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Likely impacts of oil and gas activities on the marine environment and integration of environmental considerations in licensing policy

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Likely impacts of oil and gas activities on the marine environment and integration of environmental considerations in licensing policy

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1. Introduction

1.1 This paper provides an initial review of the impacts of oil and gas exploration and production on the marine, coastal and estuarine environments. It is intended as a precursor to the more thorough review of sensitivity currently being undertaken through the Joint Nature Conservation Committee.

1.2 The impacts of oil and gas exploration and production fall into two categories. Those arising from routine operations and those resulting from accidents.

1.3 This paper includes a wide range of impacts arising from routine operations and identifies two of the more significant - pollution by produced water and smothering of benthic communities by cuttings.

1.4 The most important risk factor in accidents is the discharge of oil. Cases are documented where this has occurred at all stages in the process, drilling, storage and transport. The impact of oil pollution is related to the proximity of the spill to the feature of interest as well as to volume and type of oil spilled. A small spill in the wrong place can have a major adverse impact on a wide range of marine and coastal organisms as well as sea birds.

1.5 Some case studies of spills resulting from exploration and development activities are listed in Appendix 1 with examples of recovery of marine life from oil spills and field trials included in Appendix 2.

2. Impacts on nature conservation interests

2.1 The major activities associated with oil and gas development which have potential impacts on the marine and coastal environments can be summarised as follows:

Activity	Potential effects
Evaluation	
Seismic surveying	Noise effects on fish and cetaceans. Physical disturbance.
Exploration	
Rig emplacement	Initial seabed disturbance due to anchoring
Drilling	Discharge of drilling fluids and cuttings; potential risk of blow-outs.
Rig servicing	Discharges from support vessels
Development and production	
Platform	Initial seabed disturbance resulting from placement and subsequent presence of platform.
Drilling	Larger and more heavily concentrated discharges of drilling fluids and cuttings; potential risk of blow-outs.
Completion	Increased risk of oil spills
Separation of oil and gas from water	Presence of oil
Pipeline installation	Initial seabed disturbance, effects of structures.
Transfer to tankers and barges	Increased risk of oil spills; acute and chronic inputs of petroleum.
Pipeline operations	Risk of oil spills.
Fixed structures	Collisions with shipping.
Abandonment and decommissioning	Discharges/wastes from decommissioning Physical presence Fisheries interaction Method of abandonment Long-term requirements/post decommissioning (eg monitoring)

Source Neff *et al* 1987.

2.2 Environmental impacts are possible at all stages of oil exploitation. During the initial surveys to locate reserves, air guns used can disturb fish and cetaceans and other seismic survey techniques interfere with commercial fishing. Certain species of fish are more resistant to these effects than others. Fish with cylindrical bodies and thick-walled swim bladders will be more resilient to the effects of air guns than fish with flat bodies and thin-walled swim bladders.

2.3 One of the more significant impacts of the exploration stage is the effect of drill cuttings on marine wildlife. Most of the research on the impact of cuttings has been done on cuttings produced by oil-based muds. Two types of adverse effects of discharges of cuttings can be distinguished. These are:

Physical smothering

2.3.1 Drill cuttings blanket the seabed, creating anoxic conditions and the production of toxic sulphides in the bottom sediment with the almost total elimination of the benthic fauna. Surrounding this area, there is a recovery zone showing a succession of, first, opportunistic species such as the polychaete worm *Capitella capitata,* then of species able to tolerate stressful conditions and to out-compete the less tolerant species which gradually re-appear further from the centre of disturbance. (Clark, 1992).

Chronic pollution of the benthos

2.3.2 Monitoring of the piles of contaminated cuttings around some of the worst affected platforms can show severe effects on zoobenthos within 0.5 - 1km of the platform. These appear to be related to the use of Oil-Based Muds (OBMs) and diesel OBMs. After drilling has ceased, with time, the oil in the sediment becomes less harmful. This may be attributable to changes in chemical composition and bioavailability of the oil due to weathering and/or adaptation phenomena in the benthic communities at those sites. No signs of macrobenthos recovery have been observed in highly contaminated zones six years after cessation of discharges of oil-contaminated drill cuttings, while in moderately affected zones, recovery usually occurs within two to three years. (North Sea Quality Status Report 1993).

2.3.3 Davies *et al* (1988) attempted to estimate the total area affected by the discharge of drilling muds in the UK North Sea sector. Based on 40 development and 380 single well sites drilled with oil-based muds, the estimated areas of seabed affected by major deleterious effects on the benthos accounted for 106km^2, representing about 0.04% of the UK North Sea. Approximately 400km^2 (0.13% of the total UK North Sea) was estimated as being subject to subtle biological effects with about

1,600km^2 (roughly the size of Cambridgeshire - 0.55% of the total UK North Sea) showing oil-based mud contamination. (GESAMP Report No. 50, 1993).

2.3.4 More recent evidence suggests that hydrocarbon contamination may be more widespread and that a large part of the East Shetland Basin may have sediment hydrocarbon levels several times the original background concentration (Cairns 1992). The disposal of oiled drill cuttings at the site of drilling has now virtually ceased in the Norwegian sector and only the UK still permits the disposal of such cuttings on site (due to cease this year for exploration wells and in 1997 for all wells in accordance with the Paris Commission guidelines).

