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The Beatrice oilfield is the first nearshore development in United Kingdom waters. Situated in an area of major ecological and nature-conservation importance, the development of Beatrice has demanded thorough attention to environmental planning and monitoring through all stages.

Assessment of the environmental implications of the development was a major concern from the earliest stages of project planning. A range of baseline studies was performed to provide a basis for future monitoring. During the planning phase, as later in the field's development, consultation and communication with the statutory bodies and local community was a priority. The environmental assessment and its component studies were discussed with all concerned. As well as providing the detailed scientific data, the work was also presented in summary form to the local communities. The local community as well as the authorities needed to be reassured that the environment would be protected.

Monitoring of the marine environment of the Moray Firth is a continuing activity involving a wide range of studies by specialist teams in four main areas: (1) ornithological studies; (2) intertidal monitoring; (3) sublittoral studies; (4) others, including structural fouling by marine growth. The long-term monitoring programme is built on extensive baseline data gathered before oil was produced at Beatrice. The scope of this work will be outlined in this paper and examples given of some of the results. In addition to the monitoring aspects, the data is often of considerable academic interest, and Britoil encourages publication of scientific papers arising from the programme. The overall conclusions are that only very localized environmental impact has been caused beneath and in the immediate vicinity of the drilling platforms and that development and operation of the Beatrice field has not damaged the marine environment and resources of the Moray Firth.

Introduction

The Beatrice field was discovered in 1976 and at a distance of only 12 miles off the Scottish mainland is currently Great Britain's nearest inshore oilfield (figure 1). The development consists of four offshore platforms, a 49 mile long pipeline and a storage and tanker loading terminal at Nigg Bay in the Cromarty Firth. These various facilities are operated by Britoil on behalf of a consortium consisting of: Britoil plc, Deminex U.K. Oil & Gas Ltd, Hunt Overseas Oil Inc., Kerr–McGee Oil (U.K.) Ltd and Lasmo North Sea plc.

Developed within sight of land, and surrounded by an environmentally significant coastline, the Beatrice Field and associated facilities demanded that special attention be given to protect and monitor the environment. From the early days of the development, indeed before the development plan was approved, biological data has been obtained from a wide range of studies throughout the area.

The aims of this work were twofold: to establish a series of environmental baselines

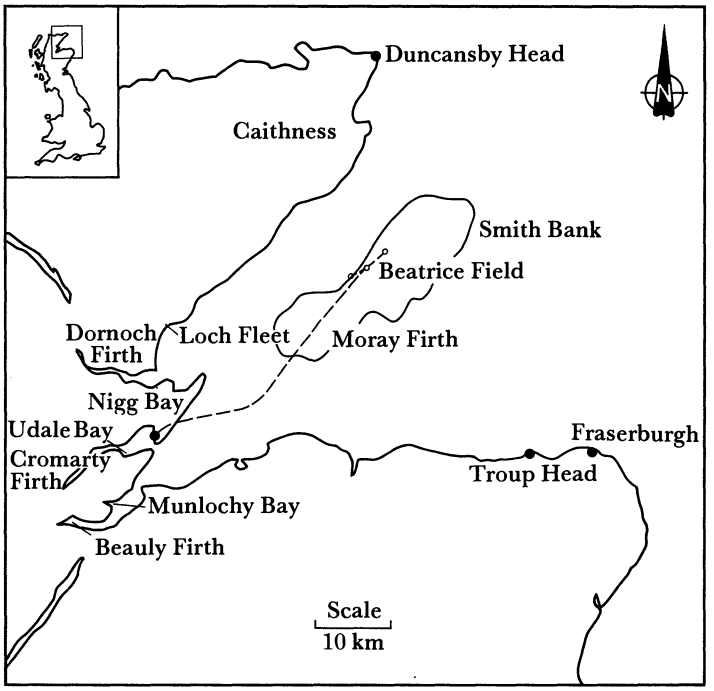

FIGURE 1. Location of the Beatrice oilfield, 12 miles off the coast of Caithness, in the Moray Firth, and the Nigg Oil Terminal in the Cromarty Firth.

representing biological and chemical conditions before the start up of oil production from the field; to use these reference points as a basis for comparison with subsequent data gathered through the continuing monitoring programme.

A large quantity of information on the marine environment of the Moray Firth has been gathered resulting in a number of publications. Much of the information gathered up to 1985 was presented at a symposium at Aberdeen University in March 1985 (ed. R. Ralph 1986). This present paper outlines the range of investigations, carried out in the environmental monitoring programme sponsored by the Beatrice Consortium, and provides examples of results from each part of the programme with the aim of illustrating both the relevance for monitoring of oilfield operations and the biological interest.

ORNITHOLOGICAL STUDIES

The Moray Firth is an area of international importance for a variety of bird species associated with the coastal and marine environment. Throughout the year major concentrations of birds occur both at sea and at several sites along the coastline. It contains some of the best estuary sites in Great Britain and is a main arrival point for immigrant birds which have come from Iceland and northern Scandinavia. The Cromarty Firth itself qualifies under the criteria set down by the International Waterfowl Research Bureau, as an area of international importance.

