

Marine Growth Studies on the North Sea Oil Platform Montrose Alpha

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ABSTRACT: Montrose Alpha oil platform was installed in the North Sea during August 1975. Samples and photographs of marine growth on the platform jacket have been analysed since 1977. Marine growth is depth related, with particular organisms or group of organisms dominant at various depths. Seaweeds dominate the sunlit surfaces extending down to a depth of –10 m. On shaded surfaces in the sunlit zone, arborescent bryozoans cover most of the substrate and continue down to –31 m. In the range –31 m to –51 m calcareous bryozoans cover large areas of the available substrate but hydroids are also common. Between –51 m and –71 m, encrusting bryozoans dominate the community but below –71 m the aggregate tubeworm *Filograna implexa* and deep-water barnacle *Balanus hameri* are common. Changes have taken place in the dominant species over the years. There have been relatively rapid changes in the depth range M.L.W. to –31 m and a more gradual change in the mid-water levels. Reasons for these changes are discussed. Marine growth on Montrose is compared with that on contemporary jackets in the Forties field, 40 km to the north-west. Causes for the observed differences are discussed.

INTRODUCTION

Ecological studies of oil and gas platforms off the coasts of California and Louisiana (USA) have shown that these structures act as artificial reefs and support a great diversity of life (Carlisle et al., 1964; Shinn, 1974; Bascom et al., 1976; Mearns and Moore, 1976; Simpson, 1977; George and Thomas, 1979; Wolfson et al., 1979). In the North Sea, studies have been largely confined to fouling predictions and have tended to concentrate on those organisms which are important with regard to hydrodynamic loading and corrosion (Freeman, 1977; Goodman and Ralph, 1979; Ralph and Troake, 1980; Ralph et al., 1981).

In the United Kingdom sector of the North Sea, operators of oil and gas production platforms are required to report to a certifying authority on the state of marine growth present on their structures. The Offshore Marine Studies Unit of the University of Aberdeen Zoology Department was established in 1977 in direct response to oil industry requests for expertise in designing and analysing marine growth inspection programmes. The Unit has collected data from 14

North Sea platforms over the past 4 yr and now has a better understanding of the previously little-known ecology of many of these unique structures situated many kilometers from coast-lines.



Fig. 1. Location of the Montrose Alpha oil production platform

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The first oil field to be discovered in the North Sea was the Montrose Field and a steel production platform was installed there in August 1975. The platform stands in 90 m of water, 195 km east of Peterhead, North East Scotland (57°27'N, 01°23'E; Fig. 1). This paper describes the spatial distribution of the dominant marine organisms living on the steel surface of the platform jacket in 1980 and discusses major changes which have taken place in the species composition between 1975 and 1980. The structure of the community living on the Montrose jacket is compared with that found on jackets in the neighbouring Forties oil field.

MATERIALS AND METHODS

The Montrose Alpha jacket has 8 vertical legs linked by a complex arrangement of diagonal and horizontal members. Major horizontal members occur at –10 m, –31 m, –51 m, –71 m and –91 m below M.L.W. and conveniently divide the jacket into 5 elevations (Fig. 2).

Marine growth samples were collected during July and August in 1977, 1978, 1979 and 1980. Four sampling sites were established at each of the 5 major elevations of the jacket with 2 sites on a leg and 2 sites on a major horizontal member at a position mid-way along the member. On the legs, 1 site was on the outward facing surface and 1 on the inward facing surface. On horizontal members, 1 site was on the upper surface and 1 on the lower surface. At each site a