2.3.5 The extent and degree of benthic damage from the discharge of water-based muds and cuttings is much lower in oil development and production drilling than when oil-based muds are used. The use of water-based drilling muds barely shows an impact beyond that of physical disturbance in which smothering by the cuttings pile appears to be the most important factor (Neff 1981; Petrazzuolo 1981), although residual toxicity and organic enrichment may also have a significant effect (Davies *et al.* 1984). The Paris Commission is currently seeking to define `oil contaminated cuttings', i.e. to determine the level of contamination by mineral oil below which the environmental effects are no more damaging than those from the discharge of typical cuttings from drilling with water-based muds. Indeed, licence conditions now specify that 'water-based muds must be used whenever technically possible'. This is welcome but there will still be an impact on the seabed from muds and cuttings.

2.4 Produced water

2.4.1 The toxicity of produced waters has not been studied on a wide scale. In general, produced water is considered as being non-hazardous using the GESAMP standards for toxicity. A recent example for the North Sea is given for the copepod *Acartia tonsa* (Girling and Streatfield 1988). Zooplankton appear to be the most vulnerable group to produced water, the phytoplankton and fish larvae (herring and cod) being more robust to any direct effect (Gamble *et al* 1987).

2.4.2 Toxicological and ecological effects of production water have been reviewed in detail by Middleditch (1984), Neff *et al* (1987) and Somerville *et al* (1987). Their conclusions, which address concerns raised in both the USA and North Sea jurisdictions, can be summarised as follows:

- the concentrations of toxic chemicals in most production waters are well below individual species 96 hour LC_{50} levels, indicating that there should be no toxicity beyond the immediate vicinity of the discharge. However, there may be localised impacts due to the presence of corrosion inhibitors and other contaminants such as metals in produced water arising from on-shore installations near sensitive sites;

- the measured toxicity in production water is probably due to the presence of biocides;

- dispersion models show that dilution from the discharge point occurs rapidly to some 1,000 fold dilution within 50 metres of discharge, lending support to the assumption that sub-lethal effects are unlikely beyond this range;

- few laboratory studies have been carried out on the sub-lethal or chronic effects of production water on marine organisms and:

- there is, however, the possibility of ecological effects of the discharge of production water on benthic communities for production sites under special circumstances of enhanced environmental vulnerability such as shallow coastal or estuarine waters. (GESAMP Report No. 50, p.118).

2.4.3 Concerns about production water exist because hydrocarbons and other toxic materials are released to the marine environment over the production life of an oil field. This evokes questions about long-term accumulations of contaminants in the sea and gradual ecological change of exposed marine systems.

2.5 Effects of oil spills

Birds

2.5.1 Whatever other effects oil pollution may have, the loss of seabirds tends to attract the greatest public concern. Unlike most other organisms in the sea, seabirds are harmed through the physical properties of floating oil. The high affinity between oil and plumage renders them particularly vulnerable and few seabirds seem able to detect and avoid oil. Although oil ingested during attempts to clean plumage may be lethal, the most common causes of death are from loss of body heat, starvation and drowning following damage to the plumage by oil. Plumage is essential to flight, heat insulation and waterproofing and even small effects on any of these functions can result in death. Quite small quantities of oil ingested by birds during the breeding season depress egg-laying and, of the eggs that are laid, the proportion that hatch successfully is reduced. If oil is transferred from the plumage of an incubating bird to the eggs, the embryos may be killed.

2.5.2 Those species most at risk are auks, guillemots, razorbills and puffins and some diving sea ducks: scoters, velvet scoters, long-tailed ducks and eiders. These birds spend most of their time on the water and so are particularly likely to encounter floating oil and because they dive rather than fly up when disturbed, they are as likely as not to resurface through an oil slick so becoming completely covered by oil.

2.5.3 Oil slicks drifting through concentrations of birds resting on the sea may inflict very heavy casualties quite disproportionate to the quantity of oil spilled. For example, when 230,000 tons of crude oil were lost from the Amoco Cadiz on the Britanny coast, the known seabird casualties numbered 4,572. On the other hand, the much smaller spill of 35,000 tons of crude oil following the grounding of the Exxon Valdez resulted in over 30,000 known seabird deaths and probably very many more. Almost as large a death toll occurred in Skagerrak in January 1981, when 30,000 oiled birds appeared on beaches. This appears to have been caused by very small amounts of oil discharged by two vessels (Clark, 1992).

2.5.4 It is usually impossible to estimate more than crudely the number of birds killed by oil pollution. The only reliable figures are of the number of oiled birds or carcasses found on the shore, although an unknown proportion of the carcasses may have become oiled after death from other causes. An unknown number of oiled birds never reach the shore and depending on wind speed and direction, sea conditions, distance from shore of the bird flocks and accessibility of the coast to observers, it is likely that counts of oiled birds coming ashore underestimate actual casualties by anything up to 90%.

2.5.5 It is acknowledged that the most serious causes of oil pollution are accidental spills and illegal tank washings. However, with more blocks now being licensed closer to shore, the risk of spills is potentially more serious as there would be little or no time to organise clean-up operations.

Benthic systems

2.5.6 The benthic ecosystem comprises the plants and animals that live in or on the sediments of the seabed and intertidal zone. The most obvious impact of a spill on the benthos will occur if substantial quantities of oil are sedimented onto the seabed or are washed up as the tide recedes. In such cases, the small animals living in the mud or sand are vulnerable to smothering by oil. Many benthic organisms feed by sifting food particles out of the water through delicate filtering apparatus. Oil can coat both this feeding apparatus and their gills. The benthos may also suffer long-term effects from the toxicity of the oil.

Populations may be wiped out to be replaced in the short-term either by large numbers of a few species which are able to tolerate the oil or by opportunistic colonisers of space. As in the water column, oil on the seabed will eventually be degraded with the help of bacteria - a process which can take from months to decades depending on oil type and spill location.