The ornithological studies therefore constitute some of the more important aspects of the environmental monitoring programme. The main objectives have been to provide a database

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to allow long-term monitoring of bird populations and to assist the development of appropriate contingency measures for use in the event of any pollution incident.

Work on seabirds and sea ducks has been carried out by the Royal Society for the Protection of Birds (R.S.P.B.) and on shorebirds by the Nature Conservancy Council (up to 1985 after which routine long-term shorebird monitoring has been incorporated in the R.S.P.B. programme).

Breeding seabirds

Available information on the sizes and locations of seabird breeding colonies in the Moray Firth is reviewed by Mudge (1986). The most abundant species being guillemot, with a population of approximately 149000 individuals spread over 13 main colonies. The bulk of the populations of breeding species occur on the coast of east Caithness. Data are presented by Mudge from census study plots which were set up in 1980 to monitor any long term and large annual changes in population size. A comparison with counts made in 1969 (table 1) permits assessment of longer term changes, whereas new data from the period 1980–84 allow shorter term comparisons from year to year.

TABLE 1. WHOLE COLONY COUNTS OF SEABIRDS AT PRINCIPAL SITES IN THE MORAY FIRTH. A COMPARISON BETWEEN 'OPERATION SEAFARER' AND MORE RECENT SURVEYS

(From Mudge (1986).)

	east Caithness		North Sutor of Cromarty		Troup, Lion's and Pennan heads	
	1969	1977	1969	1984	1969	1979
fulmar	16161	21679	779	1393	1180	1612
cormorant	823	284	87	203	0	0
shag	1114–1292	1863	24	30	83	81
kittiwake	32282–34322	53025	400	329	11425	14267
razorbill	12274–13173	14196	60	41	629	1959
guillemot	49483	126251	750	933	8869	21827
tystie	197	408	0	2	+	1
puffin	4722–28203	915	0	0	397	523

Count units: fulmar, apparently occupied sites; cormorant and shag, nests; kittiwake, apparently occupied nests; auks, individual birds.

In summary, it appears that a substantial increase in population size occurred in the 1970s for most species although this trend of increase has now ceased for guillemots, razorbills and kittiwakes. The trend of change over the 1980–84 period for these species may have been downwards (see, for example, figure 2) but there are major difficulties of extrapolation from limited counts so any recent trends cannot be statistically substantiated. It can, however, be concluded that no major decline in population has occurred up to 1984 after the general increases over the 1970s.

In addition to counts in the breeding season, out-of-season attendance has been monitored using automatic surveillance cameras. (Mudge *et al.* 1985). Two species, fulmar and shag, were found to frequent the colonies over a large part of each non-breeding season. There was, however, only a low level of winter colony occupancy by auks, which contrasted with reports from colonies elsewhere. Mudge *et al.* (1986) suggested that the main current constraint is a paucity of local-breeding adults wintering within easy reach of the colonies which in turn

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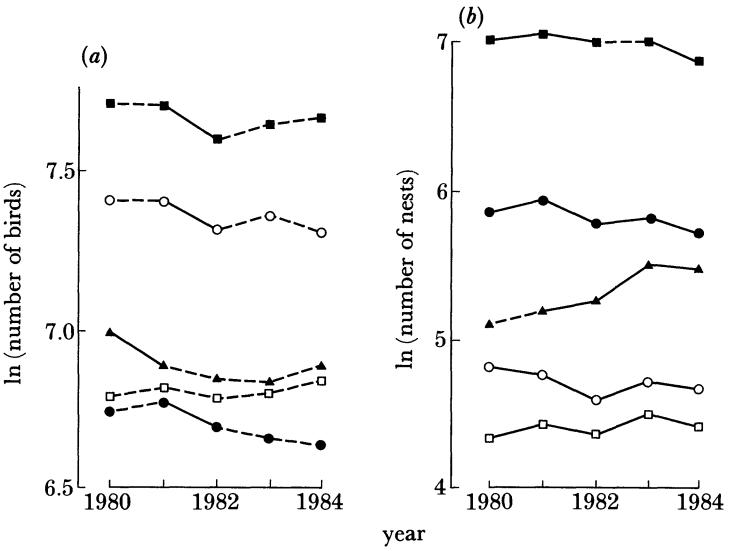

FIGURE 2. Numbers of (*a*) guillemots (individual birds) and (*b*) kittiwake nests in east Caithness plots 1980–84. (From Mudge 1986.)

may be because of recent declines in winter stocks of fish prey in the Moray Firth. Standard ringing techniques have been used to build up an understanding of migration movement and mortality. Coordinated counts offshore at the Beatrice platforms and at the cliff sites have provided information on feeding patterns and daily movements to and from the colonies.

