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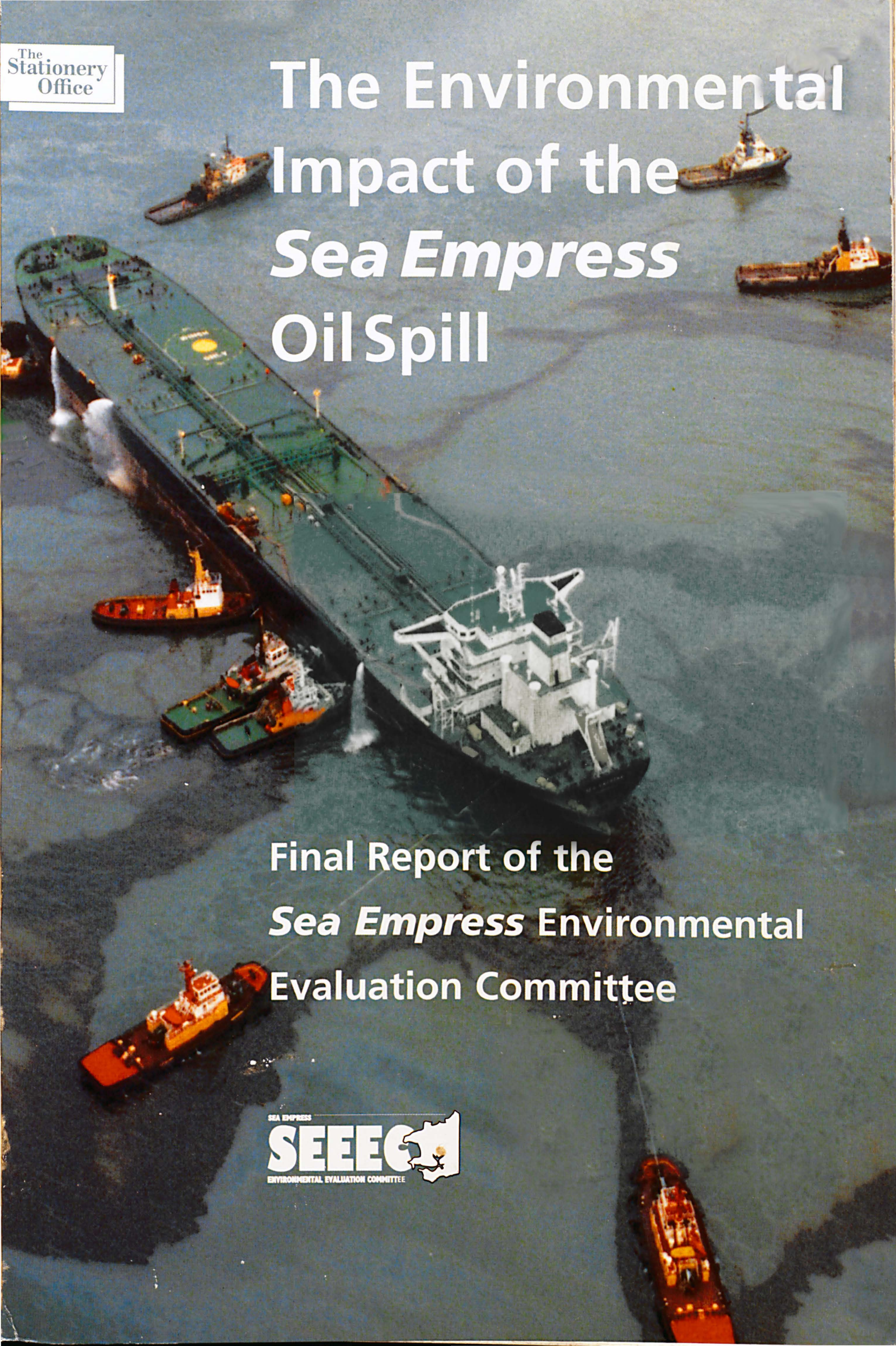
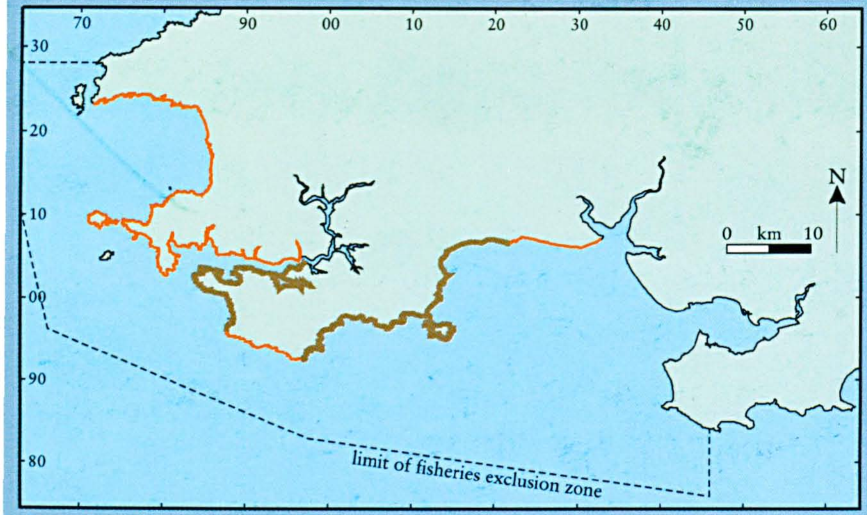
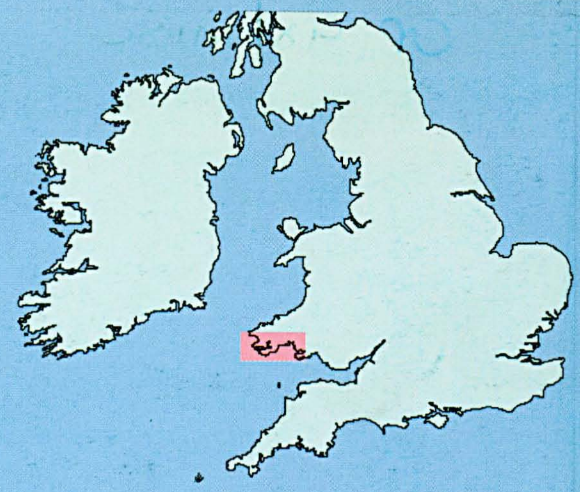


The Environmental Impact of the *Sea Empress* Oil Spill

Final Report of the *Sea Empress* Environmental Evaluation Committee

SEA EMPRESS
SEEEC
ENVIRONMENTAL EVALUATION COMMITTEE





Coastline affected by the oil

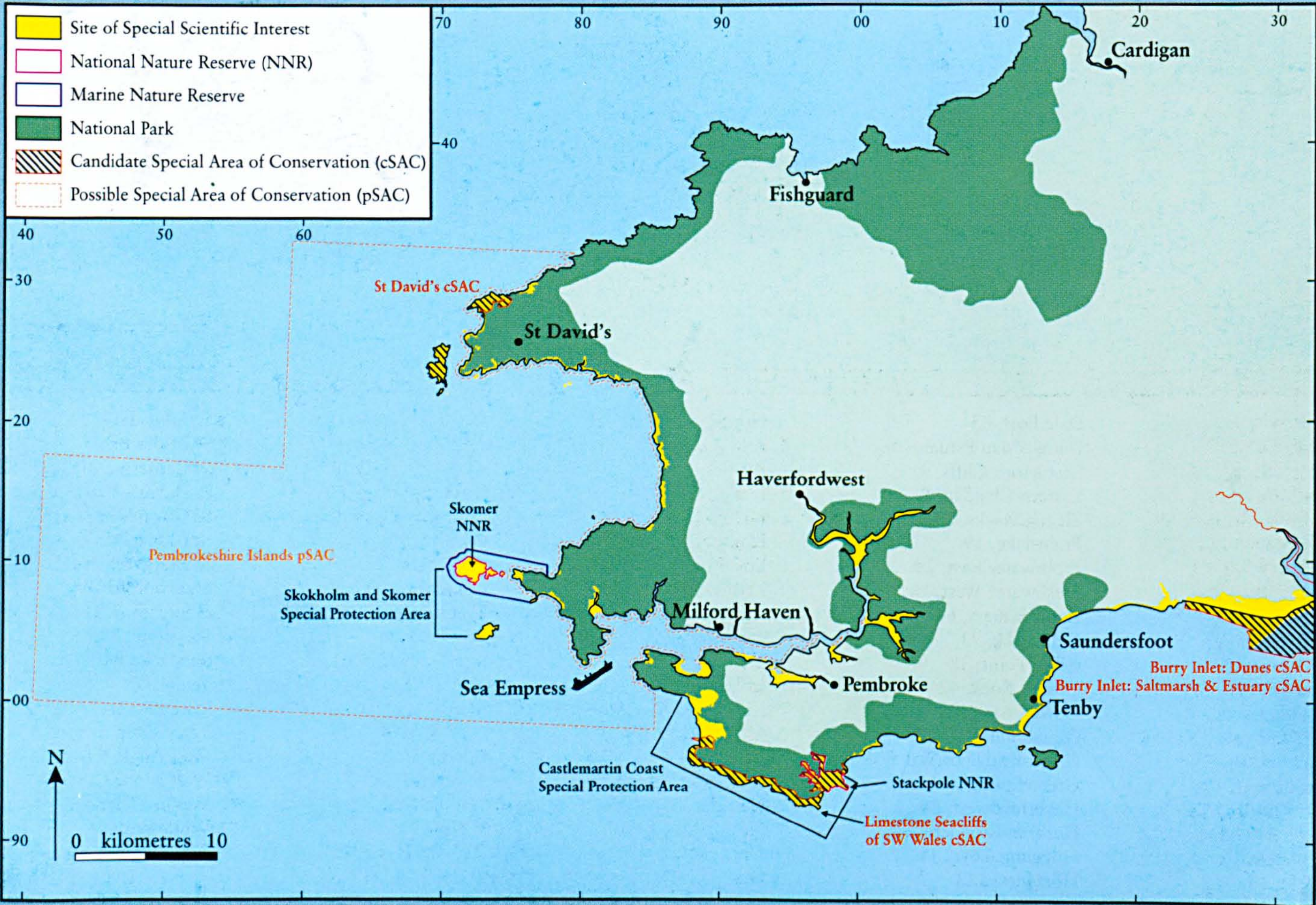
(Note: There was considerable variability in the level of oiling, and this map should be taken only as a rough indication.)

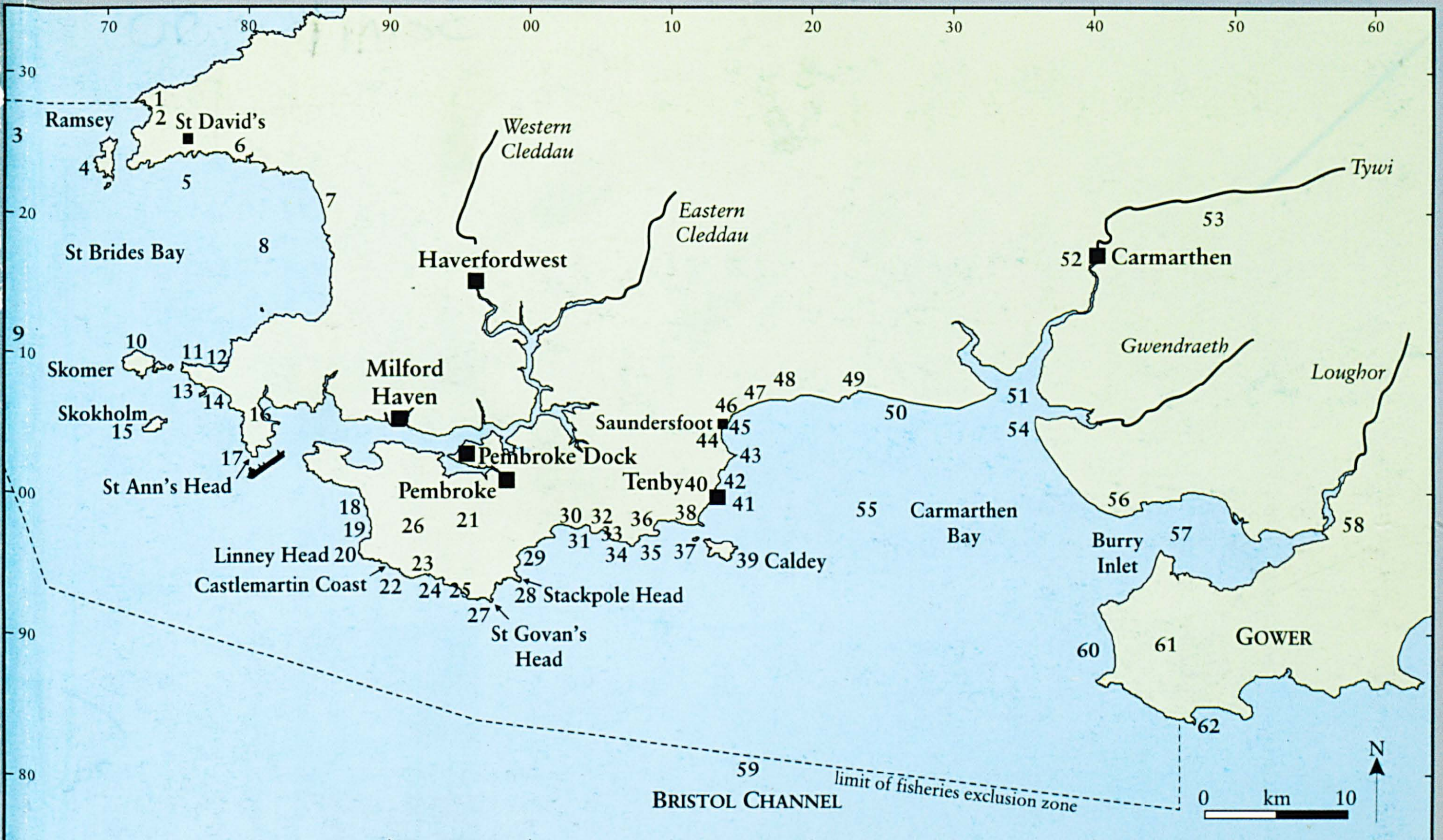
SEA EMPRESS

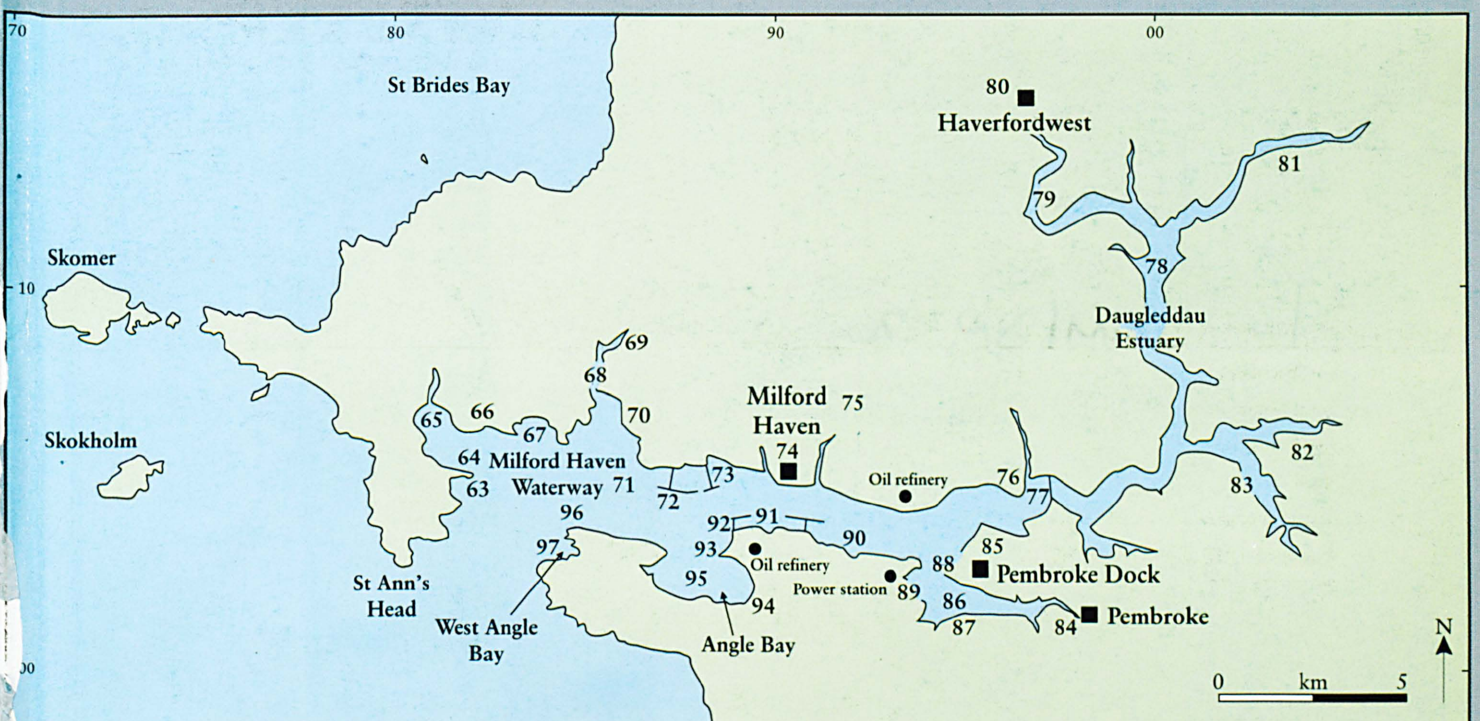
SEEEC

ENVIRONMENTAL EVALUATION COMMITTEE

Designated areas in south-west Wales







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The Environmental Impact of the ***Sea Empress*** Oil Spill

Final Report of the ***Sea Empress*** Environmental Evaluation Committee

London: The Stationery Office

Chairman's Preface

When the *Sea Empress* Environmental Evaluation Committee (SEEEC) came into existence the consequences of the *Sea Empress* oil spill were of widespread concern and commanded intense media coverage. The likely impact on the environment, on human health, the local economy and natural resources was not known. It was our responsibility to assess some but not all of these impacts. Our terms of reference established by Government (see §1.4) focused on the establishment and co-ordination of monitoring programmes to assess the impact of the *Sea Empress* oil spill on the environmental resources of the area, including fisheries, agriculture, amenity and wildlife conservation, and to assess their recovery. The committee was asked to publish its principal findings and make recommendations where changes in procedures might improve responses in the event of a future major oil spill: that we have done in this Report.

Our terms of reference excluded public health matters which were primarily the responsibility of the relevant health authority, although we assisted in supplying information on aerial concentrations of pollutants which were gathered for other purposes. Furthermore, economic impact assessments were rapidly commissioned by the local authority and other public bodies and have been reported elsewhere.

Our first task was to establish what work had already started to assess environmental impact and how best this work might be co-ordinated. We then had to identify and prioritise the gaps in the existing programme, find resources to carry out the most important projects using the best contractors available and integrate these projects within a programme which could make an overall assessment of impact. To assist in this preparatory work we established three task groups (see §1.5), comprising both SEEEC members and experts in relevant fields, many with a great deal of local knowledge. We agreed that this organisational structure, supported by cross-membership, provided assurance that our programme would be of high quality and comprehensive.

In July 1996 we published our *Initial Report* which described our preparatory work and invited readers to comment on our proposals. With few exceptions, relating to priorities assigned to projects, these proposals were widely accepted.

Professor
Ron Edwards, CBE

The programme of further work identified in our *Initial Report* was accepted by Government and funds were provided to support it. The task groups were retained to oversee the progress of these studies, and a system of professional project management, provided principally by the Count-ryside Council for Wales, the Environment Agency and MAFF, was established to ensure we received value for money and that our strict time-table for delivery was achieved.

In this final report, we have had some difficulty in striking a balance between producing, on the one hand, a detailed and comprehensive account of all our studies – inevitably a very technical document – and, on the other hand, a selective account of these investigations for a much wider non-specialist readership, focusing particularly on those studies which showed, reliably, either significant impacts or an absence of them. In general, we have sought primarily to satisfy the wider readership – perhaps not always successfully! The full list of studies we have commissioned is shown in *Appendix C* and reports of these studies are available to those readers with specific interests who wish to obtain more detailed information which underpins our conclusions. But, as with all investigations of this nature – and particularly ecological ones – attributing environmental changes after oil spills directly or indirectly to the effects of the oil is not always easy, for the environment is inherently variable, and many populations of animals and plants fluctuate from year to year. Conclusions are sometimes therefore equivocal and cautionary, and, where doubt has arisen about changes being a consequence of the oil spill, we have sought to draw the reader's attention to our reservations. There were two subject areas within our remit which we regarded as especially sensitive, namely the effectiveness of the clean-up procedures and the collection, cleaning and rehabilitation of oiled seabirds. Both were of great concern to many people and, conse-quently, of wide media interest. The committee set up special arrangements to instigate a review of these subject areas. The conclusions of our review on clean-up arrangements were generally reassuring although some important general issues were identified, particularly in relation to the disposal of oiled beach material, which must be addressed urgently. The review of bird cleaning and rehabilitation raises serious doubts about the conservation and animal welfare benefits of such exercises – at least for some important species – which some may find unpalatable or contentious; it also proposes a major improvement in the organisational arrangements for any future bird collection and cleaning.

During the course of our investigations we have become increasingly concerned by the lack of national and local planning for assessing the environmental impacts of major oil spills (or, more generally, any spill of damaging substances) in coastal waters. Such plans that would ensure that effective monitoring arrangements are set in place immediately. We have proposed a revision of these arrangements which will require the immediate participation of the main organisations with responsibilities within the coastal and marine environment.

In making our recommendations, we have tried to distinguish those which relate more specifically to Milford Haven and the adjacent area – in part because of the continued high risk and the high environmental value of the area and in part because that was the area we studied intensively – and those recommendations which apply more generally to the UK coast. In accordance with our terms of reference, our conclusions are to inform Government, but where it is possible to identify organisations which are likely to be affected by our recommendations we have sought to do so in the expectation that these organisations will critically examine the recommendations we have made.

Looking back to the time of the spill in February 1996 and the immediate visual impact of the 72,000 tonnes of oil spreading along the coast, many observers anticipated that the environmental consequences would be widespread and of long duration. In the event, most of the oil evaporated or dispersed at sea and the majority of the bulk oil that stranded on beaches was removed by Easter. The restrictions on both commercial and sport fisheries were of comparatively short duration. Although some wildlife populations were damaged (some severely) and a few may take years to recover, the great majority proved resilient and, after two years, have regained their former abundance. But this is no cause for complacency. Our good fortune is, in part, due to the time of the year that the spill took place, when many fish species were not in the affected area and before most of the migratory seabirds had returned to breed. In addition, the type of oil, and the pattern of winds and tides, which carried much of the oil away from sensitive parts of the Pembrokeshire coast and islands, helped mitigate the effect.

On a personal note I wish to pay tribute to the work of the members of the committee and the commitment they have shown. Whilst perhaps invidious to be selective I must mention the task group chairmen, John Portmann, Malcolm Smith and Charlie Pattinson. But I must also acknowledge the wider body of people and organisations associated with the work of these task groups and whilst this Report is that of the committee appointed by the Secretary of State for Wales, it could not have been produced without the unstinting help of these many supporters.

Finally, on behalf of the committee, I wish to express our thanks for the help and guidance we received from our extraordinarily patient and conscientious Secretary, Tim Kirby, and his supportive and enthusiastic assistants Sarah Norton (up to August 1997) and Helen Jenkins (from August to December 1997).

Acknowledgements

The committee would like to thank the following:

All the members of the task groups and subgroups for their expertise and help with the programme of studies and preparation of this report – and in particular the task group secretaries Mr Andrew Franklin, Dr Mandy Richards and Mr Colin Strange. (Task group members are listed in *Appendix B.*) Special thanks should go to Miss Jane Hodges whose detailed knowledge proved indispensable, and Miss Jennifer Dack who organised the myriad studies commissioned by CCW and played a vital role throughout.

The contractors and staff who carried out the projects, and the project managers.

The main contributors to this report (in addition to committee members) who include:

Mr Blaise Bullimore
Miss Jennifer Dack
Mr Stephen Evans
Mr Bob Haycock
Miss Jane Hodges
Dr Tim Lunel
Mr Roger Milne
Dr Jon Moore
Ms Dale Rostron
Mr Tim Thomas.

The Environment Agency for providing facilities and support for the Secretariat.

Contents

Abbreviations

BTO	British Trust for Ornithology.
CCW	Countryside Council for Wales.
CEFAS	Centre for Environment, Fisheries and Aquaculture Science (formerly the Directorate of Fisheries Research at MAFF).
DETR	Department of the Environment, Transport and the Regions – formerly the Department of the Environment and the Department of Transport.
DNA	Deoxyribonucleic acid – the genetic material in cells.
EA	Environment Agency – established on 1 April 1996, taking over from the National Rivers Authority and Her Majesty's Inspectorate of Pollution.
FEPA	Food and Environmental Protection Act 1958.
HFO	Heavy fuel oil.
IOPC Fund	International Oil Pollution Compensation Fund.
JRC	Joint Response Centre – organisation which co-ordinated the shoreline clean-up operation.
MAFF	Ministry of Agriculture, Food and Fisheries.
MHWEMSG	Milford Haven Waterway Environmental Monitoring Steering Group.
MPCU	Marine Pollution Control Unit – part of the Coastguard Agency.
MRC	Marine Response Centre – in charge of the response operation at sea.
NERC	Natural Environment Research Council
NETCEN	National Environmental Technology Centre – part of AEA Technology.
OPRU	formerly the Oil Pollution Research Unit.
OSRL	Oil Spill Response Ltd.
PAH	Polycyclic aromatic hydrocarbon – see *Box 2.2.*
PCNPA	Pembrokeshire Coast National Park Authority
RSPB	Royal Society for the Protection of Birds
RSPCA	Royal Society for the Prevention of Cruelty to Animals.
SCAT	Shoreline Clean-up Assessment Team – See Chapter 10.
SEEEC	*Sea Empress* Environmental Evaluation Committee.
SPA	Special Protection Area – designated under the EC Birds Directive 1979.
spp	Species
SSSI	Site of Special Scientific Interest.
SWSFC	South Wales Sea Fisheries Committee.
THC	Total hydrocarbon – all the components of oil present. See *Box 2.2.*
WTWW	Wildlife Trust West Wales (formerly DWT, the Dyfed Wildlife Trust)
WWF-UK	Worldwide Fund for Nature - UK.
WWT	Wildfowl and Wetlands Trust.

Glossary of some terms used throughout the report

Algae	Non-flowering water plants such as seaweeds and some types of plankton.
Amenity	Aspects of the local environment which local residents and visitors use and enjoy. See Chapter 9.
Benthos / benthic	Animals and plants living on the sea bed
Bio-degradation	Breakdown of oil by micro-organisms. See *Box 2.3*
Biota	Animals and plants.
Bivalve mollusc	Molluscs such as mussels and razorshells which have two hinged shells.
Bulk oil	Oil in large quantities.
Crustacean	Member of group of hard shelled, mainly aquatic animals, such as crabs, lobster,etc.
Emulsion	A mixture of water in oil.
Fresh oil	Oil before it emulsifies.
Intertidal	Between the low and high water mark.
Molecular weight	The weight of each hydrocarbon molecule. See *Box 2.2.*
Mollusc	Member of group of animals including snails, mussels etc.
Moribund	Dying.
Mortality	Death
Narcotisation	Equivalent to being drugged – arising from exposure to certain components of the oil.
Neap tide	Tide at the times of the month when there is least difference between high and low water – cf **Spring tide**
Opportunist	Adapting to take advantage of increased availability of food, space etc.
Plankton	Small plants and animals carried passively by currents in the near surface waters.
Quadrat	A representative area chosen for detailed study.
Rehabilitation	Cleaned birds successfully returned to live in the wild.
Sedentary	Animals living stationary in the sediment or attached to rocks.
Sediment shores	Shores composed of mud, fine sand or coarse sand.
Sheen	Very thin oil.
Splash zone	Area just above where high tide reaches.
Spring tide	Tide at the times of the month when there is greatest difference between high and low water – cf **Neap tide**
Strandline	Line along upper shore where debris is deposited at high water.
Subtidal	Below the low water mark.
Transect	A line across an area chosen for study.
Volatile	Evaporating quickly.
Water column	The body of water between the sea's surface and the sea bed.
Weathered oil	Oil that has undergone physical and chemical changes.

UNITS

mg/kg mg/l dry wt / wet wt	Microgram (ie one millionth of a gram) per kilogram (kg) or per litre (l) – units for hydrocarbon concentrations. "Dry wt"(weight) or "wet wt" refers to the way the analysis was carried out.
ha	Hectare – unit of area equal to 10,000m^2 or about 2.5 acres.
Knot	1 nautical mile per hour, or 1.85 km/h
ppm	Parts per million.
±	"Plus or minus". 10 ± 2 means somewhere in the range 8 to 12.

1 Setting the Scene

1.1 Introduction

On 15 February 1996 the *Sea Empress*, a tanker bringing crude oil to a refinery in Milford Haven in south-west Wales, ran aground and over the following week released 72,000 tonnes of crude oil and 480 tonnes of fuel oil into the sea. Despite a rapid response at sea, oil came ashore along 200 km of coastline - most of which is in a national park - in an area of international importance for its wildlife and natural beauty. A ban was imposed on commercial and recreational fishing in the region and there was concern that tourism, important for the local economy, would be badly affected by the heavily-oiled beaches. Thousands of oiled birds washed ashore, leading to a major collection, cleaning and rehabilitation operation. The events prompted widespread fears of an environmental catastrophe.

Over the following weeks, a massive shoreline operation managed to clean the main amenity beaches sufficiently for tourists' use during the Easter holiday period, and it became apparent that in several cases the environmental impact was not as severe as many people had initially feared. The ban on taking fish was lifted in May 1996 and within 18 months of the spill the fisheries were all open and there were few visible signs of the effects of the oil except in the most heavily oiled areas where some continuing clean-up was required.

This report describes the impact the oil has had on the environment, both at sea and along the shore. It also looks at the response to the spill - the clean-up operation, the environmental monitoring programme and the cleaning and rehabilitation of oiled birds - and, from the experience gained, recommends improvements for assessing and responding to future spills.

The report has been prepared by the *Sea Empress* Environmental Evaluation Committee (SEEEC), an independent committee appointed by the UK Government and chaired by Professor Ron Edwards CBE. Over the course of 20 months, the committee brought together teams of experts and commissioned about 80 scientific studies. The results of these studies, along with earlier research on the ecology of the region and work carried out by other organisations, provided the information on which this report is based. This has been a large-scale exercise involving people from a wide range of organisations including government and public bodies, universities, voluntary organisations, research institutions, and companies specialising in oil spill or ecological assessment work.

Onlookers at St Ann's Head (E Bent)

This chapter sets out what the committee was asked to do and how this work was carried out, and gives background information on the region affected by the spill.

1.2 Other investigations

Our report is only one of a number of investigations of the *Sea Empress* incident. The accident itself and the salvage operation were investigated by the Marine Accident Investigation Branch of the Department of the Environment, Transport and the Regions (DETR)* , which published its report in July 1997[1]. The Marine Pollution Control Unit (MPCU) has produced a detailed account of the clean-up operation[2]. The effects of the spill on public health are being investigated by Dyfed Powys Health Authority[3], with SEEEC providing information on vapour levels to assist with their longer-term research. Pembrokeshire County Council and other public bodies commissioned a study of the potential economic consequences of the spill (see §9.2.6).

1.3 Early environmental monitoring

Environmental monitoring started very soon after the grounding of the *Sea Empress*. Initially, much of the environmental monitoring work

* *Note: Since the oil spill several organisations have undergone reorganisation or have changed their names. Throughout this report these organisations are referred to by the names current at the time of writing the report. The Abbreviations list gives lists these organisations' former names.*

was driven by the Environment Team of the Joint Response Centre (JRC, the organisation co-ordinating the shoreline clean-up operation) at a time when they were under extreme pressure. The Countryside Council for Wales (CCW), together with OPRU, started to co-ordinate an early scientific response, particularly with regard to birds; and ideas and proposals – such as the establishment of leave-alone sites where oil was left untreated – were discussed and agreed with key members of the JRC. The Ministry of Agriculture, Fisheries and Food (MAFF) rapidly set up a team to advise on fisheries and to assess the scale of the spill and the species most at risk.

South-west Wales benefits from having many locally based scientists who were able to react quickly to the incident, often under contract to CCW. These included ecologists, ornithologists and marine biologists in a variety of organisations. Many devoted a considerable amount of time to mapping and recording, on a daily basis, the effects of the oil on the local flora and fauna and setting up other studies to determine the effects of the spill. In many cases, samples were taken from areas of particular interest just before the oil reached them to provide up-to-date information for later comparison.

Musselwick Sands (E Bent)

This early work was funded from a variety of sources, with many of the organisations involved using their own resources. CCW was provided with an initial £250,000 by the Secretary of State for Wales, which was used to start a more comprehensive monitoring programme.

During March and April 1996, a co-ordinating group met on two occasions to exchange information on the work carried out by the various agencies involved, and SEEEC itself took over from this group at the start of April.

1.4 Key questions

The establishment of SEEEC was announced on 27 March 1996 by the Secretary of State for Wales. The terms of reference set for SEEEC by the UK government are given in *Box 1.1* and *Appendix A* lists the members of the committee.

To fulfil its terms of reference, SEEEC has sought answers to a number of key questions:

- Where did the oil go and what has since happened to it?
- What have been the short-term and long term effects of the oil on the species, ecosystems, fisheries and amenity of the region?
- Was the clean-up operation carried out effectively and did it cause any additional environmental damage?
- Was the environmental monitoring programme effectively organised and carried out?
- How effective was the collection, cleaning and rehabilitation of oiled birds?
- What lessons have been learnt to help improve the response and environmental impact assessment of any future oil spill?

Box 1.1 SEEEC's TERMS OF REFERENCE:

- To co-ordinate monitoring work carried out by government departments and other public bodies to assess the environmental impact of the *Sea Empress* oil spill and the subsequent clean-up activities.
- To ensure that a comprehensive set of monitoring data on environmental distributions and impacts is obtained, taking account of studies by other organisations and the need to avoid gaps and overlaps.
- Through these monitoring programmes, to assess the overall impact of the incident on environmental resources of the area affected, these resources to include fisheries, agriculture, amenity and wildlife conservation, and to assess the subsequent recovery of these resources. Information on the distribution of pollutants relevant to human health will be passed to public health authorities for assessment.
- To publish the principal findings and conclusions of these studies with the purpose of informing the Government, the public and those specific groups directly affected by the incident. Recommendations will be made where improvements in procedures or further actions are required, which might have wider application.

Box 1.2 NATURAL VARIABILITY AND BIOLOGICAL RECOVERY

The marine and shoreline environment is not stable and variations in species composition and numbers arise for several reasons. For example, at sea unusually cold or warm conditions may affect the hatching of eggs or the survival of larvae of a certain species; or a particularly strong year-class of fish may prey unusually heavily on another species. Many species are opportunists and, regardless of the cause, will exploit opportunities such as a temporary gap in the species web with resultant short term explosions in numbers. Such natural events are often difficult to distinguish from effects caused by humans, and it is important to recognise this when interpreting the results of studies investigating the impact of a particular event such as the *Sea Empress* oil spill.

Biological recovery, in the context of getting back to normal after an oil spill, can mean a number of different things depending on the expectations of the observer. A definition which is fairly widely accepted[4] is that recovery has been achieved when a healthy biological community has been re-established in which the plants and animals characteristic of that community are present and are functioning normally. This does not necessarily mean all the same species are present again nor does it mean that the age structure previously present is replicated. Furthermore, because of the natural variability in what is normal, even if there are differences, it will often be impossible to establish whether those detectable differences are attributable to the oil spill.