2.5.7 Sessile animals, such as barnacles and mussels, are able to close themselves off and can survive several days beneath a temporary blanket of oil. Grazing animals, like limpets and winkles, are more likely to succumb to the toxic nature of the oil. Dominant species may recover quickly with individuals from neighbouring areas helping to recolonise a stretch of shore, though rarer species will take much longer.

Pelagic systems

2.5.8 The pelagic ecosystem comprises everything in the open water and can generally be divided into plankton and nekton. Plankton are the aquatic organisms that drift in the water column and the nekton are the free-swimming animals. Most plankton species are vulnerable to very low concentrations of oil and localised kills may occur following a spill. The plankton contains many larvae which are often less able to withstand the toxic effects of oil than the adults. An oil spill may therefore cause more damage immediately following the spawning season than at other times of the year.

Shorelines

2.5.9 Impact is usually most obvious on shores where oil naturally tends to accumulate, the extent of damage depending on the degree to which oil is retained and the sensitivity of the biota.

2.5.10 As shorelines are exposed at low tide and the oil is stranded on the shore, direct contact between organisms and oil can occur and large mortalities are sometimes seen. These result from toxic components in the oil or, once the oil has weathered, from smothering. Animals may be narcotised by even small amounts of oil, subsequently detaching from rock surfaces or leaving sand burrows where they may be eaten by predators or may be washed into areas where they cannot survive.

2.5.11 Shores which are exposed to strong wave action or currents tend to self-clean themselves of oil relatively quickly. These shorelines are often rocky and have communities of highly adapted species, especially grazers and filter-feeders. If grazers are killed by oil, seaweeds rapidly settle, followed by a slow return of grazers by recolonisation and recruitment. Although recovery to an apparently normal balance often takes less than five years on North Sea coasts, the complete re-establishment of a shore community can take many years in extreme situations where very large areas are affected or species are close to the limits of their range (Cairns 1992).

2.5.12 Intertidal fine sediments (fine sands and mudflats) and estuaries are particularly important for wildlife. They support large populations of migrating birds as well as shell fisheries and may also function as nursery areas. Apart from the immediate toxic and smothering effects of the oil, sediment penetration has often occurred which tends to delay recovery. In these areas, the upper shore fringe is often dominated by saltmarsh plants which although generally only temporarily harmed by single oilings, can take more than 10 years to recover naturally if badly damaged (Cairns 1992). Long-term damage is more usually the result of using inappropriate clean-up techniques than as a direct consequence of oiling.

Estuaries

2.5.13 Potential damage to wildlife interests by oil increases because of the reduced dilution capacity and low-energy nature of the environment with ecosystems in enclosed shallow seas, lagoons or estuaries exposed to higher concentrations for longer periods.

2.5.14 Some animals that live in large numbers in estuaries form the basis of important shellfish industries, such as cockles, oysters, mussels and shrimps. Many fish species live at the seaward end of estuaries and a number of important commercial species spend some of their life cycle within estuaries. Estuaries are also important areas for many birds, such as waders and waterfowl, which nest or overwinter on the fringing vegetation and feed on the large numbers of shellfish, worms, sea grasses and algae.

2.5.15 Saltmarshes at the edges of estuaries provide important feeding and roosting areas for birds. They are often dominated by a few plant species which stabilise the shore by trapping sediment. The network of small creeks commonly found here may be home to juveniles of commercially important species of fish and a variety of other animals. Oil tends to be trapped in saltmarshes which are thus one of the habitats most sensitive to oil spills. They have survived small amounts of oil but the effects of a major spill may be severe and long-lasting. Severe pollution kills the grass shoots with the result that sediments are no longer bound together and thus may be vulnerable to erosion.

2.6 Response to spills nearshore and onshore

2.6.1 Once oil reaches coastal waters, it will be necessary to concentrate efforts on protecting key areas, such as sensitive wildlife sites, fishery areas, by containment booms if possible.

2.6.2 Once oil is ashore, there are still occasions when the best course of action will be to do nothing, for example when attempts to remove or treat stranded oil will be far more damaging. Thus sensitive areas, such as saltmarshes, which have been shown to recover relatively quickly by natural processes from a single oiling, have still shown evidence of damage for many years following physical disturbance caused by trampling and vehicles. Some shorelines are either inaccessible, self-clean well or are not adequately cleaned by any currently available techniques and may also be best left. Examples include exposed, rocky coastlines with high cliffs and broken boulder and cobble beaches.

Response to spills at sea

2.6.3 There are two main responses, containment and collection of oil and chemical dispersion. Most of the devices so far developed, eg booms and skimmers, do not operate effectively in anything but calm conditions. Many recovery systems are also only effective with a limited range of oil types with severe limitations on the pumping of viscous oils and water-in-oil emulsions. Added to these difficulties is the tendency of the oil to spread and fragment rapidly.

2.6.4 Whilst the use of chemical dispersants is not limited by weather conditions to anything like the same extent as containment and collection, the technique remains controversial despite the low toxicity of modern products. An assessment of dilution potential is a key factor in determining whether dispersants can be used safely. In the open sea, elevated concentrations do not persist for more than a few hours in surface layers and significant biological effects are therefore improbable. More caution with dispersant application is needed in shallow coastal waters.

2.7 Subsidence

2.7.1 The issue of subsidence is of concern with respect to offshore installations. In 1985, Phillips Petroleum Company announced that they had recognised a serious sea floor subsidence problem associated with the Ekofisk Reservoir in the Norwegian sector of the North Sea. Measurements indicated that the settlement was large and that its rate was approximately 0.5 metres per year. Between Autumn 1984 and Summer 1987, the operator conducted a detailed analysis of this problem and eventually carried out the successful jacking operation of the Ekofisk complex (Jones 1990). The total subsidence is now of the order of 6m and anticipated to be as much as 20m (Jones, pers comm).