Seabirds at sea

Until recently, very little was known of seabird distribution and movement within the Moray Firth as a whole. However, a large study was carried out in 1982 and 1983 to determine the feeding areas of key seabird species and their pattern of distribution throughout the year (Mudge & Crooke 1986). This has highlighted areas that may be particularly threatened by any oil spillage. A sea area of approximately 8000 km² was systematically studied by using a survey grid of 5′ latitude by 10′ longitude. Using a 'dedicated vessel', observations were made from a sheltered cabin above the wheelhouse by using methods that have evolved for seabird at sea studies in other countries and since developed and tested in British waters (Tasker *et al.* 1984). From monthly surveys over the two-year period, a very large quantity of data has been acquired and is stored and analysed on a computer database by using systems compatible with other systematic ship-based observations elsewhere in the North Sea. The information can be summarized for individual species or groups of species or for different times of year.

Mudge & Crooke (1986) describe the pattern of overall seabird abundance (figure 3) which showed fewest numbers in late winter, but rapidly increasing up to April, before the commencement of breeding. A slight drop occurred in most species during the breeding season. (May to July in most species.) At the end of the breeding season large flocks of auk chicks and moulting adults (all flightless) were present, peaking in August. It is at this time when seabirds in the Moray Firth are probably most vulnerable to any oil pollution incident. In September and October, as flocks disperse, the numbers of birds at sea drop off rapidly.

From the wealth of information gathered on seabird species distribution and variations in

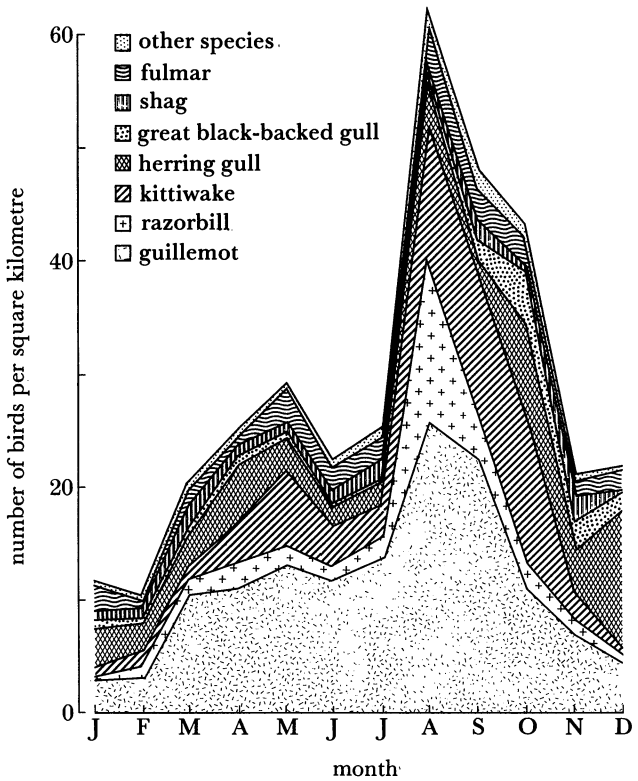

FIGURE 3. Average numbers of birds, and species composition at sea from month to month based upon data from 1982 and 1983 (From Mudge & Crooke 1986.)

this from month to month, perhaps the most useful summaries in relation to oil spill contingency planning are maps of selected species or groups of species at different times of the year. For example, figure 4 contrasts the distributions of razorbills which are found throughout the Moray Firth in summer, with shags which have a much more confined distribution close to their breeding site, throughout the year.

Mudge & Crooke (1986) note several important features which emerge from maps such as those in figure 4. Two areas in particular are held by large numbers of seabirds at all times of the year. One was an inshore area near the border of Caithness and Sutherland, and the other is the Troup Head and Fraserburgh area. The importance of the northeast corner of the Smith Bank was also noted as the location of the main daytime concentrations of seabirds for much of the year, and particularly in the pre and post breeding period.

Seaduck

Surveys of seaducks have been carried out as part of the Beatrice environmental programme since 1981. Campbell *et al.* (1986) reviewed the current status and distribution of seaducks in the Moray Firth and also compared recent data with earlier information to determine any trends and also present an overall conservation assessment of Moray Firth seaduck population. The main species and their estimated populations are shown in table 2, from which the importance of the Moray Firth seaducks in terms of the populations of the British populations is clear. For common and velvet scoter and long-tailed duck the Moray Firth holds more than