Some of these questions could be answered with a single study while others required a whole suite of studies. By far the greatest number were directed at the second question – the effects on species and ecosystems. It was clearly impossible to study the impact of the oil spill on every species in every part of the region affected or on every possible fishery in the area. Choices had to be made. We have tried to cover all the main types of onshore and marine environments – such as rocky shores, sediment shores, the water column and seabed – and have chosen to consider some key species in the following categories:

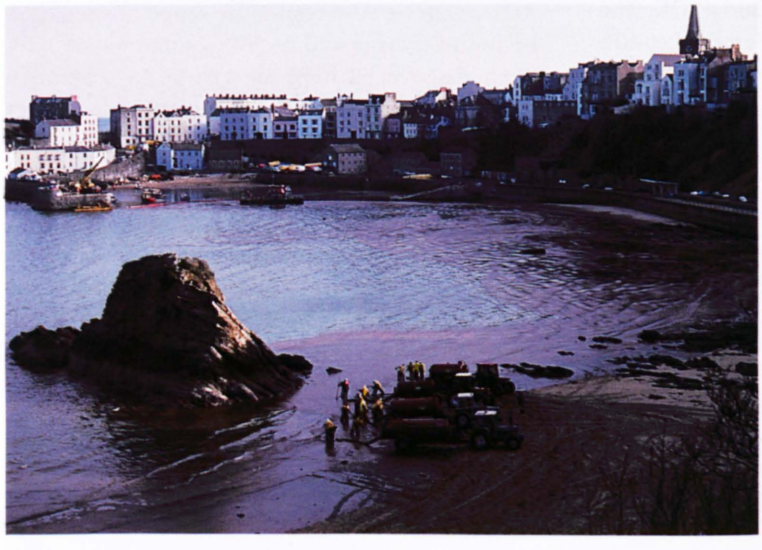
- heavily impacted by the spill;
- indicative of the health of the environment under consideration;
- of conservation importance in the area – such as those which are rare or which have populations of national importance;
- important in the marine food chain;
- of economic value.

Skrinkle Haven (PCC)

The studies chosen also had to be practical and likely to produce results which were scientifically reliable. They were also required to make best use of the wealth of available scientific data, expertise and experience – benefiting from the ecological studies carried out in Pembrokeshire over many This years was important due to the natural variability of many populations (*see Box 1.2*)

1.5 How the committee tackled its task

To make its task more manageable – and to bring in extra technical and scientific expertise – the committee established three task groups to provide advice on marine impacts, shoreline impacts, and matters related to the behaviour of the oil and to the clean-up operation. These task groups included some members of the main committee along with invited experts from a wide range of organisations. Experts were chosen for their individual knowledge rather than as representatives of their organisations,



Oil at Tenby Harbour (E Bent)

and the aim was to have a balanced range of expertise to cover all aspects of each group's remit. Two of the groups additionally set up subgroups targeted at specific issues such as birds, amenity impacts and the effectiveness of clean-up. The members of each task group are given in *Appendix B.*

The task groups began by reviewing the work already underway and then designed studies to fill in the gaps and particularly to answer those questions listed in §1.4. These studies were presented in the committee's *Initial Report*[5]. *Appendix C* gives a full list of the projects mostly commissioned on behalf of SEEEC. Reports arising from the studies (and, in a few cases, work carried out independently of SEEEC) were reviewed by small teams with relevant expertise and then by the task groups. Some of the key reports were also sent for review to nationally recognised experts in the field not associated with SEEEC. The Government and government agencies provided funding for these studies (apart from a few which were already being funded by other organisations). In addition, CCW, the Environment Agency (EA) and MAFF provided project management and contract administration.

This programme of work has involved around 50 people from 25 or so different organisations on the committee and its task groups, with more than 50 different contracting organisations carrying out the projects. The programme has cost nearly £2 million, with most of this money coming from the Welsh Office, CCW, MAFF, DETR, MPCU, EA and the European Commission (EC). The Worldwide Fund for Nature - UK, The Wildlife Trusts, Texaco and Pembrokeshire Coast National Park Authority have also sponsored studies.

1.6 SOUTH-WEST WALES

1.6.1 Natural environment

South-west Wales is an area of great natural beauty and ecological interest which attracts thousands of visitors each year.

The highly indented coast and numerous islands provide a wide range of habitats which scientists have been studying in detail for many years. Within the zone affected by the spill, thedominant type of shoreline is of rocky cliffs, rock platforms and boulders (58%). Sand habitats make up 21% of the shoreline and mudflats 2%, while shingle shorelines (mobile boulders, cobbles and pebbles) comprise 19% and saltmarshes less than 1%[6].

Oil at Green Bridge of Wales, Castlemartin (PCNPA)

These various coastal habitats are especially rich in birds. For example, in the breeding season around half of the world's breeding population of Manx shearwaters *(Puffinus puffinus)* can be found here; Grassholm Island supports the world's third largest population of gannets *(Morus bassanus)*, and Carmarthen Bay shelters large, wintering flocks of common scoter *(Melanitta nigra)*, a species of sea-duck. There were around 8,000 scoters in the Bay during early to mid-February 1996, a population considered to be of European importance.

Within the region, marine plants and animals characteristic of relatively warm Atlantic waters occur alongside those characteristic of colder Arctic waters. As a result, the range of species to be found is large and includes some which have been discovered here as well as lesser-known species of corals, jewel anemones and the sea fan, *Eunicella verrucosa*.

An area of great scientific and economic importance to the area is the Milford Haven waterway, part of a drowned valley (or "ria") which includes the Eastern and the Western Cleddau rivers. The Haven's coastline is approximately 110 km long, with tidal influences extending 7 km upriver of the confluence of the two Cleddau rivers. The nature of the waterway results in a diverse range of habitats which are of great conservation value.

Another important area is Carmarthen Bay, a wide, shallow bay on the south coast of Pembrokeshire and Carmarthenshire with extensive sandflats, dunes and four important estuaries with sand, mud and saltmarsh habitats. These, along with other marine and coastal environments within the bay, are of considerable ecological importance.

1.6.2 Species and habitat protection

Most of the coastline affected lies within the Pembrokeshire Coast National Park which is the only national park in Britain primarily designated for its coastal and estuarine landscapes. In the main area affected by the spill there are around 35 Sites of Special Scientific Interest – places designated as being important as habitats for plants and animals, or for geological features. Two National Nature Reserves have been declared at Stackpole and Skomer as exceptional examples of wildlife habitats and geological features. The sea and intertidal areas around Skomer and the Marloes peninsula forms one of the United Kingdom's three Marine Nature Reserves, a designation for conserving specially important marine habitats and wildlife; and much of the south-west Wales coastline has been defined as Heritage Coast.

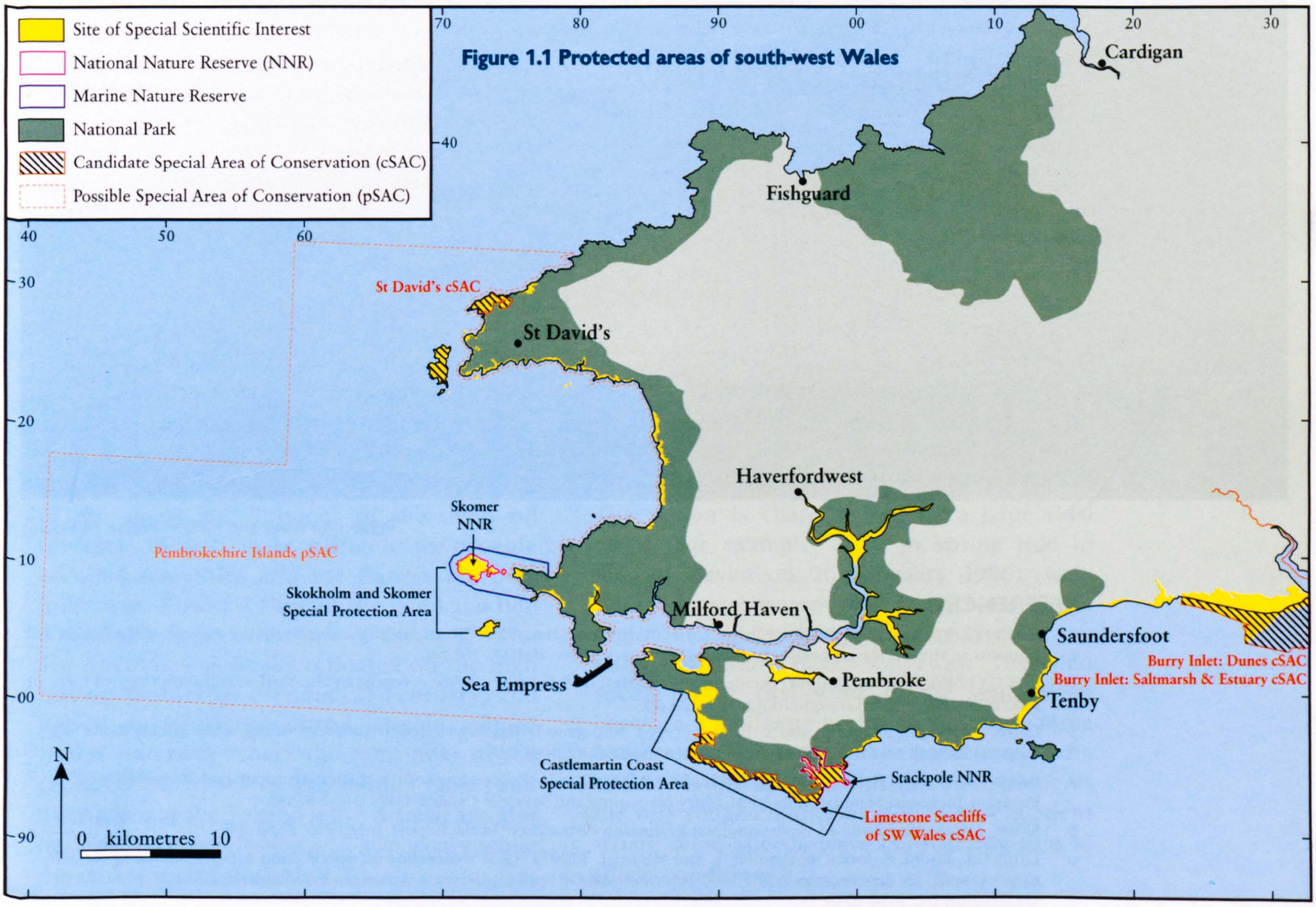
Further protection has been given to parts of the region through European Commission designations which require rigorous assessment of any proposed development in the designated area. Special Protection Areas designated under the EC Birds Directive 1979 are listed in *figure 7.1*. These are intended to conserve the habitats of migratory birds and birds which are either rare or vulnerable. The UK Government has proposed three Special Areas of Conservation under the Habitats Directive, along the Castlemartin coast, a large sea area around some of the Pembrokeshire islands and the Milford Haven waterway, and Burry Inlet saltmarsh and estuary. (See *figure 1.1*)

1.6.3 The economy

The main centres of population in south-west Wales are the towns of Carmarthen (population 14,600 (1991 census)), Milford Haven (13,600), Haverfordwest (13,300), Pembroke Dock (8,600) and Pembroke (7,200).

The economy of the region faces substantial problems resulting from closures of major industrial and defence establishments and from the decline in some agricultural sectors. Unemployment rates within the county of

Figure 1.1 Protected areas of south-west Wales



Pembrokeshire are amongst the highest in Wales, and attracting new industry to the area is difficult due to the poor infrastructure and its distance from major centres. The region's economy relies heavily on a few key industries, particularly the oil industry, tourism, agriculture and fishing.

Tourism plays a vital role in the economy of south-west Wales as thousands of visitors are attracted each year to its sandy beaches and spectacular scenery. Many of these visitors stay in the vicinity of the popular seaside resorts of Tenby and Saundersfoot which lie along the west coast of Carmarthen Bay. Other visitors are attracted by the abundant wildlife or by the educational opportunities offered by the field studies centres in the region. In 1995, tourists spent an estimated £160 million in Pembrokeshire.

The fishing industry is centred around Milford Haven waterway which is one of the most productive commercial fisheries in Wales, taking advantage of the abundant shellfish, crabs and lobsters, sea bass and other fish within the area. South-west Wales also has a number of fine fishing rivers – supporting salmon and sea trout – which attract many anglers. Fishing continues to be an important commercial and recreational activity within Pembrokeshire and supports an estimated thousand land- and sea-based jobs. Agriculture in the region includes early potatoes and other vegetables, dairy and livestock farming.

The Milford Haven waterway has had a long history as an oil port, chosen during the 1950s for its deep waters and natural shelter, features which make it ideal for large tankers. Today, Milford Haven continues to be the second busiest port in Britain for petroleum products, taking delivery of crude oil and shipping refined products world-wide. High transport costs of oil-based products from Pembrokeshire have, however, led to the oil refineries becoming less competitive.

Pembroke River and Milford Haven (A Poole)

REFERENCES

1. MAIB (1997). Report of the Chief Inspector of Marine Accidents into the grounding and subsequent salvage of the tanker *Sea Empress* at Milford Haven between 15 and 21February 1996. HMSO. 161 pp.
2. MPCU (1996). The *Sea Empress* Incident, Milford Haven 15 February 1996. A report by the Marine Pollution Control Unit, December 1996. The Coastguard Agency. 128 pp.
3. Lyons, R., Temple, M., Evans, and S. Palmer (1996). Report to Dyfed Powys Health Authority on the acute affects of the *Sea Empress* oil spill on the health of the South Pembrokeshire population. 13 pp.
4. Baker, J.M, Clark, R.B, Kingston, P.F, and Jenkins R.H (1990). In: Proceedings of the thirteenth Arctic and Marine Oil Spill Program Technical Seminar, pub. by Ministry for Supply and Services Canada, ISBN 0-662-57535-0
5. SEEEC (1996). *Sea Empress* Environmental Evaluation Committee: Initial Report, July 1996. 27pp.
6. Little, D.I., Rhind, P., Jones, R., Bennett, I. and Moore, J. (1997). CCW's shoreline oil distribution surveys following the *Sea Empress* spill. In: Proceedings of the 1997 International Oil Spill Conference American Petroleum Institute, Washington DC 1036-1038

2 Fate of the Oil

2.1 INTRODUCTION

This chapter describes what happened to the oil over the days and months following the spill. Several different processes - both natural and resulting from clean-up activity - acted on the oil, and these determined where the oil went, its fate, and, to a large extent, its impact on the environment.

Monitoring work and surveys, along with data from previous field trials using the type of oil spilt from the *Sea Empress*, were used to estimate the amounts of oil which evaporated, dispersed at sea, stranded on the shore or were removed by the clean-up operation. These estimates were used to construct a series of mass balance budgets showing the fate of the oil progressively during the period following the spill.

2.2 THE RELEASE OF OIL

On the evening of Thursday 15 February 1996, the *Sea Empress* -- laden with more than 130,000 tonnes of crude oil intended for the Texaco refinery - ran aground in the entrance to Milford Haven waterway, with an initial loss of oil. Although quickly refloated, the tanker listed badly and was anchored to await another tanker into which the oil could be transferred. During the night of Saturday 17 February, tugs were unable to hold the tanker against a combination of wind and strong tides and the *Sea Empress* was swept onto rocks near St Ann's Head with a further loss of oil. Further groundings occurred over the next few days, and oil was lost in the hours around each low tide, with the largest release occurring on Monday 19 February. *Table 2.1* gives estimates of the times and volumes of the main oil releases, though it is difficult to provide accurate quantities and the figures are only indicative. *Figure 2.1* shows the wind and tide conditions around the time of the spill. The *Sea Empress* was finally refloated on the high tide on Wednesday evening (21 February) and moved to the Herbrandston jetty in Milford Haven waterway where the remainder of the crude oil was transferred to another tanker and discharged at the Texaco jetty. A small amount of crude oil was released on 22 February while the tanker was at the jetty.

Sea Empress with tugs in attendance at the entrance to Milford Haven (ITOPF)

It is estimated that 230 tonnes of heavy fuel oil - the oil used to power the tanker - was lost before the tanker was brought into the Milford Haven waterway, with a further 250 tonnes released after the tanker was alongside Herbrandston jetty, mainly on the night of 21/22 February. A relatively small quantity of this oil had been trapped beneath the damaged tanker or in its internal structure, and this was released on 27 March when the tanker was turned at the start of its journey to Belfast for repairs, causing recontam-ination of a stretch of coastline within Milford Haven waterway.

These estimated quantities were based on observations and logs on board the tanker, data from remote sensing aircraft and the balance of the crude oil finally transferred from the tanker. Some of these figures, particularly those for the fuel oil, differ from estimates made soon after the spill, and some observers estimated the initial loss on 16 February to be higher: for example, the tanker's captain reported about 5,000 tonnes lost.

Box 2.1 describes the *Sea Empress* spill in a worldwide context.

2.2.1 Conditions at the spill

The region is characterised by a large tidal range (for example, a 7.6 m spring tide in Milford Haven on 20 February 1996), well-mixed coastal waters, strong currents and a region of rapidly changing water flows in the mouth of Milford Haven waterway. The wind speed in the first week of the spill varied between a moderate breeze to near gale force conditions (*figure 2.1*) - comparable with the *Exxon Valdez* incident but not as extreme as the very rough conditions at the *Braer* incident where wind speeds were consistently gale to storm conditions.

Box 2.1 THE SEA EMPRESS OIL SPILL IN CONTEXT

With all the media attention given to major tanker spills in recent years, it is not surprising that there is a general perception that such events are becoming more frequent. In fact, since the start of the 1980s through to the present day there have on average been fewer than nine tanker spills greater than 700 tonnes world-wide each year. This is about one-third of the equivalent figure recorded in the 1970s. However, the low incidence of large tanker spills is understandably of little relevance to those whose coastal areas and resources are affected by such events.

The UK can be considered unfortunate to have suffered three of the world's 20 largest spills, two of them only three years apart. The grounding of the *Sea Empress* in February 1996 followed the wrecks of the *Braer* in Shetland in January, 1993 (where 85,000 tonnes of oil was released) and the *Torrey Canyon* in the Western Approaches in March, 1967 (119,000 tonnes of oil).

The volume of oil lost is, however, only one of the factors which determine how serious a spill is in terms of clean-up requirements and the impact on the environment and on economic resources. The behaviour of the spilled oil, its effects and where it ends up depend on a combination of factors including the type of oil, weather and sea conditions, and the physical, biological and socio-economic characteristics of the spill location. The time of year and the type (and effectiveness) of clean-up measures will also have an influence. In consequence, brief descriptions and simple comparisons between spills can be highly misleading.

One of the most significant factors is oil type. For example, light crude oils and light refined products (such as petrol) evaporate rapidly and dissipate easily and so do not normally remain on the sea surface for any significant time. There is usually only a limited requirement for clean-up, and any coastal contamination is generally short-lived. Light oils contain a high proportion of toxic components, but these are generally lost rapidly through evaporation, and so in turbulent, well-mixed waters lethal concentrations leading to mortalities of marine life will be rare and highly localised.

In contrast, heavy crude oils and heavy fuel oils are more viscous and have fewer components which evaporate. They are therefore more persistent on the sea surface and can travel great distances from the original spill location. These oils are also resistant to many clean-up techniques, particularly at sea and in coastal waters, and so can lead to widespread contamination of coastal areas and resources. Whilst generally of low toxicity, heavy crude oils and heavy fuel oils pose a particular threat to seabirds, marine mammals and intertidal organisms which can become coated in the oil, resulting in the impairment of normal functions such as respiration, feeding and movement. In some circumstances, particularly where there are high quantities of sediment particles in the water, heavy oils can sink, thereby transferring problems to the sea bed and causing severe difficulties to fisheries which rely on bottom trawling or on pots and traps.

There have been comprehensive studies of the behaviour and effects of only a relatively few oil spills. These include:

- *Amoco Cadiz*, which lost its entire cargo of about 223,000 tonnes of Arabian light and Iranian crude oil when it grounded on the Brittany coastline in France in March 1978 causing wide-spread coastal contamination and requiring a major shoreline clean-up operation;
- *Exxon Valdez*, which released some 37,000 tonnes of Prudhoe Bay crude into the subarctic environment of Prince William sound, USA in March 1989, leading to extensive contamination of the Alaskan coastline and a clean-up response on an unprecedented scale over many hundreds of miles of remote shorelines; and
- *Braer*, which was wrecked on the southern tip of Shetland, UK in January 1993 with the loss of its cargo of about 85,000 tonnes of Gullfaks crude oil. In the prevailing severe weather and sea conditions the light crude oil dispersed naturally, rendering a major clean-up operation unnecessary, both at sea and on shore.

Even though two of these spills occurred around the same time of the year as the *Sea Empress* in areas with broadly similar environmental conditions to south-west Wales, the different oil types, weather and sea conditions resulted in significantly different environmental and economic impacts. Comparisons are made throughout this report with the results of the studies conducted following these three major spills, as well as with others such as the *Torrey Cannon*.

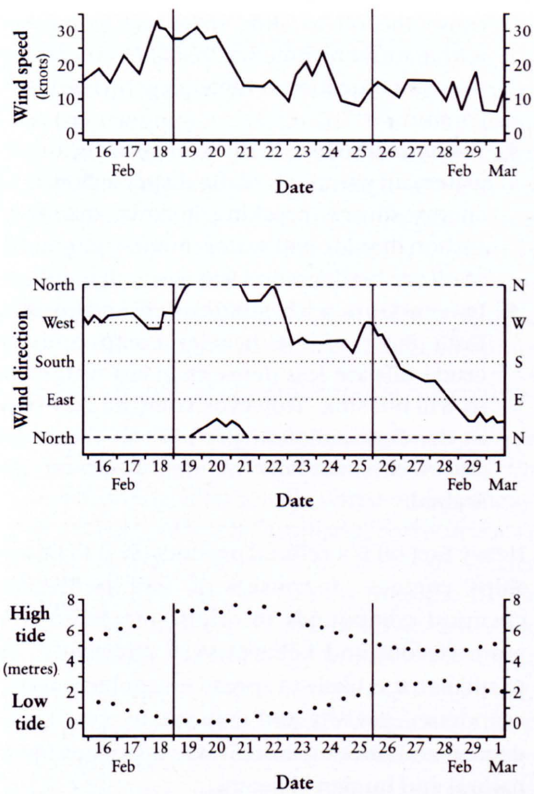


Figure 2.1: Wind speed and direction and tides around the time of the spill

2.3 OVERVIEW OF THE CLEAN-UP OPERATION

The clean-up operation is reviewed in detail in chapter 10, but an overview is given here to provide a context for the discussions later in this chapter.

Within a few hours of the *Sea Empress* going aground, two centres had been set up to oversee the clean-up operation: the Marine Response Centre (MRC) to handle the response at sea and the Joint Response Centre (JRC) to co-ordinate the shoreline response. The main approach for the clean-up at sea was to use planes to spray chemical dispersants onto relatively fresh oil; this resulted in the oil mixing more readily into the water column (see §2.7.1), reducing the amount of oil left on the surface of the sea. Dispersants were only used more than 1 km away from the shore to avoid shallow water where the dispersed oil would not dilute so rapidly and where, consequently, marine organisms could become exposed to elevated concentrations of dispersed oil. The dispersant operation at sea continued until 22 February.

Complementing the use of dispersants, mechanical recovery vessels were used to collect oil from the sea surface. Initially two small recovery vessels were used in the Milford Haven waterway, but larger vessels able to work outside the waterway arrived on 21 February and on subsequent days. Recovery vessels only function effectively in relatively calm conditions, and so were mainly used in the Milford Haven waterway and in the inshore waters of Carmarthen Bay around Tenby. These areas were relatively sheltered and were too close to the shore to use dispersants.

Around 200 km of shoreline was contaminated by oil, requiring a major clean-up operation lasting many months. The worst affected areas were West Angle Bay to Linney Head, western Carmarthen Bay and the southern shore of the Milford Haven waterway. The first phase of the shoreline clean-up was the removal of bulk oil at all accessible sites along the whole coastline affected. The operation then turned to cleaning the residual oil and trying to tackle bulk oil along inaccessible areas of coast.

A wide range of techniques was used, depending on the complex interaction between the oil and different types of shoreline material. Rocky shores away from the main amenity areas, inaccessible cobble and boulder shores, mudflats and saltmarshes were left to clean naturally, along with several sites left untreated for study purposes.

Table 2.1: Estimate of the main releases of crude oil from the *Sea Empress*

Date (Feb. 1996)		**Time** (GMT)	**Wind Speed** (knots)	***Wind** Direction (°)	**Estimate of oil released** (tonnes)
Thur	15	20:00 - 22:00	16	290	2,000
Fri	16				
Sat	17	20:00 - 23:00	19	250	5,000
Sun	18	10:00 - 13:00	31	290	2,000
	18	21:00 - 24:00	28	020	5,000
Mon	19	10:00 - 13:00			8,000
	19	22:00 - 01:00	29	020	20,000
Tue	20	10:00 - 13:00	26	040	15,000
Wed	21	00:00 - 02:00	21	030	10,000
	21	11:00 - 14:00	13	350	5,000
TOTAL					72,000

** the direction the wind comes from is measured clockwise from the north*

The clean-up operation generated a large amount of oiled waste material including liquid waste collected during the mechanical recovery at sea, oiled sand, and oiled materials such as beach debris and protective clothing. The liquid waste was taken to the Texaco refinery where it was reprocessed to recover the oil. Oiled sand was mostly taken to Texaco's landfarm, where conditions are maintained which promote the breakdown of oil by bacteria. The remainder of the oiled material was taken to a landfill site.

2.4 BEHAVIOUR OF OIL

Crude oils are a mixture of many chemical compounds (*Box 2.2*), and the composition and properties of different crude oils vary, as does their behaviour when spilled. A number of natural processes take place when oil is spilt at sea, and these are supplemented by further processes resulting from the clean-up response.

The processes are:

- **Evaporation:** This is one of the most important processes. As it is the lighter compounds in the oil which evaporate most readily, evaporative loss is often very pronounced (up to 40% in the case of light, volatile crude oils), whereas with heavier oils it is far less. The loss of the light compounds through evaporation changes the composition and properties of the oil which remains.
- **Spreading and drifting on the sea surface:** Oil normally spreads very rapidly to form a thin slick which is ransported across the sea surface by wind and currents. Tidal currents reverse direction periodically, so it is wind and waves which dominate where the oil is carried over a period of days.
- **The formation of an emulsion:** Once the lighter components have evaporated, physical processes can mix water into the oil to form an emulsion. This increases the volume of the oil by a factor of 3 to 4 and also makes it more viscous and much harder to disperse. Chemical "demulsifiers" can be used to break an emulsion down into oil which can then be dispersed.
- **Natural dispersion:** The physical action of waves and turbulence in the water column breaks oil which has not emulsified into small droplets which become suspended in the water. Some of the lighter components of the oil also dissolve.
- **Chemically-enhanced dispersion:** When chemical dispersants are applied to fresh oil, the oil forms droplets much more readily and so the natural dispersion process is enhanced. Although dispersants do not cause the oil to sink, their use, combined with natural turbulence, results in increased oil concentrations throughout the water column.
- **Biodegradation:** Micro-organisms in sea water can use much of the dispersed oil as an energy source, breaking it down mainly to carbon dioxide and water. Some compounds of oil are biodegraded less easily than others.
- **Interaction with suspended sediments:** Even most of the heavier compounds in crude oils are less dense than sea water and so will not sink. However, some oil may stick to the fine sediment particles in the water and will eventually be deposited on the seabed.

Heavy fuel oil is a refined product used to power ships' engines. It consists of only the heavier chemical compounds in crude oil and so it is more viscous and behaves very differently. In particular, it is likely to spread less quickly and to evaporate, emulsify and disperse to a far lower degree; and once onshore it is less susceptible to natural and human clean-up.

The following sections discuss how the above processes applied to the Forties Blend crude oil and heavy fuel oil spilled from the *Sea Empress*. Forties Blend crude oil combines oils from 16 different North Sea fields, but a good deal of research - both in the laboratory and through controlled experiments at sea - has been carried out on oil of this type, and so its behaviour is well understood.

2.5 EVAPORATION: OIL IN THE ATMOSPHERE

Evaporation was one of the most important processes affecting the Forties crude oil. Eight samples of surface emulsion were taken during the early stages of the spill to check the proportion of oil which had evaporated. These samples were from oil which had been on the sea surface for between 9 and 37 hours, and showed that between 35% and 45% of the volume of the oil had evaporated. This agreed well with the results of previous field trials on Forties Blend crude (*figure 2.2*) and suggested that, over the course of the first week or so, between 24,000 and 32,000 tonnes of the lighter fraction of the oil entered the atmosphere. There, it would be expected to disperse rapidly and widely due to air movement and, over a period of days to weeks, to be deposited in very low concentrations over a large area or to be broken down by sunlight and chemical reactions.

Box 2.2 COMPONENTS OF CRUDE OIL

Crude oil typically consists of many thousands of different components. Most of these are **hydrocarbons** - carbon and hydrogen atoms arranged in chains or rings. **Molecular weight** (ie the weight of each hydrocarbon molecule) principally depends on the number of carbon atoms, which can vary from one to more than 100. A **light oil** has a greater proportion of the low molecular weight components, while a **heavy oil** has more of the high molecular weight components. The refining process separates the crude oil into fractions with similar molecular weight; petrol, for example, includes only relatively light components. The lower molecular weight components, particularly those with fewer than 15 carbon atoms, evaporate rapidly. The presence of higher molecular weight components tends to make the oil more viscous (ie thicker).

Several groups of components are referred to in this report, including:

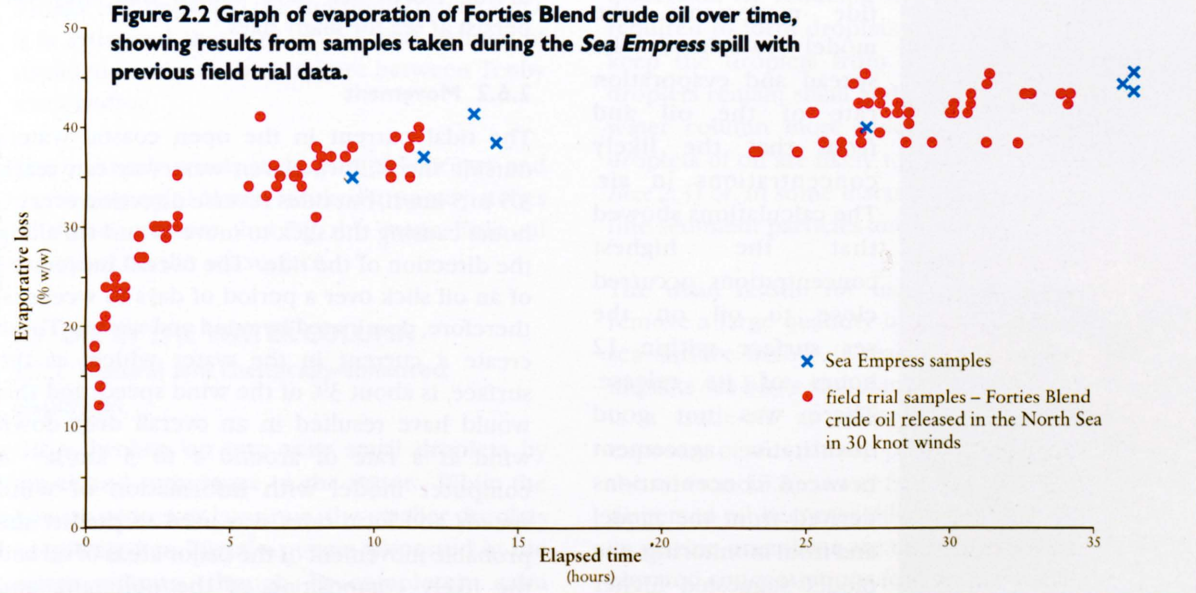
- The **"BTEX" fraction** (ie benzene, toluene, ethyl benzene and xylene): These have a single ring of carbon atoms and are acutely toxic. They have very low molecular weights and evaporate very quickly when oil is spilled.
- **PAHs** (polycyclic aromatic hydrocarbons): There are a large number of different PAHs - all with two or more rings of carbon atoms - covering a range of molecular weights. PAHs evaporate, but less rapidly than the BTEX fraction. Several PAHs (or the products they are broken down into within an animal's body) have been implicated in cancer. PAHs occur naturally and are also a product from combustion.
- **n-alkanes:** These have straight chains of carbon atoms. Some of these can have a narcotic effect on animals, though the animals generally recover when exposure ceases.
- **Asphaltenes:** These have high molecular weights and do not break down readily.

There are different techniques available for measuring the concentration of components of oil in samples, for example to test for specific PAHs, the total amount of PAHs or total hydrocarbons (THC - the total concentration of all the components of oil present). By using a technique which measures the relative proportions of different molecular weight components in a sample of oil, samples can be compared to see if they are of the same oil type.

The proportion of oil which evaporated was higher than at many other incidents; for example, there was around 20% evaporation at the *Braer* and *Exxon Valdez* incidents where Gullfaks and Alaskan North Slope crude oils were spilt. The difference is due to the Forties Blend crude oil containing a larger proportion of volatile components.

According to the field trial data, evaporation is most rapid within the first few hours of the oil being spilt. Even if oil is dispersed, a similar proportion of the oil will eventually evaporate - though the process may be slower. The remaining oil becomes more viscous and persistent on the sea surface, but it is also less toxic as many of the most toxic compounds are amongst those evaporating.

Figure 2.2 Graph of evaporation of Forties Blend crude oil over time, showing results from samples taken during the *Sea Empress* spill with previous field trial data.



Heavy fuel oil is a refined product with a much lower proportion of volatile components than crude oil, and only 5% will evaporate over 24 hours.

2.5.1 The oil vapour

Vapour from recently spilt crude oil contains some of the more toxic components of the oil, and an atmospheric monitoring programme was established on the evening of the 17 February to monitor vapour levels. With the possibility of explosion, the emergency services took the precautionary measure of evacuating St Ann's peninsula. Vapour levels were monitored continually at St Ann's Head and downwind on the Angle peninsula. However, these gave no cause for concern; the highest levels recorded peaked at 9 parts per million (ppm) at West Angle and 3 ppm around Dale and St Ann's Head.

It was agreed, given the circumstances specific to this spill, that measurements exceeding 50 ppm would be reported immediately to the support team which would advise anyone working outside to wear personal protective equipment; and if the vapour were likely to pass near to residential areas they would advise members of the public to remain inside. If the concentration had risen higher than 100 ppm, evacuation would have been considered.

Computer modelling was used to estimate concentrations in oil vapour of total hydrocarbon and of specific toxic components (the BTEX fraction *(see Box 2.2)* and 1,3 butadiene) around the Milford Haven waterway in the days following the spill[1]. Using estimates of the volume and time of oil releases, and knowledge of wind and tide movements, the model calculated the spread and evaporation rate of the oil and from that the likely concentrations in air. The calculations showed that the highest concentrations occurred close to oil on the sea surface within 12 hours of its release. There was not good quantitative agreement between concentrations derived from the model and from monitoring: the model suggested higher maximum levels (averaged over an hour) than were measured of benzene and toluene over land and of all compounds over sea. Nevertheless, the model confirmed that concentrations over land would generally be low as the predominant wind direc-tions were seawards throughout most of the period when oil was evaporating.

Heavily-emulsified crude oil with mechanical recovery vessel (ITOPF)

2.5.2 Aerosols

Winds caused a small quantity of oil to be blown ashore as an aerosol (ie as fine droplets). This oil was deposited near to the coast: measurements of polycyclic aromatic hydrocarbons (PAHs – see *Box 2.2*) in grass samples found the greatest quantities around St Ann's Head and along the Castlemartin coast *(see* §5.2 and *figure 5.1).*

2.6 OIL IN THE SEA SURFACE

2.6.1 Water-in-oil emulsion

Once the lighter components of the oil had evaporated, the crude oil left on the sea surface readily formed a water-in-oil emulsion or "mousse". This resulted from turbulence near the sea surface which caused small droplets of water to be incorporated into the oil slick. The emulsion consisted of around 70% water and 30% oil, which increased the volume of pollutant by a factor of three to four. This meant that after 40% of the oil had evaporated, the remaining oil had the potential to form an emulsion with double the volume of the oil originally spilt. The emulsion was much more viscous than the crude oil: samples taken at the spill showed that in 15 to 30 knot winds the crude oil was forming viscous emulsions within 6 to 12 hours of being released. Forties Blend emulsions do not disperse readily, and field trials in the North Sea have shown that they can persist at sea for many days.