2.7.2 Britain's gas fields are generally subject to larger changes in reservoir pressure than oil fields. This increases the potential for reservoir compaction. The possibility that subsidence may occur over one or more of the gas reservoirs must be considered. The available data indicate that the majority of Britain's gas reservoirs are developed in relatively strong rocks which compact little under the increased effective overburden stress caused by pressure depletion. Unfortunately, rock compressibility data are not available for many of the gas reservoirs and measurements made by Sediment Deformation Research indicate a significant variability in the compressibility of the Rotliegendes sandstones (Jones 1990). We recommend that rock strengths should be estimated for areas currently under discussion and the possibility of subsidence examined.

2.7.3 The 5-6 mm per year sea level rise is correlated with serious coastal erosion in South-East England. Subsidence could provide a serious problem as it contributes to direct sinking of the coastline and increased coastal defence problems. The Government needs to consider this issue seriously when licensing blocks in the light of their commitment under the Biodiversity Action Plan 'to implement new approaches to coastal flood defence and coast protection which work with natural processes'. Subsidence that is relatively minor by comparison with Ekofisk, such as a few centimetres, could have potentially disastrous consequences for coastal defences.

Summary of impacts of oil spills on marine habitats

2.8 Environmental impacts of spills on the marine environment differ as a result of:

- ❑ type and amount of oil spilled (particularly No. 2 fuel oil or diesel oil are generally more toxic than crude oils);
- ❑ degree of weathering that occurs before the oil affects a given habitat (weathered oil is less toxic to marine organisms);

- environmental conditions at the time of the spill (water depth, currents, winds, temperature etc);
- extent of contact with the oil (may cause smothering);
- differences in the sensitivity of individual species to petroleum hydrocarbons;
- time of year in which the spill occurs (spawning and migration are highly seasonal);
- clean-up method employed;
- amount of oil (if any) recovered.

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3. Impacts on fisheries

3.1 Wild fish are able to detect and avoid oil which contaminates the water column and are thus seldom affected by oil pollution. However, fish eggs and larvae are less mobile than adults and are, therefore, more vulnerable to toxins associated with oil.

3.2 Fish farms where fish are held captive are particularly vulnerable to contamination and tainting. A slick of oil drifting through such an installation may inflict commercial damage quite incommensurate with the size of the spillage.

3.3 Most commercial species of invertebrates are not mobile, especially those living on the sea bed. They are more vulnerable because of their close association with and exposure to oil contaminated sediments.

3.4 Oil pollution is a particular concern in areas where fisheries are central to the local economy, eg Shetland - Braer; Prince William Sound - Exxon Valdez; Brittany coast -Amoco Cadiz. Although contamination and tainting of fish will, over time, fall to background levels, the legacy may remain for a longer period when peoples' perception of contaminated fish causes significant declines in the sale of fish produce.

3.5 Most of the harmful effects of oil on fisheries refer to shell fisheries, either intertidally, or in shallow water, and the damage may persist for years. A spillage of 700 tons of diesel fuel oil in Buzzard's Bay, West Falmouth, USA in 1969 contaminated shellfish beds, saltmarshes and beaches and oil became incorporated in the sub-littoral sediment. There was an immediate kill of fish particularly in shallow creeks and bays which shelter juveniles of commercial species such as flounders and blue fish. Lobsters, crabs, shrimps and bivalves were killed in large numbers and commercial shellfish beds had to be closed because of tainting on a long-term basis due to the continued risk of contamination by oil released from the shifting sediments. Detailed studies of the subtidal benthic community revealed instability persisting for more than five years in the most polluted parts of Wild Harbor; less contaminated areas began to show a successional recovery two years after the spillage (Clark 1992, pp 40-41).

4. The nature of acute risks

4.1 Acute risks to the environment occur as a result of short-term and unplanned discharges. In the case of oil exploration and production activities, these are largely of crude oil, diesel, bunkers, contaminated ballast water, base oil, drilling muds or chemicals. Large-scale hydrocarbon gas releases can occur, and have done so, but the resulting hazards relate primarily to the safety of the personnel work at the installation.

4.2 Other potential causes of large spillages of crude oil are major accidents involving offshore installations or tankers and damage to pipeline systems. The potential for large spillages from tanker operations is well known but accidents such as Piper Alpha in July 1988 and the Fulmar FSU incidents have also resulted in significant spillages of oil. For instance, when the Fulmar FSU, a floating crude oil storage unit broke away from its moorings in bad weather in December 1988, 1,200 tonnes of crude oil were spilt from the severed supply pipeline. A spillage from the Claymore pipeline of 1,000 - 2,000 tones of crude oil is the largest that has occurred in the North Sea as a result of pipeline failure. It was caused by a crack in the weld at the junction of the Claymore and Piper pipelines (see Appendix 1).

4.3 Other causes of spillage generally give rise to smaller releases. Diesel spillages to the sea have occurred during offshore transfer of diesel from supply boats, but a common type of spillage in recent years has been of oil-based muds or the base oils with which they are formulated.

4.4 Onshore, spills may occur due to tank overflows, equipment failure etc. The opportunities for containment are much greater because of the extensive tank bunding and oily-water drainage systems in use therefore the quantities of oil likely to reach the environment are reduced. The consequences, however, of onshore oil spills are potentially greater than of those offshore, because of the potential for relatively large volumes of undiluted and unweathered oil to pollute sensitive areas.