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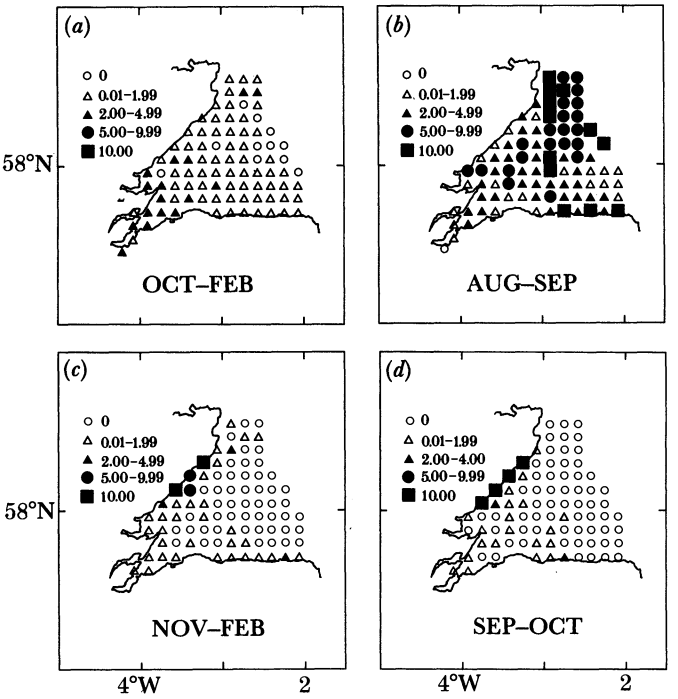

FIGURE 4. Seasonal changes in the distribution and abundance at sea of (*a*, *b*) razorbills and (*c*, *d*) shags. An amalgamation of transect data from 1982 and 1983, Units: birds per square kilometre. (From Mudge & Crooke 1986.)

TABLE 2. SUMMARY OF CURRENT WINTER SEADUCK POPULATION ESTIMATES IN THE MORAY FIRTH

(From Campbell *et al.* (1986).)

	Population estimates		
	Moray Firth	Great Britain	Western Europe
eider	3000	50000	2000000
common scoter	10000	35000	500000
velvet scoter	5000	3000	200000
long-tailed duck	15000	20000	500000
goldeneye	1000	15000	200000

1% of the estimated European population which on those criteria makes it an internationally important site for those species.

Considering the patterns of numbers and distribution over a period of time, Campbell *et al.* conclude that although individual sites (figure 5) may appear outstanding for one or more species, for conservation purposes the Moray Firth should be considered to be a single seaduck site, within which local flock distribution patterns may vary considerably from year to year.

In the context of oil pollution, the sensitivities of wintering seaduck may be different from the generally more widely dispersed auks. The relative confinement of seaduck flocks in small areas or loose concentrations where they may be present locally at very high density may render them vulnerable not only to widespread or large volume incidents, but also to much more localized or small scale events (Campbell *et al.* 1978).

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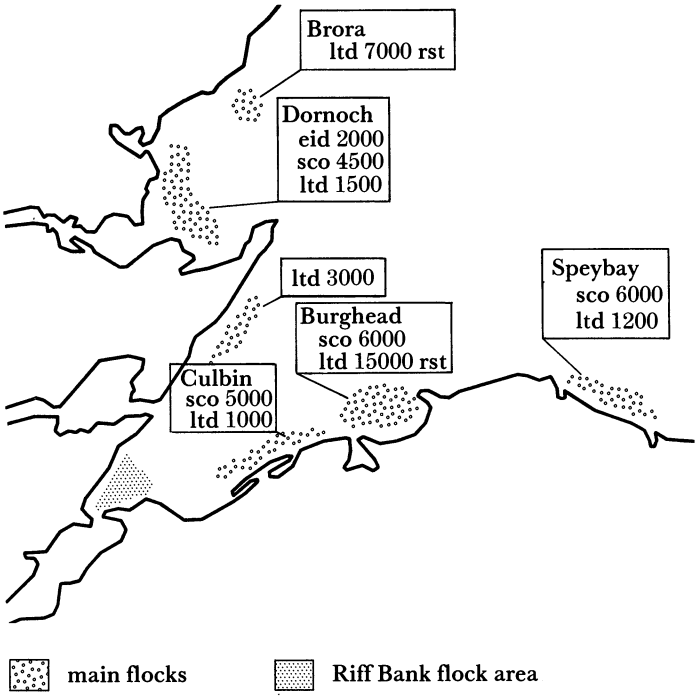

FIGURE 5. The location and approximate size of flocks of wintering eider (eid), scoters (sco) and long-tailed duck (ltd) in the Moray Firth in 1981–82 and 1982–83 (From Campbell *et al.* 1986.) rst, represents roosting flocks.

Shorebirds

The Moray Firth is of international importance for waders and wildfowl, supporting up to 36000 waders on mudflats in the area and up to 45000 dabbling ducks. A research programme between 1981 and 1985 was carried out by the Nature Conservancy Council as part of the Beatrice environmental monitoring programme. The aims of this work were to provide up to date counts of total populations, identify major feeding and roosting sites for each species, estimate movement between sites and assess the relationship between the Moray Firth and other intertidal areas. In all of these the underlying objective was to provide a basis for long-term monitoring of shorebird populations. The procedures used and main results have been summarized by Symonds & Langslow (1986).