2.6.2 Movement

The tidal current in the open coastal waters outside the Milford Haven waterway can reach 3.5 to 5 km/h, but tides reverse direction every 6 hours causing the slick to move to and fro along the direction of the tide. The overall movement of an oil slick over a period of days to weeks is, therefore, dominated by wind and waves. These create a current in the water which, at the surface, is about 3% of the wind speed, and this would have resulted in an overall drift down wind at a rate of around 1 to 3 km/h. A computer model with information of wind speeds and local tides was used to predict the probable movement of the major areas of oil and the likely composition of the pollutant, and surveillance aircraft were used throughout the operation at sea to track the location and extent of the oil.

Flights early on 16 February showed that oil had come ashore south of the mouth of the Milford Haven waterway at Linney Head and West Angle Bay, confirming initial modelling predictions [2]. Over the next two days, westerly winds continued to keep the surface oil close to the coastline *(figure 2.3a)*. Had the wind remained in this direction during the main period when oil was released, all the oil would have quickly stranded near the Haven, allowing little chance of any response at sea. However, on the evening of the 18 February, when the wind veered to the north, most of the oil was driven south into open water where the use of dispersants was possible. *Figure 2.3b* shows the surface pollution for the morning of 21 February, by which time most of the oil spilt during the incident had been released. The continuing northerly winds on 22 February kept the oil offshore.

In the early hours of the 22 February, after the *Sea Empress* had been brought into Milford Haven waterway, an estimated 250 tonnes of heavy fuel oil was released. Winds drove this rapidly onto the waterway's southern shoreline, and oil entered Pembroke River and Angle Bay. Some also stranded on the north shores of the waterway.

On the morning of 23 February the winds backed to the south-west and the remaining surface oil at sea was pushed onto the beaches of Carmarthen Bay *(figure 2.3c,d,e)*. The wind continued to come from this general direction, and by 28 February much of the oil on the sea surface had impacted the shoreline *(figure 2.3f)*. It is estimated that 70% of the total volume of stranded emulsion came ashore between Tenby and Pendine.

The northerly winds at the end of February and the beginning of March resulted in some patches of sheen offshore, but by this stage little oil remained on the sea surface.

2.7 OIL IN THE WATER COLUMN

2.7.1 Natural and chemically-enhanced dispersion

Oil is broken up into very small droplets by waves and turbulence in the water. While the mixing processes continue, the smaller droplets - typically 1 to 70μm^3 - remain dispersed in the water column, though in completely calm conditions they may tend to float slowly back to the surface and form a sheen. When oil forms an emulsion, dispersion decreases significantly. Forties Blend crude oil has a relatively low viscosity and it would be expected that under typical winter conditions it would disperse at around 1% per hour over the first few hours after release, but only 10% to 20% of the oil would disperse naturally over a period of days to a week due to emulsification. The heavy fuel oil released was very viscous and so as little as 2% was expected to disperse naturally.

Chemical dispersants increase the natural rate of dispersion by reducing the amount of energy required to form droplets of oil, and they then keep the droplets from recombining so that droplets remain small and disperse through the water column more quickly. Eventually, the droplets of oil are likely to be biodegraded (see *Box 2.3*) or, in some instances, to combine with fine sediment particles and sink.

The main reason for using dispersants is to remove a large quantity of oil quickly from the sea surface before it reaches the coastline or impacts sea birds and mammals. This, however, is a trade-off as dispersion increases the exposure of animals and plants within the sea to the oil (see §3.2). Away from shallow water the dispersed oil becomes diluted very rapidly, and so marine organisms are unlikely to experience elevated concentrations for long periods.

Box 2.3 BIODEGRADATION

The dispersion process does not remove oil from the marine environment but rather makes the oil available to the many kinds of micro-organisms in sea water that can use hydrocarbons as an energy source (ultimately converting the oil principally to carbon dioxide and water). The most easily biodegraded oil components are those with straight chains of carbon atoms (n-alkanes and paraffins) and the low molecular weight aromatics (such as naphthalenes and phenanthrenes).

Forties Blend crude oil is a relatively biodegradable oil and once the light (low molecular weight) compounds have evaporated then 95% of the remaining oil can be biodegraded. By contrast, a considerably smaller fraction - approximately 40%, depending on the exact composition - of the heavy fuel oil can be degraded readily. Under typical conditions for UK waters, biodegradation of crude oil will take a period of weeks to months.

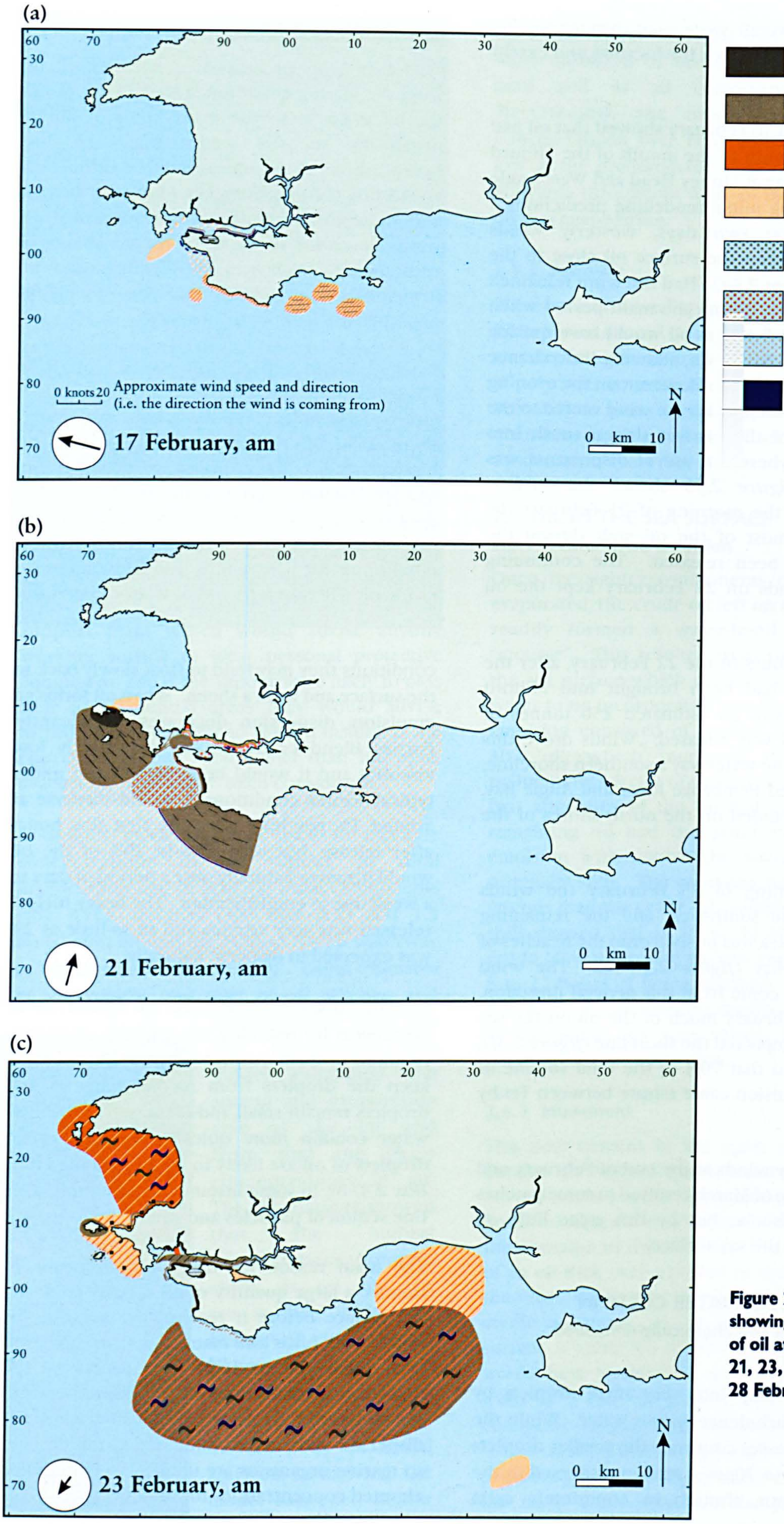
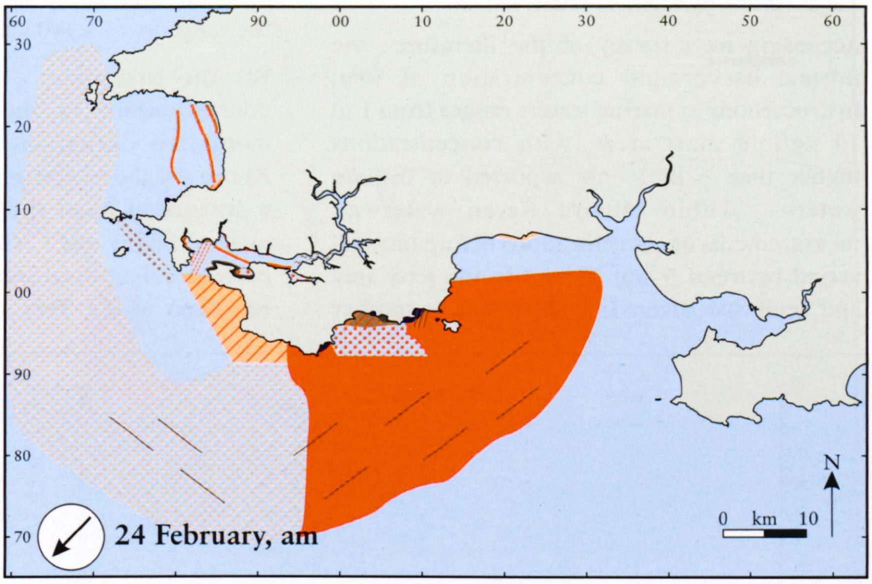


Figure 2.3 Maps showing the position of oil at sea on 17, 21, 23, 24, 25 and 28 February

(d)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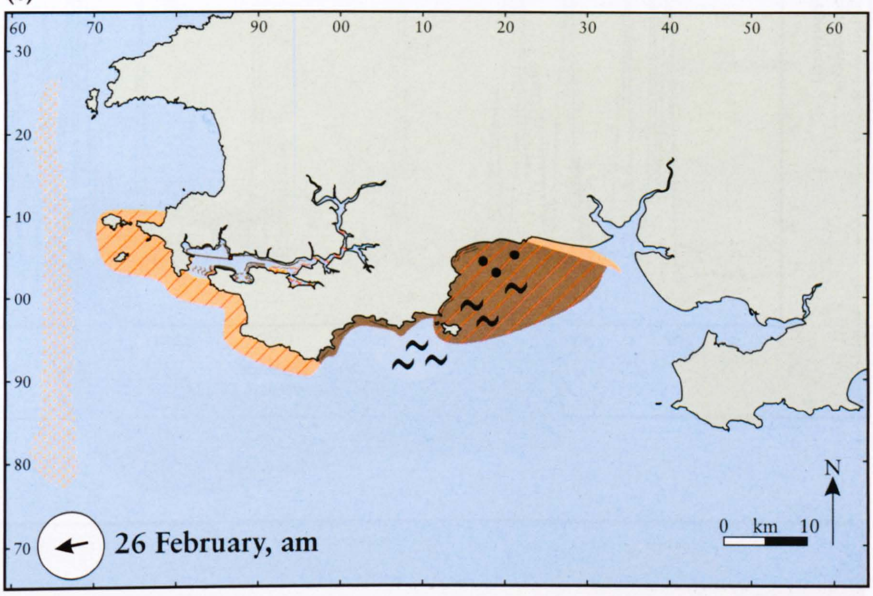
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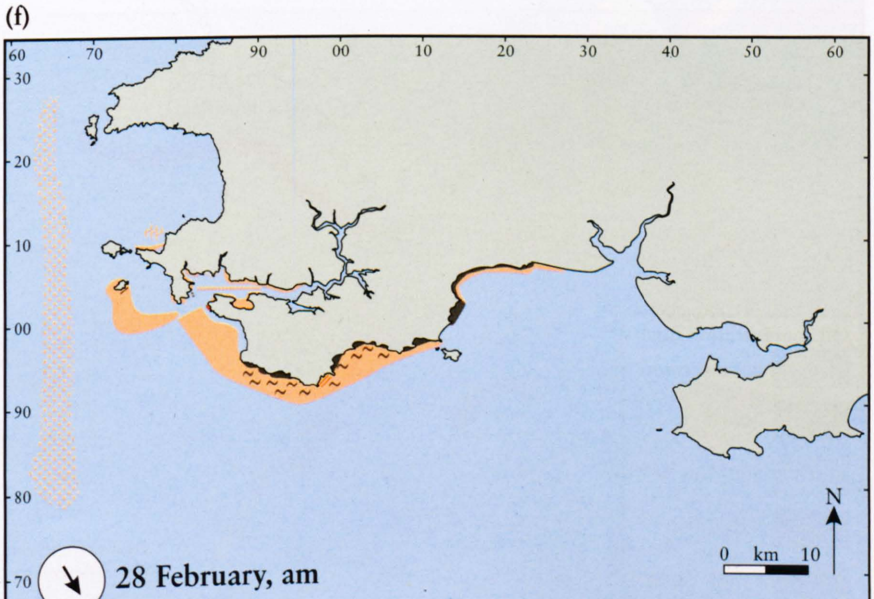
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2.7.2 Concentrations of dispersed oil

According to a survey of the literature[4], the normal background concentration of total hydrocarbons in marine waters ranges from 1 to 10 µg/l in most areas, with concentrations higher than 3 µg/l only reported in inshore waters. Within Milford Haven waterway, measurements of concentrations before the spill varied between 5 and 53 µg/l in the jetty area and Pembroke River. In comparison, at another port – Southampton – concentrations were in the range 90 to 1,900 µg/l.

For the first time at a major oil spill, oil concentrations in the water column were monitored during the dispersant operation. *Figure 2.4* shows concentrations measured over a distance of 2 km at depths of 1 metre and 4 metres below oil. The right hand section corresponds with an area where dispersants had not been used. Very little oil had reached a

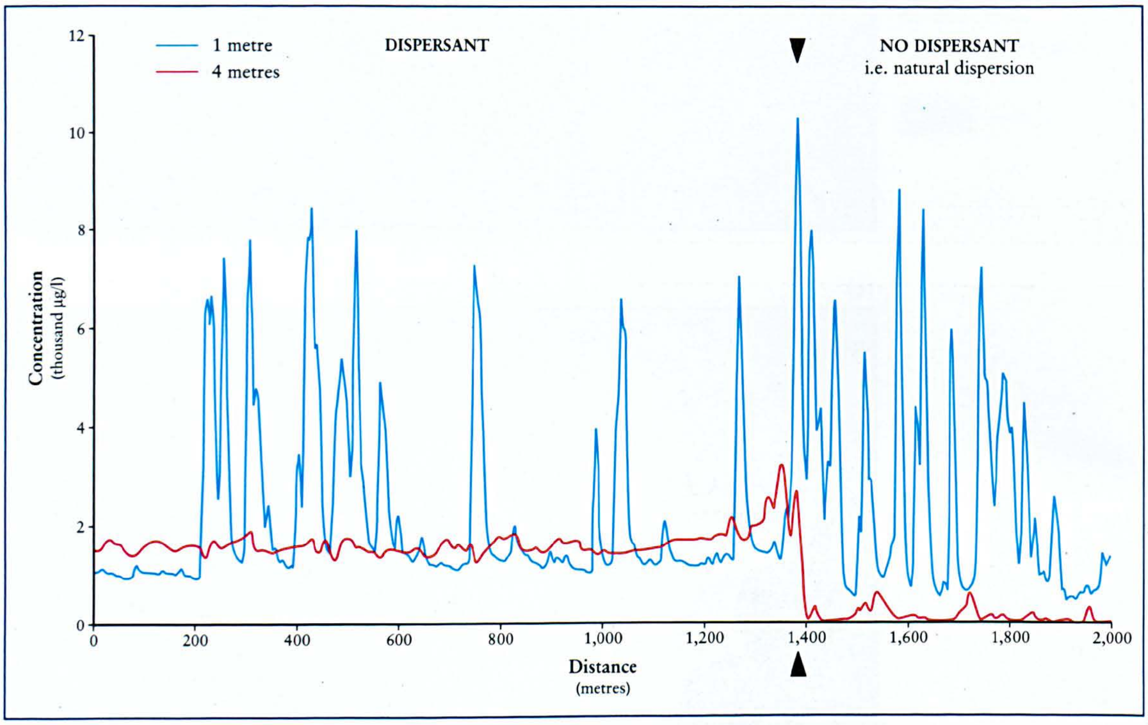


Figure 2.4 Graph of hydrocarbon concentrations at depths of 1 metre and 4 metres below oil, showing the effect of dispersant use

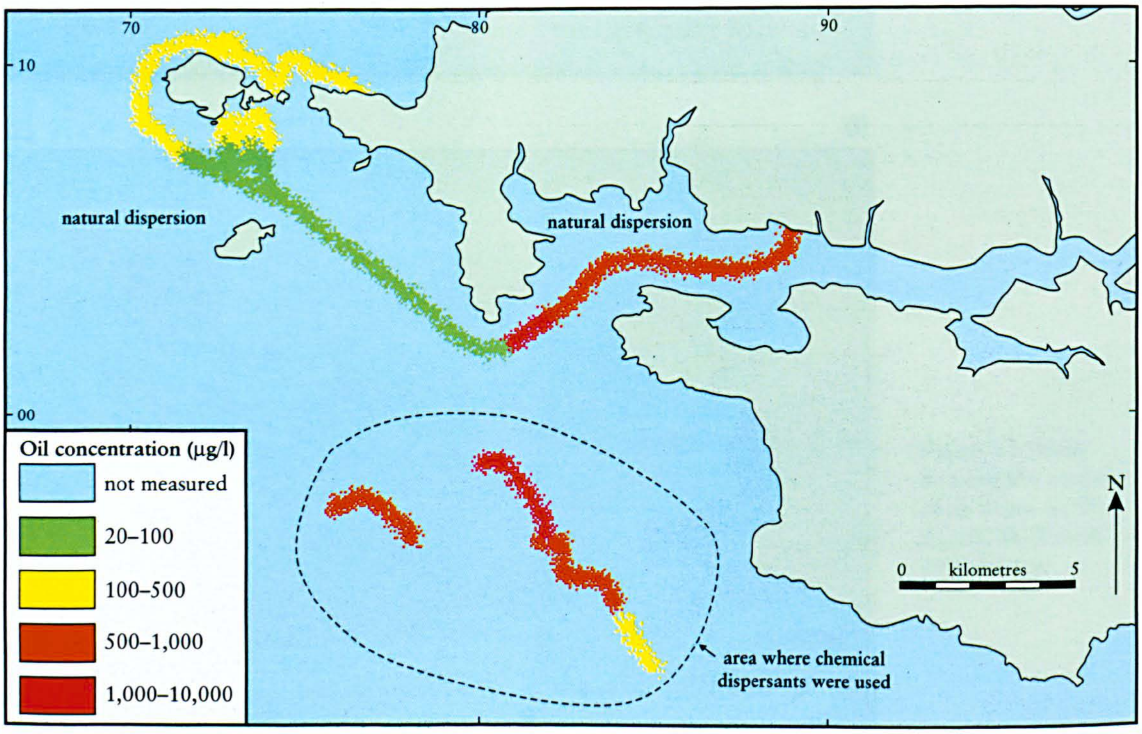
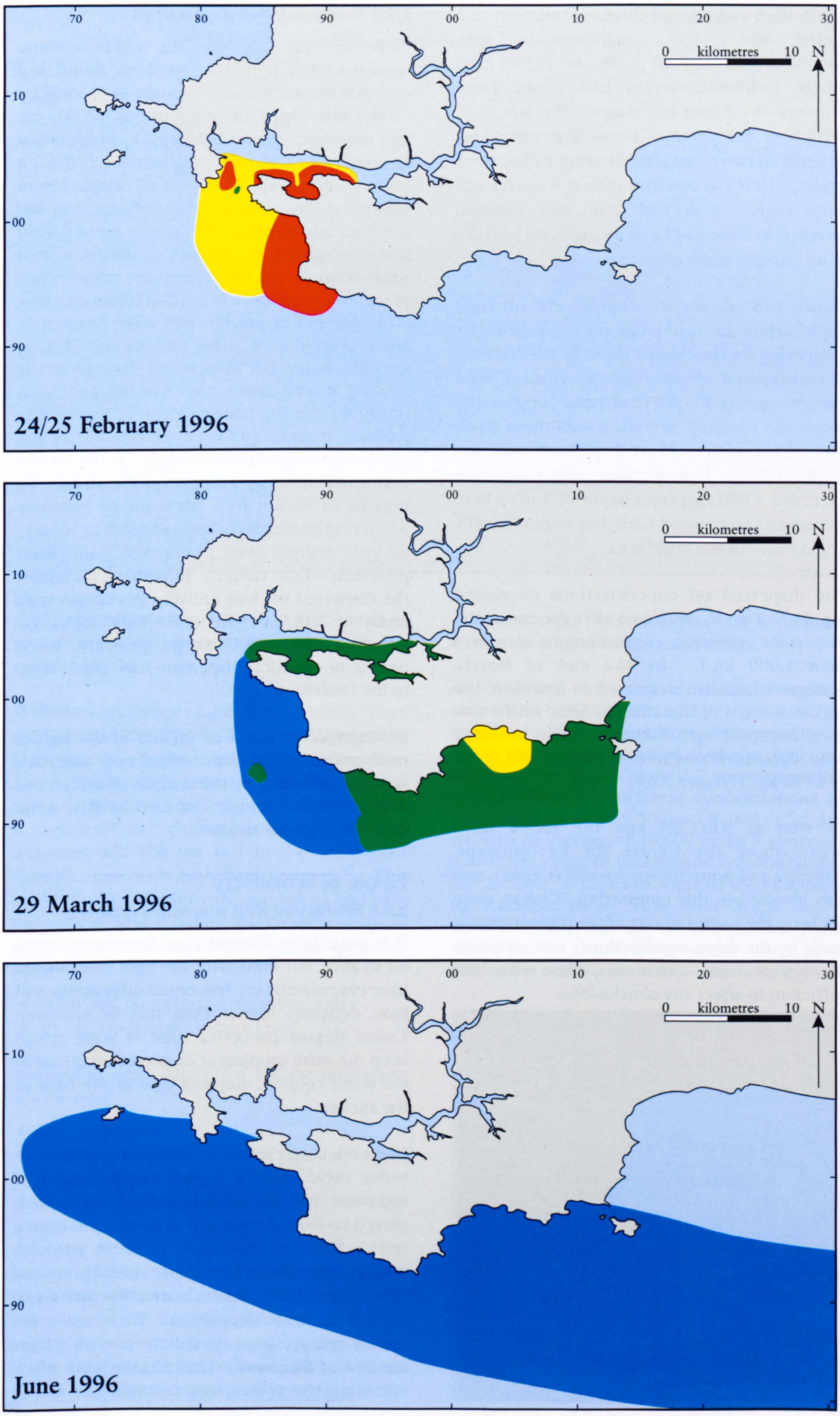


Figure 2.5 Total hydrocarbon concentrations near to and away from the dispersant operation.



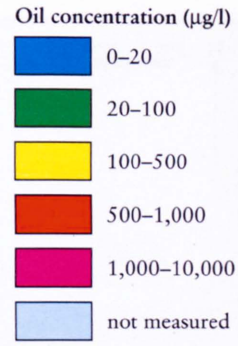


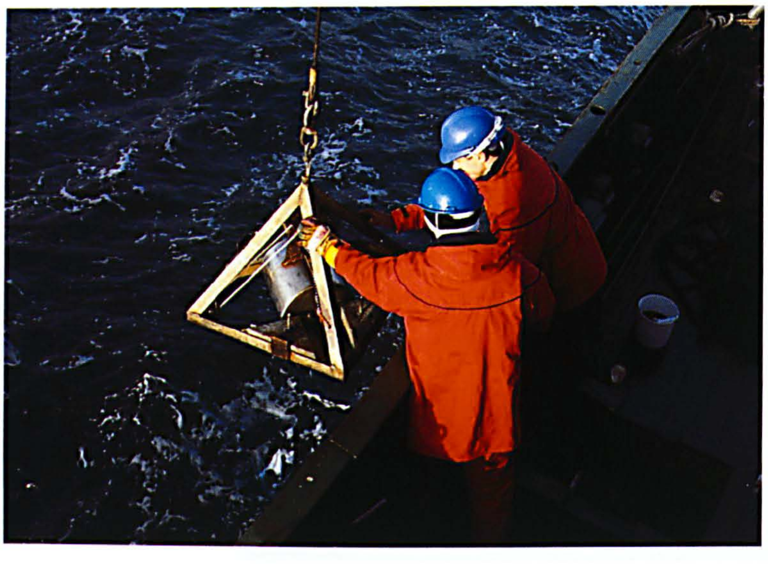
Figure 2.6
Maps showing the decreasing hydrocarbon concentration in water

depth of 4 metres, and the concentration at 1 metre was very patchy, with peak concentrations around 5,000 to 10,000 µg/l where individual waves had mixed large droplets of oil into the water. The left hand section of the diagram shows concentrations beneath oil two hours after dispersants had been applied. Here the concentration at 4 metres was much higher, at around 1,500 µg/l, showing clearly that there had been a significant transfer of oil into the water column.

Figure 2.5 shows concentrations of total hydrocarbon in two areas on 22 February[5,6], combining measurements made by the National Environmental Technology Centre of AEA Technology (NETCEN) directly under the dispersant spraying operation with those made by the EA in an area where dispersants were not used. Total hydrocarbon concentrations exceeded 1,000 µg/l (to a depth of 5 m) where dispersants were being used, but were generally much lower in the other area.

The dispersed oil concentrations decreased rapidly[5,6]. Two to three days after the end of the dispersant operation, concentrations were less than 1,000 µg/l. By the end of March, concentrations had decreased to less than 100 µg/l over most of the affected area, with a few local "hot-spots" up to 500 µg/l; and by the end of June, concentrations were at background levels (1 to 10 µg/l) *(figure 2.6)*.

As well as NETCEN and the EA, a third organisation, the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), was also involved in this monitoring. Checks were made on the comparability of the measurements made by the three organisations[4], and, although there were some differences, these were not sufficient to affect any conclusions.



Taking sediment samples (CEFAS)

2.7.3 Composition of dispersed oil

Once oil dispersed into the water column, mixing caused it to become more dilute and currents moved it away from the area. Several factors influenced the composition of this oil, and therefore its possible impact. Evaporation removed the lighter components of the oil rapidly (see §2.5): analysis of oil sampled from near the tanker suggested that within one to two hours of release about 25% of the oil had been lost to evaporation - enough to remove a large proportion of the low molecular weight toxic components, and all the BTEX fraction *(see Box 2.1)*. Natural dispersion may have resulted in small quantities of these components mixing into the water, but dispersants were generally applied several hours after the oil had been released from the tanker. Much of the oil was released at night, and even releases during the day were not sprayed immediately as the oil was within the limit of 1 km from the shore. (A notable exception took place on 19 February when dispersants were applied to oil as soon as it had drifted away from the immediate proximity of the tanker.) In general, therefore, the dispersed oil was unlikely to contain high levels of BTEX or the other light molecular weight components except, possibly, when natural or chemical dispersion took place close to the tanker.

Biodegradation removed further of the lighter components of the dispersed oil over time; this was demonstrated by the analysis of samples of dispersed oil reaching Carmarthen Bay, some distance from the tanker[7,8].

2.8 OIL IN SEDIMENTS

2.8.1 Interaction with suspended sediment

It is sometimes thought that dispersants cause oil to sink, but even after the light compounds have evaporated very few crude oil residues will have densities higher than that of seawater. Unless mixing processes such as wave action keep the small droplets of dispersed oil mixed in the water column, they will tend to rise back to the surface.

However, under turbulent conditions in shallow water there may be a high concentration of sediment and silt particles which have been stirred up from the sea bed or discharged from a river. Some oil may stick to these particles which may sink, eventually ending up in "sediment sinks" where currents are weak enough to allow deposition. These sinks are usually characterised by sediments with a high content of fine mud. This process took place following the severe storm conditions at the

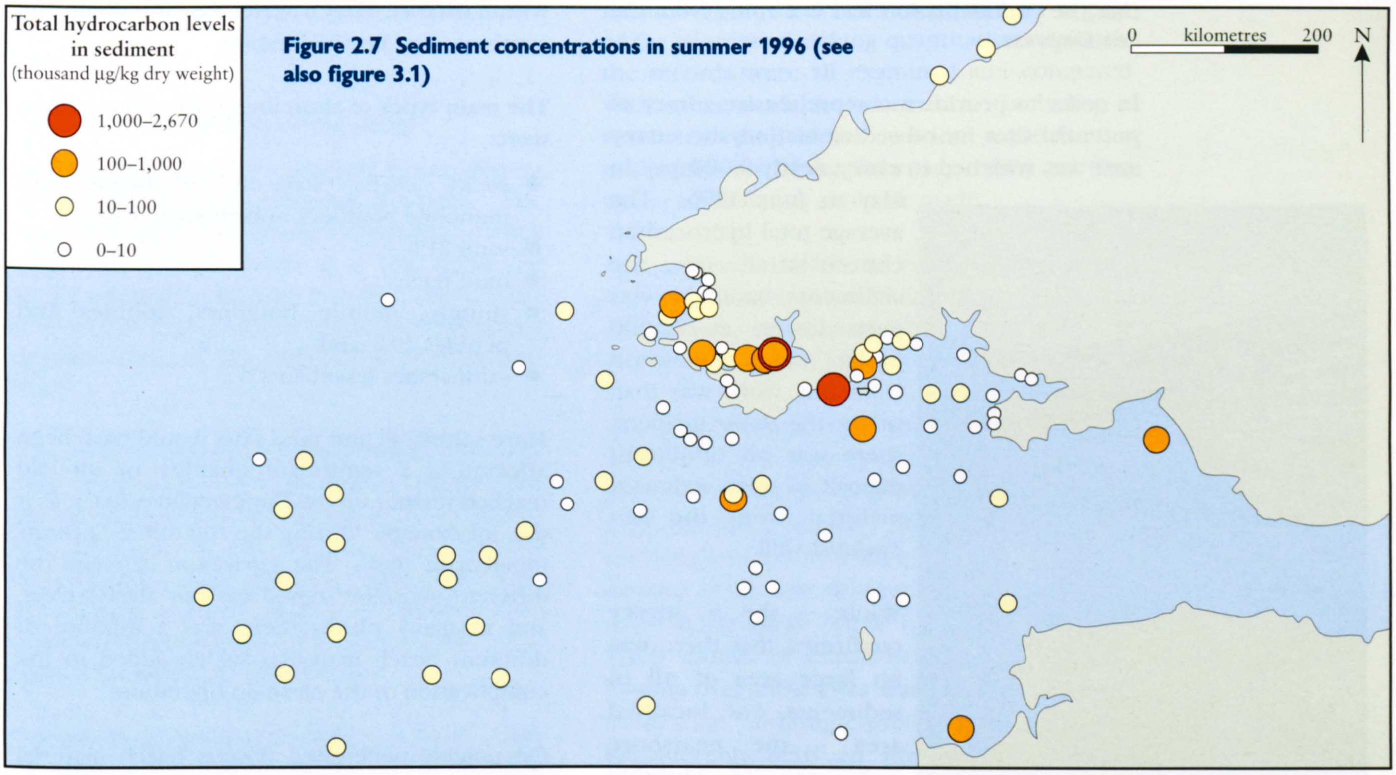


Figure 2.7 Sediment concentrations in summer 1996 (see also figure 3.1)

Braer oil spill where a significant proportion of the oil (up to 35%) was deposited in deep water sediment sinks[9].

With the experience of the *Braer* in mind, effort was spent in considering where oiled sediment from the *Sea Empress* spill might accumulate. The first stage was to identify potential sites for sedimentation through computer modelling and a review of the characteristics of sediment transport and the sea bed in the region (to identify areas with high mud content)[7,10]. The areas identified both by the modelling and by a literature review of potential sediment transport paths and the location of fine sediment deposits were:

- inner and outer Carmarthen Bay, and
- 15 km south of St Govan's Head.

Additional areas identified by the literature review were:

- the Celtic Deep,
- inner St Brides Bay,
- inner Cardigan Bay,
- Wexford Harbour, Bideford, and Newport Bay.

Since oil in sediments can remain for months or years, the presence of oil cannot necessarily be linked to the *Sea Empress* spill, and a literature survey showed the background concentrations in the sediments in these areas to vary between 10,000 and 100,000 µg/kg depending on the sediment type, with the fine silt sediments having the higher background values[4].

An extensive survey of sedimentary regions carried out by CEFAS over summer 1996 covered an area of 1,500 km^2, including all the areas listed above apart from Wexford Harbour, Bideford and Newport Bay. *Figure 2.7* summarises the results. Total hydrocarbon concentrations in sediment ranged from 500 to 180,000 µg/kg dry wt with an average of 40,000 µg/kg - generally within the range of background concentrations for the area. Analysis of some of the samples - for example those from West Angle Bay - showed clearly that the oil was Forties Blend crude; but for many of the others - such as St Brides Bay and Swansea Bay - the tests showed

Oil at Lindsway Bay (PCNPA)

that the contamination had not come from the *Sea Empress*.

In order to provide a comprehensive survey of potential sites for oil sedimentation, the survey area was widened to cover nearly 9,000 km² in May to June 1996. The average total hydrocarbon concentration in the sediments sampled was even lower, at 22,000 µg/kg. The conclusion from this work was that, unlike the *Braer* incident, there was no significant deposit of oiled sediment material from the *Sea Empress* spill.


Oil on a shingle beach (E Bent)

While the survey confirmed that there was no large area of oil in sediments, one localised area – the nearshore sediments of Skrinkle Haven – did have very high total hydrocarbon conc-entrations, the highest concentration being 2,700,000 µg/kg three to four months after the spill. Analysis confirmed this was Forties Blend crude oil. It is thought that the high concentration of hydrocarbons resulted from delays in assessment and the difficulty of access to Skrinkle Haven by clean-up teams which prevented large quantities of emulsion on the shore from being removed before it became buried by sand. Later re-working of this buried oil by the action of the sea may then have resulted in some of it being deposited in near-shore waters.

2.9 OIL ON THE SHORELINE

2.9.1 Different shoreline types

It is the oil stranding on the shoreline which has the greatest environmental impact in most oil spills. It also determines to a large extent the public perception of the scale of an oil spill.


Oiled beach (H Prosser)

A survey soon after the spill (see §2.9.2) showed that oil had affected about 200 km of the region's very varied coastline, with the worst hit areas being within Milford Haven waterway and along the south coast of Pembrokeshire.

The main types of shoreline in the affected area were:

- rocky cliffs, wave-cut platforms and immobile boulders, approximately 58%;
- sand 21%;
- mud flats 2%;
- shingle, mobile boulders, cobbles and pebbles 19%; and
- saltmarshes less than 1%[11].

More saltmarsh and mud flats would have been affected if a significant quantity of oil had reached further up the Daugleddau estuary, as it did, for example, during the 100 tonne *El Omar* incident in 1988. The separation between the different shoreline types was not always clear, and in many places there was a mixture of different beach materials which added to the complication of the clean-up operation.

Oil quickly penetrated porous beach material (where the size of the sediment grains left gaps for the oil to move into), collecting in pockets on top of non-porous layers beneath – such as bedrock or clay. In some instances these pockets of oil caused later recontamination of areas of cleaned beaches. Even the heavy fuel oil was able to penetrate shingle and gravel to a greater degree than expected. Oil generally strands at the high water mark, but in places like Angle Bay oil also penetrated mud below the original high tide stranding.