5. Approaches to oil and gas licensing in other countries

Norway

5.1 Norway's Petroleum Act 1985 contains a number of provisions aimed at the protection of the environment, specifically with regard to the regulation of the opening of new areas and removal of installations. On the former, there is a requirement under Chapter 2 of the Act that: 'Prior to the opening of new areas, with a view to the granting of production licences or initiation of exploration drilling, an evaluation shall be undertaken of the various interests involved in the relevant area. In this evaluation, an assessment shall be made of the environmental impact of such activities and possible risks of pollution, as well as the economic and social effects that such activities may have on other trades or industries and on adjacent districts'.

5.2 This assessment of the positive and negative effects of oil activity in a particular area provides the basis on which the Norwegian Parliament decides whether or not the area should be open for licensing. The Parliamentary debate could in certain instances conclude that fisheries and environmental conditions are such that the area should not be open for petroleum activity. One alternative might be that geographical limits are imposed on the activity, another would be for an activity to be permitted only at certain times of the year, eg drilling would be forbidden in potential oil reservoirs during periods where there are high concentrations of fish eggs or seabirds in an area.

United States of America

5.3 The National Environmental Policy Act 1969 requires an environmental impact statement to be prepared for all major federal actions significantly affecting the quality of the human environment.

5.4 The Outer Continental Shelf Lands Act Amendments of 1978 outlines the types of environmental studies that must be conducted and how they should be used, ie:

- ❑ Each OCS area or region is studied to establish the environmental information needed for assessment and management of environmental impacts resulting from oil and gas development.

- ❑ This information must be used in decisions concerning post-lease operations, management and leasing.

- ❑ Studies must predict impacts on marine biota and on affected onshore and coastal areas from chronic low-level pollution, large spills, drilling muds and cuttings, pipeline construction and on affected onshore and coastal areas from offshore development (2).

5.5 This system has led to moratoria on exploration being declared in areas of high environmental sensitivity, eg areas off South-West Florida and Northern and Southern California.

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6. Conclusion

6.1 Some of the risks highlighted in this paper, eg seismic activities and drilling, can be alleviated by the imposition of strict conditions to safeguard wildlife interests. However, the risk of oil spills from development activity can never be ruled out, irrespective of how detailed and thorough a company's oil spill contingency plan might be. The 14th Oil and Gas Licensing Round represented the first major incursion into inshore waters and if there were to be a spill within any of these blocks, there would be little time to organise an appropriate response. A spill in a high-profile amenity and wildlife area (for example in blocks on the Devon/Dorset coast awarded to Amoco and Kerr McGee in the 14th Round) would be damaging and would reflect very badly on the oil company concerned and attract intense public criticism.

6.2 During the past five years, despite the best efforts of the oil industry, there have been a total of 1,103 reported spills from offshore installations resulting in the loss of 1,714 tons (1). It is true to say that the size of oil spills arising from exploration and production thus far has been negligible. However, a relatively small spill in the wrong place and at the wrong time can have serious consequences for wildlife. For example, a spill of only 25 tons from a fractured pipeline at the British Steel plant on the Welsh side of the Severn Estuary led to 1,500 birds being affected. 40% of oiled birds found on the English side of the Estuary died (2).

6.3 The approach taken to licensing in the USA requires a full environmental impact assessment of a leasing proposal before a decision is taken (see paragraph 5.4). This approach allows full account to be taken of nature conservation considerations before exploration commences. In 1989, intensive public concern on the impacts of oil and gas production on the US outer continental shelf led to a congressional moratorium on exploration in several OCS areas, notably areas off south-western Florida, northern and southern California.

6.4 It has been argued that the size of a sensitive wildlife site within a block is relatively small and therefore that it could be protected by strict environmental conditions. However, experience suggests that conditions cannot eliminate the risk. The unpredictable nature of the British climate means that oil can travel particularly quickly and affect such a site. The Rosebay spill in May 1990 was a case in point. Oil which initially came ashore near Bigbury Bay in Devon eventually affected shores as far west as Cornwall over a week later.

6.5 Any licensing for oil and gas development must be considered in the light of the UK's obligations under existing international conventions, treaties and other agreements, eg EC Directives on Habitats and Species and Conservation of Wild Birds, Biodiversity Convention, *ASCOBANS and Ramsar Convention. Under ASCOBANS, the UK has agreed to work towards preventing acoustic disturbance which could pose a threat to cetaceans and is obliged under the Habitats Directive to avoid the deterioration of and disturbance to habitats and species within Special Areas of Conservation (SACs). The DTi will have a statutory duty under the regulations to comply with the terms of the Habitats Directive in exercising their duties in the marine area (3). We consider this duty to apply both within SACs and to operations which could have an effect on these areas.

* Agreement on the Conservation of Small Cetaceans in the North and Baltic Seas.

References

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Appendix 1: Oil pollution case studies

The following case studies are examples of spills through transportation of oil, operational accidents and blow-outs which highlight the risks and impacts on wildlife interests. They are taken from the proceedings of International Oil Spill Conferences organised by the American Petroleum Institute.

Spills from pipelines

Mersey Oil Spill

On 19 August 1989, a fracture occurred in a pipeline carrying Venezuelan crude oil from a shipping terminal at Tranmere to the Shell (UK) Ltd oil refinery at Stanlow on the Mersey Estuary. 150 metric tons of oil were released into the estuary before the pipeline was sealed. Although the Mersey Estuary is heavily industrialised, it does retain extensive areas of saltmarsh and inter-tidal mudflats which are internationally important for wildfowl and wading birds.