Counts over the winter between 1981 and 1985 recorded peak oystercatcher and redshank numbers in excess of 1% of the total northwest European population. Bar-tailed godwit and knot exceeded this in 1984–85. Seasonal and annual trends in population levels were described both for the individual species and the total wader population (see, for example, figure 6). Summer numbers are low, comprising mainly immature oystercatchers. The rapid rise between July and October is made up first of oystercatcher and godwit, followed by redshank. Largely juvenile knot and dunlin arrive in October, followed by a further influx of bar-tailed godwit and adult knot and dunlin in November and December.

Wildfowl arrive in the Moray Firth from their breeding grounds from August to October before dispersing to wintering sites elsewhere in Britain. These autumn concentrations of wildfowl are the largest in Britain, and some areas continue to support large numbers throughout winter.

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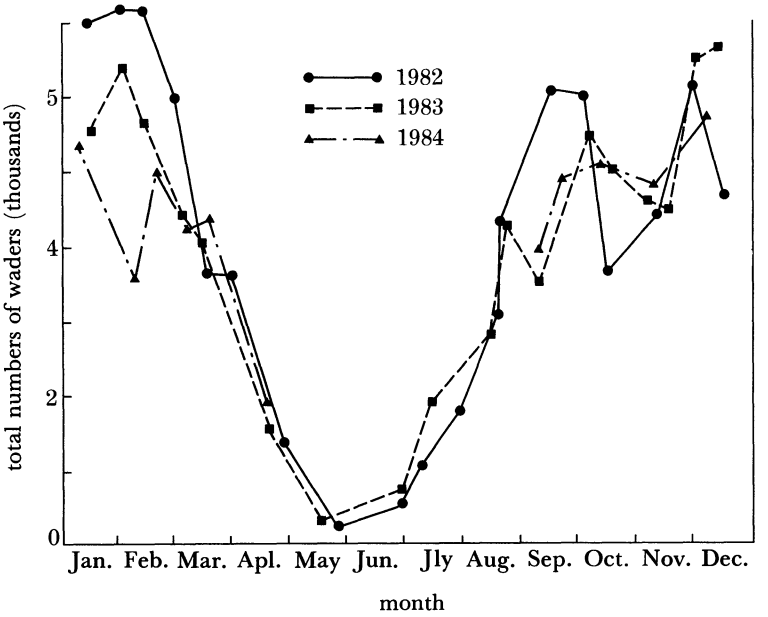

FIGURE 6. Total wader population in the Cromarty Firth 1982–84. (From Symonds & Langslow 1986.)

Loyalty of different species to feeding areas and movement between sites was studied by colour marking birds caught in cannon-netting exercises. Various patterns of movement emerged. Curlew, turnstone, oystercatcher, redshank and ringed plover remained attached to their selected areas, whereas mobile species such as dunlin, knot and bar-tailed godwit moved frequently between feeding areas.

Discussing the results in relation to nature conservation interests, Symonds & Langslow (1986) stress the major importance of the Moray Firth as a migration staging post and wintering area for both waders and wildfowl. Loss or damage to intertidal sites through reclamation pose threats the effect of which would be difficult to quantify. However, it is clear that future conservation planning policies must consider factors such as winter movements of birds and the local distribution of some species, as well as simply the total population sizes. The continuing long-term monitoring of shorebirds in the Moray Firth should greatly help understanding of these aspects.

INTERTIDAL STUDIES

A very wide range of shore habitats lies between Duncansby Head and Fraserburgh and into the Cromarty and Beauly Firths. Shingle ridges and sand dunes are present, and silt and mud in the major estuaries have resulted in the extensive flats at Nigg, Udale and Munlochy Bays, Loch Fleet and the upper Beauly Firth. The rocky shores occur mainly along the outer, more exposed areas of the Moray Firth.

The aims of the intertidal studies carried out by Aberdeen University Marine Studies Ltd have been to monitor shoreline conditions and community structures and to detect any long-term changes. The methods used enable comparison with results from elsewhere. The information, particularly from soft-shore monitoring is highly relevant to other investigations such as shorebirds and wildfowl.

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Rocky shores

An intertidal rocky shore monitoring programme was established in the Moray Firth in 1981, covering 34 different locations between Duncansby Head and Fraserburgh (figure 7). The aim was to describe the range of shore communities present, relate these to the physical characteristics of the different shore types and also provide a basis for detecting any long-term biological changes on the shores of the Moray Firth.