Movement of sand off and back on to a beach was very important. During the winter of 1995/96, sandy beaches along the south Pembrokeshire coast were scoured down to their lowest level for several years. The subsequent build-up of sand (as much as 2 metres at Precipe) buried oil which is likely to remain for several years until exposed by future movement of the beach material.

The speed with which beaches are cleaned naturally depends on several factors. Although oil can penetrate more readily into sediments with a coarse grain size, the oil can subsequently be flushed out more easily by water. Wave action in exposed areas will also result in faster cleaning. On the other hand, oil which has penetrated mud in sheltered areas is likely to persist for longer and to become associated with the organic layer surrounding the fine mud particles. Biodegradation is relatively slow where oxygen is limited, such as in very fine-grained sediments or the interior of thick layers of oil.

2.9.2 Initial levels of shoreline oiling

Estimating the quantity of oil which stranded on the shoreline was a difficult process. The approach taken was to use a qualitative survey which categorised levels of oiling along the whole coastline, and then to relate these levels to estimates of shoreline oiling gained through a detailed study of the amount of oil at several sites[12].

This method cannot provide an accurate answer with confidence - for reasons given below - but the aim of this work was simply to get an idea of the amount of oil which came ashore. Nevertheless, the method used the best information available and it is unlikely that, without far greater resources, the estimate could have been improved substantially.

During the period 23 February to 9 March 1996, 12 teams undertook a walking survey of some 300 km of coastline. Visible oil in the different habitats was classified as "thick mousse", "heavy oiling", "moderate" and "light" (including sheens). However, almost a quarter of the affected area could not be surveyed with the same degree of reliability due to dangerous conditions, or sheer or overhanging cliffs. The teams had not been trained in assessing oil and there was inevitably a substantial degree of subjectivity in their assessment, and so, as part of the process of making quantitative estimates, the records were all examined and compared with other available information (including a video recording of the coastline made from a helicopter on 21/22 February 1996) so that minor adjustments could be made.

Approximately 200 km of coastline were found to be oiled, with about 98 km in the combined categories of "mousse" and "heavy"; 34 km classified as "moderate" and 66 km as "light"[12].

The linear data from the shoreline survey were converted to a very approximate oil mass by reference to estimates of oil loading that were available for a number of heavily oiled sites covering a total of 19.4 km of coastline. The total amount of oil over all these sites was estimated to be in the range 740 to 1,060 tonnes (2,200 - 3,200 tonnes of emulsion). The average oil loading over these sites was therefore 38 to 54 tonnes/km, although the oil loading varied considerably between sites. Based on this estimate of oil loading and the visual assessments of oiling made during the survey, it was estimated that approximately 3,700 to 5,300 tonnes of oil (11,000 to 16,000 tonnes of emulsion) stranded along the coast. (Estimates of oil on the moderate and lightly oiled coastline have not been included since they add little to the estimate for heavily oiled beaches, given the errors in estimating oil quantities.)

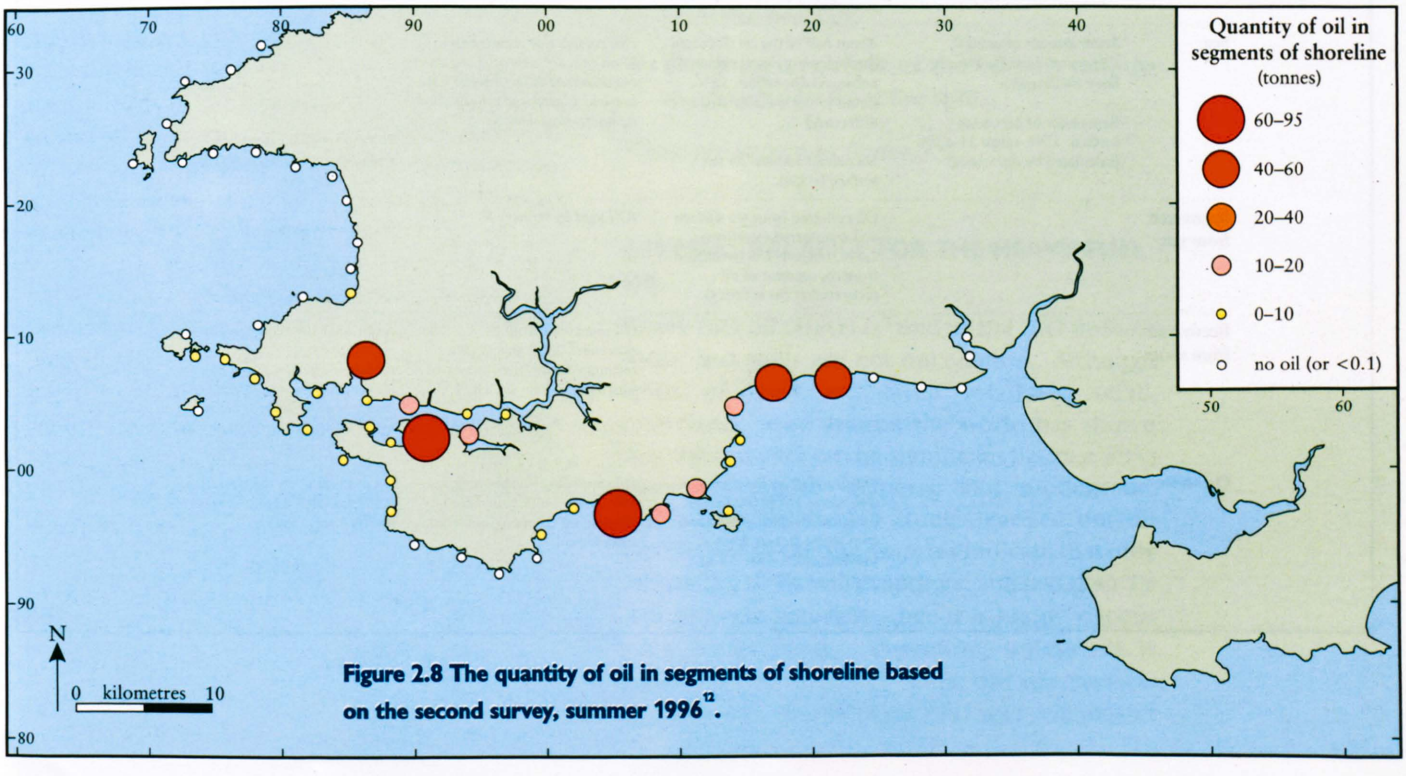
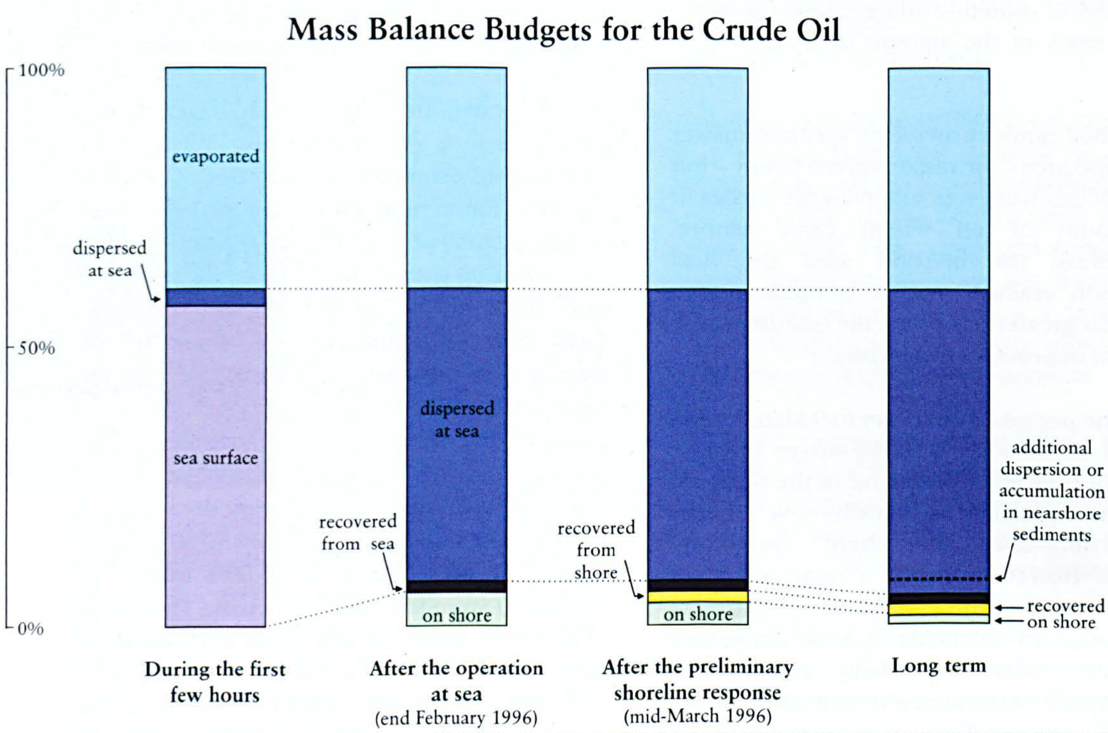


Figure 2.8 The quantity of oil in segments of shoreline based on the second survey, summer 1996[12].

Figure 2.9 Mass balance budgets for the crude oil



	During the first few hours	After the operation at sea (end February 1996)	After the preliminary shoreline response (mid-March 1996)	Long term
Atmosphere	Oil evaporating rapidly: **40%**, range 35–45% (confirmed by tests)	*(Oil in atmosphere will have become very dilute and will have been deposited over a very large area or broken down by sunlight.)*		
Sea	Small amount of natural dispersion. Initially **1% per hour** (field trials). Remainder of oil on sea surface: **57%**, range 51–63% (calculated by difference)	About half of the oil dispersed through natural and chemically enhanced dispersion: **52%**, range 45–59% (calculated by difference) Very small amount on sea surface (**<1%**).	*(No evidence of accumulation of oil in sediments offshore, so the dispersed oil is likely to have become diluted and biodegraded by micro-organisms.)*	Some oil washed from beaches and dispersed or accumulated in nearshore sediments.
Recovered from sea		Oil collected from sea surface and transferred to refinery: **1.5%**, range 1–2% (estimated from the amount of oil recovered at the refinery)	*(Oil used by refinery.)*	
Recovered from shore			Oil recovered from the shoreline: **2%**, range 1–3% (estimated from the amount of waste retrieved – see 10.9)	Additional **1%** recovered by clean-up. *(Liquid waste (2%) used by refinery; oil in sand (1%) landfarmed at Texaco; oil on waste and oiled beach materials (<<1%) taken to landfill.)*
On shore		Oil stranded on the shoreline: **6%**, range 5–7% (estimated using survey information and conversion factors from previous spills – see 2.9.2)	Oil remaining on the shoreline: **4%**, range 2–6% (calculated by subtracting recovered oil from stranded oil)	Oil remaining on the shoreline: **<1%** (estimated from survey results – see 2.9.3)

The survey took place at a time when there was still considerable re-mobilisation of oil due to tidal activity, opening up the possibility of some double counting. On the other hand, clean-up operations – concentrating on the removal of bulk oil – were already underway on many of the beaches, suggesting that initial levels of oiling may have been higher than 5,300 tonnes.

Inside the Milford Haven waterway many areas were also contaminated with heavy fuel oil. Very little quantitative information was recorded on fuel oil stranding, but it was estimated from the amount of fuel oil lost in the waterway that typical levels were initially 4 to 5 tonnes per km along about 50 km of coastline.

2.9.3 Rate of oil removal from the shoreline

The rate at which stranded oil was removed by clean-up operations and natural cleaning varied considerably between beaches and even for different areas of the same beach, depending on shoreline type, type of oil and the exposure of the beach to wave action.

A further, more detailed survey of the coastline was carried out in summer 1996, mainly between late April and July, but with some segments surveyed in August and September. This survey was carried out by staff with some training in the assessment of oil on shorelines, and so the results were probably not directly comparable site-by-site with the earlier survey. However, by the height of the summer holiday period an intensive clean-up operation, as well as natural removal and weathering processes, had removed most of the free oil (see *figure 2.8*). The length of coastline categorised as having "heavy" oiling had consequently been reduced from a little under 100 km to about 10 km. On the basis of the same calculation as followed for the first survey (§2.8) this was equivalent to approximately 500 tonnes of oil.

Most of the surface oil was in western Carmarthen Bay where it had originally been stranded between 24 and 27 February during a period of calm weather and neap tides. Successive tides had then pushed it high up the shore. Much of the oil remaining at the time of the survey was thought to be in subsurface deposits, and this was more difficult to assess. Using detailed data from five test sites to estimate oil thickness and burial depths over the whole affected coastline, the estimated quantity of oil remaining was split between:

- surface oil: 120 - 280 tonnes
- sub-surface oil: 170 tonnes.

In summary, the analysis of data from the two shoreline surveys suggested that, during summer 1996, the quantity of oil stranded on the shorelines of Pembrokeshire was reduced from between 3,700 and 5,300 tonnes to about 500 tonnes.

2.10 MASS BALANCE FOR THE FORTIES BLEND CRUDE OIL

Heavy fuel oil (E Bent)

The purpose of the mass balance budgets is to account for the 72,000 tonnes of oil spilt and to provide a basis for assessing whether the response methods were effective. Most of the elements of the budget – evaporation, dispersion, collection from the shoreline etc. – have already been discussed. This section brings these together to provide a snapshot of the fate of the oil at a series of times, in particular:

- **The first few hours** after the release of oil, where the process of evaporation dominated.
- **At the end of the use of dispersant at sea** – ie at the end of February 1996, when only sheens remained.
- **After the primary shoreline response** – ie in the middle of March 1996 when the majority of the bulk oil had been removed from the beaches.
- **The long term fate of the oil** – six months to one year on from the spill.

These are shown in *figure 2.9*.

2.11 MASS BALANCE FOR THE HEAVY FUEL OIL

Heavy fuel oil (HFO) is used as the fuel in most ships, and spills are not uncommon. Although spills of HFO are often relatively small, experience from around the world has shown that their impact can be significant because HFO does not readily disperse and biodegrade. Laboratory weathering studies carried out on the HFO from the *Sea Empress* indicate that only around 2% to 5% will evaporate, and less than 5% will disperse naturally since it is highly viscous even when fresh. Therefore, unless oil is recovered mechanically from the sea surface, typically 90% to 95% of an HFO spill will impact the shoreline.

The precise fate of the 480 tonnes of HFO released at the *Sea Empress* spill depended on whether it was released as a mixture with the Forties Blend crude (230 tonnes) or as HFO alone (250 tonnes)[13].

The 230 tonnes of HFO released at the mouth of the Haven between 15 and 22 February will have mixed into the large quantities of Forties Blend crude released during this period and the properties of the resulting mixture are likely to have been dominated by the properties of the crude oil. The HFO will therefore simply have made up a small proportion of the oil in the Forties Blend mass balance budget. At the *Braer* incident a similar mixing of HFO into the crude oil – aided by the stormy conditions – explained how the HFO dispersed into the water column.

Table 2.2 The crude oil mass balance for the *Exxon Valdez*, the *Braer* and the *Sea Empress* spills after the first stage response at sea and on the shoreline.

Oil Fate	*Exxon Valdez* 1989 [14,15,16,17]	*Braer* 1993 [18]	*Sea Empress* 1996
Total amount spilled	37,000 tonnes	84,000 tonnes	72,000 tonnes
Evaporated	20% - 30%	9% - 19%	35% - 45%
Dispersed	20% - 25%	46% - 56%	45% - 59%
Recovered at sea	4% - 8%	0	1% - 2%
Recovered from the shoreline	7% - 15%	0	1.5% - 3.5%
Stranded on the shoreline	22% - 51%	<1%	2% - 6%
In subtidal sediments		35%	

The 250 tonnes of HFO which was released on 22 February inside the Haven was not mixed with Forties Blend. Surveys have shown that the areas most heavily impacted by the HFO were in and around Milford Haven waterway. The proportion of contamination due to HFO ranged from almost entirely HFO at Pwllcrochan to around a third of the total contamination at Gelliswick. The length of affected coastline inside the Haven was around 50 km. With an estimated 90% to 95% of the HFO coming ashore, this meant that on average 4 to 5 tonnes of HFO came ashore per kilometre. It was estimated that a year after the spill between 10% and 50% (25 to 125 tonnes) of the HFO remained on the shoreline.

2.12 A COMPARISON WITH OTHER SPILLS

This section compares the mass balance budget from the *Sea Empress* with two recent spills representing two extremes for the fate of crude oil.

The *Braer* spill is an example where the fate of the oil was determined entirely by natural processes, with almost the entire crude oil cargo evaporating, dispersing or becoming attached to sediments. The response to the *Exxon Valdez* concentrated heavily on containment and recovery rather than chemical dispersion. A significant volume of the oil spilled at the *Exxon Valdez* was stranded on the shoreline.

Although the weather conditions at the *Sea Empress* were similar to those at the *Exxon Valdez* – and significantly less severe than at the *Braer* incident – the crude oil mass balance was closer to that observed at the *Braer* incident except for the absence of large quantities of oil trapped in sediments. With both the *Braer* and the *Sea Empress*, evaporation and dispersion of the oil dominated the oil mass balance, with less oil stranding on the shoreline than at the *Exxon Valdez*.

2.13 CONCLUSIONS

At the *Sea Empress* spill, monitoring teams were mobilised to measure concentrations of oil at the same time as the response to the spill. As a result, the oil budget and the potential sources of oil contamination resulting in any environmental impacts have been more fully characterised than for most previous spills. Monitoring the natural fate of the oil and the effects of the response has considerable operational benefits, such as providing information on the proportion of oil evaporating and dispersing.

The part of the budget with the greatest degree of uncertainty was the estimate of the quantity of oil stranding on the shoreline. In some previous spills, such as the *Exxon Valdez* in 1989, an extensive shoreline survey was carried out by a Shoreline Clean-up Assessment Team (SCAT) using a standardised methodology as part of the integrated response operation. This was carried out to guide the clean-up operation, but the results of the survey were also used to estimate the volume of oil stranding on the shoreline. Although a shoreline survey was carried out shortly after the *Sea Empress* spill (see §2.9.2), the staff carrying out the work had not had appropriate training and this initial survey did not use standardised methodology. Whilst it provided some useful information, it did not meet all the needs of those studying the environmental impact of the spill on the shoreline.

Estimating the quantity of oil on the shoreline at future oil spills by using SCAT-type methodology would - in addition to assisting the clean-up operation - provide valuable information for the assessment of the environmental impact of the spill. The necessary protocols would need to be **developed and in place before the spill, with appropriate training linked with pre-spill simulation exercises.**

Heavy emulsified crude oil in Tenby Harbour (ITOPF)

REFERENCES

1 Carruthers DJ., Ellis K., "Prediction of Ambient Concentration of Volatile Organic Compounds (VOC's) from the *Sea Empress* Oil Spill using Vapour and Oil property Models, CERC report to EA (SEEEC project P9), 1997.

2 Rusin J., Lunel T. & Tyler A. Spill Modelling as part of the Response and Monitoring Strategy at the *Sea Empress* Incident. Proc. 1997 International Oil Spill Conference, Fort Lauderdale, Florida, 930-932, 1997.

3 Little A.D., Benchmarking of Hydrocarbons in the area affected by the Sea Empress oil spill, report to EA (SEEEC project P4), 1997.

4 Lunel T., Dispersion: Oil drop size measurements at sea. Proc. 16th Arctic and Marine Oil Spill Programme, Canada, 1023 - 1057, 1993.

5 Lunel T., Swannell R., Rusin J., Bailey N., Halliwell C., Davies L., Sommerville M., Dobie A., Mitchel D., McDonagh M., & Lee K. Monitoring of the effectiveness of response options during the *Sea Empress* incident: A key component of the successful counter-pollution response. Spill Science & Technology Bulletin., 99-112, Vol. 2, (Published in 1996) 1995.

6 Lunel T., Rusin J., Bailey N., Halliwell C., & Davies L. The Net Environmental Benefit of a Successful Dispersant Operation at the *Sea Empress* Incident. Proc. 1997 International Oil Spill Conference, Fort Lauderdale, Florida, 185-194, 1997.

7 Lee K., Lunel T., Stoffyn-Egli P., Wood P., Swannell R. Shoreline Clean-Up by Acceleration of Clay-Oil Flocculation Processes. In Press Proc. 1997 International Oil Spill Conference, Fort Lauderdale, Florida, 1997a.

8 Lee K., Weise A., Lunel T. Marine Oil Spills: Enhanced biodegradation with mineral fine interaction. 4th International In Situ and On-site Bioremediation Symposium. New Orleans. April 1997b.

9 Lunel T., Lee K., Swannell R., Wood P., Rusin J., Bailey N., Halliwell C., Davies L.stranding on the shoreline than at the *Exxon Valdez*. Sommerville M., Dobie A., Mitchel D., & McDonagh M. Shoreline clean up during the *Sea Empress* incident: The role of surf washing (clay-oil-locculation), dispersants and bioremediation. Proc. 1996 Arctic and Marine Oil Spill Programme (AMOP), 1521-1540, 1996.

10 Little A.D., "Sediment transport paths outside Milford Haven, in relation to long-term transport of *Sea Empress* oil", report to EA (SEEEC project P8), 1997.

11 Little, D.I., Rhind P., Jones, R. Bennett, I. and Moore, J. (1997). CCW's shoreline oil distribution surveys following the *Sea Empress* spill: In: Proceedings of the 1997 International Oil Spill Conference. American Petroleum Institute, Washington DC 1036-1038.

12 Somerville D., Little D., Wood P., Lunel T., Refinement of the estimated shoreline figure in the oil budget. SEEEC P6

13 Maritech Ltd., Independent assessment of clean-up operations, report to Welsh Office, 1997 (SEEEC project P1)

14 Wolfe et al. (*Exxon Valdez* Oil Spill Symposium) 1991

15 Galt J. Environmental Science & Technology 1991

16 Miller S. ES & T 1991

17 Maki A.W. The *Exxon Valdez* Oil Spill: Initial environmental impact assessment. Envir. Sci. Technol. 25, 24-29, 1991.

18 ESGOSS. Ecological Steering Group on the Oil Spill in Shetland. The environmental impact of the wreck of the BRAER. The Scottish Office, Edinburgh 1994.

3 Marine Impacts

3.1 INTRODUCTION

This chapter describes the results of a wide-ranging investigation of possible effects of the *Sea Empress* oil spill on the marine environment below the low water mark. It explains why it was necessary to impose a closure order to restrict fishing temporarily in the region affected by the oil, and how the closure order was lifted gradually as hydrocarbon concentrations in samples returned to normal levels. There is then a discussion of the mass strandings of some species on the shoreline shortly after the spill, followed by descriptions of the impact on fish, commercially-exploited shellfish, benthic species generally (ie animals living on the sea bed) and plankton (ie small plants and animals – including eggs and larvae of marine animals – that are carried passively by currents in the near surface waters). The chapter closes with a discussion of possible effects of the clean-up operation.

Analysing cod (CEFAS, Crown Copyright)

The region affected by the spill has a wide variety of commercially-exploitable species which are of local economic importance, although the fisheries are mostly small compared with total UK landings. There are fisheries for whitefish such as bass, and for shellfish such as crabs, lobsters, mussels and cockles; and a new export fishery for whelks was developing in the years just before the spill. The region also has several important salmon and sea trout rivers with important recreational fisheries.

The timing of the spill was, in some respects, fortunate. Commercial fishing was at a relatively low level, several species were absent through migration, and in many other species feeding and other activity was at a seasonal low. The region had been well studied over many years and there was therefore a relatively good

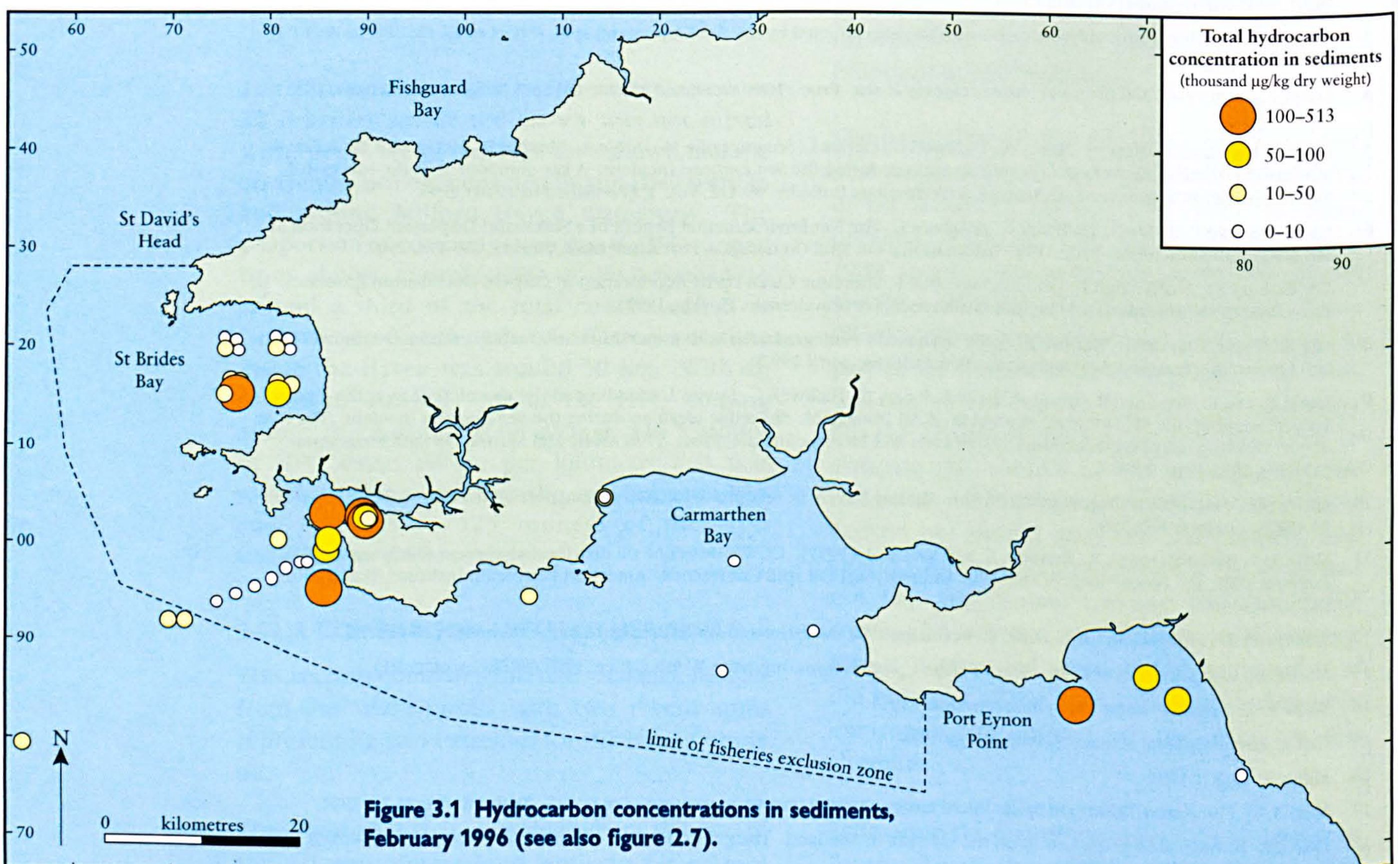


Figure 3.1 Hydrocarbon concentrations in sediments, February 1996 (see also figure 2.7).

understanding of the local marine eco-system and the species most likely to be affected. There have been a number of small scale oil spills around Milford Haven waterway, and many of the potential effects were therefore well understood; this proved useful when assessing the impact of the *Sea Empress* spill.

This knowledge of the area, along with information on the geographical extent of oiling, allowed studies to be targeted on those areas of the environment most likely to be affected. Inevitably, this meant that not all habitats and species would be studied in depth. Accordingly, care was taken to select representative species and communities from the major habitats within the spill area. By focusing effort in this way it was considered that it ought to be possible to make appropriate extrapolations if concern arose about other species or communities. Apart from the instances where large numbers of dead or moribund organisms are washed onto beaches, the effects of an oil spill on subtidal marine organisms are often not obvious. For example, behaviour such as migration patterns may be affected, animals may absorb oil and become more susceptible to disease or suffer breeding failure, and fish and commercially-exploited shellfish may become unpalatable to consumers. Studies were therefore designed to investigate all these possibilities.

Some of the results presented here are preliminary. For several species, there will not be full confirmation that breeding in 1996 was successful until the animals born that year reach an age where they can be legally caught in commercial fisheries. Several future studies have therefore been suggested.

3.2 THE EXTENT OF CONTAMINATION

Perhaps the most important issue to address immediately after the spill, and then to keep under review, was the area in which oil could be detected and the level of contamination within that area.

Sections 2.4 - 2.7 in the previous chapter described the movement of the oil and the range of concentrations found in the water column and sediments. It was rapidly established that significant amounts of oil had affected or were likely to affect an area extending from St David's Head in the north-west to Port Eynon Point in the south-east, including the Milford Haven waterway.

Concentrations of oil in water were shown in §2.7.2, and *figure 3.1* shows the concentrations of oil found in sediments during the period 23 to 28 February. Generally the levels of total hydrocarbon in the surveyed area were well above background (see *Box 3.1* overleaf) in both water and sediment. However, the oil contamination in Swansea Bay was not related to the *Sea Empress* (see §2.8.1) Samples taken during the spill (see §2.7.2) suggested that, in the early days, relatively little oil penetrated further than the top few metres of the water column - except where dispersants were used, when the oil tended to mix much more completely into the full water depth.

The extent of water and sediment contamination meant that many marine animals and plants were likely to have been affected. At previous spills such as *Torrey Canyon, Amoco Cadiz* and *Braer*[1,2,3], commercially-exploited species were shown to have taken up oil, either directly from the water or through their food. Samples of fish, molluscs, crustaceans and seaweed were therefore collected at sea and along the shoreline in the affected region of south-west Wales. Some of this sampling was done by the Centre for Environment Fisheries and Agriculture Science (CEFAS) scientists and South Wales Sea Fisheries Committee (SWSFC) officers working from a research vessel and shore bases. Some sampling was carried out by local fishermen who had voluntarily suspended commercial fishing in the area very soon after the spill. Similarly, samples of salmon and sea trout were obtained for CEFAS by Environment Agency (EA) staff working with local fishermen. In addition, samples of particular commercially-exploited species and a wide variety of other species were collected by field workers from other organisations.

The first samples arrived for analysis at the CEFAS Laboratory at Burnham-on-Crouch on 22 February. The early results clearly demonstrated the presence of oil in most samples of mussels, although levels of oil in the samples of fish were only slightly higher than background levels. These results showed that oil had contaminated some shellfish species which are consumed by humans and indicated that some fish and shellfish might therefore taste unpleasantly of oil.

3.3 THE CLOSURE OF FISHERIES

Contaminated fish or shellfish could potentially be unsafe to eat because of elevated levels of PAHs (components of oil which are known to be harmful to humans and other species – see *Box 2.2*). As with other components of oil, low concentrations of PAHs are found in the tissue of most marine species around the UK. Although there are no formal standards in the UK, these low concentrations are similar to those found in a variety of other foodstuffs and are considered acceptable.

Box 3.1 BACKGROUND CONCENTRATIONS IN VARIOUS SAMPLE MATERIALS

Oil is a natural material, and in some areas there are natural seepages into the sea. A wide variety of industrial and other human activities also result in inputs of hydrocarbons, as do various biological processes. As a consequence, there are always some hydrocarbons present in the water and sediments around the UK, with higher concentrations in industrial areas. The table gives details of concentrations that can be considered normal ("background") for non-industrialised areas. Concentrations of hydrocarbons measured in samples of organisms, water or sediments were compared with these background levels to judge whether the samples had been contaminated and when the concentrations had returned to normal.

As the background concentrations detailed below are those to which marine species are normally exposed, concentrations of that order or a few times higher are unlikely to prove harmful. Concentrations more than about ten times background might be expected to cause harmful effects, including mortality, in sensitive species and this is borne out by the results of laboratory toxicity experiments. Slightly elevated concentrations too low to be harmful to the animals themselves may still cause fish and shellfish to have an unpleasant flavour or "taint" when eaten.

	Location	THC	Total PAH
Sea Water (µg/l)	North Sea	0.2 - 1.5	<0.0001 - 0.017
	Irish Sea	0.2 - 0.9	<0.0001 - 0.015
	Clean estuary	up to 20	<0.0001 - 0.001
Sediment (µg/l dry weight)	Clean sand	up to 3,000	
	Clean mud	up to 10,000	75
	Estuary sand	1,700 - 14,000	50
	Estuary mud	up to 200,000	100
Biota (µg/l wet weight)			
whelk	sw Wales	2,000 - 10,000	10-30
lobster	sw Wales	1,000 - 3,000	4-46
crab claw	sw Wales	1,000 - 3,000	4-20
mussels	sw Wales	5,000 - 20,000	20-60
whiting	Shetland	0.3 - 10	
whiting	sw Wales	500 - 2000	10-11
plaice	Shetland	2 - 37	
plaice	sw Wales	700 - 2000	7-43
dab	Shetland	5 - 42	
dab	sw Wales	900 - 2000	7-35

In the early stages it was important to establish the degree and spread of contamination and so samples were analysed using a relatively rapid fluorescence technique which indicates the concentration of oil in tissue. To establish whether or not PAH compounds were present required more complex and time-consuming analysis using mass spectrometry (a method that allows identification of individual compounds). However, it was considered prudent to formalise the local fishermen's voluntary suspension of fishing and to prohibit all fishing in the entire area thought likely to be affected. This was done on 28 February using powers under the Food and Environment Protection Act 1985 (FEPA). The closure area (shown on *figure 3.1*) was based on results from the samples analysed up to that date and on expert judgement on the likely further spread of significant concentrations of oil. Sampling and analysis continued in order to check whether the designated area needed to be modified, but no extension was considered necessary.

The FEPA Exclusion Order was designed to protect consumers by placing a statutory ban on fishing activities within a designated area off part of the south-west Wales coast. The Order covered all fishing activities for fish, shellfish (ie edible molluscs and crustaceans), edible seaweed and samphire. Recognising a possible risk with salmon and migratory trout (which may have passed through contaminated water during migration), a separate Order was made on 20 March to include these species in all rivers and streams discharging into the designated area between Port Eynon Point and St David's Head. The areas affected by the two Orders covered a total of 2,100 km^2.

The Orders were imposed as a precautionary measure. Although there was obvious contamination of species such as mussels, only low concentrations of oil were ever found in fish. Contamination levels in crustacean shellfish (eg crabs and lobsters) were generally between the two. The Orders also served to protect the good reputation of the local fishing industry by preventing the sale of products that could be unpalatable or potentially unsafe to eat. It is apparent – from reports received from people connected with the fishing industry, fish and shellfish marketing and the recreational fishing and angling community – that the precautionary nature of the Orders was not sufficiently clear to everyone. Despite efforts to communicate the situation to those concerned via news releases and direct contact with representative groups, some people were under the mistaken impression that all species in the closure area were severely contaminated, very unsafe to eat and likely to die or be seriously harmed. There also appeared to have been some confusion over how the return to normality would be assessed.

Once it was established that there was no scientific or technical need to expand the geographical boundaries of the closure area, analytical procedures were extended to include the more time-consuming measurement of PAH concentrations. This allowed the maintenance of the Orders to be kept under review to ensure it could be lifted, in total or in part, as soon as it was judged safe to do so – ie when concentrations had declined to background for a particular species. Before lifting the Order for a particular species, taste tests were carried out by a trained taste panel as a further check of consumer acceptability. In all cases the panel confirmed the absence of any oily taste in samples that had been declared clear of contamination following chemical analysis.

3.4 LIFTING OF FISHING RESTRICTIONS

3.4.1 Salmon (*Salmo salar*) and sea trout (*Salmo trutta*)

During the *Braer* spill, salmon in sea-cages at fish farms to the west of Shetland were exposed to high concentrations of oil in the water which they were unable to avoid. Concentrations of up to 14,000 µg/kg PAH were found in these salmon 10 days after the spill[4]. In contrast, PAH concentrations were much lower in wild salmon caught off the coast or in estuaries after the *Sea Empress* spill, ranging from 12 to 186 µg/kg. Very soon after the spill, all the measured concentrations were within or below the background values found in fish from outside the area. The restrictions on salmon and sea trout fishing were therefore lifted on 3 May 1996.