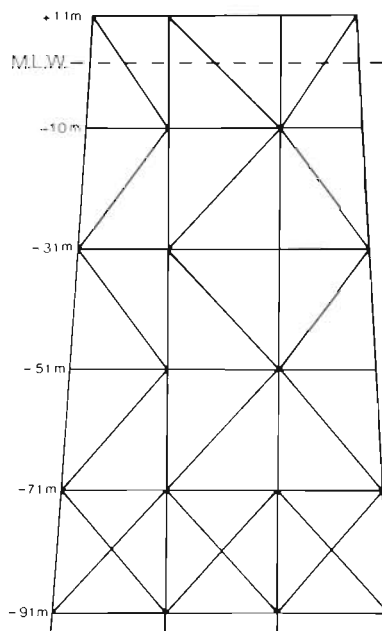


Fig. 2. Major elevations of the Montrose Alpha jacket. M.L.W.: Mean low water

30 cm × 30 cm frame was held against the substrate by magnets and the site photographed in colour to show the marine growth *in situ*. Marine growth within the quadrant was scraped off and organisms identified in the laboratory. A series of general stand-off colour photographs were also taken showing greater areas of the surface of leg or member in the vicinity of the sampling sites. Samples and still colour photographs were analysed in conjunction with black and white video recordings. Considerable areas of the jacket were surveyed each year using video cameras mounted on remote controlled vehicles and although not specifically made to study marine growth, the recordings have been useful in identifying the extent and abundance of the dominant organisms at all elevations and faces of the jacket. Some of the video material available showed the marine growth in winter or early spring and seasonal comparisons in the text are based on analysis of this material.

RESULTS

Forty-five species were recorded from the Montrose Alpha jacket in 1980, of which 40 species were sessile forms. The sampling method did not prevent the majority of the motile species escaping and this probably accounts for the relatively low numbers of motile species recorded. Table 1 gives the range and abundance of the taxa on the Montrose jacket in 1980; it can be seen that seaweeds, hydroids and bryozoans were well represented. Sixteen of the species identified were considered to be rare since they were present in

Table 1. Range and abundance of taxa on the Montrose Alpha jacket in 1980

Phylum	No. of species	% Total
THALLOPHYTA	10	22.2
PORIFERA	1	2.2
CNIDARIA		
Class Hydrozoa	8	17.7
Subphylum Anthozoa	3	6.6
ENDOPROCTA	1	2.2
ANNELIDA		
Class Polychaeta	4	8.8
CRUSTACEA		
Class Cirripedia	1	2.2
Class Malacostraca	2	4.4
MOLLUSCA		
Class Gastropoda	1	2.2
Class Bivalvia	3	6.6
BRYOZOA	10	22.2
ECHINODERMATA	1	2.2
Total	45	

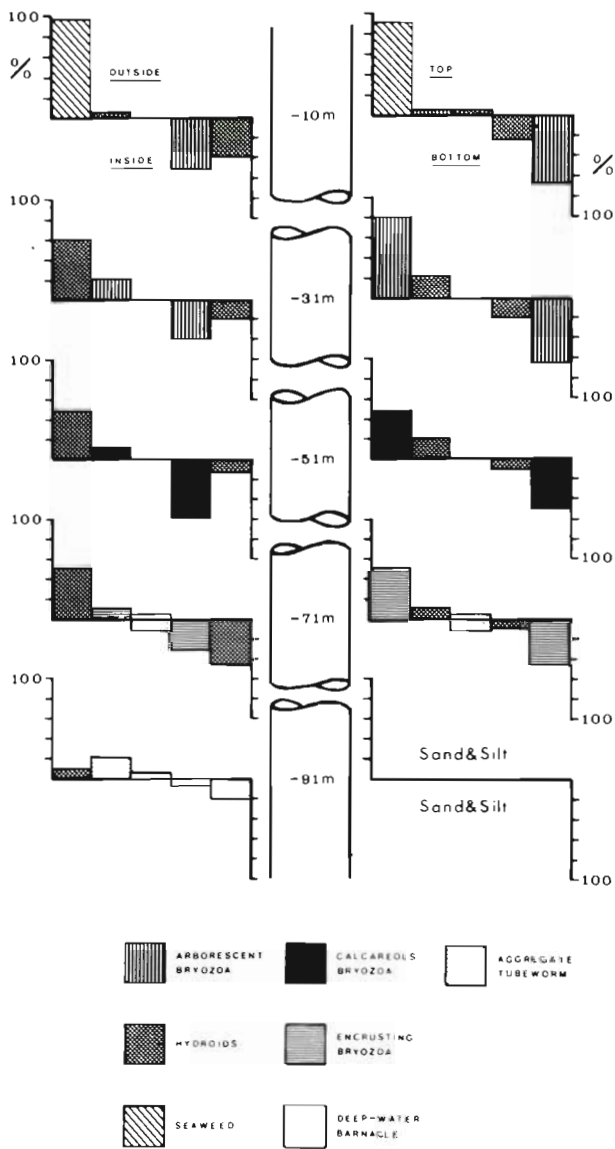


Fig. 3. Estimated percentage cover of marine growth on the Montrose jacket in 1980. Estimates based on an analysis of still colour photographs showing a 30 cm x 30 cm scale

only 1 or 2 of the samples or seen in very few of the photographs and video recordings.