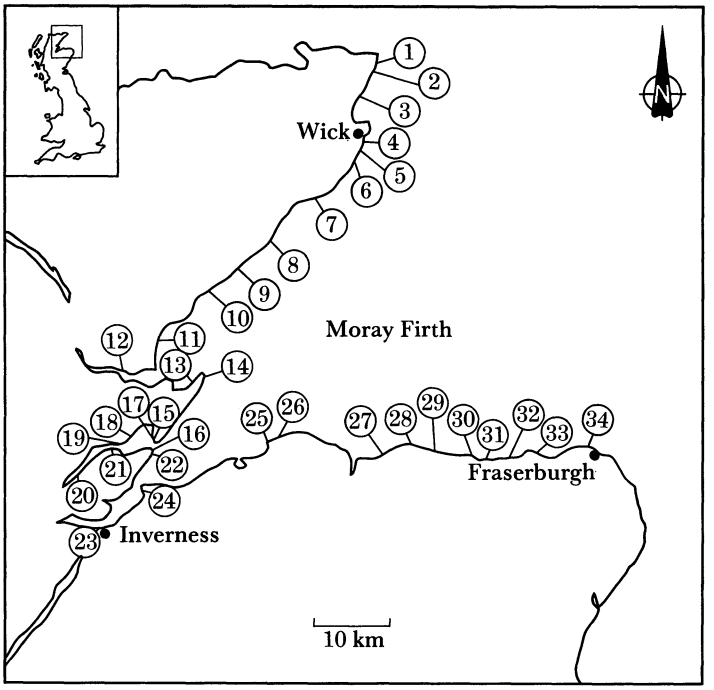

FIGURE 7. Location of rocky shore monitoring transects. (From Terry & Sell 1986.)

The survey methods used and the main results are described by Terry & Sell (1986). The methods used in this monitoring programme have been designed for the variety of shore topographies and biological communities encountered in this region. It is based on analysis of data from shoreline appraisal and transect studies, using a fixed-point quadrat method. Detailed species lists have been compiled for each permanent quadrat at each transect visit. Species composition has been related to exposure and substrate type. The dominant communities and the principal factors affecting species abundance and distribution at each transect location have been described (Terry & Sell 1986). One difficulty in rocky-shore monitoring programmes is interpretation of changes detected, whether natural, or pollution induced. One of the aims of this work has been to ease possible future interpretation by building up a history of the particular communities and identifying the community processes operating.

Nigg Bay sediments

A series of monitoring surveys in Nigg Bay by Aberdeen University Department of Zoology has provided an assessment of the major biological resources of the intertidal sand and mudflats,

and the physical factors associated with the distribution and abundance of these resources (Raffaelli & Boyle 1986). Changes in species composition and abundance have been described in relation to natural fluctuations in physical parameters such as sediment silt content.

Information gathered from these studies is relevant to a number of interests. Firstly the aim was to detect any possible effects of the Nigg Oil Terminal, which is situated on reclaimed land at the mouth of the bay. In this context, measurement of physical sediment characteristics are particularly important, and it has been concluded (Raffaelli & Boyle 1986) that fluctuations in sediment silt content probably reflect natural changes from year to year in the sediments of Nigg Bay. Similarly, the biological data permits analysis of change, and the conclusion is drawn that the biological variations have been entirely natural and unrelated to the terminal.

Beyond the immediate monitoring value, the Nigg Bay biological data has considerable interest for conservation planning purposes. Mapping and quantification of shorebird food species (see, for example, figure 8) should greatly facilitate assessment of conservation interests in Nigg Bay.

In addition to the ecological investigations, sediment hydrocarbon concentrations have been

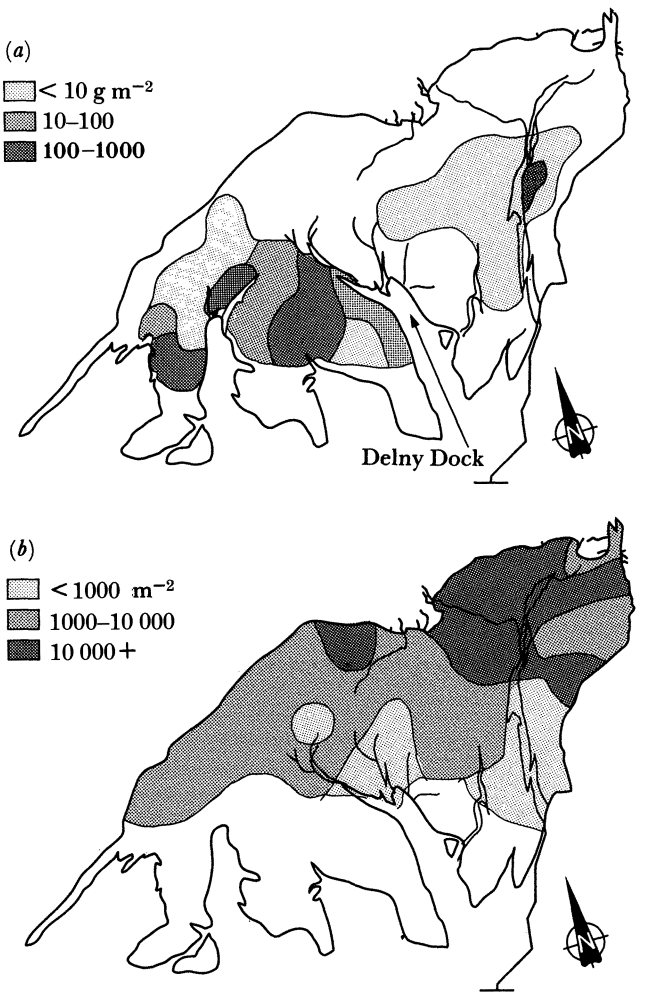

FIGURE 8. (*a*) Biomass of *Mytilus edulis*; (*b*) distribution of *Hydrobia ulvae* in Nigg Bay. (From Raffaelli & Boyle 1986.)