Most of the spilled oil was deposited high on the shore and its heavy viscous nature meant that little remobilisation occurred after stranding. The area from the Widnes-Runcorn bridge to Warrington suffered almost complete oiling of the upper shore along the northern bank and patchy oiling along the southern bank.

The inner estuary was mostly affected on the north shore and included areas of oiled saltmarsh, a very vulnerable habitat. There was patchiness in the severity of the oiling in these marshes and, in general, only localised areas of vegetation were affected, particularly at extreme high water mark or along creek edges. Little oil was observed to affect the intertidal sediments. A monitor-only option was agreed for oiled saltmarsh as it was realised that any attempted clean-up would cause greater long-term damage than leaving the oil to degrade naturally.

The extensive areas of saltmarsh comprising the south banks of the inner estuary were untouched by oil. This was highly fortuitous as these marshes and associated mudflats are feeding, roosting and over-wintering grounds for internationally and nationally important numbers of certain species of wildfowl and waders (including shelduck, wigeon, teal, pintail, dunlin and redshank).

Thistle-Dunlin

On 7 April 1980, production from the Thistle oilfield was shut down following a break in the Thistle-Dunlin pipeline. The rupture was discovered following a pressure drop in the seven mile line. Subsequent investigations suggested that the line had been seriously damaged by a vessel dragging its anchor over it. Kornberg (1981) records that the spill, which continued for some 25 minutes, occurred before the automatic cut-off device installed on the line had become fully operational and resulted in the loss of about 1,000 tonnes of crude oil.

Claymore pipeline

On 26 November 1986, Occidental reported a spillage of oil from its Claymore pipeline close to its junction with the main Piper-Flotta oil line. Subsequent investigations revealed that the leak arose from a fracture not in the pipeline but in a valve spool which may have been triggered by fluctuations in operating pressures. The defect occurred through the most brittle region of the valve body-casting and was associated with a surface irregularity. Extensive examination produced no evidence of fatigue but high stresses were found to be present, mainly originating from thermal expansion. Once the sighting of oil 10 km north of the Claymore platform had been confirmed as a pipeline leak, production on the main Piper, Claymore and Tartan platforms was shut down. The total volume of oil spilled was estimated at between 1,000 and 2,000 tonnes and the slick was monitored by aerial surveillance.

Operational accidents

American Trader Oil Spill

A spill of approximately 9,500 barrels of Alaskan North Slope crude oil occurred on 7 February 1990 when a US flag tank vessel "American Trader" grounded on one of her anchors while attempting to manoeuvre into Golden West Refining Company's Huntingdon Beach offshore mooring, USA.

Environmental degradation did occur along affected shorelines. Despite extensive rescue efforts, 1,017 oiled birds were found and brought to two rescue centres for treatment. 515 birds were released after treatment but the other 502 were either dead on arrival at the centres or died during treatment. Bird species most susceptible to oiling during this spill were surfscoters, western grebes, brown pelicans, cormorants and gulls. Of the 1,017 birds recovered, 141 were brown pelicans - an endangered species. 68 of the pelicans, approximately 1.5% of the population, subsequently died.

Sivand Oil Spill

In September 1983, the 218,000 deadweight ton VLCC Sivand collided with the jetty while berthing at the Immingham oil terminal on the River Humber. As a result of the collision, a 66 foot gash was sustained in the ship's hull below the water line and about 6,000 tons of Nigerian light crude oil was released into the Humber. A combination of fast currents and south-easterly winds carried the oil over a wide area of the estuary, polluting dock areas and river creeks, and threatening a number of sensitive areas.

The clean-up following this incident, potentially the most serious in the UK since the Torrey Canyon, was a co-ordinated operation involving Government, local authority and industry resources. Four hundred tons of oil were recovered from docks, rivers, creeks and inlets using disc and vacuum skimmers. A further estimated 2,000 tons was dispersed chemically using boats and aircraft.

After the worst of the spill was over, a meeting was held to discuss the effects of the spill and to make recommendations for future work, eg

- Bird counts - the number of dead birds totalled 161 and there was a minimum of 380 heavily oiled birds which were not expected to survive. The total number of lightly oiled birds was estimated to be between 3,000 and 4,000. Most of these were expected to live as moulting was in progress.

- Invertebrates - substantial kills of *Nereis, Cerastoderma, Macoma, Arenicola* and *Hydrobia* were reported. Long-term effects on their populations would need to be monitored.

The Department of Biology, University of Hull, investigated certain marine organisms. For the clams *Cardium* and *Macoma,* the results did not show significant change from pre-oil spill data, indicating either a delayed effect (ie not yet detected), no effect, or an effect followed by a very rapid recovery. A similar picture was observed for *Nereis diversicola* and, although large numbers of moribund ragworms were observed during the spill, the overall impact on the population appears to have been minimal.

Blow-out incidents

Ixtoc 1 Spill

On 3 June 1979, the Ixtoc 1 oil platform in the Bay of Campeche blew out and began to release oil into the Gulf of Mexico. The initial rate of release was approximately 30,000 barrels per day. Released under pressure at the sea floor, the oil thoroughly mixed with sea water to form a thick mousse-like emulsion that floated on the surface. Fingers of the oil emulsion were slowly pushed northward during June-July by prevailing winds and currents and, by early August, the first oil patches were observed in Texas waters. By mid-August, small quantities of oil began to reach the beaches of the Texas barrier island chain.