Legs and members did not have a uniform cover of marine growth on them. Fig. 3 shows the percentage cover of the organisms on the outside and inside surfaces of the legs, and top and bottom surfaces of the horizontal members between M.L.W. and the mud-line. It can be seen from this figure that percentage cover was depth related; the greatest cover was in the depth range M.L.W. to -31m; the least between -71m and the mud-line. Particular groups of organisms tended to dominate surfaces in between the various elevations.

In the depth range M.L.W. to -10m, the outside surfaces of the legs and top surfaces of diagonal and horizontal members were covered by a lush carpet of seaweeds. Near the surface, the sea-lettuce *Ulva lactuca* L. and the filamentous green alga *Enteromorpha intestinalis* (L.) covered up to 95% of the substrate but below -1.5m, *Polysiphonia urceolata* Grev. and *P. Brodiaei* Grev. became increasingly abundant. Both *P. urceolata* and *P. Brodiaei* were present down to a depth of about -13m but reached their greatest percentage cover (95-100%) between -6m and -10m. The kelps *Laminaria hyperborea* (Gunnerus) and *L. digitata* (Huds.) were scattered over the legs and members but did not form discrete beds. Some individual plants reached a length of up to 2.5m but most of the plants were about 1.5m. *Alaria esculenta* (L.) was found to form a small bed on one leg between -3m and -10m with some plants reaching a length of nearly 3m. Elsewhere, *A. esculenta* were present in small groups or as solitary individuals. Although seaweeds dominated the community here, hydroids, particularly *Obelia dichotoma* (L.) and *Bougainvillia ramosa* Van Beneden, were not uncommon. The common mussel *Mytilus edulis* L. did not form beds but individuals were scattered amongst the seaweeds, many of them overgrown by epiphytes.

The depth range and extent of the seaweed community on Montrose Alpha was determined by the level of incident light rather than availability of suitable substrates. On sunlit surfaces of legs and members in the depth range M.L.W. to -10m there was a profuse cover of seaweeds, but on shaded surfaces this was entirely replaced by hydroids and bryozoans. Below -10m, the seaweeds rapidly gave way to hydroids and bryozoans on all leg and member surfaces. The hydroids *Obelia dichotoma*, *Laomedea flexuosa* Hincks and *Bougainvillia ramosa* were all common down to a depth of -31m. Some colonies of *Tubularia larynx* Ellis and Solander were also recorded but these were more or less restricted to diagonal and horizontal members with few colonies on the legs. The arborescent bryozoans *Bicellariella ciliata* (L.) and *Bugula avicularia* (L.) were found amongst the hydroids but in the absence of seaweeds, the dominant organism to a depth of -31m was the bryozoan *Electra pilosa* (L.). This species covered between 90% and 95% of the available substrate, where it formed dense, bush-like colonies.

Below -31m, arborescent bryozoans were steadily replaced by calcareous bryozoans. Dense patches of *Omalosecosa ramulosa* (L.) and *Tubulipora liliacea* (Pallas) were present on legs and members. These calcareous bryozoans covered at least 80% of the substrate but colonies of the hydroids *Obelia dichotoma*, *Laomedea flexuosa* and *Bougainvillia ramosa* con-

tinued to be present, although somewhat more scattered than in the depth range -10 m to -31 m. Below -51 m, the calcareous bryozoans were largely replaced by encrusting bryozoan species, in particular *Alcyonidium hirsutum* (Fleming), which formed extensive mats over much of the substrate down to a depth of -71 m.