3.4.2 Other fish

Although a variety of commercially-exploited fish were collected from throughout the closure area, all were found to have low concentrations of both total hydrocarbons and PAHs – no more than 5 times background levels. This was not unexpected for a number of reasons. Many species are mobile and able to avoid oiled areas, and only low concentrations of oil were ever detected in water samples from anywhere other than places where large amounts of oil were present on the water surface. At the time of the incident many species were not actually feeding in the area. In addition, the digestive system of fish includes an enzyme system that allows them to metabolise and excrete PAHs quite rapidly. The PAHs detected were primarily those of low molecular weight (see *Box 2.2*) which would only have been at elevated concentrations in the water column for a short period. Although some of these compounds have a potential for taint (unpleasant flavour), the concentrations in all samples were always low and by mid-May were indistinguishable from background levels. The trained taste panel did not detect any taint and the Exclusion Order on all species of fin fish was lifted on 21 May 1996.

3.4.3 Crabs and lobsters

Edible crabs *(Cancer pagurus)*, velvet crabs *(Necora puber)*, spider crabs *(Maja squinado)* and lobsters *(Homarus vulgaris)* were all sampled across the entire closure area, with a few additional samples taken outside it for reference. Within Milford Haven waterway, total PAH concentrations of between 100 and 2,450 µg/kg wet weight were found in samples of edible crabs, velvet crabs and lobsters during February, March and April. However, by May 1996 concentrations were decreasing outside the Haven with only the samples from sites such as Angle and close to the mouth of the Haven proving to have concentrations greater than 100 µg/kg. As with the fish, it was mainly the low-molecular weight PAHs which were detected, but by late June the concentrations of even these compounds had decreased to background. Following a taint test by the taste panel, restrictions on fishing for all crustaceans – except those within Milford Haven waterway – were lifted on 29 August 1996. The restrictions for crustaceans within the waterway were lifted on 19 October 1996.

Before the decision to lift restrictions on crustaceans, several samples of crabs were reported to have been found with what looked like oil contamination of their gills and lower surfaces. Samples of these crabs were eventually supplied for analysis. No traces of oil were found, and it was concluded that the black material on the crabs was either anoxic mud or decomposing algae or egg mass. Such phenomena have been recorded elsewhere[5] and are unrelated to oil contamination. However, the additional testing triggered by these observations delayed the re-opening of the crustacean fishery.

3.4.4 Whelks *(Buccinum undatum)*

In the two to three years prior to the *Sea Empress* oil spill, a new fishery for whelks had been established off the south-west Wales coast,

Whelk (SWSFC)

with almost the entire catch being exported to the Far East.

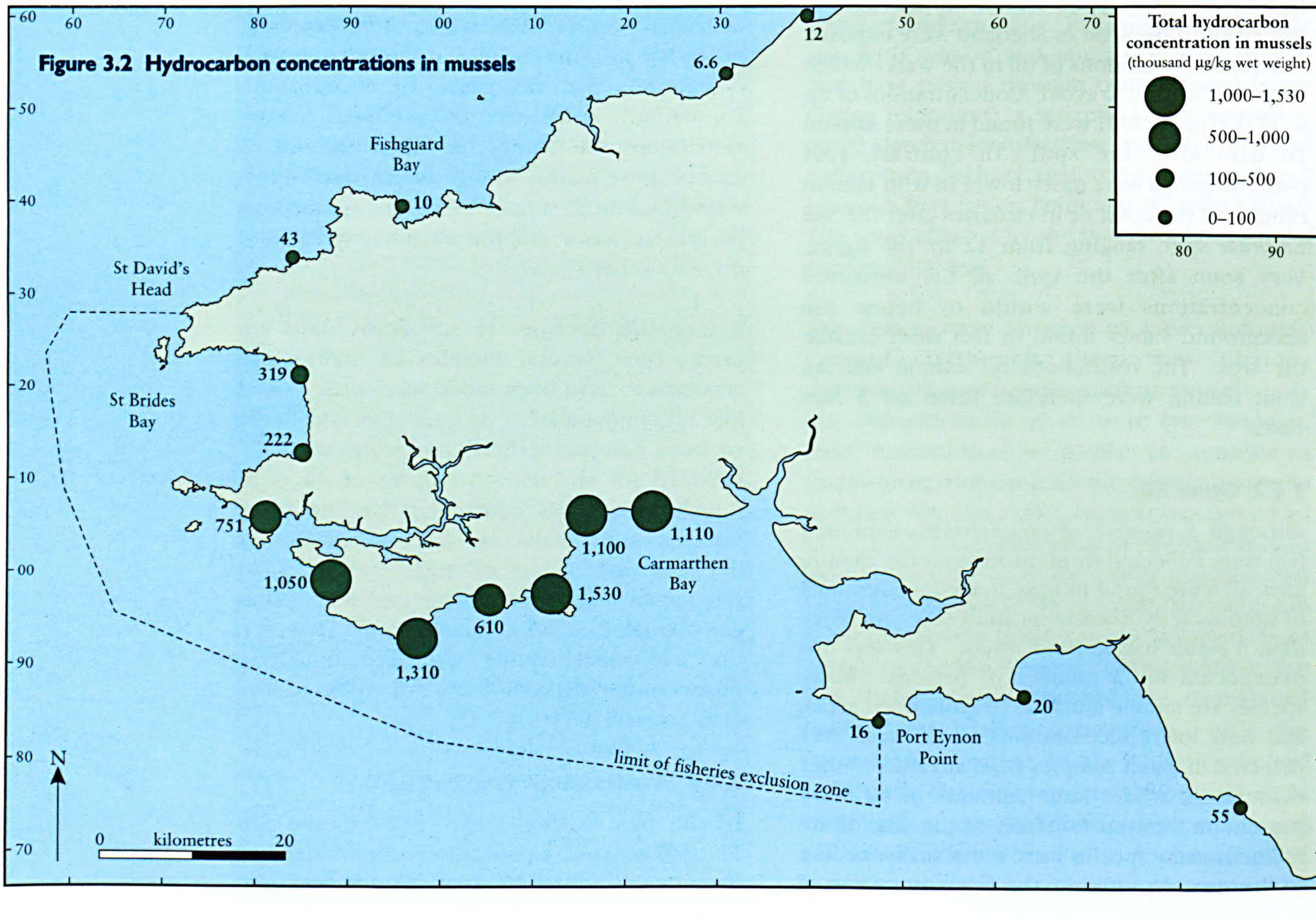
Following the spill, the first samples of whelks -- collected on 25 February when oil was observed coming ashore around Carmarthen Bay -- showed contamination by oil, with total hydrocarbon concentrations (THC) of about 40,000 μg/kg wet weight and PAH concentrations up to 3,800 μg/kg. Levels of contamination varied, and some samples seemed only to have background concentrations; it is therefore likely that the contamination was fairly localised. By early June, whelks sampled over the entire area between Carmarthen Bay and the Isle of Lundy contained only low concentrations of PAH (less than 50 μg/kg). As with other species, low molecular weight compounds predominated. No smell of oil could be detected by the taste panel. However, there were continuing reports from fishermen of oiled pots and tainted whelks from particular areas, but additional detailed sampling failed to confirm these concerns and the Order was eventually lifted for whelks on 29 August 1996.

3.4.5 Other shellfish

There are commercial fisheries for cockles *(Cerastoderma edule)* and mussels *(Mytilus edulis)* in the Three Rivers and Burry Inlet areas of Carmarthen Bay. Pacific oysters *(Crassostrea gigas)* are reared at Carew and there is also a small fishery for native oysters *(Ostrea edulis)* close to this site. Mussels are collected non-commercially at many sites along the coast.

Hydrocarbon concentrations in both cockles and mussels rose rapidly following the spill and reached high concentrations (more than 3 million μg/kg THC) in some of the most severely oiled populations outside of the Burry Inlet and Three Rivers estuaries. *Figure 3.2* illustrates hydrocarbon concentrations in mussels sampled in March along the coast from New Quay to Ogmore-by-Sea, showing that contamination extended from Three Rivers in the east to Newgale Sands in St Brides Bay to the west. Further samples of mussels were taken at intervals from all of the originally sampled sites and, although concentrations did not rise further, their decline was relatively slow.

Figure 3.2 Hydrocarbon concentrations in mussels



Mussels only have a limited ability to metabolise oil and the concentrations in their body tissue largely reflect the concentrations to which they are exposed. There was little evidence of weathering or metabolism of the oil in the mussels, and the decrease seems to have depended on the slow decline in background concentrations in water and sediment and the weathering of oil on the shore. Similar observations were made at the *Amoco Cadiz* spill on the Brittany coast[6].

Cockles in the Burry Inlet were only very lightly contaminated and concentrations in samples decreased to background by late June; the Order for these was therefore lifted on 3 July 1996. Restrictions remained in force for the Three Rivers area until 12 September 1996 – around a month later than the normal start of commercial fishing – by which time concentrations had returned to background.

Riddling cockles, Penclawdd (SWSFC)

Concentrations in mussels from more heavily-contaminated sites continued to remain above background, with occasional local increases caused by re-oiling incidents (some of which did not involve oil originating from the *Sea Empress*). However, by early summer 1997 they had returned to background, with the exception of samples from within Milford Haven waterway and around Skrinkle Haven where oil still remained. All restrictions on the gathering of shellfish from the intertidal zone between St David's Head and St Ann's Head were lifted on 10 June 1997. The only remaining restriction on fishing at that date applied to bivalve molluscs in Milford Haven waterway, including the oyster

Mass stranding of bivalves, Angle Bay, February 1996 (E Bent)

farm at Carew. Restrictions on the casual gathering of shellfish in the intertidal zone between St Ann's Head and Port Eynon Point remained in force until 12 September 1997 when all remaining restrictions were lifted.

3.4.6 Edible plants and seaweeds

Intertidal plants and seaweeds were fairly extensively coated with oil in some locations, including those areas where some species such as *Porphyra umbilicalis* and *P purpurea* (the species normally collected and used for making laver bread), *Chondrus crispus*, *Rhodymenia pseudopalmata* and samphire *(Salicornia spp)* are commercially exploited. Most of the oiling was probably surface contamination rather than true absorption by the plant tissues but it persisted throughout 1996. New growth in 1997 saw a marked reduction in concentrations of both total hydrocarbons and PAH, and restrictions on the gathering of edible seaweeds were lifted on 10 June, 1997.

3.5 STRANDINGS

In the weeks following the spill large numbers of dead or moribund marine animals were washed up on beaches in the spill area. Most of these animals were bivalve molluscs and other sediment dwelling species normally living in the lower shore or shallow subtidal zones. While it is not unusual for many of these species to become occasionally washed out of the sediment and stranded in moderately large numbers,

Stranded bivalves (E Bent)

particularly after winter storms, the extent of the strandings during the spill was very unusual. The timing and geographic extent of the strandings, the large numbers involved, the range of species, and the levels of hydrocarbons present in some tissue samples, suggests that most strandings resulted from the spill. Strandings of a similar range of species have been observed following other spills[7]. The expectation that strandings would occur prompted the Environment Team of the Joint Response Centre (JRC) to establish a recording and sampling programme.

The first observations were of moribund razorshells *(Ensis siliqua)* on the lower shore of Dale beach on the 19 February. Hundreds of razorshells (in densities of around 4 per m^2) were protruding from the muddy sand and most died in that position over the following few days. This area would have been one of the first to be subjected to high concentrations of oil in the water. Dead cockles *(Cerastoderma edule)* were then observed in Angle Bay on 23 February though, in common with commercially exploited stocks of fish and crustaceans, no commercially-exploited stocks of cockles were affected. Over the next week, increasing numbers of dead and moribund cockles were observed around the strandline of Angle Bay. These bivalves are present in large numbers in the intertidal muddy sand on this beach, which received large quantities of fresh crude oil in the first few days of the spill.

Over the next few weeks strandings occurred on many other beaches with individual stranding events usually involving a single species. This was particularly noticeable on Dale beach where many spiny cockles *(Acanthocardia aculeata)* were found lying on the surface with their feet protruding on 24 February (5 days after the razorshells) and this was followed by strandings of hundreds of heart urchins *(Echinocardium cordatum)* in the first days of March. The reason why the different species stranded at different times is not known, but it may be that different species were subjected to the oil contamination at different times, that they each have different tolerances to oil or that other factors caused a delayed response in strandings of some species. Unusual timings of strandings also occurred in west Carmarthen Bay.

In west Carmarthen Bay the first strandings of large numbers of bivalve molluscs occurred at Pendine Sands, soon after the surface oil reached that area on 25 February. These were mainly striped Venus shells *(Chamelea gallina)* and cockles. However, it was not until 27 February that large numbers of cockles washed up around Tenby and Saundersfoot and not until 5 March that dead cockles were recorded at Wiseman's Bridge and Amroth. Between then and 17 March (mainly between 9 and 14 March), many thousands of cockles, banded wedge shells *(Donax vittatus)*, rayed trough shells *(Mactra stultorum)*, razorshells and egg-shell razor *(Pharus legumen)* were washed up between Tenby North beach and Wiseman's Bridge. All of these species are present in large densities in the shallow subtidal and extreme lower shore sands of west Carmarthen Bay. It has been shown[8] that several species of bivalves, including razor shells react to oil and other contaminants with a rather unexpected escape response which propels them out of their burrows. It seems likely that similar escape responses to the elevated concentrations of hydrocarbons, or in some species a simple narcotisation effect, resulted in these animals being washed out of the sediment and onto the beaches in a moribund state. Analysis of hydrocarbons from bivalves sampled in this area showed elevated concentrations (up to 669,000 µg/kg THC in cockles from Saundersfoot). Concentrations in live razorshells from Saundersfoot were still elevated in early May (105,000 µg/kg THC on 3 May). However, observations from a brief diving survey of the shallow subtidal area off Saundersfoot in late July 1997 found large populations of egg-shell razor, razorshells, striped Venus shells and heart urchins[9], suggesting that only a proportion of the original population had been killed by the spill.

Notable strandings of starfish, heart-urchins and crabs also occurred along the beaches of west Carmarthen Bay during March. The first event involved many hundreds of common starfish *(Asterias rubens)* washed up on Tenby North beach on 2 and 3 March, which attracted large numbers of scavenging gulls. These starfish are present in large densities in this area where they feed on the subtidal sediment bivalves and on mussel beds. Hundreds of heart urchins and many masked crabs *(Corystes cassivelaunus)* were washed up on Caldey Island, and the beaches between Tenby and Wiseman's Bridge during March. A much later event, on 3 May, involved over 100 masked crabs emerging from their burrows in a narcotised state on the extreme lower shore at Monkstone Point near Saundersfoot.

It should be noted that stranding events do occur naturally - for example after storms, unusually cold weather or toxic plankton booms - and although the incidents described above probably were caused by the oil spill, the evidence in most cases is circumstantial rather than definitive. A stranding event of particular interest occurred on 3 April at Rhossili Bay on the Gower which was not obviously affected, at least by surface oil, when thousands of moribund rayed trough shells washed up there. Initial thoughts were that this might be a natural event, as it was not thought likely that high concentrations of dispersed oil could have occurred so far from areas of significant surface oiling. However, oil was clearly detectable (54,000 to 620,000 µg/kg THC) in tissue samples of these bivalves, and it seems likely that it was attributable to the spill though quite how or when oil reached this area so long after the spill is unclear. A similar mass stranding of bivalves and heart urchins occurred some distance away from and some time after the *Amoco Cadiz* spill[10], although in this case it was associated with observed contamination by emulsified oil.

Strandings of small numbers of various other species were recorded in the spill area. These included a few individual inshore fish (particularly blennies) and various worms.

Emerging razorshell (E Bent)

Some species of fish and crustaceans live in rock pools and inlets round the coast, and a number of these were found dead immediately after the spill. However, samples of wrasse collected within a few weeks of the spill proved not to be seriously contaminated, and, given that there were no other reports of dead fish, it seems likely that the smaller fish suffered only light mortalities, except perhaps in very severely oiled locations such as Angle Bay.

There were no reports at all of mortalities of commercially-exploited crustaceans or fish (including salmon and sea trout). These species are mobile and can take evasive action if they find conditions unattractive to them; and, at the time when oil concentrations in the water column were at their highest, crabs, lobsters and fish near the shore would not have been actively feeding, while species such as crawfish, spider crabs and many fish would still have been in their winter feeding grounds away from the affected area.

3.6 SUB-LETHAL EFFECTS ON FISH

3.6.1 Salmon and sea trout

Salmon and sea trout live in rivers until they are two or three years old, then leave to spend a number of years at sea, finally returning to spawn in the river where they were born. South-west Wales has several fine salmon and sea trout rivers, particularly the River Tywi, which are important both for commercial netting and for recreational angling. There was concern that, because salmon and sea trout returning to these rivers may have passed through contaminated water shortly after the spill, they may have become contaminated or otherwise adversely affected.

A literature review of the effects of oil on salmon and sea trout suggested that continuous exposure to concentrations of oil of the order of a few thousand µg/l for a period of days might cause death under laboratory conditions[11]. However, such conditions did not pertain at sea, and in any case the fish are able to detect and avoid oil-contaminated water. Concentrations of oil in water around Milford Haven waterway reached several thousand µg/l on occasion, but no dead salmon or sea trout were reported.

Other potential effects of oil demonstrated under laboratory conditions were interference with the homing instinct and with vital enzyme systems which might subsequently affect health or breeding success. These effects had not, however, been observed outside the laboratory.

Studies on salmon and sea trout were commissioned. The first was a laboratory experiment[12] which investi-gated the effects of dispersed oil on salmon behaviour, and the second examined whether stocks had changed by analysing rod and net catches, estimating the numbers of juvenile fish in the rivers, and enquiring whether the numbers of anglers and the frequency of visits had been affected[13].

The laboratory experiment was designed to assess whether the migratory behaviour of salmon might be affected by oil. The results confirmed that the fish, under laboratory conditions, could detect and avoid concentrations of oil in excess of 4–5 μg/1 THC, ie below background concentrations of THC in estuarine water and only just above those considered background in open sea water.

To find out whether sea trout had been exposed to oil, maturing fish were caught by electrofishing in August 1996 from the Rivers Tywi, Eastern Cleddau and Dee (which is in north Wales and was used as a control)[14]. As the study was conducted some time after the spill, two methods were used to show whether the fish had been exposed to oil. Analysis was carried out on the enzyme system cytochrome P450 which acts as a marker of previous exposure to oil, and samples were also tested for breakdown products of oil. There was a wide variability in the levels of P450 in fish from the Tywi and Dee, and although two of the Tywi fish had the highest concentrations there was no statistically significant difference between the rivers in the mean level of P450. All the fish caught in all three rivers showed similar evidence of breakdown products of oil in their bile. As they had probably all only recently migrated into the rivers (judging by the presence of sea lice), it was concluded that if there had been any exposure to *Sea Empress* oil, it was no more severe than the level of exposure to oil that fish experience normally around the Welsh coast.

There are no fish counters or traps on any of the rivers affected by the Fisheries Exclusion Order and so it was not possible to monitor directly adult salmon and sea trout stocks. However, one indication of whether numbers of salmon and sea trout had changed following the spill was provided by examining records of catches on the Tywi and the Teifi (a river in the same region but outside the affected area). To allow proper comparison, the catches were expressed in terms of "catch per unit effort" (CPUE), ie the number fish caught per tide fished (using nets) or per hour of fishing effort (using rods). For commercial net catches, the CPUE of salmon on both rivers was within the normal range and it followed the normal seasonal progression on the Tywi. Anglers' log books showed that angling CPUE for salmon on the Tywi was the highest for the period 1990 to 1996.

The picture for sea trout was somewhat different. Both net and angler CPUE levels were markedly lower in the Tywi in 1996 compared with previous years. The coracle catch of sea trout on the Teifi was also lower, though to a lesser degree. These differences were particularly marked during May, June and July after which catches improved to a level comparable with earlier years. Anecdotal evidence suggested, however, that there were similar trends on other rivers and this needs to be established before a suggested local impact on sea trout fisheries can be substantiated. A more detailed analysis of statutory licence returns from the rod and net fisheries has therefore been started. This should establish whether CPUE declined in a similar way on neighbouring rivers outside the closure area.

The sale of rod licences to salmon and sea trout anglers showed an overall decline compared with other parts of England and Wales[15]. A questionnaire survey of local and visiting anglers indicated that the oil spill was a contributing factor in this decrease, but this was no more significant than a number of other factors such as poor river flows (which generally reduced numbers of fish) and an increase in the licence fee. A higher than usual number of anglers upgraded their fishing licences to salmon licences during the year, suggesting their perceptions changed over time.

Even if salmon and sea trout returned to their spawning grounds in normal numbers, it was possible that their ability to breed successfully may have been influenced by exposure to oil whilst at sea. This will only become clear in future years. To allow a proper assessment to be made, baseline information was collected on the numbers of juvenile salmon and trout present in rivers within the affected area (the Tywi, East and West Cleddau, and the Taf) and in two control rivers outside the closure area, the Teifi and Conwy, to provide a baseline against which any impact could be assessed.

3.6.2 Sea bass (*Dicentrachos labrax*)

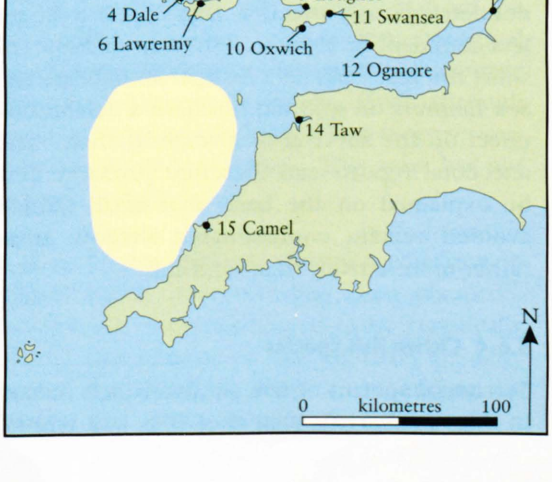
The bass is probably the single most important species of marine fish exploited along the south Wales coast. As the young fish spend much of their early life in very shallow water, there was concern that the oil spill might have affected their survival.

Over a number of years, CEFAS scientists in association with Swansea University have been studying the breeding success and general behaviour of the Bristol Channel stock of bass. The number of sites studied was increased in 1996[16] to assess any effects of the spill, with the additional sampling taking place in September and October 1996, and in 1997. The main spawning ground for bass and the sampling sites are shown in *figure 3.3*. Except at the new sites in Milford Haven waterway, previous experience allowed sampling to be targeted at locations known to be favoured by 0–group fish (ie fish born that year). These fish normally reach their nursery areas in the Bristol Channel in late June or early July.

The first arrivals were somewhat later in 1996 than in 1995 – especially along the south Wales coast where no 0-group fish were detected before the end of May. The distribution of these fish between the south side of the Bristol Channel and the south Wales coast had also changed, with a greater abundance along the south side instead of the more equal distribution observed in previous years. The abundance along the south side of the Bristol Channel was also higher than recorded in that area during recent years. The abundance of 0–group bass at sites within Milford Haven waterway seemed to be lower than elsewhere on the south Wales coast, but the lack of previous data for the Haven made it difficult to establish whether this was unusual. Factors other than the oil spill may have been responsible for these changes. For example, during cold years (such as the 1995/96 winter) the spawning ground moves south, increasing the distance the bass larvae have to travel to get to the south Wales coast.

Other aspects of the study did not show a clear–cut relationship with oil contamination. Furthermore, some of the more detailed features of the results suggested that more natural factors may have been involved. Growth rates of the fish were measured at two sites on the south shore of the Bristol Channel (Taw and Camel) and two sites on the south Wales coast (at Loughor within the area marginally affected by the spill, and at Swansea outside this area). The Loughor result (0.60 mm/day) was not significantly different from the results at the Taw and Camel sites (0.75 and 0.67 mm/day). The growth rate at the Swansea site, however, was much poorer (0.34 mm/day) and a much higher proportion of 0–group bass at sites on the south Wales coast failed to reach the length of 60 mm by the end of the summer, compared with those along the south Bristol Channel shore. This length is believed to be critical for winter survival, and further studies are being undertaken to assess whether more fish died as a result.

Fig 3.3 Bass spawning ground and sampling sites



The greatest abundance of 0–group bass in the south Wales sites was found in the Nyfer and Teifi estuaries which had not been affected by the oil, but the fish from the Teifi were in poor condition and the weight of their stomachs was generally found to be low. In contrast, at the sites where the greatest impact of oil might be expected – Ferryside and Milford Haven waterway – the condition of the fish (including stomach fullness and average stomach weight) was similar to or better than at other sites in south Wales.

The slower growth rates, lower abundance and late arrival of the 0–group bass suggested that increased mortality of eggs and larvae occurred along the South Wales coast in 1996 and could well affect future catches along that coast and possibly the Bristol Channel as a whole. Only continued collection of detailed catch statistics and age data will establish whether that prognosis is correct and its significance. Even then it will be necessary to assess whether natural causes such as a cold late spring affected the location of the spawning area in 1996 or whether the oil spill was the cause of any clear changes in recruitment.

3.6.3 Sand eels and other shoaling fish

Although sand eels are not of great commercial importance, they are an important part of the marine food chain and provide a major source of food for some seabirds and larger fish such as sea trout and bass. The fishery is regulated by the Sea Fisheries Committee, and fishermen intending to catch sand eels using a beach net are required to hold a special permit and to submit catch data on each fishing operation. The FEPA Exclusion Order was lifted at about the time of year (21 May) when fishing would normally have started.

Sand eels live in shallow waters and bury into the sand. The main species found on the south Wales coast is *Ammodytes tobianus* which spawns either in February to April or in September to November. Three samples of adults were collected from Tenby South Beach between 10 April and 19 May and were analysed for total hydrocarbons. By the third sample, concentrations were down to 3,400 µg/kg THC, ie around background level.

Puffin with sand eels (E Bent)

In addition to analysing catch returns[17] the South Wales Sea Fisheries Committee sent a carefully-designed questionnaire to all the 1996 permit holders. They received 52 returns, of which 26 were suitable for detailed consideration (some permit holders do not always fish for sand eels, holding their permits only as a precautionary measure in case they do). Confidence that the responses received were reasonably objective was gained from the range and type of response returned, and the actual catch returns, plus knowledge of the behaviour of the species and its response to oil[18].

The main fishing areas are around the sandy beaches between Tenby South Beach and Broadhaven, but reports were received from fishermen along the coastline between Whitesands (near St David's) to the north and the Gower to the east. About one third of the fishermen reported a decline in catches compared with previous years, but the remainder considered catches to be normal and a few reported an increase. Most other fishermen recorded catches as being normal at Tenby South and at Manorbier and Skrinkle. No mass mortalities, such as those observed after the *Torrey Canyon* spill[19], were reported. It was concluded that there had been little, if any, impact on sand eels.

Telephone enquiries in 1997 showed that catches (up to late August) were very good, with one fisherman reporting many small sand eels – from a successful spawning in either autumn 1996 or spring 1997 – passing through his net. This was in line with observations after the Braer spill where, although there was clear evidence of exposure of adult and larval sand eels to oil, there appeared to be normal survival of the sand eels born that year[20].

Records of fish caught with the sand eels or which escaped from the nets were generally not comprehensive. Little can be concluded other than that small flatfish greater than 75 mm were observed, but a few sand eel fishermen reported that they thought there were fewer small flatfish (ie the young of that year) present than normal.

Other shoaling fish such as whitebait, herring and sprat were reported to be present in 1997 in greater numbers than normal. Only low numbers of small flatfish have been reported, tending to confirm the anecdotal reports from sand eel fishermen in 1996.

Although no formal observations were carried out on young flatfish in 1996, CEFAS carry out a young fish survey in the Bristol Channel every year. Their records have been examined to assess whether or not the 1996 year class was affected by the spill. The records show that in 1996, sole from that year were rather scarce as 0--group fish but that in 1997, as 1-group fish, they were especially abundant. The 1996 year class of plaice appears to be a little less abundant as 1-group fish in 1997 than the previous two year classes were at that age. However, in 1997, the 1994 and 1995 year classes were more abundant than similar aged fish were in 1995, the year before the spill. This suggested that plaice were not detrimentally affected. Dab appear to be no less abundant in 1996 or 1997 than in 1995. In short the year class data for flatfish indicate the *Sea Empress* oil spill did not have a deleterious effect on the survival of juvenile flatfish. The anecdotal reports can therefore probably best be explained on the basis that small flatfish avoided certain contaminated shallow areas rather more actively than sand eels.

3.6.4 Other fish species

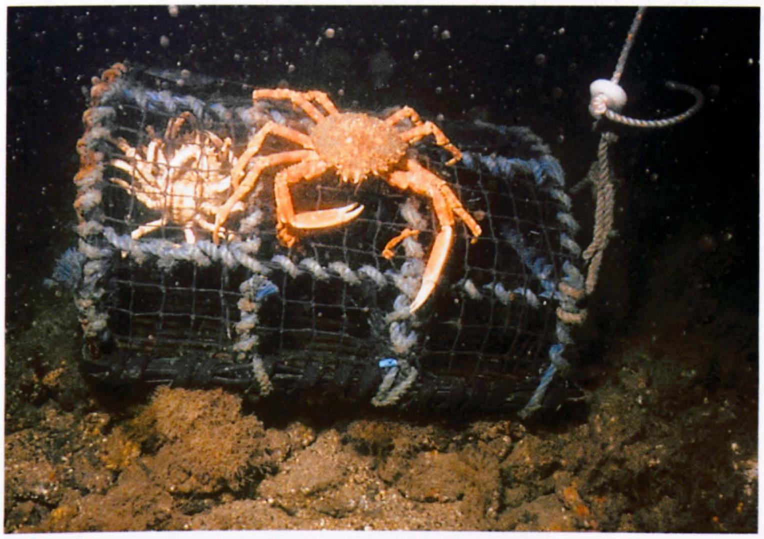
Territorial species of fish (ie fish which remain in one small area), such as gobies and wrasse, were likely to be affected by the oil to a similar extent as the sand eels. A few samples were analysed, and in all the samples total hydrocarbon concentrations were low and similar to those found in sand eels and other fish. Few mortalities of these fish were reported. Further analysis of these and other species was therefore considered unnecessary.

Two other studies on fish were conducted[21,22]. The first investigated the induction of EROD, an enzyme system which metabolises components of oil[23]. A limited amount of induction was observed in some fish, suggesting that these might have been recently exposed to oil. However the degree of EROD induction is also affected by other contaminants and by seasonal factors, especially spawning behaviour which raises the natural level of EROD. In the observations made in this study many of the fish were either spawning or had spawned and it was difficult to establish a baseline from which to relate induction to levels of exposure to oil.

The second study sought to investigate possible long-term genetic effects and carcinogenic damage to fish. The main approach used was to investigate the extent to which DNA adducts (chemicals which physically bind to the DNA) had been formed. This technique provides an indication of abnormalities caused by exposure to oil which, if not repaired, may develop later into more serious problems including the development of neoplasia, which in turn can lead to tumour formation. The first results of this programme demonstrated that in summer 1996 levels of adduct formation in blennies *(Blennius pholius)* taken from rock pools, and dab and plaice in Carmarthen Bay, were elevated when compared with samples taken from reference sites. However, the preliminary findings of repeat samples taken from offshore in summer 1997 showed decreased levels of adduct formation. As these results relate to different fish from those examined in 1996 it will be necessary to subject material from the 1997 fish samples to histopathological examination to establish whether any damage they may have suffered in 1996 through exposure to oil has developed into more serious neoplasia or tumour stages. This work has not yet been completed.

A study of the effect of the oil on herring in Milford Haven waterway had been planned[24]. The herring stock is believed to be genetically distinct and spawns in late February or early March; and in some years - depending on demand and the availability of other species - there is a local fishery for these herring with a typical yield less than 10 tonnes. The stock had been the subject of previous investigations and there were therefore reasonable background data on its biology. Unfortunately, it was too late to establish the success of spawning in 1996, but special arrangements were made to investigate the 1997 spawning using commercial fishermen to collect samples of adult herring, eggs and lavae. However, because abundant and cheap supplies of herring were available from Scandinavia, no commercial fishing for herring took place in Milford Haven waterway in 1997, and the contractor failed to make any assessment of spawning success. Nevertheless a few samples of adult herring were collected. They were found to be in good spawning condition or to have recently spawned, suggesting that even if there had been an effect in 1996 spawning was normal in 1997.

The success of spawning in 1996 and 1997 could be assessed by studying the age structure of fish in spring 1998 via the use of growth rings. The committee's experience suggests it would be unwise to rely on obtaining samples via commercial fishermen.



Spider crab (SWSFC)

3.7 SUB-LETHAL EFFECTS ON SHELLFISH

3.7.1 Crabs and lobsters

At the time of the oil spill, the South Wales Sea Fisheries Committee was already conducting a study on the population structures of edible crabs and lobsters, but this was not due to be completed until after the completion of this report. Only a partial analysis of data collected between April and June in 1995, 1996 and 1997 has therefore been possible for this report[25]. A permit scheme for crab and lobster fishing has been in operation in the region since 1980.

Following the *Amoco Cadiz* oil spill, large numbers of crustaceans were found dead along the shoreline[26], but this was not the case after the *Sea Empress* spill. The *Amoco Cadiz* spill was also reported to have led, in both the year of the spill and the following year, to unusually low numbers of egg-bearing lobsters and spider crabs (and possibly edible crabs - though these were not caught in sufficient numbers to be sure)[26]. If the *Sea Empress* spill had had a similar effect on young crabs spawned in 1995 or in 1996 (or on lobsters past the egg stage) a decreased number of young crabs (and young lobsters) born in 1995 and probably 1996 would be expected. However, this would not become apparent until these animals became old enough to be caught in numbers in commercial traps, ie from 1998 onwards. There was a clear increase between 1995 and 1997 in the numbers of egg-bearing lobsters in all areas from St David's Head to the Gower, though not along the Gower coast itself. This suggested that the spill had not affected lobster mating and egg--carrying behaviour. The catch data analysed suggested that both crab and lobster fisheries continued to be very productive. Fishermen have reported that catches, particularly of lobsters, have been better in 1997 than in previous years, both in numbers and in size. These results may have been due to decreased fishing pressure during 1996 while the fishery was closed. The closure, however, led to increased fishing outside the closure area, such as along the Gower and to the north of St David's Head.

More detailed analysis of the full 1995–1997 records is required to establish the actual status of the stock, and studies are needed for up to three years, starting in 1998, in order to show whether the crustaceans born in 1995 and 1996 were affected by the spill.

3.7.2 Whelks

A study was commissioned[27] to establish whether the spawning of whelks had been affected by the spill and to investigate any impact on numbers and size distributions. There had been a few anecdotal reports -- without independent corroboration - that egg masses had been found less frequently on pots and substrata in 1996, but preliminary results of the study suggested that there was no loss of a year class in 1996, nor any significant effect on the numbers or sizes of whelks being caught. However, any firm conclusions were hampered by the newness of the fishery and lack of baseline data. Whelks normally mature at about 3 years of age (and live for about 6 years) and so it will not be possible to confirm that the 1996 year class was not affected until at least 1998.

3.7.3 Mussels

"Scope for growth" (SFG)* an indicator of condition, was measured in mussels around the Irish Sea as part of a study already underway at the time of the spill[28]. The study included two sites within the closure area, St Ishmaels in Milford Haven and St Brides. In June 1996, SFG was lower in mussels from St Ishmaels (and, to a lesser degree, St Brides) than at Fishguard, though it was lower still at some other sites on the Irish Sea coast. Tissue PAH concentrations were not raised in the St Brides samples, suggesting that the effect seen here was not due to the spill. PAH levels were clearly elevated in the St Ishmaels samples, but so too was the concentration of tin-based compounds used in anti-fouling paints which are used on tankers using the port, and these compounds are acknowledged to have a detrimental effect on molluscs, including mussels.