The percentage of total birds with oil on their plumage never exceeded 10% (Table 1) but some species seemed more prone to oiling than others. During the initial stages of oil impact, royal terns were the most heavily oiled birds. While loafing, the royal terns sat along the high tide line where the greatest concentration of tar balls occurred. By the end of August, approximately 40% of the royal terns had oil on their breast feathers. However, by mid-September, royal terns avoided the high tide line and congregated above the tar concentrations of the bern.

Table 1: Percentage of birds on the Padre Island National Seashore with obvious oil on feet and plumage.

Date	Number of total birds	Number of oiled birds	Percentage oiled
14 August	4,654	372	8.0
17 August	4,349	139	3.2
21 August	5,183	91	1.8
24 August	2,617	187	7.1
29 August	2,364	159	6.7
31 August	2,081	171	8.2
4 September	2,177	37	1.7
8 September	1,516	20	1.3
11 September	2,072	23	1.1
21 September	3,287	40	1.2
22 September	2,936	46	1.6
25 September	13,429	54	0.4
27 September	6,973	43	0.6
29 September	4,289	27	0.6
2 October	6,397	12	0.2

Ekofisk incident

On 22 April 1977, an uncontrolled blow-out occurred at a production well on the Bravo platform in the Ekofisk field in the Norwegian sector of the North Sea. Oil mixed with about 30% gas, and a temperature of 75° C, was discharged from a well-head 20 metres above sea level and was, because of the high pressure, forced another 30 metres up in the air before spraying over the platform and the sea surface.

Damage caused to seabirds

Very few heavily oiled sea birds were recorded in the polluted area. Only about 15 individuals (*F. glacialis* and *Laridae sp*) were registered by Norwegian ornithologists observing seabirds in the oil spill area. However, it was impossible to see any damage on these birds. They behaved just as normal, apparently unaffected by the presence of the oil film. It is quite possible that the birds' metabolism and plumage may have been affected, even when there was no visible damage.

Many oiled sea birds may have been missed due to difficulties of observing them on the sea surface (this applies especially to dark birds such as auks) or because they had already drowned and sunk.

The microscopic marine plant life (phytoplankton) relies on the available nutrients, sunlight and water stability for its growth and multiplication but in mid-late April 1977, water column stability was poorly developed and very localised. It was apparent that near the platform there was measurable inhibition of phytoplankton growth. The zooplankton that feed on the plant life were also less abundant in that area and, very close to the platform, repeated samples brought up dead zooplankton, witness of the toxic effects of the fresh oil.

The restricted extent of acute damage caused by the Ekofisk blow-out must largely be attributed to a set of fortunate circumstances. The time of the year was favourable since most of the breeding populations had already returned to their nesting grounds. The wind and current conditions in the area at the time of the blow-out were favourable and prevented oil from spreading and drifting to the coasts of the North Sea countries. Weather conditions were also suitable for a quick degeneration of the oil slick. A blow-out closer to British or Norwegian coasts would certainly have been much more disastrous to seabirds. A blow-out in the North sea during the winter would have the same serious consequences.

Appendix 2: Recovery rates of habitats following oil spills

Shore Type	Location	Oil	Observations on Recovery	Reference
Rock reef	Godrevy Point, Cornwall, SW England	Kuwait mousse from the *Torrey Canyon* spill, 1967 (no direct dispersant use on this moderately oiled shore)	Good recovery after 2 years.	Southward and Southward (1978)
Rock shelf	NW coast of the State of Washington	Navy Special fuel oil from *General MC Meigs* spill, 1972	Effects on urchins and algae for at least 1 year. No marked long-term effects on community balance. Hydrocarbon residues present in mussels after 5 years; attributed to recontamination by winter discharges from wreck.	Clark *et al.* (1978)
Rock/ boulders/ cobbles	Sullom Voe, Shetland	Heavy fuel oil from the *Esso Bernicia* spill, 1978	9 years after, 5 km of shore still showed successional changes (resulting mainly from use of bulldozers in clean up).	Westwood *et al.* (1989)
Rock/ boulders/ cobbles	Sullom Voe, Shetland	*Esso Bernicia* oil and subsequent inputs	Winkles *Littorina littorea* collected 1981 had significant enzyme changes indicating lysosomal destabilisation.	Moore *et al.* (1982)
Exposed rock	Hurlstone Point, N Somerset, England	Experimental applications of Forties crude, 1979	Reductions in limpets and small littorinid winkles during the year following treatment.	Crothres (1983) Baker *et al.* (1984)
Exposed rock	Hurlstone Point, N Somerset, England	Experimental applications of Flotta residue and mousse, 1981	Only significant change after 6 months was an increase of colonisation by barnacle larvae in oiled plots.	Baker *et al.* (1984)
Rock platform	Watchet, N Somerset, England, 1979	Experimental applications of Forties crude	Main change in all plots including controls was increase of fucoid algae, interpreted as a continuation of a long-term trend.	Baker *et al.* (1984)
Rocky shores	Swedish archipelago, Baltic Sea	No. 5 fuel oil and some bunker oil from the *Tsesis* spill, 1977	Dominant alga *Fucus vesiculosus* not affected. Faunal density within algal zone was 8-10% of previous level 2 weeks after spill. Recovery began within 2 months, with normal densities after 1 year at some sites. Recovery varied depending on severity of oiling and species involved. After 1 year, hydrocarbon concentrations in mussels approached normal conditions except at the most heavily oiled sites, though there were still elevated levels of substituted naphthalenes.	Notini (1980) Linden *et al.* (1979) Boehm *et al.* (1982)