Towards the -71 m elevation, small aggregations of the tubeworm *Filograna implexa* Berkeley were present and these became much more common with increasing depth. Between -71 m and the mud-line (-91 m), domed, discrete masses of these worms and deep-water barnacles, *Balanus hameri* (Ascanius), were attached to legs and diagonal members. The percentage cover of marine growth in this depth range was significantly less than was present elsewhere on the jacket (Fig. 3).

Several sessile species were ubiquitous but never sufficiently abundant to be included in the percentage cover analysis. The tubeworms *Pomatoceros triquetus* (L.) and *Hydroides norvegica* Gunnerus were scattered over the steel surfaces of the jacket but between M.L.W. and -31 m most individuals were overgrown by seaweeds, hydroids and bryozoans. Both species of solitary tubeworms reached their greatest abundance below -71 m. A few individual anemones *Metridium senile* (L.) and soft corals *Alcyonium digitatum* L. also were present at all elevations. The sponge *Leucosolenia complicata* (L.) formed small colonies on legs and members but was rarely found below -51 m.

It was difficult to identify the distribution and abundance of motile organisms. However, the amphipod *Jassa falcata* (Montagu) and sea-slug *Dendronotus frondosus* (Ascanius) were consistently recorded amongst samples of hydroids, whereas the polychaete *Nereis pelagica* (L.) was found in most samples and showed no obvious preference for a particular depth range or habitat. The seastar *Asterias rubens* L. was very common on the sea-bed around the platform but few specimens were present in samples or seen in video and still photographs of the jacket.

DISCUSSION

Although the methods used to assess the marine growth on the Montrose platform were largely qualitative it was clear that species composition on the jacket changed with depth. It was possible to identify 5 depth zones on the jacket each of which was dominated by a different group of organisms (Table 2).

There have been some notable changes in the species composition on the Montrose Alpha jacket since its installation in 1975. By Year 2 (1977), the hydroid *Tubularia larynx* had become established over

most of the steel surfaces between M.L.W. and -31 m, and continued to dominate this depth range in Year 3. The rapid colonisation by *T. larynx* is difficult to explain. Pyefinch and Downing (1949) and Crisp (1981) point out that there is no free swimming stage in this hydroid. Laboratory experiments by Pyefinch and Downing showed that after liberation, the actinulae slowly sink through the water and as a result the majority of actinulae settle in close proximity to the parent colony. However, the rapid and successful colonisation by *T. larynx* on the Montrose platform clearly shows that this species has much greater powers of larval dispersion than has previously been suggested. During the summer *T. larynx* is able to complete its life-cycle within a few weeks and there are several generations per year (Barnes and Powell, 1950; Meadows, 1969). Therefore, it is possible that the large numbers of colonies on the Montrose jacket by Year 2 were solely the result of colonisation by actinulae liberated from mature colonies on the seabed in the vicinity of the platform. Further studies on the larval biology of this species are necessary.

By the summer of Year 4, *Tubularia larynx* was largely replaced by seaweeds, hydroids and arborescent bryozoans. The continuing decline of *T. larynx* between Years 4 and 5 on the Montrose jacket appears to have been the result of a gradual reduction in the area of substrate suitable for larval settlement. The majority of seaweeds on the jacket are species which do not die back in the winter, for example the kelps, and species which are pseudo perennials, such as *Polysiphonia*. Pseudoperennials have become increasingly abundant since Year 3 and the overwintering cells of *Polysiphonia* have given rise to substantial new growth by May of each year, covering large areas of the available sunlit surface. On the other hand, the actinulae of *T. larynx* are not usually released before June by which time only limited areas of substrate are available for settlement in the depth range colonised by seaweeds. Once an established colony of *T. larynx* dies in the seaweed zone, it is apparently not replaced

Table 2. Dominant organisms in various depth ranges of the Montrose jacket

Depth range (m)	Dominant organisms
Sunlit M.L.W. to sunlit -10	Seaweeds
Shaded M.L.W. to -31	Hydroids & arborescent bryozoans
-31 to -51	Calcareous bryozoans
-51 to -71	Encrusting bryozoans
-71 to mud-line	Aggregate tubeworms and deep-water barnacles

by a new colony arising from the settlement of an actinula. It is not known if the brown and red algae present on the jacket produce inhibitors but hydroids have been shown to be sensitive to chemicals produced by some similar species of algae (Sieburth and Conover, 1965; Pinter, 1969).