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monitored from time to time (by M-Scan Ltd) since before the terminal became operational. As figure 9 shows, the background levels of hydrocarbon in Nigg Bay are low, with some patchiness, which in part can be accounted for by rainwater run-off from the road on the western shore. There has been no build up of hydrocarbons in Nigg Bay sediments since the terminal became operational.

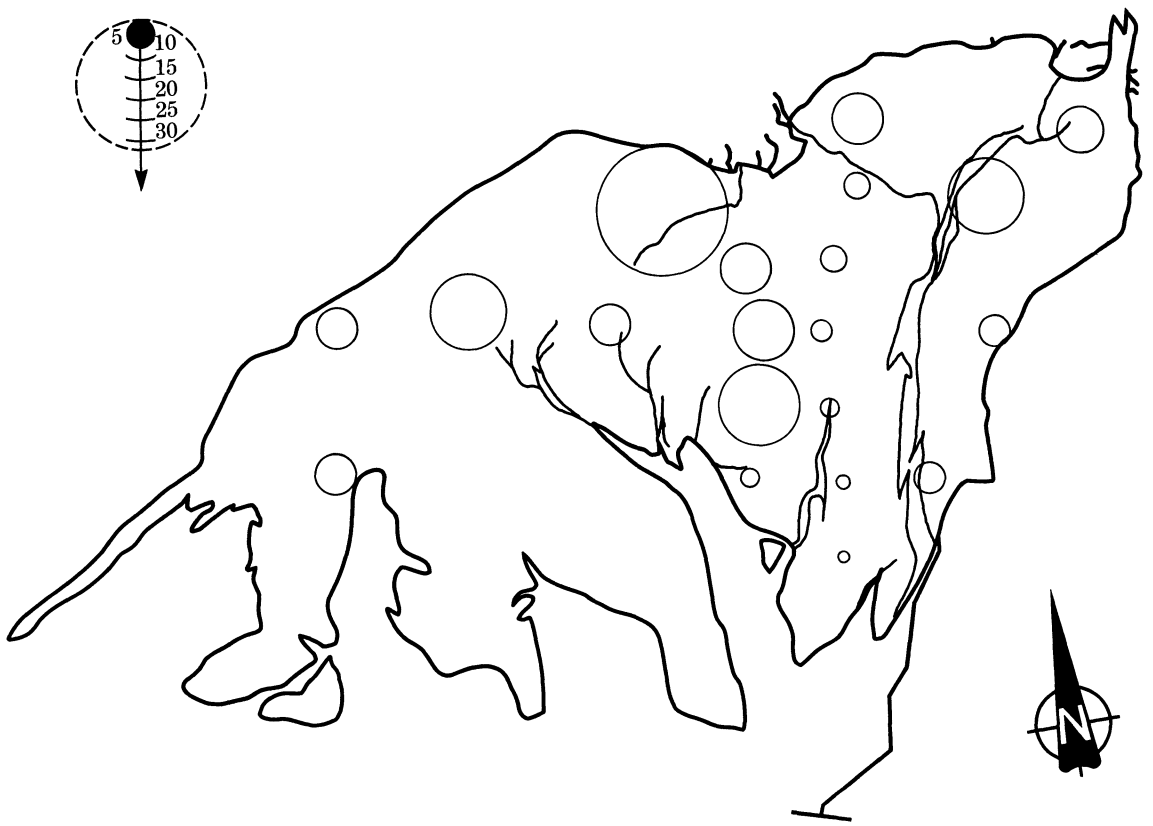

FIGURE 9. Baseline aliphatic hydrocarbon concentrations (parts per million by dry mass of sediment) in Nigg Bay sediments, before commissioning of the Nigg Oil Terminal.

SUBLITTORAL STUDIES

A series of biological, physical and chemical investigations have been carried out since 1977 at the Beatrice Field by the Field Studies Council, Oil Pollution Research Unit and M-Scan Ltd. These are of particular relevance to the fishery interest on the Smith bank, and the surveys are designed to monitor the seabed community and the effect of discharges from the Beatrice platforms. Pre-production seabed ecological surveys in 1977, 1980 and 1981 used extensive replicate sampling from grids of stations over a wide area. This permitted a detailed description of the natural seabed community (Hartley & Bishop 1986). No trends or anomalies were detected that could be attributed to industrial activity. However, the grid stations were all more than 500 m from the platform so it was clear that a study of the effects of drilling discharges would need to involve a different sampling strategy which included stations very close to the platforms. These more recent studies which began in 1982 have described the effects of

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discharges of cuttings contaminated with oil-based drilling mud (Addy *et al.* 1984). The gradients of sediment hydrocarbon concentration, and the species succession away from the platform are similar to those found in the other North Sea fields (see, for example, Davies *et al.* (1984); Kingston this symposium). These effects, which are consistent with organic enrichment are illustrated in figures 10 and 11 which show the temporal and spatial changes in seabed chemistry and macrobenthic diversity between 1982 and 1983. The effects of Beatrice drilling discharges are very localized and are expected to be largely temporary.