SFG was also measured as part of the special studies of the impact of oil undertaken by CEFAS. Samples of mussels were taken from the shoreline at 15 sites from New Quay in mid-Cardigan Bay, southwards to Dale in Milford Haven and eastwards to Ogmore-by-Sea. The results are summarised in *figure 3.4*. In March 1996, SFG was negative in the samples measured at four sites - Dale, Amroth, Pendine and Port Eynon. In October there was an increase in SFG in the mussels from most sites due to seasonal factors related to spawning and feeding, but mussels from the four sites which had negative SFG in March still exhibited SFG close to zero, with a negative value for the sample from Pendine. The shorelines at Pendine, Amroth and Dale were heavily impacted by oil from the *Sea Empress* with some oiling also at Port Eynon. It would appear that the negative SFG measured in mussels from these sites was caused by oil contamination. This was in part borne out by the mussel tissue, total hydrocarbon residue data from these sites.

Sub-lethal effects on the immune system of mussels - associated with high concentrations of total hydrocarbons in their tissues -- were observed in samples from sites along the south Wales coast[29]. Mussels are a fairly robust species and generally survive even heavy oiling. However, in addition to the short-term "scope for growth" effects, mussels from the affected area also revealed significant modulations in cell-mediated immunity that correlated well

**SFG is a measure of the energy of the surplus which, under normal circumstances, is available for the mussel to grow. SFG is reduced when less food is available or when the mussel requires more energy, for example when breeding or due to stresses such as the effects of oil.*

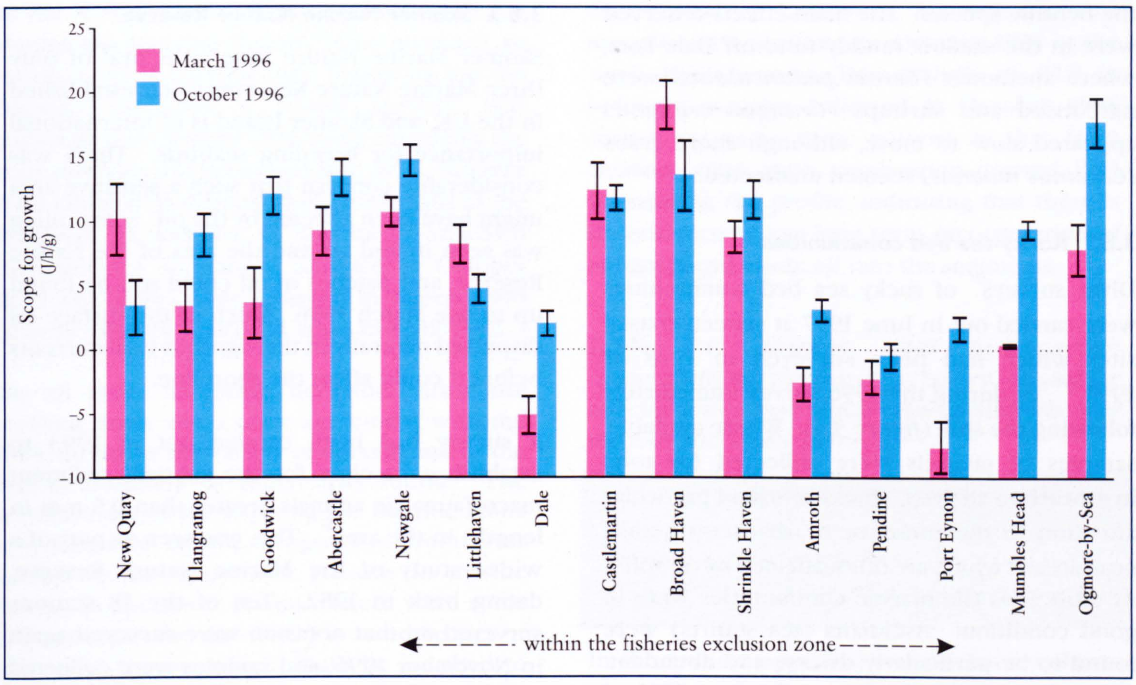


Figure 3.4 Scope for growth measured in mussels in March and October 1996.

with total PAH and total hydrocarbon concentrations. However, the immune response of contaminated mussels gradually improved and generally showed no difference compared with other mussels 11 weeks after the spill. By then the total hydrocarbon content of the contaminated mussels had declined by 70–90% and the PAH content by over 90%.

3.8 BENTHIC SPECIES

Section 3.5.1 described strandings of dead or moribund animals. These strandings showed that benthic animals (ie those living in or on the sea bed) had been affected by the oil, and several studies were designed to examine how widespread the impact had been. The areas considered to be of particular priority were the Skomer Marine Nature Reserve, areas directly impacted by the tanker (such as the mid-channel rocks), and areas which had been studied intensively in the past, such as within the Milford Haven waterway.

The first study, which was carried out by divers very shortly after the spill (between 23 and 27 February 1996)[30], examined six sites within the mouth of Milford Haven waterway and two just outside, including the mid-channel rocks on which the tanker grounded. The effects were surprisingly limited, even though oil in the water column must have come into contact with

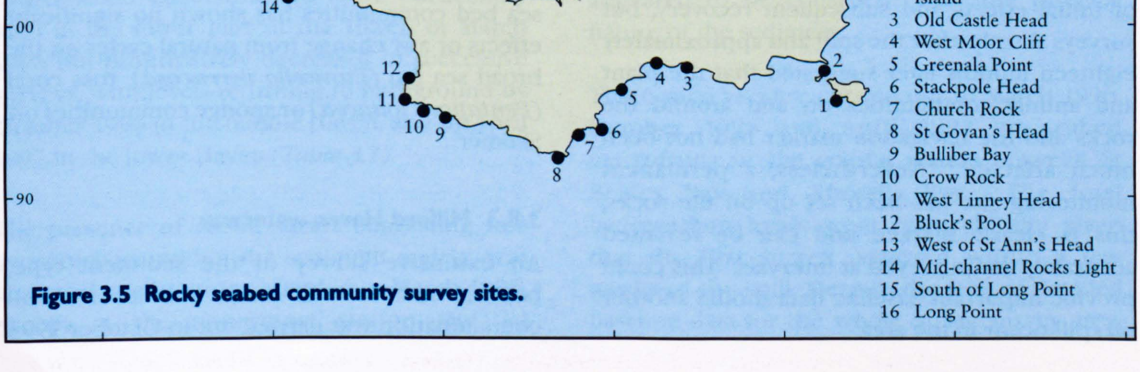


Figure 3.5 Rocky seabed community survey sites.

the benthic species. The main effects observed were in the shallow muddy sand off Dale Fort, where anemones *(Cereus pedunculatus)* were narcotised and shrimps *(Crangon crangon)* appeared slow to move, although shore crabs *(Carcinus maenas)* seemed unaffected.

3.8.1 Rocky sea bed communities

Diver surveys[31] of rocky sea bed communities were carried out in June 1997 at sixteen coastal sites which had been surveyed in 1978 or 1993[32,33], or during the 1996 survey immediately following the spill (*figure 3.5*). Where available, samples of mussels were collected for total hydrocarbon analysis. The divers paid particular attention to the presence or absence of small crustaceans which are often affected by oil spills. At most sites the marine communities were in good condition. Ascidians (sea squirts) were found to be particularly diverse and abundant. However, at sites around the entrance to Milford Haven waterway there were very few small crustaceans such as amphipods and isopods - although these species were found at other sites, sometimes in abundance.

At the base of Eastmoor Cliff at Manorbier many empty razor shells *(Ensis spp)* were found, possibly resulting from the same mortalities that gave rise to shells stranded on beaches shortly after the spill. The mussel samples did not contain elevated concentrations of total hydrocarbons, indicating that the sites where these had been taken - Eastmoor Cliff and the north side of St Margaret's Island - were no longer contaminated.

A detailed comparison with the results of the 1978 survey will probably not be possible. Although the sites surveyed were the same (so far as it was possible to judge), the survey and observation techniques used in 1997 - which followed current standards - were different from those used in 1978.

The mid-channel rocks where the *Sea Empress* grounded were expected to be a good indicator of initial effects and subsequent recovery, but surveys shortly after the spill and approximately eighteen months later suggested that the plant and animal communities on and around the rocks and the navigation marker had not been much affected. Nevertheless, a permanent monitoring site has been set up on the rocks; this is clearly marked and can be revisited accurately and surveyed at intervals. This could provide important baseline data should another oil spill occur in the area.

3.8.2 Skomer Marine Nature Reserve

Skomer Marine Nature Reserve is one of only three Marine Nature Reserves so far established in the UK, and Skomer Island is of international importance for breeding seabirds. There was considerable concern that such a sensitive area might have been affected by the oil. Some oiling was seen in and around the area of the Nature Reserve, and patches of oil could still be found up to late March 1996. Much of the surface oil dispersed naturally in the vigorous tidal currents before it could affect the shoreline.

A survey had been carried out in 1993 to establish a baseline for the subtidal sediment macrofauna (ie animals greater than 0.5 mm in length) in the area[34]. This was seen as part of a wider study of the Marine Nature Reserve, dating back to 1982. Ten of the 18 stations surveyed on that occasion were surveyed again in November 1996, and samples were collected of benthic fauna and sediments. The sediment samples were analysed for total hydrocarbon concentrations and for particle size.

The benthic fauna appeared to be markedly less diverse and abundant in 1996 compared with 1993. In particular, there was an absence of small crustaceans, a feature which had also been noted at subtidal rocky sites around the mouth of Milford Haven waterway (see §3.8.3). Total hydrocarbon concentrations in the sediment samples were above background levels (though by less than a factor of ten), and it was likely that the absence of the small crustaceans was due to the oil spill as such species are known to be sensitive to oil pollution[35]. The larger scale changes in benthos may, however, have been due in part to changes in sediment structure (possibly caused by unusually severe wave action during extreme October 1996 storms), with more fine or very fine sand present at most of the sample sites in 1996 compared with 1993. The finer the sediment the more suitable it is for animals that burrow rather than those that shelter in gaps or settle on coarser material.

Long term photographic monitoring of rocky sea bed communities has shown no significant effects or any change from natural cycles on the broad sea fan *(Eunicella verrucosa),* ross coral *(Pentapara foliacea)* or sponge communities off Skomer.

3.8.3 Milford Haven waterway

An extensive survey of the sediment type, benthic invertebrate fauna and level of oil contamination was carried out in October 1993 by the Milford Haven Waterway Environmental Monitoring Steering Group[36]. This provided an excellent set of baseline data. Following the *Sea Empress* oil spill, a repeat survey[37] was undertaken in October 1996 using essentially the same methods and personnel as in 1993. Samples were taken at 36 stations along the length of the waterway. In addition, 11 stations (9 of which corresponded to stations sampled in October 1993 and 1996) were sampled in March 1996 (shortly after the spill) and again in April 1997.

On all three sampling occasions after the incident there was a close agreement with the 1993 survey in the variety of species and in the overall numbers of individuals found. The predominant factor affecting the benthic fauna was found to be the progression from river habitat in the uppermost stations to marine habitat in the lower Haven. There were some differences in the distributions and densities of individual species which could be ascribed to changes in the sediment type resulting from small changes in the position of the samples, or to natural variability. One notable feature, however, was the absence, in samples taken after the spill, of certain species of amphipod crustaceans at many sites, particularly those in the lower reaches of the waterway. These animals do show considerable variation in abundance naturally, but similar effects have been observed in other studies (see §3.8.1 and 3.8.2) and in previous surveys of the impact of major oil spills.

The range of total hydrocarbon concentrations in the Milford Haven waterway sediments sampled in October 1993 (4,000 to 1.2 million µg/kg dry weight, most greater than 50,000 µg/kg) indicates that most are contaminated by hydrocarbons to some extent. Detailed analysis of PAHs, which are constituents of oil but can also be formed during combustion processes, indicated that the PAH in the sediments were predominantly derived from combustion. Nevertheless it would appear that total hydrocarbon concentrations in sediment were elevated relative to the levels found in the 1993 survey, ie before the *Sea Empress* spill. Total hydrocarbon concentrations were particularly high in the lower part of the Haven in March 1996 but progressively decreased in successive surveys, with levels returning to background by October 1996 in the middle Haven, and by April 1997 in the lower Haven *(Table 3.1)*.

The presence of an oil sheen, suggesting free hydrocarbons within the sediment matrix, was observed at all stations sampled in March 1996, except at the uppermost station situated downstream of Lawrenny. No such sheening was observed in either the October 1996 or the April 1997 surveys. The analysis of PAH in sediment samples collected in October 1996 shows the same basic pattern as that from October 1993, with combustion-derived PAH dominating the profile, indicating that there is no evidence of any long term incorporation of Forties Blend crude oil into the sediments.

Table 3.1: Average total hydrocarbon concentrations (thousand µg/kg dry weight) for selected lower and middle Haven stations over the four successive surveys:

	October 93	March 96	October 96	April 97
Middle Haven (3 stations)	295	415	269	255
Lower Haven (3 stations)	64	658	208	91

In short, there appeared to have been a short-term oiling of sediments in the lower reaches of the Milford Haven waterway, but sampling in October 1996 and April 1997 suggested that there has been no long-term accumulation of oil from the *Sea Empress* in the subtidal sediments of the waterway. The only major effect on the benthic fauna which might be attributed to the spill was the marked absence of certain species of amphipod crustaceans. This latter finding is, however, significant as these crustaceans are a favoured food species for many animals such as fish and the larger crustaceans. Further surveys at the same sites and times of year to monitor the re-establishment of these amphipods would seem advisable.

3.8.4 Other benthic studies

Samples of benthos were collected from the Celtic Deep[38] and other sites during the surveys, looking for possible areas where oil might have accumulated in offshore sediments (see §2.8.1 and *figure 2.7*). As the samples showed no evidence of the deposition of *Sea Empress* oil, detailed analysis of benthic structure was not warranted, but visual inspection at the time of collection suggested that the species present appeared to be consistent with the physical nature of the sediment.

Three surveys were carried out in March 1996, October 1996 and April 1997 on seabed macrofauna in the coastal waters between St Brides Bay and Rhossili Bay[39]. The total hydrocarbon levels were relatively low given that the first survey occurred within a few weeks of the spill. Despite the lack of detailed baseline data for the whole of the survey area, where such data were available (such as for Carmarthen Bay) the macrobenthic communities agreed well with historical descriptions. There was little, if any, direct evidence of impacts from the spill and the major factors influencing the seabed macrofauna appeared to be water depth and sediment type. The effects on amphipod fauna seen at sites in the Milford Haven waterway were not apparent outside the Haven[40].

Scoter ducks in Carmarthen Bay were believed to be feeding at the time of the spill on egg-shell razors (*Pharus legumen*) which may have been contaminated by oil that had dispersed into the water column (see §7.3.3). Attempts to collect samples of this species were unsuccessful and it is not possible to say whether egg-shell razors were contaminated or not. However, it is likely that egg-shell razors demonstrated the same response as larger razor shells (*Ensis spp*) and emerged from their burrows when exposed to low concentrations of oil. The *Ensis spp* were only very lightly contaminated with oil and were collected from the same area just after the spill. It therefore seems unlikely that the egg-shell razors were seriously contaminated.

3.9 EFFECTS ON PLANKTON

At previous spills any effects on plankton (ie small plants and animals, including fish and shellfish larvae, which are found suspended in the water) were of short duration and limited overall ecological significance[41]. Nevertheless, several studies were commissioned - mostly based on investigations already underway - to look for possible effects of the *Sea Empress* oil on plankton[42,43].

The Sir Alister Hardy Foundation for Ocean Science (SAHFOS) sampled plankton along specific shipping routes using a Continuous Plankton Recorder. The results for 1996 in the area affected by the oil were compared with a model of the plankton community based on 25 years of data. The only unusual finding was the absence of barnacle larvae in the spring 1996 samples, but this was probably a reflection of the pattern of currents and sampling time as there was a good settlement of barnacles on the south Pembrokeshire coast in May 1996[44].

Routine monitoring of phytoplankton (ie plant species of plankton) has been carried out by CEFAS since 1993 in Milford Haven waterway, as part of a national programme of monitoring for the occurrence of those species which cause bivalve shellfish to become toxic to humans. The limited data available from this programme showed nothing abnormal in 1996[45].

The EA also has a routine programme checking for unusually large concentrations of phytoplankton (blooms) as part of its monitoring of compliance with the EC Directive on bathing water quality and in relation to the Urban Waste Water Treatment Directive. Records showed that blooms of *Phaeocystis spp* (algae which produce brown coloration and foam) occurred at all nine bathing water sites in the area affected by the oil, and at four of these the blooms lasted longer than at any time since 1991. However, similar blooms also occurred at 24 sites outside the affected area and were of record duration at three of these. Blooms in the affected area were generally of similar density to those observed in previous years, except at Amroth where the density was lower. A bloom of the diatom *Asterionella* was observed at Pembrey, lasting four weeks - an unusually long period for this area, though similar blooms of this species have been recorded at other sites around the Welsh coast in the past. The overall conclusion of these investigations was that the *Sea Empress* oil spill did not appear to have affected the dynamics of phytoplankton populations.

A study at various sites around the coast of Britain of the effect of sediment oil contamination on eggs of calanoid copepods (types of small crustacean) was extended following the spill to include four sites in Milford Haven waterway: West Angle Bay, the east side of Angle Bay, west Pwllcrochan Flats and Pembroke Flats. Copepod eggs settle naturally out of the water column (most copepods are planktonic) and into the sediment. Sediment samples from these sites were collected between April 1996 and April 1997 and analysed for total PAH using a fluorescence method that does not distinguish between PAH compounds. The samples were treated in three different ways to assess the viability of eggs (ie the proportion of the eggs which hatched).

There was a marked reduction in egg viability in the April 1996 samples from Milford Haven waterway compared with the other sites around Britain. Viability increased in the June 1996 samples, and by November 1996 egg viability at the Milford Haven sites was not significantly different from that found at the other sites.

The reduction in copepod egg viability was consistent with previous studies[46] and was likely to have been caused by oil contamination.

However, the change in viability did not correlate with total PAH concentrations in the sediments. A possible explanation of this is that in April 1996 there were more of the low molecular weight PAH compounds present, and these were more toxic and more readily available to be absorbed by the copepod eggs. The rapid recovery of egg viability suggested that the sediments were cleansing quite rapidly and that there were good prospects for an early recovery of other small crustaceans, including amphipods. For the sedentary species, this will also depend on the rate of recruitment into the areas affected from outside. Studies of amphipods in other areas (see §3.8) tend to confirm the forecast of an early recovery.

3.10 EFFECTS OF CLEAN-UP

Dispersants played an important role in the clean-up operation at sea following the oil spill (see §2.3 and §10.4). Modern dispersants are not particularly toxic: the types of dispersants used at the spill were required to have passed a test demonstrating that dispersant plus chemically-dispersed oil was no more toxic for a number of species than the same concentrations of naturally-dispersed oil. Although toxicity varies with species, extensive consultation and a literature review have indicated that it is unlikely that the oil plus dispersant will be more toxic to marine organisms than oil of similar droplet size dispersed naturally. Tests following the *Braer* spill showed that the dispersants did not cause oil to be dispersed into smaller droplets than those resulting from natural dispersion by wind and wave turbulence[47,48]. The only effect of dispersants, therefore, would have been to increase the amount of oil in the water column and its availability to species in the water column and on the sea bed.

The earlier sections of this chapter suggest that dispersed oil did not have a major effect on plankton and other species in the water column such as fish, though it did probably affect species living on the sea bed. Small crustaceans, especially amphipods, appear to have suffered major mortalities, similar to those observed following the wreck of the *Amoco Cadiz* on the French coast. Effects on bivalves and other shallow subtidal burrowers were also observed including some stranding events a long way from the original source of the oil (§3.5.1). It is possible that these animals may not have come into contact with comparable concentrations of dispersed oil if dispersants had not been used, and so the use of chemical dispersants may have contributed to their loss. Such possibilities need to be taken into account when considering the net environmental benefits of using dispersants alongside the more predictable impacts of the treated and untreated oil on fisheries, birds, shoreline species and amenity interests.

Two further aspects of the clean-up operation could potentially have resulted in impacts on the marine environment: the bioremediation study which, because it involved the addition of nutrients, may have led to increased algal growth, and washing of cobbles in the surf zone which might have raised hydrocarbon levels locally. Monitoring of these activities is described in §10.7.6 and §10.7.4, but no impacts were noted.

3.11 CONCLUSIONS

Almost all of the effects observed have been typical of major spills involving oil of a similar type to that released from the *Sea Empress,* though concentrations of oil in contaminated fish and shellfish returned to background levels somewhat faster than might have been expected. This was probably due to the oil dispersing widely and out of the area rather than becoming incorporated into sediments in high concentrations (as occurred following the *Braer* spill); and many of the commercially-exploited species were out of the area at the time of the spill when oil concentrations in the water column were at their highest.

There were a number of strandings of dead or moribund bivalves and other benthic species similar to those observed at other spills. Elevated hydrocarbon concentrations in tissue linked some of these strandings to the spill, but it is not clear whether others – in particular the stranding of rayed trough shells in April in Carmarthen Bay -- were caused by the oil. Although on balance it seems likely that oil was the cause, it remains unclear how this species was exposed to lethal concentrations.

There appears to have been no lasting effect on plankton, and some fish species (such as sand eels) that breed inshore appear not to have been affected.

It is not yet certain whether the 1996 year classes of edible crabs, lobsters and whelks survived, and this will not be apparent until at least 1998 when the first of these should start to be found in the catching pots. There is, however, clear evidence that the adult populations remained healthy and they appeared to breed normally in 1997.

It is suggested that work is undertaken in 1998 to establish whether there have been any effects on the herring stock in the Milford Haven waterway, though it is known that the fish spawned normally in 1997 and so the fishery is unlikely to have been affected severely. There is evidence that there were fewer young bass on the south Wales coast in 1996, but natural factors have not been ruled out as the cause. No effects have been observed on the salmon and sea trout fisheries (apart from the decrease in sales of licences to anglers in 1996), though it will be some years before a more comprehensive assessment on stocks can be made: however, on the evidence available so far, major effects seem unlikely.

For the remainder of the offshore marine community, the impact of the oil seems to have been minimal - apart from a reduction in small crustacean species such as amphipods in some localities. This effect is likely to be of relatively short duration as amphipods, despite not having a planktonic stage, will eventually spread from unaffected areas.

It is difficult to forecast when populations and community structures will return to "normal", but it is likely that by the end of 1998 almost all the species expected to be present in the area will be close to their usual numbers. There is the possibility that a year class of a particular species may be reduced in numbers, but the effect this has on future year classes is unlikely to be detectable against the variability that occurs naturally, for instance due to weather fluctuations at breeding times.

If a fishery Exclusion Order needs to be imposed at a future spill, it is important that the reasons behind the order and the criteria for lifting it are explained and communicated effectively - particularly differentiating between an order imposed to protect consumers and markets from an established risk, and one imposed as a precautionary measure while adequate data are collected.

A number of further studies are suggested:

- A study of the age structure of herrings in the Milford Haven fishery, carried out by an organisation with an established track record of successfully completing such investigations, could establish whether breeding success in 1996 and 1997 has been affected.
- A similar study on the age structure of whelks in Carmarthen Bay and to the west of Milford Haven waterway would also be beneficial.
- Continued observations of the age structure of bass in the Bristol Channel would establish whether the suspected poor recruitment and survival of the 1996 year class along the south Wales coast was serious enough to affect overall stocks, and it would also assess whether it was due to natural events or was influenced by the oil spill.
- Continued observation of crab and lobster catches until at least 1999 would establish whether the 1996 year class entered the fishery in normal numbers.
- The installation of fish counters or traps on key major rivers could obtain baseline data on adult salmon and sea trout runs.
- Benthic surveys - at the same sites and time of year as those described above - would be useful to establish when the small crustaceans become re-established in the lower Milford Haven waterway, off Skomer and elsewhere. Resurveying a number of the coastal sites studied in June 1997 as part of a long term monitoring study would also provide baseline data against which to measure future change.

REFERENCES

1. Smith, J. E., 1968. Ed. Torrey Canyon Pollution and Marine Life. A Report by the Plymouth Laboratory of the Marine Biological Association of the United Kingdom. Cambridge University Press. pp. 196.
2. Berthou, F., Balouët, G., Bodennec, G. and Marshand, M.,1987. The occurrence of hydrocarbons and histopathological abnormalities in oysters for seven years following the wreck of the *Amoco Cadiz* in Brittany (France). *Marine Environmental Research*, 23, 103–133.
3. Topping, G., Davies, J. M., Mackie, P. R. and Moffet, C. F., 1997. The impact of the *Braer* spill on commercial fish and shellfish. In: Proc. Roy. Soc. Edinburgh. The impact of an oil spill in turbulent waters: The *Braer*. Stationery Office. Eds. J. M. Davies and G. Topping. pp. 121–143.
4. Whittle, K. J., Anderson, D. A., Mackie, P. R., Moffat, C. F., Shepherd, N. J. and McVicar, A. H., 1997. The impact of the *Braer* oil on caged salmon. In: Proc. Roy. Soc. Edinburgh. The impact of an oil spill in turbulent waters: The *Braer*. Stationery Office. Eds J. M. Davies and G. Topping. pp. 144–160.
5. S. Lovewell. Pers. Comm.
6. Marchand, M. and Cabane, F., 1980. Hydrocarbures dans les moules et les huitres. Rev. Int. Oceanogr. Med. LIX, 3–30.
7. Chassé, C. and Guenole–Bouder,A., 1981Comparison quantitative des populations benthiques des plages de St-Efflam et St-Michel-en-Gréve avant et depuis le naufrage de l'*Amoco Cadiz*. In: Procedings of an international symposium, Centre Océanographique de Bretagne, Brest, November, 1979: *Amoco Cadiz* – fates and effects of the oil spill. Pub. Centre National pour l'Exploitation des Océans, Paris. ISBN z-90272-09-9.
8. The International Tanker Owners Pollution Federation Ltd, 1987. Response to marine oil spills, p. I-24.
9. Jon Moore, pers comm.
10. Hess, W. N., ed. 1978. The Amoco Cadiz oil spill; a preliminary scientific report. NOAA/EPA Special Report NTIS PB 285–805. pp. 201–205.
11. Croudace C.P, A review of the impact of crude oil on salmonids. June 1997 (SEEEC Project M10)
12. Moore A., Olfactory sensitivity of mature male atlantic salmon exposed to the water soluble fraction of forties crude oil and for oil dispersants used in the Sea Empress incident. 1997 (SEEEC project M10)
13. Ellis, J.R., The impact of the oil on the whelk fishery of Carmarthen Bay, University of Wales, Swansea, in prep. (SEEEC Project M13)
14. Bird, D.J., Rotchell, J.M., & Newton, L.C. The *Sea Empress* oil spill: Cytochrome P450 levels, Ethoxyresorufin-O-Deethylase Activity and Bile Metabolites in migrating Sea Trout *(Salmo trutta)*. Report to the Environment Agency (SEEEC Project M10).
15. Marketing Focus Ltd. Report to EA on *Sea Empress* amenity impact survey. 1997 (SEEEC Project M9)
16. Lancaster, J.E., & Dalton, N.O. The impact of the oil spillage from the *Sea Empress* on the recruitment of bass in south-west England and Wales. University of Wales, Swansea. In prep. (SEEEC Project M1)
17. Coates, P.J, 1997. The possible effects of oil on sandeels and bait fish: the significance of predators. SWSFC report to MAFF.
18. Pinto, J. M., Pearson, W. H. and Anderson, J. W., 1984. Sediment preferences and oil contamination in the Pacific sand lance *Ammodytes hexapterus*. Marine Biology, 83, 193–204.
19. Reay, P. J., 1970. Synopsis of biological data on North Atlantic Sandeels of the Genus Ammodytes. FAO Fisheries Synopsis No. 82.
20. Wright, P. J., Stagg, R. M. and McIntosh, A. D., 1997. The impact of the *Braer* oil spill on sandeels around Shetland. In: Proc. Roy. Soc. Edinburgh. The impact of an oil spill in turbulent waters: The *Braer*. Stationery Office. Eds J. M Davies and G. Topping. pp. 161–181.
21. Lyons, B., Harvey, J., Parry, J.M. The genetic and potentially carcinogentic consequences of the *Sea Empress* incident and genetic damage in fish by PAHs. In prep. (SEEEC Project M6 and M7)
22. ibid
23. Galgani, F. and Payne, J. F., 1991. Eds. Biological effects of contaminants: Microplate method for measurement of ethoxyresorufin-O–deethylase (EROD) in fish. Techniques in Marine Environmental Science. No. 13. Publ. ICES. pp.11.
24. Impact on Herring stocks in Milford Haven (SEEEC Project M2)
25. Davies, C.G., The possible effects of the *Sea Empress* oil spill in Lobster (Homarus gammarus) and edible Crab (Cancer pagurus) within the South Wales Sea Fisheries District). Progress Report (SEEEC project M12)
26. Laubier, L., 1980. The *Amoco Cadiz* oil spill – A biological impact study. Ambio. 9 (6), 268–302.
27. Ellis, J.R., The impact of the oil on the whelk fishery of Carmarthen Bay, University of Wales, Swansea, in prep. (SEEEC Project M13)
28. Widdows, J., Donkin, P., Brinsley, M. D., Evans, S. V., Salkeld, P. N., Franklin, A., Law, R. J. and Waldock, M. J., 1995. Scope for growth and contaminant levels in North Sea mussels *Mytilus edulis*. Marine Ecology Progress. Ser. 127, 131–148.
29. Dyrynda, E. D., Law, R. J., Dyrynda, P. E. J., Kelly, C. A., Pipe, R. K., Graham, K. L. and Ratcliffe, N. A., 1997. Modulations in cell–mediated immunity of *Mytilus edulis* following the *Sea Empress* oil spill. J. mar. biol. Ass. UK. 77, 281–284.
30. Hill, T. O. and Northern, K. O., 1996. Preliminary observations of the shallow sub–tidal benthos following the Sea Empress oil spill in Milford Haven. MNCR Field survey report JNCC Contractor Report to CCW, pp.8.
31. Rostron, DM, Bunker, D, 1997 Assessment of sub littoral epibenthic rock communities and species following the Sea Empress oil spill. Report to CCW. pp21 including appendices.
32. Cartlidge, D. and Hiscock, K., 1979. Field surveys of sublittoral habitats and species in South Pembrokeshire. Nature Conservancy Council, Huntingdon/Field Studies Council Oil Pollution Research Unit, Orielton Field Centre, Pembroke, VI and 53pp.

33. JNCC, 1994. MNCR survey 467, unpublished survey data.

34. Rostron, D. M., 1994. The sediment infauna of the Skomer Marine Nature Reserve. A report to the Countryside Council for Wales from Sub Sea Survey, Pembroke. 56pp + appendices.

35. Dauvin, J. C., 1982. Impact of *Amoco Cadiz* oil spill on the muddy fine sand *Abra alba* and *Melinna palmota* community from the Bay of Morlaix. Estuarine, Coastal and Shelf Science, 14, 517-531.

36. Levell. D, Smith, J, and Hobbs G 1994. Milford Haven macrobenthic Survey, October 1993. Report to Milford Haven Waterway Environmental Monitoring Steering Group from the Field Studies Council Research Centre, Pembroke report no.FSC/RC/11/94pp. plus tables, figures and appendices.

37. Levell, D.(Editor), Hobbs, G., Smith, J. and Law, R.J (1997). *The effects of the Sea Empress oil spill on the sub-tidal macrobenthos of the Milford Haven waterway: a comparsion of survey data from October 1993 and October 1996.* Report to the Environment Agency. OPRU/CORDAH, Neyland, Pembrokeshire. Report No.OPRU/12/97 Vil 1: 32pp. plus tables and figures -Appendices in Vol.2 (SEEEC Project M16).

38. Subtidal benthic survey of Celtic Deep (SEEEC Project M18)

39. G. Hobbs. (1997). *Macrobenthic monitoring in Milford Haven and the adjacent coastal waters following the Sea Empresss oil spill of February 1996.* Report to the Environment Agency. OPRU/CORDAH, Neyland, Pembrokeshire. Report No. OPRU/29/97. 10pp. plus tables, figures and appendices.

40. Hobbs, G. and Smith, J., 1997. *Macrobenthic monitoring in the coastal waters adjacenrt to Milford Haven following the Sea Empress oil spill of February 1996.*Report to the Environment Agency from OPRU/CORDAH, Neyland, Pembrokeshire, Report no. OPRU/25/97. 18pp, plus tables, figures and appendices.

41. National Academy of Sciences, 1985. Oil in the Sea. Inputs, Fates and Effects Chapter on Effects Section on Marine Plankton p.404

42. Wood G., Rutt G., Hugghes R., An assessment of the impact of the *Sea Empress* Oil Spill on phytoplankton in the effected coastal waters of south west Wales. September 1997. 24pp including tables (SEEEC project M14)

43. Batten, S., Allen, R., and Wotton, C. The effects of the *Sea Empress* oil spill on the plankton of the southern Irish Sea. SAHFOS (SEEEC Project M15).

44. Moore, J. (1997), Rocky shore transect monitoring in Milford Haven, October 1996 Impacts of the *Sea Empress* oil spill. A report to the Countryside Council for Wales from OPRU/CORDAH, Neyland, Pembrokeshire. report no. OPRU/12/97. 30 pp plus appendices

45. S. Milligan. Pers. Comm.

46. Lindley, J. A., George, C. L., Donkin, P. and Evans, S. V. Viability of calanoid copepod eggs from intertidal sediments of 3 estuaries in relation to hydrocarbon content. Submitted to Marine Ecology Progress Str.

47. Rycroft, R., Matthiessen, P. and Portmann, J. E. (Compilers), 1994. MAFF review of the UK oil dispersant testing and approval scheme. Internal Report by DFR to MAFF pp.89.

48. MAFF, 1997. The approval and use of oil dispersants in the UK. pp.22.

4 Shoreline Impacts

4.1 INTRODUCTION

In the days following the spill, oil and emulsion came ashore along about 200 km of coastline. This chapter describes the impact of this oil on the shoreline environment between the low and high water marks (the intertidal zone).

Shoreline study, Wiseman's Bridge (A Little)

The degree of exposure to the oil varied considerably from site to site. As described in §2.9.2, some stretches of shoreline were more heavily oiled than others and the composition (and toxicity) of the oil varied. The areas most heavily oiled were West Angle Bay to Linney Head, western Carmarthen Bay and the southern shore of Milford Haven. Some sites close to where the tanker grounded (such as West Angle Bay and areas within the waterway) were oiled repeatedly with fresh oil, while some sites further away were exposed only to sheens or weathered oil.

The length of time the oil remained on the shore depended on a number of factors, including the type of beach material, clean-up activity, exposure to wave action and whether any oil became buried or trapped. As well as the bulk oil which tended to be stranded at the high water mark, the whole intertidal zone in many areas was exposed to raised levels of hydrocarbon in the water washing over it during each tide in the days following the spill. Natural cleaning by the waves and tide - and some clean-up activity - also resulted in stranded oil being washed back into the sea, possibly resulting in further exposure. *Figure 2.8*, based on shoreline surveys carried out between April and September 1996 (see §2.9.3), provides an indication of the degree of oiling in that period.

This chapter is divided into two parts. The first discusses impacts on species found on rocky shores -- the rock platforms, rockpools, boulders and cobble and shingle beaches which cover approximately three quarters of the affected area. The second considers the sediment shores - the areas of sand and mud which make up most of the remaining coast.

A study was carried out to assess the environmental impacts of various shoreline clean-up techniques. This is reported in §10.8.

Rocky Shores

4.2 INTRODUCTION

Rocky shores dominate much of the coastline of Pembrokeshire and the Milford Haven waterway. A large number of species live in these habitats, including familiar animals such as limpets and barnacles, large brown seaweeds and a host of smaller animals and plants. Each species is adapted to live in a specific rocky shore habitat and there is a wide variety of those habitats - including open bedrock surfaces, rockpools, crevices, shaded underhangs, boulders and shingle. Some species are nationally rare or scarce and are of conservation importance, and some of these were affected by the spill. This section describes the effects of the oil spill on the rocky shore species and the balance between them.