Tubularia has elevated feeding organs and therefore is generally resistant to the effects of overgrowth (Grosberg, 1981). This species was expected to compete successfully with most of the hydroid and bryozoan species found on shaded surfaces between M.L.W. and -31 m. The reason for the reduction in colonies of *T. larynx* in this assemblage was due to the growth pattern exhibited by *Electra pilosa*. The growth form of *E. pilosa* is known to be very variable and in certain cases the colonies will encrust branched or cylindrical surfaces such as the hydrocaulis of hydroids, resulting in the formation of arborescent colonies independent of the substrate (Ryland and Hayward, 1977). This growth form is the most common type found on Montrose Alpha. *E. pilosa* has become increasingly evident since Year 3 and covers large areas of the steel surface between M.L.W. and -31 m in characteristic, arborescent colonies which have been formed by encrusting the colonies of *T. larynx* and probably *Bougainvillia ramosa*. The ancestrulae of *E. pilosa* settle in late summer and early autumn and subsequent colonial growth is rapid (Ryland and Hayward, 1977). The settlement period of the ancestrulae would more or less coincide with the start of the winter die-back period of *T. larynx*; growth of *T. larynx* is rapid only during the summer months (Pyefinch and Downing, 1949; Barnes and Powell, 1950; Meadows, 1969). Colonies of hydroids encrusted by *E. pilosa* are most unlikely to be able to regenerate in the following spring since they become totally smothered by this bryozoan. Further recolonisation by *T. larynx* will require the successful settlement of actinulae but there is no indication of this having taken place.

These observations suggest that the actinulae of *Tubularia larynx* are not able to establish new colonies if there is considerable competition for space on a surface. It would be interesting to know if the actinulae can recognise the density of the dominant species already present, and reject substrata when that density exceeds a certain threshold. Grosberg (1981) has found evidence of such behaviour in several marine invertebrates, and Scheer (1945) and Skerman (1959) list several organisms which have been shown to replace *T. larynx* but do not make reference to the seaweeds *Polysiphonia* spp. or bryozoan *Electra pilosa*.

Surfaces in the depth range -31 m to the mud-line were colonised initially by sparse colonies of hydroids, in particular, *Bougainvillia ramosa*, but also *Obelia dichotoma* and *Laomedea flexuosa*, a few solitary

tubeworms, *Pomatoceros triqueter* and *Hydroides norvegica*, and small groups of deep-water barnacles, *Balanus hameri*. By Year 3, between -31 m and -51 m, colonies of *B. ramosa* had increased in abundance on the members and *O. dichotoma* and *L. flexuosa* had become more common on the legs. In Year 4, surfaces in this depth range were colonised by the calcareous bryozoans *Omalosecosa ramulosa* and *Tubulipora liliacea*. Between -51 m and -71 m, hydroids were more in evidence but the overall density of hydroids was significantly less than in shallower depth ranges of the jacket and by Year 4, many hydroid colonies were overgrown by the encrusting bryozoan *Alcyonidium hirsutum*. The most significant change between -71 m and the mud-line has been the colonisation of legs and members by aggregations of the tubeworm *Filograna implexa*. These were first recorded in Year 3 and have continued to increase in size and abundance.

The fouling on the Montrose jacket cannot be compared directly with the published information on fouling of jackets in North American waters, where water depths rarely exceed 35 m and the species concerned are largely endemic. More meaningful comparisons can be made between the Montrose jacket and jackets in the neighbouring Forties field which lie only 40 km to the north west. Two of the jackets in the Forties field were installed at the same time as the Montrose jacket. General descriptive accounts of the marine growth on the Forties platforms have been given by Ralph and Troake (1980), and Goodman and Ralph (1981).