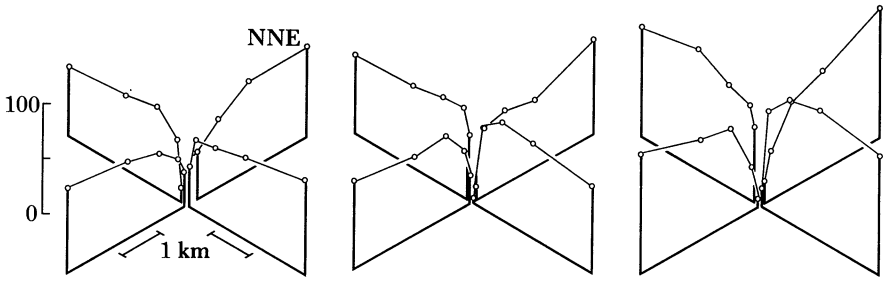

FIGURE 10. Total number of taxa recorded from two grab samples (each 0.1 m²) at each station in February 1982 (left), May 1982 (centre) and September 1983 (right). (Addy *et al.* 1984.)

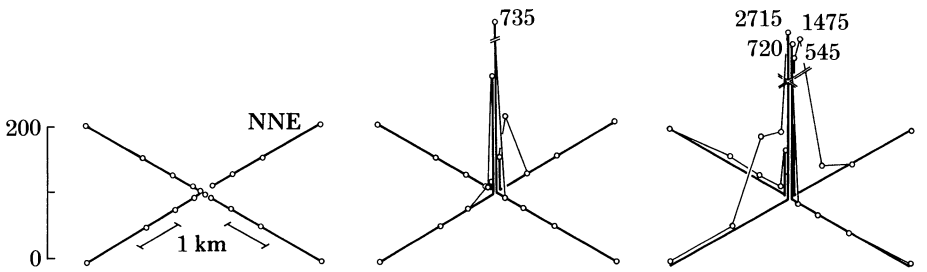

FIGURE 11. Estimated number of *Capitella capitata* per square metre at each station in February 1982 (left), May 1982 (centre) and September 1983 (right). (Addy *et al.* 1984.)

The development drilling phase at Beatrice is now completed and future monitoring, using the same sampling strategy, will follow successional changes and recovery in seabed biology now that the discharge of organically-rich cuttings has ceased.

OTHER STUDIES

Various supplementary studies are done from time to time, usually in relation to specific aspects of operations. For example, air-quality and noise surveys have been performed at Nigg. Sediment hydrocarbon levels are regularly monitored around the terminal effluent discharge point. This provides a check on the receiving environment, complementing the routine chemical analyses done by Britoil plc and the Highland River Purification Board on the discharge itself. The plant and animal communities living on the platform structures in the Beatrice field are surveyed routinely for structural monitoring purposes (Picken 1986). These communities may also give an early indication of any adverse environmental conditions at the centre of operations.

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The future

The monitoring programme is not fixed in its scope or methodology. The studies outlined above represent the main parts of the programme to date, but it is emphasized that sufficient flexibility has been built in to enable modifications or special studies in the future. To a large extent the programme has evolved in parallel with the Beatrice development. In the early days the emphasis was on acquisition of descriptive baseline data from extensive biological surveys. Having provided the necessary basic descriptive information, the work in recent years has concentrated on monitoring either selected communities or habitats, or specific operational discharges. This change in emphasis can be illustrated with reference to the offshore seabed investigations, where there has been a shift from extensive wide ranging grids of stations to radiating transects with a concentration of stations very close to the platform to define the effects of drilling discharges.

Similarly, in the case of seabirds, the two-year programme investigating seabirds at sea has provided a wealth of useful descriptive and distributional data but the main emphasis of the ornithological studies is now on the colonies themselves and the populations of wintering sea duck and shorebirds.

It is recognized that the information gathered is frequently of a wider interest from a conservation planning point of view or for its intrinsic academic interest, and publication of results is encouraged. Britoil plc also recognizes the importance of presenting the work in a form readily understandable to a wider audience. To this end, a public relations summary of the programme has been produced and is freely available to schools and any other interested parties, particularly on the Moray Firth coastline.

Conclusion

The various component studies briefly outlined above which make up the Beatrice environmental monitoring programme have concluded that the presence of the platforms, pipeline and terminal have had only very localized effects on the surrounding environment. Long-term monitoring continues as an integral part of the Beatrice development. The studies to date have shown that it is possible to operate an oilfield in a very sensitive coastal area without damaging the marine or coastal resources. For detailed information on any part of the programme, those interested are referred to the published information, or alternatively invited to contact Britoil plc direct.

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