In some areas the bedrock is found only on the upper shore, but boulders and shingle (which are colonised by typical rocky shore species) often continue across the shore into the subtidal zone. Oiling of rocky shore habitats was extremely patchy, and only a few areas - such as

West Angle Bay - were covered across almost the whole shore (see §2.3). In most areas oil was concentrated on upper shore rocks, particularly at the backs of coves and amongst the shingle in sheltered bays. However, a high proportion of the rest of the rocky shore area will also have been subjected to some contamination, at least temporarily, by light sheens and high concentrations of oil in water.

Considerable pre-spill data exist for the rocky shore communities in Milford Haven and on Skomer, but there are only limited data and some anecdotal records for other areas of the South Pembrokeshire coast. *Figure 4.1* shows the sites where there were pre-spill surveys and established monitoring programmes. Fortuitously, most of these sites had been surveyed less than 6 months before the spill. These pre-spill studies were funded and co-ordinated by the Milford Haven Waterway Environmental Monitoring Steering Group (MHWEMSG), the Countryside Council for Wales (CCW) and the Field Studies Council (FSC). In addition, local biologists initiated a number of surveys of oiled and likely-to-be-oiled sites and habitats in the weeks immediately following the spill to provide some reference data from which to follow the effects of the spill and the clean-up.

4.3 EFFECTS ON LIMPETS, OTHER SHORELINE GRAZING ANIMALS AND ALGAE

4.3.1 Initial impact on limpets and other grazers

Within a few hours of oiling, limpets (*Patella spp*) were seen to fall off the rocks in affected areas and two weeks later there had been over 90% limpet mortality in some parts of West Angle Bay[1] (*table 4.1*). Limpets are known to be particularly sensitive to the narcotising effect of fresh oil and individuals rarely survive after they have become detached. Occasionally, individual limpets had lost their shells but remained attached to the rock. Significant reductions in limpet densities were also described from other monitoring sites around the entrance to Milford Haven[2]. Elsewhere, observations of dead limpets and recent 'home-scars' (marks on the rocks where limpets had previously been attached) were reported from many sites along the South Pembrokeshire coast between West Angle Bay and Saundersfoot.

West Angle Bay (N.) (wave-exposed south facing slope)

Date	Mean Density (limpets per 0.25 m^2)	Standard deviation	No.of quadrats
April 30 1995	43.83	10.13	36
March 9 1997	10.43	4.63	21

West Angle Bay (S.) (wave-sheltered plateau)

Date	Mean Density (limpets per 0.25 m^2)	Standard deviation	No.of quadrats
April 30 1995	9.76	7.39	43
February 28 1997	4.16	2.21	25

Table 4.1 reductions in densities of limpet populations at West Angle Bay. Note: Student t-tests found the differences to be significant at P<0.005.

It must be emphasised that acute effects were extremely patchy. Many shores in the affected area showed few signs of spill-related mortality and no dead limpets were recorded from any areas west and north of St Ann's Head. Previous studies have shown that the mortality rate of oiled limpets can vary enormously, depending

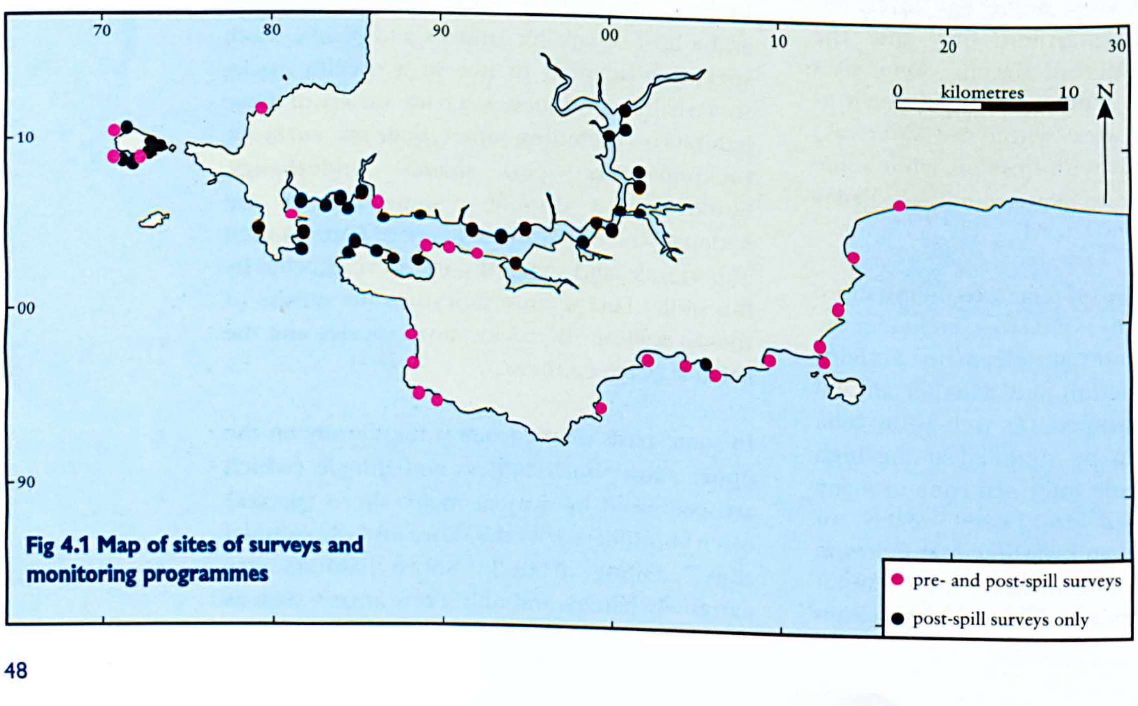


Fig 4.1 Map of sites of surveys and monitoring programmes

on the freshness (and therefore the toxicity) of the oil, the period of direct exposure and the activity state of the limpets at the time of oiling[3]. The *Sea Empress* oil that affected West Angle Bay was more acutely toxic than the relatively weathered oil which affected areas further away (see §2.7.3). However, an empty 'scar' does not necessarily mean that the limpet is dead, but may be a result of it moving away from the oiled rock. Such avoidance was observed at West Angle Bay and Dale where numbers of limpets were seen to increase in some rockpools and on the un-oiled backs of some rocky ridges[4].

While limpets were the most noticeable victims, other herbivorous gastropods were also acutely affected. Dead topshells *(Gibbula umbilicalis* and *Monodonta lineata)* and the periwinkles, *Littorina saxatilis* and *L littorea* were found at heavily oiled sites, though not extensively. Many live topshells were seen apparently feeding amongst mid-shore rocks and boulders that were heavily oiled and then continually exposed to oily sheens for many months. Nevertheless, populations of these creatures were certainly reduced at sites around the entrance to the Haven[2], and this in turn will have had an effect on the abundance of algae. It has been hard to estimate the geographic extent of such impacts due to the difficulty of monitoring densities of mobile gastropods on boulder and shingle shores. Re-surveys of some local populations studied in the mid-1980s[5] are underway.

Oiled limpets
(J Moore, OPRU)

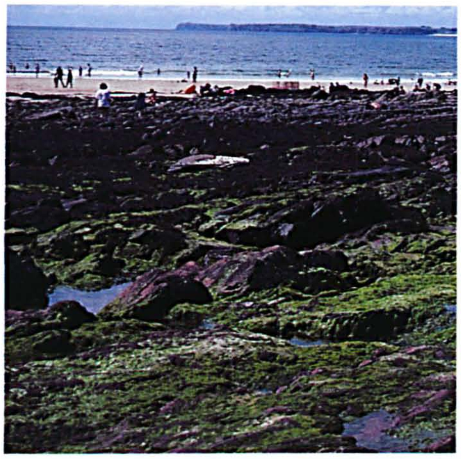
4.3.2 The 'green flush' phase

The reduced grazing by limpets and other snails allowed algae to grow unchecked, with the expected result of a 'green flush' of algae over large areas of lower and mid-shore rock surfaces. It is not unusual for green algae to be found in abundance in areas of freshwater run-off and for the algae to thrive during the spring and early summer (particularly in a cold bright spring followed by a warm wet summer like that of 1996), but their dominance at many sites around South Pembrokeshire was unusual. Some lower shore rocks at West Angle Bay were coated in a dense green 'baize' of the green alga *Enteromorpha* throughout the summer of 1996, except for small halos of grazed rock surrounding the few remaining limpets. In some places this green alga competed for space with lower shore communities of red algae and prevented barnacle larvae from settling on the rocks. The contrast with adjacent areas of rock that still had large numbers of limpets was dramatic.

Dense cover of *Enteromorpha* with a small area grazed by a limpet, West Angle Bay, June 1996 (J Moore, OPRU)

However, it appears that 1996 was a particularly good year for rapid growth of rocky shore algae throughout Pembrokeshire and this was also observed in other areas of the UK. These flushes of growth in 1996 were not confined to ephemeral green algae but included the brown fucoid algae (*Fucus spiralis, F vesiculosus and F serratus*). The significant increases in cover of green and brown algae in 1996 at monitoring sites in Milford Haven waterway[2] were striking and were not correlated with the extent of oiling (although cover of *Enteromorpha* spp and *Ulva* spp was particularly high at Chapel Bay). The spill undoubtedly contributed to the unusual green algal flushes around the entrance to Milford Haven waterway, but it was not possible to relate the impact of the spill outside the Haven to the spatial distribution of green flushes.

Films of ephemeral mixed algae (ie thin layers of transitory single-celled algae of various species) and filamentous brown algae (ie mats of algal filaments a few millimetres long) were also observed in unusually high abundance on rocky shores during the summer of 1996. Samples of algal films collected from four sites during August and September 1996 were dominated by cyanobacteria with some diatoms[6]. Very little is known about these algal films and the processes that occur at the microscopic level. The



Green flush of *Enteromorpha* at Manorbier, summer 1996 (E Bent)

abundance of all ephemeral algae decreased during the winter months and then increased again during the spring of 1997, but less extensively than in 1996, even on the heavily oiled shores.

4.3.3 Colonisation of fucoid algae at West Angle Bay

In September 1996 sporelings of the brown fucoid algae *Fucus vesiculosus* and *F spiralis* settled on the rock surfaces at West Angle Bay, as they do every year. However, without the usual grazing pressure from limpets they sur-vived much better than has been observed previously at this site, and by May 1997 there was an extensive and unusually dense cover of the bladderless form of this fucoid *F vesiculosus v linearis*[7] which can grow on wave–exposed rock faces. This was expected and has been described previously from limpet exclusion experiments and from studies of the effects of oil and toxic cleaning agents in Cornwall following the *Torrey Canyon* spill[8]. The latter studies showed that large areas of shore were dominated by fucoid algae for about five years until the grazing pressure of the increasing limpet population was restored. A similar time scale of fucoid domination is expected for the rocks around West Angle Bay, but the effect has been less obvious elsewhere in the area affected by the spill.

Quadrat in West Angle Bay before the spill (March 1995) and in June 1997 showing the cover of brown fucoid algae. (R Crump, Orielton Field Centre)

4.3.4 Limpet recruitment and growth

Limpets (*Patella spp*) spawn during November and the larvae settle after only a short period in

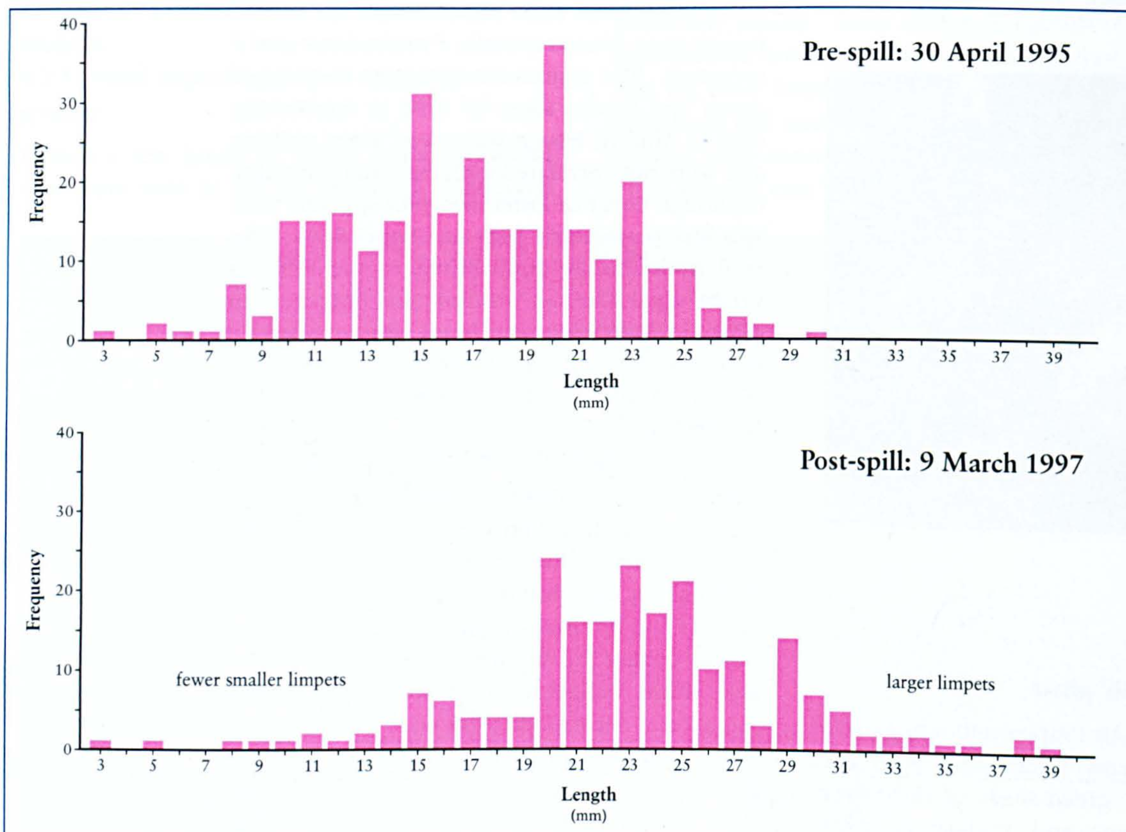


Figure 4.2 Change in the size distribution of limpets at West Angle Bay between April 1995 and March 1997. The pattern of distribution in 1997 has fewer small limpets and several limpets larger than any measured during the earlier sampling.

the plankton. The limpet spat then hide over the winter and emerge during the spring and start growing. Juvenile limpets will therefore have been present on the shore during February 1996 and will have been vulnerable to *Sea Empress* oil. It seems probable that, like the adults, these juveniles are very sensitive to oil, and mortality may have been high. One of the most consistent features of the transect surveys at sites in Milford Haven and at Manorbier was the relatively low densities of juveniles recorded during the summer and autumn of 1996, in comparison with 1995, even at sites which were only lightly oiled[1,2]. At heavily oiled sites there appeared to be almost no recruitment from the winter 1995/96 settlement (ie none of the spat became juveniles), while recruitment at un-oiled sites in the Daugleddau Estuary and outside the spill area in north Pembrokeshire was much greater. Signs of recruitment in 1997, however, were much better, with moderate densities of fast growing juveniles even at West Angle Bay. It is not known whether the oil had any sub-lethal effects on reproductive capacity of the remaining limpets at West Angle Bay, but it is clear that sufficient planktonic larvae were produced by limpets around Pembrokeshire to begin the recovery process.

Growth rates of the remaining limpets at West Angle Bay, as reflected in the change in size distribution, were much higher than in 1995, showing that competition for food was previously limiting (*table 4.2* and *figure 4.2*). Similar results have been shown at a study site near Dale. It is expected that a similar situation to that described[8] after the *Torrey Canyon* spill, where a very large proportion of the limpet population was killed, will occur at these badly affected sites in Pembrokeshire. Following the *Torrey Canyon* there was a rapid recruitment and growth of limpets over a period of 3 to 5 years, followed by a crash in populations which outgrew the available food, and then a period of smaller fluctuations until the balance between grazers and algae was restored. The worst affected sites in Cornwall took 10 to 15 years to return to normal levels of spatial and temporal variability[9]. It is possible that a similar period may be required at West Angle Bay, but other affected areas around Pembrokeshire will recover much more quickly. Populations of limpets in lightly oiled areas are not expected to have undergone any more than short term effects.

Date	Mean length (mm)	Standard deviation	No. of individuals
April 30 1995	17.04	4.98	294
March 9 1997	23.02	5.62	219

Table 4.2 Change in the size distribution of limpets at West Angle Bay between April 1995 and March 1997.

4.4 BLEACHING OF RED ALGAE

4.4.1 Coralline algae

Bleached coralline algae in West Angle Bay, March 1996 (R Crump, Orielton Field Centre)

Most algae appeared to survive the oil spill with little obvious effect on them. This is typically the case after oil spills[10] and is due in part to their protective mucous coating. However, some red algae were affected by the *Sea Empress* oil. Of particular note was the extensive bleaching of pink encrusting coralline algae (mainly *Lithophyllum incrustans* and *Phymatolithon purpureum*) on shores between Manorbier and Skomer[11]. This bleaching was very marked, appearing as a well-defined white band along lower shore and subtidal fringe rocks and surrounding the edges of rockpools. It was first reported in West Angle Bay only six days after oiling and was at its most extensive after five weeks. Anatomical studies showed that some affected plants had a layer of dead cells occupying up to 40% of the thickness of the crust, with live cells below. Other plants temporarily lost pigm-entation. The story is slightly complicated by observations of bleaching in other areas of Wales and the UK, suggesting that the hot weather in summer 1995 or cold weather in winter 1995/96 could have had an effect. However, the observed timing and distribution of severe bleaching, and the anatomical evidence from affected plants, bear out the conclusion that oil was the principal cause of the damage in Pembrokeshire.

Continued monitoring during 1996 and 1997 showed that while some plants of *Lithophyllum* and *Phymotolithon* died completely, most plants shed the dead layers and continued growing. By August 1996 most populations were pink and healthy and very few showed any evidence of the damage caused by the spill.

Similar effects were observed in the coralline alga *Corallina officinalis*, which forms a low turf in rockpools and lower shore areas. The recovery potential of this species was highlighted by results from one upper shore rockpool where the plants were dead in August 1996, but by April 1997 the rockpool sides were covered with healthy small plants.

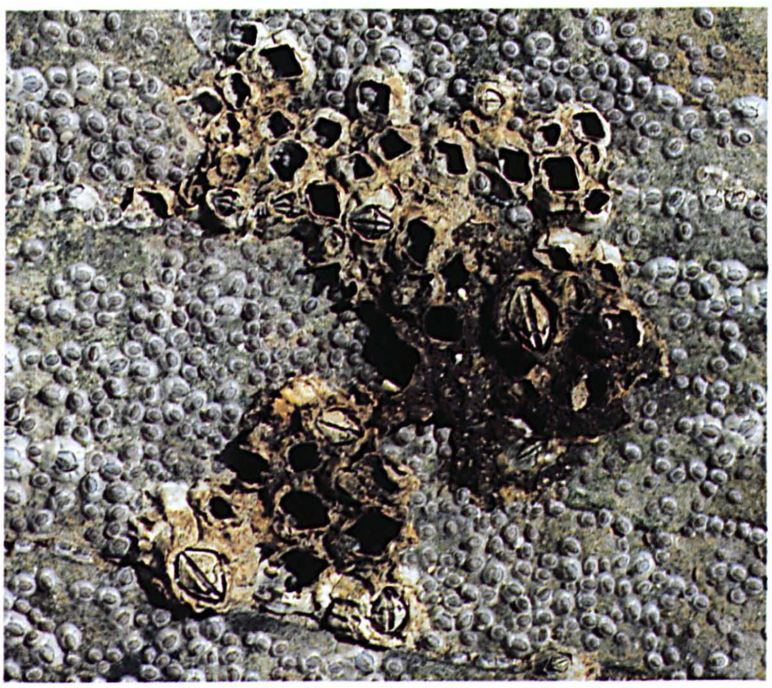
It is worth noting that while oil-induced bleaching of corallines has been observed at spills in the past, this has been the first detailed study of the effect and recovery.

4.4.2 Other red algae

Broad scale monitoring of rocky shore habitats using close-up video at selected oiled sites[7] showed that some species of foliose and filamentous red algae were bleached. These included *Chondrus crispus* and the sand-binding alga *Audouinella* which was extensively bleached in March and April 1996 but which quickly recovered and then had a very good year in 1997. Records for a few of the less common species suggest that pre-spill populations were not present in post-spill surveys at West Angle Bay.

4.5 BARNACLES AND OTHER CONSPICUOUS FAUNA

Large scale mortality of barnacles, particularly *Semibalanus balanoides* and the two species of *Chthamalus*, was reported from around Dale and in a few locations around Tenby, Saundersfoot and Pendine[12]. The mortality varied between sites and was caused by chemical toxicity, large scale physical smothering or a combination of both. However, in most areas the majority of barnacles appeared to survive, with only small patches smothered by thick oil. During May 1996 there was generally a good settlement of *Semibalanus balanoides* spat on shores throughout Pembrokeshire, although recruit-ment of juveniles on some shores around Milford Haven may have been hindered by the presence of dense algae. This was expressed as a slight reduction in adult barnacle densities recorded at a few sites in October 1996, compared with pre-spill records from October 1995[2]. Densities of other barnacles, and of *S. balanoides* at most sites, were otherwise very similar to pre-spill densities.



Oiled barnacles and new spat, June 1996 (J Moore, OPRU)

Oiled sea slater, February 1996 (E Bent)

Comparison of October 1995 and October 1996 abundances for other conspicuous invertebrates (ie invertebrates which are not hidden in crevices or elsewhere) in Milford Haven waterway showed only a very few significant changes that could be related to oil exposure[2]. The conspicuous rocky shore species that were visibly affected by oil immediately after the spill included: many sea slaters (*Ligia oceanica*), which were smothered by oil in some upper shore areas; some dogwhelks (*Nucella lapillus*), which had fallen from rocks at St Catherine's Island; some rockpool blennies (*Blennius pholis*), which were washed up around Tenby[12]. However, sea slaters had a good year in 1996 and large numbers of juveniles were observed at various sites in September.

4.6 CRYPTIC FAUNA

Effects on the many small cryptic (ie "hidden") species of rocky shore fauna which hide in crevices and algal turfs are much harder to detect, but there was evidence of impacts on certain groups. For example, many species of gammarid amphipods (small mobile crustaceans, such as sand hoppers) are known to be sensitive to oil pollution, and dead amphipods were observed under upper shore stones at some oiled sites including Chapel Bay (see also §4.13.1).

Two further studies have also shown that amphipod populations were depleted. In the first, oarweed (*Laminaria digitata*) holdfasts (ie the branching structure where oarweed fastens itself to rock, which typically contains a high diversity of small animals) were collected from 16 sites around Pembrokeshire and north Devon in March 1996[13]. Analysis of the fauna present in these holdfasts showed a strong negative correlation between numbers of species and distance from the spill site (ie there were fewer species near the spill site). Small crustaceans were particularly affected, with an almost complete lack of any amphipods at the badly oiled sites, while large numbers of *Jassa falcata*, *Lembos websteri* and *Aora typica* were present at unaffected sites. Polychaete worms (particularly *Polydora 'ciliata'* and *Fabricia sabella*) and brittlestars were also missing, but molluscs did not show a clear pattern related to the spill. These results suggest that the greatest effects were limited to sites up to 6 kilometres from the spill – ie where the oil was most acutely toxic – but an intermediate zone of effect extended to 15 kilometres. Further studies are underway to follow the recovery process.

A similarly striking loss of amphipods and other cryptic fauna was recorded in a study of fauna living in *Corallina* alga turf in rockpools at West Angle Bay[14]. In this case the comparisons were with control sites in South Devon and some pre-spill observations at West Angle Bay. Analysis of samples taken two months after the spill showed that there were very few mobile crustaceans, worms or molluscs in the West Angle Bay turf and that the brittle star *Amphipholis squamata*, which is normally characteristic of these turfs, was absent. On the other hand, there were unusually high abundances of harpacticoid copepod crustaceans, nematodes and turbellarian worms. Evidence of a fairly rapid recovery could be seen in July and October (four and eight months after the spill), through a process of adult recolonisation (from deeper areas of the pools and the subtidal zone) and the recruitment of juveniles; but the communities were still different from the expected normal situation. However, there was an apparent full recovery by March 1997, demonstrating the opportunistic nature of these species with short life histories and high fecundity. The results of this study also highlight the potential value of algal turf fauna for pollution monitoring. The acute sensitivity of the species to oil, the vulnerability of their habitat near the surface of rockpools and the ease of quantitative sampling make them almost ideal subjects for such monitoring.

4.7 OVERHANGS, UNDER-BOULDER AND ROCKPOOL COMMUNITIES

Lower shore habitats are not often oiled in oil spills and very few previous studies have described notable impacts on the communities found there. The availability in Pembrokeshire of considerable pre-spill information and experienced marine biological surveyors has been used to study some of these communities in much greater detail than has been possible at most other spills. Furthermore, during the first week of the spill the large spring tides did expose lower shore habitats to quantities of fresh crude oil. West Angle Bay was particularly badly affected and many rockpools, overhangs and under-boulder communities of this rocky shore – which is designated as a marine biological SSSI – were smothered in oil during low tide on many consecutive days. The richly colonised overhangs and caves at St Catherine's Island, Tenby, were also badly oiled.

The results of the studies to date do not, however, indicate any serious or long term damage to lower shore or rockpool communities (other than the effects on cryptic fauna described above and *Asterina* below). Typical communities of sponges, hydroids, anemones, bryozoans, ascidians and red algae were still present and apparently healthy in surveys carried out during 1996 and 1997[7,2,15,16,17].

The rockpool study[16] highlighted the profusion of the green alga *Enteromorpha* during the summer of 1996, but by March 1997 communities had returned to a more normal structure, similar to those in March 1996. Observed mortality of macrofauna was limited to some dogwhelks, periwinkles and limpets in a few small upper and mid-shore pools around the Tenby area. However, there was evidence that prawns (*Pandalus* and *Palaemon* spp etc.) and gobies (*Pomatoschistus* spp etc.) in rock pools had decreased in numbers temporarily, as decreased predation on eggs of the cushion starfish and barnacles was observed during 1996[18]. This study has also acted as a pilot study on rockpool monitoring methodologies and has listed a number of guidelines for the establishment of monitoring programmes at future oil spills.

Studies of reproductive development in the lower shore bryozoan *Alcyonidium gelatinosum*[17] have produced some puzzling results that may have been caused by the oil. Release of larvae from colonies at Angle was much later and more protracted (from October 1996 to April 1997) than at the reference site at

Solva in north Pembrokeshire (May to July), suggesting a possible delay in development. However, it seems that this was a temporary effect, as the colonies began to release larvae again in June 1997. Other stages in the life cycle of *Alcyonidium* populations do not appear to have been affected.

4.8 EFFECTS ON UPPER SHORE AND SPLASH ZONE LICHENS

The lichens in the splash zone (ie the area just above where the high tide reaches) on some rocky shores were badly oiled. This was due to the extremely high tides during the first few weeks of the spill and some strong northerly winds that drove oil high into splash zone areas on north-facing shores. The heavy fuel oil on the relatively wave-sheltered north-facing shores of Milford Haven has caused the greatest concern. An almost continuous coating of oil remains on splash zone and intertidal fringe lichen communities along a 10 km stretch of this coast, and this could remain for several years[19,20,21]. Impacts on lichens have also been described at West Angle Bay and at Hopgang Cove on the mainland within the Skomer Marine Nature Reserve[7,22,23]. There are patches of oil on splash zone lichens in many places along the south Pembrokeshire cliffs.

The clearest effects were seen in the lower splash zone. Here the foliose orange lichen *Xanthoria parietina* and the fruticose lichen *Ramalina siliquosa* showed signs of necrosis and bleaching within a few weeks of the spill, and some colonies disappeared over the following winter. The yellow lichens *Caloplaca marina* and *C thallincola* also showed some signs of stress and damage, with damaged fronds visible in many oiled thalli in spring 1997. The bulk of the splash zone lichen communities above the distinct oil tide mark were apparently unaffected. Below the splash zone it is more difficult to see the effects of oil on lichens, particularly on the black *Verrucaria maura* which dominates the intertidal fringe and appears to survive under a thin coating of oil. However, some colonies of *Lichina pygmaea* were bleached or partially bleached by oil, with a subsequent reduction in colony size.

These observations are similar to those described following a large spill in Bantry Bay, south-west Ireland[24]. The long term fate and recovery rate of oiled lichens is uncertain, and longer term monitoring could provide useful information.

4.9 SPECIES OF PARTICULAR CONSERVATION IMPORTANCE

4.9.1 Cushion starfish

Impacts of the oil spill on two pecies of cushion star – the common *Asterina gibbosa* and the rare *A phylactica* – in rockpools on the north side of West Angle Bay have generated considerable interest. The populations in these pools have been well studied[25] and the initial description of A phylactica as a new species was from specimens collected there[26]. The site is also one of only a few places where the species is known to occur in the UK, although recent interest has resulted in the discovery of some subtidal populations in north and south Wales. The population is therefore of scientific and conservation importance.

Cushion starfish *Asterina phylactica* (the small, darker-coloured starfish) and *A gibbosa* (S Schott)

The pools were heavily oiled with fresh crude oil on the first day of the spill and on subsequent occasions and, although the area was targeted for intensive clean-up effort, they remained contaminated to some extent for many weeks. The first two post-spill surveys, in late April and early June, found that the populations of starfish had been severely affected although the larger individuals of *A gibbosa* were still relatively abundant and apparently healthy[18]. Of greatest concern was the reduction of the *A phylactica* population from a pre-spill population of over 150 individuals to a post-spill total of only 13 individuals widely spaced over the area. *Asterina* do not have a planktonic larval stage and so it was expected that recovery of such a small population would take many years.

Follow-up surveys and observations over the next 12 months showed a rapid recovery of the *A gibbosa* population, with size frequency distributions very similar to those from the same months in the 1970s surveys. It is possible that the recruitment of juveniles benefited from the effects of the oil on the shrimp *Palaemon elegans*, a known predator of *Asterina* egg masses. Circumstantial evidence (see §4.7) suggested that these shrimps were missing during much of 1996, but have since returned.

Recovery of the *A phylactica* population was slower and much less certain. However, some egg masses were laid and successfully hatched during June 1997, showing that there was still some reproductive capacity in the population. There was also some evidence that the species may be capable of self-fertilisation which could compensate for the difficulty of cross-fertilisation when the population was so sparsely distributed.

4.9.2 *Paludinella littorina*

Another rare species for which there was some concern was the mollusc *Paludinella littorina* (classified as "vulnerable" in the Red Data Book and specifically protected by law). However, re--surveys in March 1997 of the only two known sites for this species in Wales - in upper shore caves in south Pembrokeshire - found the populations were apparently unaffected by the spill[27] .

Sediment Shores

4.10 Introduction

Sediment shores (*ie* those composed of sand or mud) are less common than rocky shores around the Pembrokeshire coast, making up less than a quarter of the coastline affected by the oil spill[28]. The most familiar are the sandy amenity beaches, but sediment types range from coarse sand and gravel on open, exposed shores, through finer sands in Carmarthen Bay, to mud in sheltered embayments and tributaries of the Daugleddau Estuary and Milford Haven waterway.

Coarse sand beaches support a range of a few hardy species, but the muddier shores and those with a mixture of sediment sizes are immensely productive biologically and form an important part of the marine ecosystem (*Box 4.1*). These are particularly important as fish nurseries and feeding areas for migrant birds. In sheltered bays and estuaries the strandline - the line along the upper shore where natural and man-made debris is deposited by the high tide - supports both marine and land invertebrates which feed on decomposing organic matter, and in turn these are an important food resource at certain times of the year for birds.

The impact of oil on sediment communities is determined both by the amount of oil and by the

Box 4.1 THE BIOLOGY OF SEDIMENT SHORES

Sediment shore communities can be complex and varied, often containing a vast number of different species. Many organisms have very specific requirements for food and habitat, and this largely determines which species are found in a particular area.

Micro-organisms (microflora and fauna) such as algae, bacteria, fungi and protozoans form the basis of the marine food web. The most numerous algae are the diatoms which occur in surface sediments.

Meiofauna are the many different types of animals smaller than 0.5mm which feed on the micro-organism communities. The most abundant are nematode worms and the smaller species of copepods. The **nematodes** occur most frequently in fine sediments and feed mainly on bacteria or algae. **Copepods** are crustaceans which eat algae, bacteria and detritus, and many are the prey for juvenile fish. They are found with a variety of body shapes which reflect the particular demands of the environment in which they live.

Macrofauna are animals larger than 0.5mm, and include species of molluscs, crustaceans and polychaete worms ("bristleworms"). They are a major source of food for birds and fish. The **molluscs** are generally bivalves such as cockles and razor shells. These live burrowed into the sediment, feeding and respiring through fleshy siphons. A wide variety of macrofaunal **crustaceans** can be found, ranging from small amphipods (such as sandhoppers (see §4.13.1)) to crabs. All are mobile, feeding and sheltering in the surface layers of sediment. Some crustaceans brood their eggs and young which are then released directly into the sediment close to the adults. Others release their eggs into the plankton. This is significant for the rate of recovery of populations affected by an oil spill. There are a great many species of **polychaete** worms of varying size and lifestyle.

duration of exposure, which in turn largely depends on the type of sediment. Oil penetrates readily into coarse grained sediments, but there it is also relitively amenable to being flushed out or relocated by water movement. Higher hydrocarbon levels are usually found in sediments with a high proportion of fine material as the hydrocarbon molecules become associated with the organic layer surrounding the sediment particles. The hydrocarbons are less likely to be flushed out of the finemuds where oxygen cannot reach. Sedentary species in these fine sediments are therefore at the greatest risk of long exposure to raised levels of hydrocarbons. The working of sediments by deposit feeding animals (such as many worms) is important as it leads to aeration and an increase in the populations of micro-organisms, particularly bacteria, which can metabolise the oil residues, breaking them down. These micro-organisms then provide an additional food supply for other species.

As well as these differences in exposure to oil related to sediment type, there was considerable variability in the amount of oil impacting a shore, its toxicity and the length of time it remained there (see §4.1), as well as in the concentration of oil in the water covering the intertidal areas during each tide. This highly variable exposure to oil across a spectrum of sediment types and communities was expected to result in a wide range of impacts.

The most obvious effects of the spill were the large numbers of dead and moribund animals which were washed onto beaches in the weeks following the spill. Whilst many of these may have come from intertidal areas, most probably came from the extensive shallow sand areas below low water level and so these strandings have been described in §3.5.1.

As well as recording these strandings, studies were carried out to investigate further effects on the different sediment shore communities. In order to allow proper comparison with data collected before the spill, many of these studies were confined to particular beaches and times of year, and so there was only partial overlap between the studies in the sites and timing of surveys. Details of the studies and the sites are shown in *Box 4.2* and *figure 4.3*.