Observed differences in the marine growth on the Montrose and Forties platforms are easier to follow using the terminology adopted by Aleem (1957). The stages which give the community a characteristic pattern at any given time are called a 'phase' and these are defined by the dominant organism. The successional phases on Montrose and Forties can be summarised as follows:

M.L.W. to -30 m

Montrose: Hydroids—Seaweeds (Upper stratum); Arborescent bryozoans (Lower stratum)

Forties: Mussels

-30 m to -70 m

Montrose: Hydroids—Bryozoans. The bryozoan phase includes 2 subphases; (a) calcareous bryozoans between -30 m and -50 m, (b) encrusting bryozoans between -50 m and -70 m

Forties: Solitary tubeworms—Hydroids—Anemones

-70 m to the mud-line

Montrose: Hydroids—Aggregate tubeworm

Forties: Solitary tubeworms—Aggregate tubeworms

There is a striking difference between the phases on the Montrose and Forties platforms in the depth range M.L.W. to -30 m. *Mytilus edulis* has always dominated this depth zone on the Forties platform but has remained a minor member of the marine growth community on Montrose. Ralph and Troake (1980) suggest that the presence of relatively few mussels on Montrose is due to the absence of residual coastal current systems passing by the platform. Mussel spat are carried out from breeding coastal populations into the North Sea by currents (Rees, 1954; Crisp, 1981). However, recent data collected by operators of the Montrose and Forties fields show that in general, similar currents do in fact affect both fields, in which case the failure of mussels to colonise Montrose in large numbers, following the installation of the jacket, is probably due to the length of time the coastal currents take to reach the platform. Planktonic larval life lasts for between 3 and 4 wk, after which failure to find a suitable hard substrate will result in death (Bayne, 1976). Definite conclusions as to the reasons for the failure of mussel spat to reach Montrose in large enough numbers to dominate the upper elevations of the jacket will now prove difficult because of the substantial breeding population of mussels on the Forties platforms. Mussels mature when they are about one year old and females produce on average between 5 and 12 million eggs (Field, 1922). Breeding populations on Forties platforms must have increased the chances of large and regular swarms of spat reaching Montrose, only 40 km to the south-east. It is significant that during Year 5 large numbers of mussel spat were found on samples of seaweeds taken from the Montrose platform and it would have been interesting to know whether these animals were the offspring of Forties mussels or those of more distant coastal populations. In spite of the sudden increase in spat on the Montrose jacket there are no indications at present that mussels will replace seaweeds and bryozoans in the depth range M.L.W. to -30 m. *M. edulis* has been shown to be the climax community in Californian waters (Scheer, 1945) and it has been the dominant organism on jackets in the Forties field for 5 years now (Ralph and Troake, 1980; Goodman and Ralph, 1981).

In the mid-water depths, there have been 3 successional phases recognised on the Forties platforms but only 2 on the Montrose jacket. In contrast to the Forties jackets, the photographic evidence from Montrose has shown that solitary tubeworms were never dominant organisms in this depth range. *Metridium senile* have only recently become sufficiently numerous on the Forties platforms to be considered a successional phase but on Montrose, wide ranging video coverage of the jacket has shown that there are very few anemones. Below -70 m, the pioneering solitary tubeworm phase

seen on Forties platforms was again absent on Montrose but the present phase on the jackets in the 2 fields appears to be qualitatively similar.

Silt, from drilling activities, may have been responsible for some of the differences in faunal composition between the Montrose and Forties jackets below -31 m. Video and still photographs of the Montrose jacket clearly indicated that silt was present on many of the members below -31 m, at least until Year 3. Silt will have a harmful effect on many sessile organisms colonising hard surfaces. Solitary tubeworms are most unlikely to survive in silty conditions as they do not have elevated feeding or respiratory structures; this may account for the absence of a solitary tubeworm phase on Montrose. It is also probably as a result of the accumulation of silt that the dominant hydroid species below -31 m on Montrose was *Bougainvillia ramosa* and not *Tubularia larynx* as on the Forties jackets (Goodman and Ralph, 1981). The attachment mechanism and morphology of *B. ramosa* are better adapted to silty conditions than those of *T. larynx*. *B. ramosa* may extend to a height of 10 cm and form a sparse branching, tree-like colony which is attached to the substrate by a network of stolons (Edwards, 1966). The feeding polyps are situated on the tips of the branches and the whole colony is very flexible. *T. larynx*, on the other hand, relies on a single creeping stolon for attachment to the substrate, and this single stolon gives rise to numerous erect hydrocauli, supporting large feeding polyps (Hincks, 1868). The ramifying hydrorhiza of *B. ramosa* will provide a more efficient means of attachment on silt covered surfaces than the single hydrorhiza of *T. larynx* and the shape of the colony is unlikely to gather as much silt as will *T. larynx*. Specimens examined from Montrose show that the delicate lateral branches of *B. ramosa* collect considerably less debris than is found on and between the hydrocauli of *T. larynx*. Between M.L.W. and -31 m, members are kept more or less free of silt by wave action, and on Montrose this depth range was rapidly colonised by *T. larynx*. This suggests that *T. larynx* avoids silt-covered surfaces and also that the Forties platforms have been relatively free of silt although there is no published data to confirm this at present.

