark. Usually samples are taken from levels at which there is a horizontal member rather than between elevations. Consequently, a disjointed sampling procedure has to be adopted which results in different depths being sampled on different structures and no complete picture available for any one. Most of the algae recorded in Table 2, therefore, have been found at a variety of depths since there is considerable variation in the depth of the photic zone between the different regions of the North Sea.

Records obtained from floating structures elsewhere in the British Isles, e.g. the Firth of Clyde (Grieve and Robetson, 1864), the Isle of Man (Lodge, 1949), the Solent region (Fletcher, 1980) and Sullom Voe (Tittley and Fletcher, 1984), contained more algal species than were found on the six Moray Firth navigation buoys. The Moray Firth communities were, however, only one year old and were growing on an anti-fouled surface which would be expected to restrict the species colonising the buoys. Although the algal fouling on the eight buoys in the Clyde (Grieve and Robertson, 1864) was also only one year old, the greater number of species recorded in the Clyde compared with the Moray Firth buoys is probably due to the anti-fouling. In particular, more Rhodophyceae were observed in the Clyde, especially some luxuriant growths of Polysiphonia brodiaei. This species has been one of the most widespread algal foulers of offshore structures in the North Sea. Like the structures in Sullom Voe (Tittley and Fletcher, 1984), the algal fouling communities on the Moray Firth Buoys were dominated by Phaeophyceae. In particular, extensive growths of the early kelp coloniser Laminaria saccharina were found on the buoys. This species of Laminaria is not generally found on offshore installations where L.digitata and Alaria esculenta are the most frequently found laminarians. All three species were found on a three year old jetty in the Cromarty Firth (Picken, in press). It is possible that the greater exposure offshore may limit L. saccharina

Horizontal banding of algae on floating structures has been reported previously (e.g. Milne, 1940; Fletcher, 1980 and Tittley and Fletcher, 1984). Six different algal zones extending upwards from the waterline were recognised on structures in Langstone and Portsmouth harbours (Fletcher, 1980). Only two such zones could be found, however, from the corresponding region on the Moray Firth buoys. There was a narrow Ectocarpus dominated band at the waterline and above this a filamentous green algal band of maximum depth approximately 15cm. Both Fletcher (1984) and Milne (1940) reported the presence of red algae in the lowest zone i.e. at the waterline, and the absence this zone on the Moray Firth buoys is probably attributable to a combination of the short period of immersion and the toxicity of the anti-fouling paint.

13.5. ACKNOWLEDGEMENTS

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