Shore Type	Location	Oil	Observations on Recovery	Reference
Rocky shores	Atland, Finland, Baltic Sea	Crude oil from the Soviet tanker *Antonio Gramsci*, 1979	By 4 months after spill there was new settlement of barnacles and mussels close to the remaining oil on rocks. Little difference between oiled and non-oiled areas in *Cladophora* belt; in *Fucus* belt there was some decline in mussels and mobile crustaceans.	Bonsdorff (1981)
Rocky, moderately exposed shore	West coast of Norway	Iranian crude oil from 1976 spill	13 months after spill, significant amounts of hydrocarbons remained in winkles *Littorina littorea*. No detectable effects on fertilisation, but hatching success significantly less in oiled population.	Staveland (1979)
Beaches with sand, stones and rock	Gastviken Bay, Musko Island, Baltic Sea	Medium and heavy fuel oil from the *Irini* spill, 1970; mechanical cleanup	No oil-associated effects on *Fucus vesiculosus*; severe initial depletion of fauna. Recolonisation by most species occurred within 1 year, but low population densities during the 2nd year. After 4 years, no significant evidence of lasting detrimental effects, when natural annual variations taken into account.	Notini (1978)
Variety of shores in bay	Chedabucto Bay, Nova Scotia	Bunker C fuel oil from the *Arrow* spill, 1970	6 years after, lower diversity, lower biomass of flora, smaller clams (*Mya*) and larger winkles *Littorina* at oiled sites compared with controls. Abundant lugworms (with elevated hydrocarbon concentrations) in oiled sediments.	Thomas (1978) Gordon *et al.* (1978)
Variety of shores in bay lagoons	Chedabucto Bay, Nova Scotia	Bunker C fuel oil from the *Arrow* spill, 1970	*Mya* remained under continued stress in oiled lagoons 6 years after spill.	Gilfillan and Vandermeulen (1978)
Variety of shores	Straits of Magellan	Light Arabian oil/mousse from the *Metula* spill, 1974	1977 data suggested continuing impact in areas still heavily oiled, and recovery of invertebrates in areas which had lost oil.	Straughan (1978)
Variety of shores	Straits of Magellan	Light Arabian oil/mousse from the *Metula* spill, 1974	Asphalt pavement recolonised by algae and (more slowly, from lower intertidal levels) animals, mainly mussels and the gastropod *Siphonaria lateralis*. 5 years after spill, community still relatively simple in composition.	Guzman and Campodonico (1981)
Variety of shores	Straits of Magellan	Light Arabian oil/mousse from the *Metula* spill, 1974	Persistent effects on flora and insect fauna of heavily oiled salt marsh.	Guzman and Campodonico (1981)

Shore Type	Location	Oil	Observations on Recovery	Reference
Variety of shores	Brittany	Light Arabian oil/mousse from the *Amoco Cadiz* spill, 1978	Marshes severely affected, with no recovery in 2 years at the most heavily oiled sites. 5 years after, Cantel marsh which was oiled but had no clean up was essentially restored by natural processes. 8 years after, the Ile Grande marsh which had heavy clean up was well recovered, facilitated by artificial plantings.	Gundlach *et al.* (1981) Baca *et al.* (1987)
Variety of shores	Brittany	Light Arabian oil/mousse from the *Amoco Cadiz* spill, 1978	9 months after, hydrocarbons from the spill identified in limpets from rocky shores and *Mya* from mudflats. Heavier molecular weight aromatics present in *Mya*, not in limpets.	Vandermeulen *et al.* (1981)
Variety of shores	Brittany	Light Arabian oil/mousse from the *Amoco Cadiz* spill, 1978	Japanese oysters taken from the oiled Aber Wrac'h in 1979 had reached a steady state with respect to environmental exposure to weathered oil; they were able to reach background levels during a 96-day depuration period (in Maine).	Page *et al.* (1987)
Variety of shores	Brittany	Light Arabian oil/mousse from the *Amoco Cadiz* spill, 1978	Delayed effects: declines in populations of clams *Tellina* and nematodes reported 1 year after spill at St Efflam and Bay of Morlaix, respectively.	Conan (1982)
Sediments in experimental trays	Sequim Bay, Washington	Experimental application of Prudhoe Bay crude, 1976	Initial concentrations of oil in sediments upon field emplacement were up to 5000-6000 ppm; no substantial inhibition of recruitment by benthic organisms.	Anderson *et al.* (1978)
Saltmarsh	Buzzards Bay, Massachusetts	No. 2 fuel oil from the *Florida* spill, 1969	Recovery of fiddler crab population was correlated with the disappearance of naphthalene in sediments; not complete after 7 years.	Krebs and Burns (1978)
Stonework jetty	Buzzards Bay, Massachusetts	No. 2 fuel oil from the *Florida* spill, 1969	Reasonably functioning population of oyster drill *Urosalpinx cinerea* re-established at Wild Harbour by 1975, but with greater year-to-year variation in genetic structure than at reference site.	Cole (1978)
Saltmarsh	Steart, Somerset, England	Experimental applications of Forties crude, 1979	No detectable retention of experimental oil in sediment samples of May 1981, but flora did not recover to control levels during 1981 growing season.	Baker *et al.* (1984)

Shore Type	Location	Oil	Observations on Recovery	Reference
Saltmarsh	Steart, Somerset, England	Experimental applications of Forties crude, Flotta residue and mousse, 1981	Recovery of all treated plots started during 1982, but *Spartina* density remained low in the Forties crude plot throughout 1982.	Baker *et al.* (1984)
Intertidal sea grass beds	Angle Bay, Milford Haven, Wales	Experimental applications of Nigerian crude	No visual effects on sea-grass following tidal removal of oil, but no increase in cover during growing season following treatment (compared with increase of cover in control).	Howard *et al.* (1989)

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