Succession in the mid-water levels has been slow on Montrose when compared with jackets in the Forties field. Biotic succession of the different phases of the marine growth community on hard surfaces is determined by a set of factors; mechanical support has been shown to be of great importance (Aleem, 1957). Often the increase in abundance of one organism provides another with sufficient substrate to out-compete the former for space. Initial colonisation by *Bougainvillia ramosa* and the other small hydroids present on Montrose below -31 m probably would have been more

rapid and successful had large numbers of tubeworms and other hard encrusting organisms preceded them. The tubeworms and other pioneering species would have increased the effective area of mechanical support for the hydroids. In the absence of a tubeworm phase and in the presence of silt, it will have taken longer for organisms to colonise this depth range on Montrose than on Forties. Bryozoans avoid soft substrates (Hayward and Ryland, 1979) and the silt on Montrose would have prevented their early colonisation. Following the increase in abundance of *B. ramosa* and other hydroids in Years 3 and 4, bryozoans were able to use the hydroids as a means of mechanical support, eventually dominating surfaces in the mid-water depth range.

A second important factor in determining the rate of growth of hydroids and therefore the rate of succession must have been the life cycles of the hydroids themselves. *Bougainvillia ramosa*, *Obelia dichotoma* and *Laomedea flexuosa* all pass through pelagic stages (Hincks, 1868). The planktonic ephyrae of these species are carried away from the parent colony by current systems and further recruitment must rely on chance settlement of actinulae from other sources. Species of *Tubularia* have no true planktonic stage and their export of young is negligible (Pyefinch and Downing, 1949; Crisp, 1981). The crawling actinulae of *T. larynx* are able to colonise areas of the jacket adjacent to their parents immediately. On Montrose, the mid-water depth range has been almost entirely colonised by organisms which have a pelagic life cycle but this has not been the case on the Forties jackets. The initial solitary tubeworm phase was followed by a hydroid phase, dominated by *T. larynx*, and more recently, an anemone phase. The anemone *Metridium senile* is able to produce large numbers of offspring by pedal laceration (Hahn, 1905; Cary, 1911; Stephensen, 1928 and 1935) and so again is able to colonise new areas directly.

The deep-water levels of the Montrose and Forties platforms have a similar fauna and it would seem that the *Filograna implexa* and *Balanus hameri* phase is a climax community. These organisms have continued to dominate this zone for several years now. Although *F. implexa* has possibly the widest distribution of all serpulid genera (ten Hove, 1979) very little is known about the size and formation of the aggregate domes. Regular photography of these aggregations on North Sea oil platforms will provide information on the growth rate and size of aggregations. *B. hameri* has previously been considered a rare species of barnacle and since Darwin's description of the species in 1854 additional studies have consisted of a single attempt to measure growth rate (Moore, 1935) the identification of the larvae (Crisp, 1962) and studies on the cement

apparatus (Walker, 1972). This study has shown that in the central North Sea this species is clearly not rare and further information on the biology of the species is now becoming available.

Acknowledgements. We wish to thank the Amoco (UK) Exploration Company for permission to publish these results and for their co-operation and help in carrying out the work on the Montrose Alpha Platform over the past 4 years. This study forms part of a larger programme supported by research grants to Dr. R. Ralph from the Marine Technology Directorate of the Science and Engineering Research Council.

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This paper was submitted to the editor; it was accepted for printing on January 14, 1982