4.11 MICROFLORA

The direct toxic effect of oil pollution on beach microflora is largely unknown. However, pollution may result in the increased abundance of those organisms which are able to metabolise some oil components. Diatom populations were described as flourishing at the most contaminated sites six months after the spill[6] with the highest densities recorded at West Angle, the most heavily oiled of the sites sampled. Effects varied according to the species. Species known to be tolerant of oil pollution

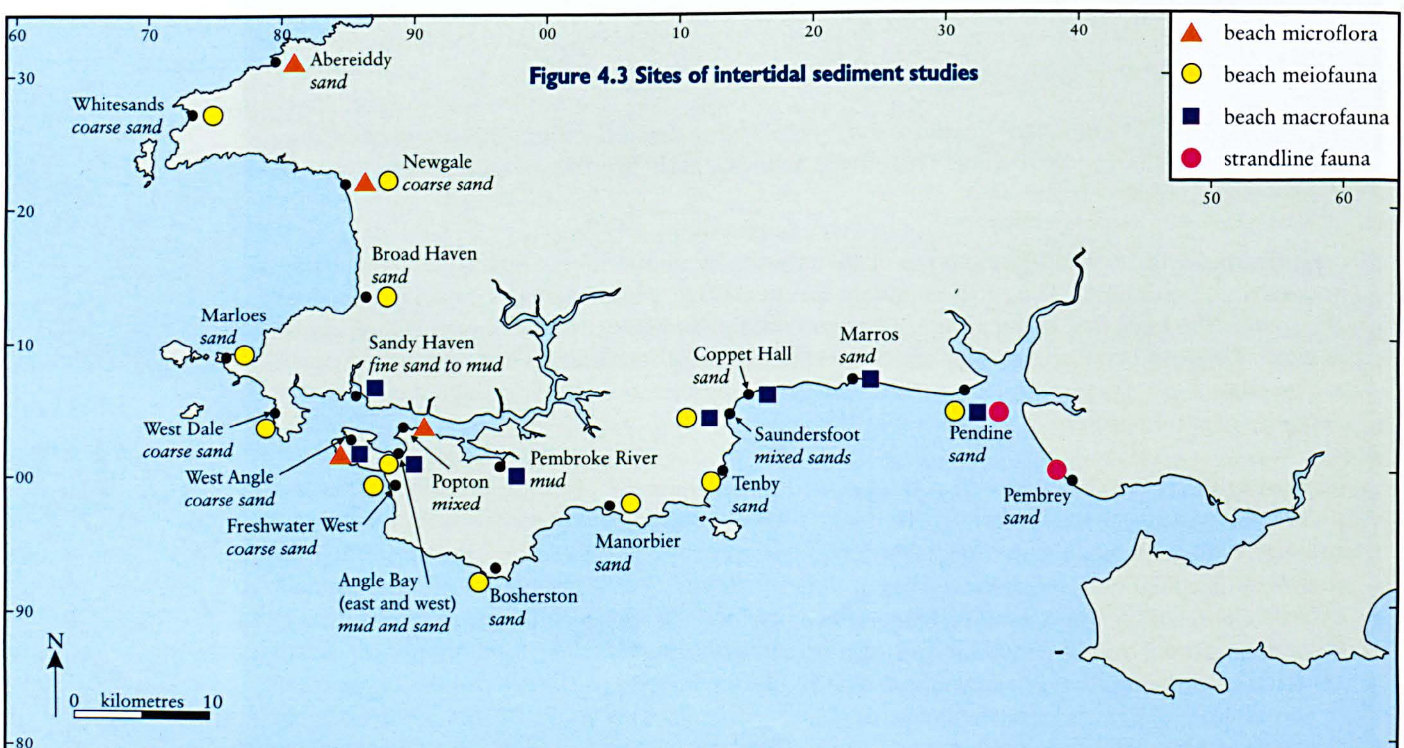


Figure 4.3 Sites of intertidal sediment studies

appeared unaffected, whilst two of the most common types, *Navicula* and *Nitzchia*, increased in abundance during the summer of 1996.

4.12 MEIOFAUNA

No convincing evidence was found for any short to medium term impact on meiofauna.

Whilst there were increases in abundance of nematode worms and ostracods (a group of small crustaceans) at the heavily oiled sites, similar increases also occurred at reference sites and therefore could not be attributed to oil. Some species of copepods were impacted at previous oil spills, but no reduction in abundance of these species was observed at the sites studied, nor was there any overall trend in copepod abundance with time.

As with abundance, there was an increase in diversity of some nematode and copepod groups but again this increase was not restricted to oiled beaches.

Box 4.2: INTERTIDAL SEDIMENT STUDIES

Beach microflora: Four beaches, including a control site, were visited on two occasions each during August and September 1996. Single samples were collected from each site[6].

Beach meiofauna: Meiofauna was collected from 12 sites during November 1996. Sites were chosen from those sampled during a survey in November 1994. Each beach was sampled at one station midway between mid-tide level and mean low water neaps[29].

Beach macrofauna: Macrofaunal samples were obtained from up to 9 shore sites on eight occasions at intervals over the period between November 1994 and August 1997. At each site, 4 to 6 stations, depending on the width of the beach, were established on a transect between low and high water. At each station 4 replicate core samples were taken[30].

Strandline fauna: Eight replicate samples of strandline fauna were collected from two extensive sites, Pendine and Pembrey, in November 1996. The Pembrey sites had previously been studied in 1994[31].

Whilst meiofauna did not change dramatically as a result of the pollution, previous studies have shown long term effects in harpacticoid copepods, including interference with normal reproductive cycles[32]. There may therefore be long term effects on these communities.

Table 4.3 Summary of changes in numbers of sediment shore macrofauna thought to be related to the spill *– see ∫4.13.1 to 4.13.2*

Species	Type of organism	Disappeared	Decreased in numbers	Increased in numbers	Appeared	Subsequent reappearance/ increase	Subsequent decrease/ disappearance
Ampelisca brevicornis	Sedentary amphipod	✔					
Haustorius arenarius	Mobile amphipod	✔				✔	
Bathyporeia spp	Mobile amphipod		✔			✔	
Gammarus salinus	Small, mobile crusacean	✔				✔	
Pseudocuma longicornis	Small, mobile crustacean	✔				✔	
Urothoe poseidonis	Small, mobile crustacean	✔				✔	
Gammarus spp	Highly mobile, pollution tolerant crustaceans				✔	✔	
Nephtys hombergii	Polychaete worm		✔			✔	
Capitella spp	Opportunistic polychaete			✔			✔
Chaetozone gibber	Opportunistic polychaete			✔			✔
Psammodrilus balanoglossoides	Opportunistic polychaete				✔		✔
Cerastoderma edule	Bivalve mollusc		✔			✔	
Hydrobia ulvae	Estuarine, gastropod mollusc		✔				✔

4.13 MACROFAUNA

The abundance and distribution of many species of macrofauna was found to have changed since a similar survey in 1994[33]. Some changes were consistent with the effects of oil pollution: these included a reduction in numbers of some species and the disappearance of others, along with some increases in abundance of opportunist species, more tolerant of pollution (see *figure 4.3*, previous page).

These opportunist species were able to take advantage of reduced competition (eg for food) from the more sensitive species that were adversely affected by the oil. Some of the differences observed, however, resulted from independent factors such as natural changes in sediment structure where estuarine channels had moved or saltmarsh had regressed, while others were due to normal fluctuations or to seasonal change.

4.13.1 Crustaceans

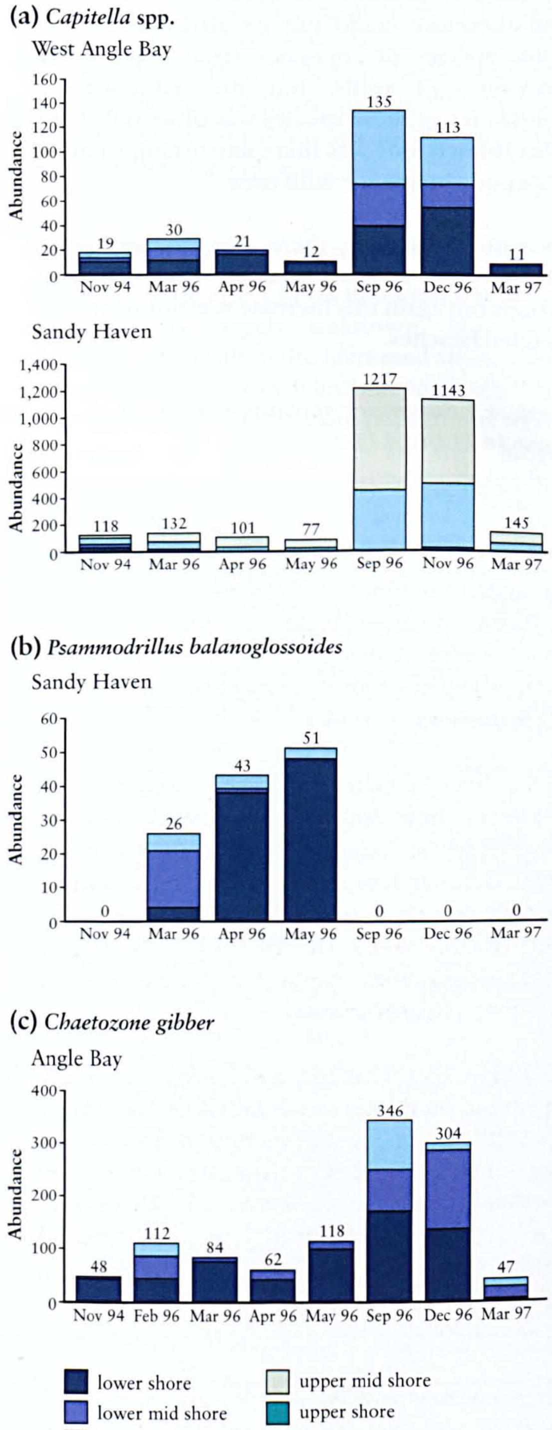
The greatest decrease observed was of small crustaceans, especially amphipods, which have been shown to be vulnerable to oil pollution in previous studies (see §4.15). It appears that the mobility of the adults is significant in determining the rate at which these populations will recover. The sedentary amphipod *Ampelisca brevicornis* was recorded from lower shore sites in Angle Bay in November 1994, but it has been absent from samples collected at this site since the spill.

Amphipod *Ampilesca brevicornis* (D Rostron SubSea Survey)

Numbers of mobile amphipods also decreased immediately after the spill, for example, *Bathyporeia* spp decreased in abundance at both Angle Bay and on the sandy beaches of Carmarthen Bay and *Haustorius arenarius* disappeared from Sandy Haven, Marros and Coppet Hall. However, these species were recovering at these sites in late autumn 1996.

Several other species of small, mobile crustaceans (*Gammarus salinus* and *Pseudocuma longicornis* at Sandy Haven and *Urothoe poseidonis* at Marros) were absent from samples collected immediately following the spill, but began to reappear in samples collected in May and September 1996. Generally the

Figure 4.4 Histograms showing the change in abundance of polychaete worms.



earliest reappearances of these crustaceans were recorded at the least contaminated sites.

4.13.2 Polychaetes

Many polychaete worms seemed to be little influenced by the oil and most populations remained generally unchanged throughout the period of study. Populations of a few species (eg *Nephtys hombergii* on the upper shore of Angle Bay) decreased for a short time after the spill but soon recovered. More common were increases in numbers or the appearance of opportunist species.

Capitella spp, present in small numbers prior to the spill, showed a large increase in abundance during the summer of 1996 at West Angle and Sandy Haven (*figure 4.4a*) and the population of *Chaetozone gibber*, present in low numbers at Angle Bay in 1994 and early 1996, increased dramatically during the summer of 1996 (*figure 4.4b*).

The small polychaete *Psammodrilus balanoglossoides*, which feeds on microflora, was observed for the first time in samples collected from Sandy Haven during the months immediately following the spill (*figure 4.4c*).

4.13.3 Molluscs

Molluscs also appear to have been impacted to different degrees. Many of the strandings (see §3.5.1) involved bivalve molluscs, particularly razor shells (*Ensis spp*) and cockles (*Cerastoderma edule*).

Razor shells burrow deeply in fine sediment on the lower shore and shallow subtidal areas and were widely stranded in Carmarthen Bay and at Dale. Those at Dale beach were seen emerging from the low shore intertidal sediments after the spill. Razor shells are known to be highly sensitive to even slightly elevated concentrations of hydrocarbons.

In Angle Bay, cockles were recorded lying moribund on the surface immediately following the spill, particularly on the upper shore where most of the oil had been stranded. There were no adults in samples collected from this site in April 1996 and numbers of juveniles decreased during the year, except in the mid-shore area which had been exposed to less oil than the upper shore.

Other species showed little or no change. For example, numbers of the bivalve *Angulus tenuis* remained generally unchanged at Marros and Coppet Hall in Carmarthen Bay, throughout the sampling period.

4.14 STRANDLINE FAUNA

Amphipods are a relatively constant component of the strandline fauna, occurring throughout the year over a wide geographical range. They are thought to be a good indicator of effects on the strandline.

Strandline amphipods were found to be less abundant at Pendine, where oil persisted in the fine sediments at least until November 1996, than at Pembrey which had less exposure to oil.

4.15 CONCLUSIONS

The studies on rocky shores have shown impacts on several species, particularly in the heavily oiled areas immediately after the spill. In many instances there have been encouraging signs of recovery, but monitoring of the recovery process will need to be carried out over several years at selected sites in Milford Haven waterway, West Angle Bay and Manorbier, and the populations of the cushion starfish *Asterina phylactica* in rockpools at West Angle Bay should continue to be monitored. Photographic monitoring of oiled and pressure-washed upper shore lichens at Sawdern Point and West Angle Bay boat pool would provide very valuable information on the fate and recovery rates of these slow-growing organisms.

The work carried out on rocky shores also highlighted issues about which it would be valuable to learn more for future studies. Very little is known of the microalgal processes on contaminated rock surfaces after an oil spill. Further studies of these processes could help to elucidate the role of microalgae in natural clean-up and recovery. The development of methods for describing algal turf fauna could provide a useful monitoring technique, and the sensitivity of some of these fauna (such as amphipods) to different oil fractions should also be tested. In addition, future attempts to monitor the effects of oil spills on rockpool communities could make use of the valuable data and experiences gained during the SEEEC rockpool study.

The initial direct effects on sediment macrofauna, including mass mortalities and strandings and the disturbance of amphipod and polychaete populations, were very similar to those observed at previous oil spills, particularly the *Amoco Cadiz*[34,35]. The initial impact on species was extremely selective. Amphipods were observed to have been very sensitive to the oil, along with other small crustaceans, certain bivalves such as razor shells and cockles, and echinoderms such as heart urchins (see *∫3.8*). These toxic effects probably resulted from elevated concentrations of hydrocarbons dispersed in the water column which would have had an immediate effect upon animals which depend on continual water exchange for feeding or respiration. Following the initial changes, opportunist species such as some polychaete worms increased in abundance. However, by late autumn 1996 there were signs of a recovery in several of the crustacean species, and the abundance of the opportunist species decreased.

Difficulties were experienced in attempting to link fluctuations in the populations of sediment shores species with any chemical data on the concentrations of oil-derived hydrocarbons. Making such a link is, in any case, likely to prove exceedingly difficult because it is almost impossible to distinguish between natural fluctuations in populations and changes induced by unnatural factors such as oil contamination.

REFERENCES

1. Crump, R., Morley, H. and Williams, A., 1997. *Intertidal Monitoring in Permanent Quadrats established at WestAngle Bay and Manorbier; Pre and Post 'Sea Empress' oil spill 1996 - 1997.* A report to the Countryside Council for Wales from the Field Studies Council, Orielton Field Centre, Pembroke, UK. 13pp plus figs, tables, plates and appendices.
2. Moore, J.J., 1997. *Rocky shore transect monitoring in Milford Haven, October 1996. Impacts of the Sea Empress oil spill.* A report to the Countryside Council for Wales from OPRU, Neyland, Pembrokeshire, UK.
3. Dicks, B., 1973. Some effects of Kuwait crude oil on thelimpet, *Patella vulgata*, *Environmental Pollution*, 5, 219-229
4. Morrell, S., 1997. *Sea Empress Rocky Shore Assessment/Monitoring: Dale Fort Field Centre Permanent Transects.* A report to the Countryside Council for Wales from the Field Studies Council, Dale Fort Field Centre, Pembrokeshire, UK.
5. Little, A.E., Dicks, B. and Crothers, J.H., 1986. Studies of barnacles, limpets and topshells in Milford Haven. Field Studies, v6, pp459-492.
6. Shubert, L.E., 1997. *Benthic / subaerial algae associated with oil contaminated coastal habitats in Wales.* Final report to the Countryside Council for Wales from the Natural History Museum, London. 14 pp, plus figures, tables and appendices.
7. Bunker, F.S.P.D., 1997. *Biotope studies on selected rockyshores of South Pembrokeshire following the Sea Empress oil spill.* A report to the Countryside Council for Wales from Marine Seen, Pembroke.
8. Southward, A.J. and Southward, E.C., 1978. Recolonisation of rocky shores in Cornwall after use of toxic dispersants to clean up the *Torrey Canyon* spill. *Journal of the Fisheries Research Board of Canada,* 35(5), 682-706
9. Hawkins, S.J. and Southward, A.J., 1992. Chapter 13. The *Torrey Canyon* oil spill: Recovery of rocky shore communities. In: Thayer, G.W. (ed.) *Restoring the Nations Marine Environment.* A Marylands Sea Grant Book, College Park, Maryland, USA. 583 619.*Research Board of Canada,* 35(5), 682-706
10. Baker, JM; Crothers, JH; Little, DI; OldhamJH & Wilson,CM (1984*Comparison of the fate and ecological effects of dispersed and non-dispersed oil in a variety of ntertidal habitats.* In: AllenT.E. (ed.). Oil Spill ChemicalDispersants: Research, Experience, Recommendations. ASTM STP 840.Philadelphia, PA. 239-279.
11. Chamberlain, Y.M., 1997. *Investigation of the condition of crustose coralline red algae in Pembrokeshire after the Sea Empress disaster 15-21 February 1996.* A report to the Countryside Council for Wales. May 1997.
12. Dyrynda, P., 1996. *An Appraisal of the Early Impacts of the 'Sea Empress' Oil Spill on Shore Ecology within South-West Wales.* Final Report, September 1996, to The Wildlife Trusts and World Wide Fund for Nature fromthe School of Biological Sciences, University of WalesSwansea.
13. Rowden, A.A., Attrill, M.J., Davey, J.T., Kendall, M.A., Widdicombe, S. and Warwick, R.N., in prep. *Impact of the Sea Empress oil spill on macro-invertebrate communities of kelp holdfasts.* [University of Plymouth and Plymouth Marine Laboratory].
14. Emson, R.H. and Crump, R.G., 1997. *Effects of the Sea Empress Oil Spill on Seaweed Animals of the West Angle Tide Pools.* A report to the Countryside Council for Wales from Kings College, London and Orielton Field Centre, Pembroke. 3pp.
15. Munro, C., 1996. *Lundy Intertidal Survey, 11th – 15th March 1996.* A report to English Nature from Marine Biological Surveys, Coombe Barton, Devon, UK. 19pp plus maps.
16. Rostron, D.M., 1997. *Impact of the Sea Empress Spill on Coastal Ecosystems: Intertidal Studies. Rockpool Monitoring.* A report to the Countryside Council for Wales from SubSea Survey, Pembroke. 21pp plus appendices and plates.
17. Ryland, J. and de Putron, S., 1997. *An appraisal of the effects of the Sea Empress oil spillage on sensitive sessile marine invertebrate communities.* A report to the Countryside Council for Wales from the School of Biological Sciences, University of Swansea, Wales, UK.
18. Crump, R.G. and Emson, R.H., 1997. *Observations on the effects of oil pollution on tidepool seastars.* A report to the Countryside Council for Wales from the Field Studies Council, Orielton Field Centre, Pembroke and Kings College, London.
19. Crump, R.G. and Moore, J.J., 1997. *Monitoring of upper intertidal lichens at Sawdern Point.* A report to the Countryside Council for Wales from the Field Studies Council, Orielton Field Centre, Pembroke and OPRU, Neyland, UK. 4pp.
20. Moore, J.J., 1996. *Rocky shore transect monitoring in Milford Haven, October 1995.* A report to the Milford Haven Waterway Environmental Steering Group from OPRU, Neyland, Pembrokeshire, UK.
21. IPIECA *Biological impact of oil polution: Rocky shores* Report No7 International Petroleum Industry Environmental Conservation Association, London.
22. Crump, R.G., 1996. *Rocky shore transect monitoring in the Skomer Marine Nature Reserve.* A report to the Countryside Council for Wales from the Field Studies Council, Orielton Field Centre, Pembroke, UK
23 Crump, R.G., 1997 *Lichen monitoring at West Angle Bay.* A report to the Countryside Council for Wales from the Field Studies Council, Orielton Field Centre, Pembroke, UK. 6pp.
24. Cullinane, J.P., McCarthy, P. and Fletcher, A. (1975) The effect of oil pollution in Bantry Bay. *Marine Pollution Bulletin,* 6, 173-176.
25. Crump, R.G. and Emson, R.H., 1983. The natural history,life history and ecology of the two British species of *Asterina. Field Studies,* 5, 867-882.
26. Emson, R.H. and Crump, R.G., 1979. Description of a new species of Asterina (Asteroidea) with an account of its ecology. *Journal of the Marine Biological Association of the United Kingdom,* 59, 77-94.
27. Light, J.M. and Killeen, I., 1997. *Assessment of the Impact of the Sea Empress Oil Spill on the Prosobranch Mollusc* Paludinella littorina. A report to the Countryside Council for Wales from Malacological Services. 25pp.
28. Little, D.I., Rhind, P., Jones, R., Bennett, I. and Moore, J. 1997. CCW's shoreline oil distribution surveys following the *Sea Empress* spill. In: Proceedings of the 1997 International Oil Spill Conference. American Petroleum Institute, Washington DC 1036-1038.
29. Moore, C.G. and Harries, D.B. 1997. The impact of the *Sea Empress* oil spill on the sandy shore meiofauna of south west Wales. Heriot-Watt University,Edinburgh.
30. Rostron, D. M. (in prep) *Sea Empress sediment shore impact assessment/monitoring: Infauna of heavily oiled shores in Milford Haven and Carmarthen Bay.* SubSea Survey, Pembroke.
31. Shackley, S. & Llewellyn, P.J. 1997 Sediment shore impact assessment/monitoring - strandline fauna. Report to CCW. 43pp.
32. Bodin, P. 1991. Perturbations in the reproductive cycle of some harpacticoid copepod species further to the *Amoco Cadiz* oil spill. Hydrobiologia 209, 245–257.
33. Rostron, D.M. 1995. The macrobenthos of the foreshore soft sediments of Milford Haven, 1994. A report to the Milford Haven Waterway Environmental Monitoring Steering Group.
34. Chasse, C. and Morvan, D. 1978. Six mois apres la maree noire de lAmoco Cadiz, bilan proisoire de l'impact ecologique. *Extrait de Penn ar Bed,* 11 (93), 311–340.
35. Dauvin, J. C. 1982. Impact of *Amoco Cadiz* oil spill on the muddy fine sand Abra alba and *Melinna palmata* community from the Bay of Morlaix. Estuarine, *Coastal and Shelf Science* 14, 517–531.

5 Maritime Vegetation & Agriculture

5.1 INTRODUCTION

This chapter describes monitoring work carried out to assess whether vegetation around the coast had been affected by the oil, and whether the oil posed any risk for the agricultural food chain.

Various types of maritime vegetation came into contact with oil from the *Sea Empress* or were affected by clean–up operations. Plant communities potentially at risk included the sea--cliff vegetation which characterises much of the exposed rocky coastline of Pembrokeshire. In less rocky areas, especially in Carmarthen Bay, sand dunes predominate, but it was the saltmarshes of the middle and lower sections of Milford Haven waterway that were in direct contact with oil for longest. Shingle vegetation and coastal lagoons are uncommon on the coast affected by the spill.

The many rare flowering plants of south–west Wales are concentrated on the major coastal limestone headlands and within the larger calcareous dune systems. Of the non–flowering terrestrial plants, the lichens of the extensive sea–cliffs are outstanding, especially where the cliffs are calcareous. Impacts of oil on lichens of the splash zone are dealt with in §4.8.

5.2 Exposure to oil above the high water mark

Unlike vegetation below the high water mark (such as saltmarsh) plants above the splash zone did not normally come into direct contact with liquid oil. The only exceptions were where minor spillages of oil, or contact with oiled material, occurred along access routes or on storage areas adjacent to beach cleaning activities (see §10.8). Because a high percentage of oil from the *Sea Empress* was lost by evaporation, maritime vegetation was exposed to vapour as well as aerosols of hydrocarbons. This section explores the evidence for contamination of vegetation by aerosols above the high water mark. There were eyewitness accounts of oil being deposited as an aerosol on sea–cliff vegetation as a result of strong onshore winds at Skrinkle Haven on 13 March 1996 and on the coast between Manorbier and Freshwater East in early March and also at Bullslaughter Bay, Castlemartin on 18 April. Maritime vegetation was therefore exposed to varying levels of hydrocarbon aerosols between February and April 1996, with the greatest geographical extent of contamination probably occurring in early March at a time when many plants were dormant.

On 24 and 25 February 1996 the Welsh Office Agriculture Department sampled grasses at coastal and inland sites from St David's Peninsula to Freshwater East. With only two exceptions, all 18 coastal sites – from the south side of St Brides Bay to Freshwater East – had considerably elevated levels of polycyclic aromatic hydrocarbons (PAHs) compared with five inland sites (*figure 5.1*). Five coastal sites on the Dale Peninsula were sampled again after 10 days and the levels of PAHs had generally fallen (on average by 40%) but all the PAH levels were still elevated above background.

The grasses sampled came mainly from sea–cliff vegetation near to the coast path, and several samples were within Sites of Special Scientific Interest (SSSI) notified for their high quality sea--cliff vegetation which includes many rare plant species. The highest PAH levels (more than 3,500 µg/kg wet weight) were found at the Castlemartin Cliffs and Dunes SSSI which is of international importance for its sea–cliff vegetation. To confirm there were no residual problems, the sites were re–sampled in May 1997, although a direct comparison with the February 1996 data is not possible (due to the increased speed of growth of grasses in May, which markedly affects the measured concentration of PAHs). In all samples the PAH levels were low, ranging from 9.5 to 45 µg/kg with no discernible pattern of distribution.

Samples of the grass red fescue (*Festuca rubra*) were sampled at four sites in March 1996. Total PAH was elevated in the samples from Manorbier and St Ann's Head compared with a reference site, with the highest concentrations at St Ann's Head (2,200 µg/kg wet weight – mean of three samples) compared with 1,700 µg/kg at Manorbier and 1,300 µg/kg at the reference site. Samples of the flowering plant, thrift (*Armeria maritima*) were taken at Manorbier and St Ann's Head, and again the highest PAHs were measured in the St Ann's Head samples (680 µg/kg compared with 350 µg/kg at Manorbier).

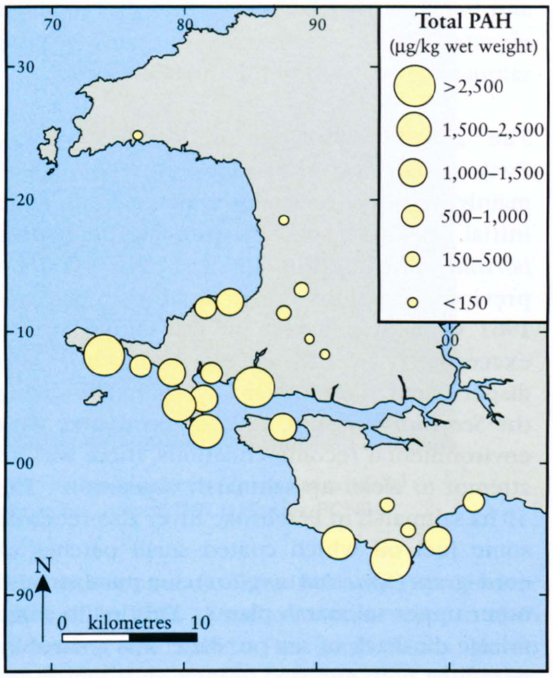


Figure 5.1 Map showing polycyclic aromatic hydrocarbon levels in grass samples from west and south Pembrokeshire, 24/25 February 1996.

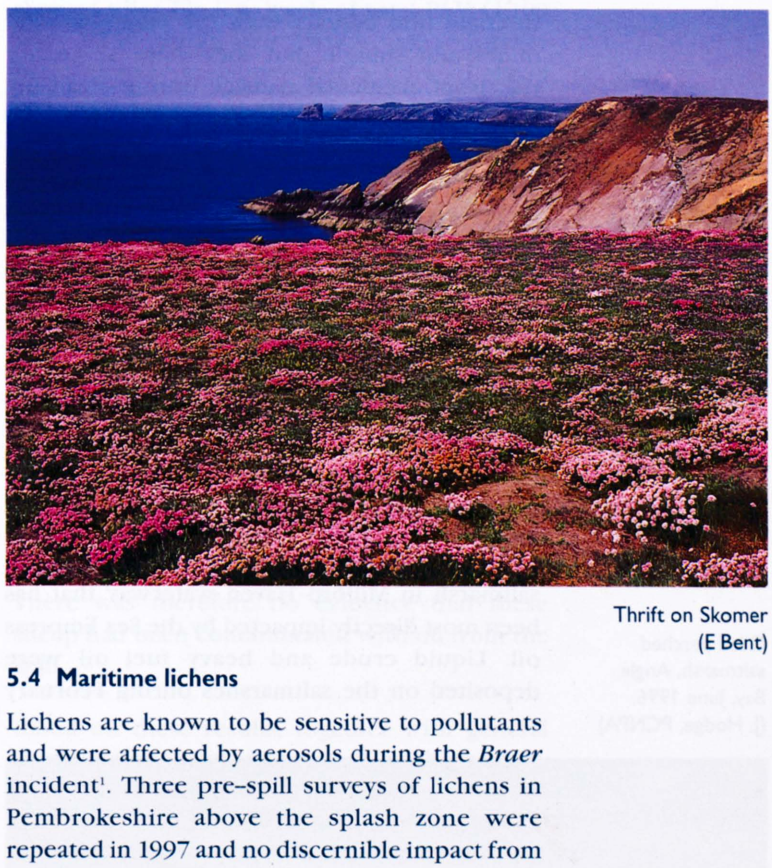
It seems possible, as was suggested for the *Braer* oil spill[1], that heavy rain would have washed off much of the fine coating of PAHs from the vegetation onto the soil surface; there, the PAHs would be less available to plants because of this low transfer rate between soil and roots.

5.3 Cliff-top vegetation

Because of exposure to aerosols and vapour from the *Sea Empress,* selected populations of rare flowering plants of the Pembrokeshire coast were surveyed in 1996 and 1997[2], targeting plants for which pre-spill data existed and which grew on exposed seaward edges of sea-cliffs where the highest levels of hydrocarbons were most likely.

No impact on rare plants of sea-cliffs was detected, but any minor short-term damage might have been missed. The nationally rare small restharrow (*Ononis reclinata*) illustrates some of the difficulties of the impact assessment. The failure to locate some of the Pembrokeshire populations of this rare annual in 1997 might suggest that it had been damaged, but it is well-known for its population size fluctuations. Furthermore, one of the three stands relocated in 1996 and 1997 was flourishing close to the location of a grass sample which had a PAH reading of 1,200 µg/kg wet wt on 24 February 1996. The lack of any measurable impact on rare plants was in part due to the tendency of the most rare plants to cluster on the exposed cliff-tops of major headlands where, although vulnerable to aerosols and vapour, they would not be exposed to direct contact with liquid oil.

In inlets adjacent to some of the major headlands, quantities of bulk oil were trapped against cliffs and oil reached into the crevice zone. Within the shelter of Milford Haven waterway, where flowering plants grow near high water mark on the low sea-cliffs, oil was also deposited in the crevice zone. Here, in a few locations, isolated specimens of common plants such as thrift (*Armeria maritima*) and red fescue (*Festuca rubra*) were killed by heavy fuel oil, but many severely impacted common plants had regrown from their roots by Autumn 1996.



Thrift on Skomer (E Bent)

5.4 Maritime lichens

Lichens are known to be sensitive to pollutants and were affected by aerosols during the *Braer* incident[1]. Three pre-spill surveys of lichens in Pembrokeshire above the splash zone were repeated in 1997 and no discernible impact from *Sea Empress* aerosols or vapour could be detected. Similarly, at Stackpole National Nature Reserve (NNR), qualitative and some quantitative work in February 1997[3], following on from a 1994 study, showed that the internationally-important terrestrial lichen communities were normal in appearance with no unusual extent of discoloration or death. On Skomer Island NNR, 40 lichen quadrats previously recorded in 1991 and 1994 were resurveyed in April 1997[4]. The quadrats covered the nationally-important lichen communities and showed no evidence of damage attributable to oil pollution.

Repeat surveys of four of the six Pembrokeshire coastal sites for the specially protected rare golden-hair lichen (*Teloschistes flavicans*) in 1996 and 1997 have also shown no impact[4,5].

In addition, one of the most exposed Pembrokeshire populations of the rare lichen, *Fulgensia fulgens*, on the very edge of the limestone sea-cliff at Castlemartin, appeared to be stable and healthy in June 1997. There were, however, impacts on lichens of the splash zone as a result of direct contact with liquid oil (see §4.8), but no rare lichen communities are thought to have been affected.

5.5 Sand dune and shingle vegetation

Liquid oil did not reach far enough up the shore to come into contact with the plants in sand dunes and shingle, but they were at greater risk from accidental damage during clean-up, especially from beach access routes. However, re-surveys in 1996 and 1997[2] of some of the many rare flowering plants found on the sand dunes of Pembrokeshire showed no changes that could have been the result of *Sea Empress* aerosols, vapour or clean-up activities. The small area of vegetated shingle at Pickleridge, Dale, experienced some disturbance from clean-up vehicles, but this had minimal impact on the vegetation which is well adapted to an unstable environment.

5.6 Saltmarsh vegetation

Of all the maritime vegetation types it is the saltmarsh in Milford Haven waterway that has been most directly impacted by the Sea Empress oil. Liquid crude and heavy fuel oil were deposited on the saltmarshes during February and 1996. In 1997, hydrocarbon levels remained elevated in the sediments of many of the saltmarshes seaward of the Cleddau Bridge.

Oiled perched saltmarsh, Angle Bay, June 1996. (J. Hodge, PCNPA)

The 2.5 ha saltmarsh at Martin's Haven, Pwllcrochan was the most severely oiled - mainly by heavy fuel oil - which caused some initial die-back of sea purslane (*Atriplex portulacoides*). This site has been oiled on previous occasions, most notably in January 1967 when the impact on the saltmarsh was exacerbated by the use of dispersants[6]. No dispersant was used near any saltmarsh during the *Sea Empress* spill, and, in accordance with environmental recommendations, there was no attempt to clean up saltmarsh vegetation. The 40 ha saltmarsh in Pembroke River also received some fuel oil which coated small patches of cord-grass (*Spartina anglica*), sea purslane and other upper saltmarsh plants. This led to some foliage die-back of sea purslane: it is a shrubby perennial with exposed branch ends which are badly damaged by oil[7]. In Angle Bay, tiny isolated areas of raised saltmarsh were severely oiled by heavy fuel oil, resulting in die-back of the saltmarsh rush *Juncus gerardii*.

On the north side of Milford Haven, the 1.5 ha saltmarsh in Castle Pill received the worst oiling whilst the 15 ha Sandy Haven and the 31.5 ha Gann Estuary saltmarshes were lightly oiled by sheen, oily scum and "pats" of both crude and fuel oil. There has been minimal obvious impact except on the tiny areas of raised saltmarsh outside the mouth of Sandy Haven where die-back of the saltmarsh rush was evident in 1996. A small area (less than1 ha) of saltmarsh at Neyland was also oiled, but saltmarshes upstream of the Cleddau Bridge were only subjected to light sheen. An assessment of the recovery of the saltmarsh vegetation has been initiated[8], and this will map the saltmarsh downstream of the Cleddau Bridge. It will also then follow the recovery of vegetation in 82 permanent quadrats and assess the impact of the spill on two nationally scarce plants, the glasswort (*Salicornia pusilla*) and lax-flowered sea-lavender (*Limonium humile*). This work will continue for several more years.

5.7 Intertidal eelgrass

The Milford Haven waterway supports important populations of the nationally scarce narrow-leaved eelgrass (*Zostera angustifolia*) at three locations: Angle Bay, Pembroke River and Sandy Haven. All three locations were contaminated by oil. Experimental work carried out in Angle Bay in the 1980s suggested that eelgrass can be damaged by oil[9].

Narrow-leaved eelgrass *(Zostera angustifolia)*
Angle Bay, August 1997 (J Hodges, PCNPA)

The three populations had been surveyed before the spill in 1994/95 and were resurveyed in 1996 following the spill. The small Sandy Haven population remained unchanged. The large Pembroke River population (which covers about 100 ha of mudflats) was dense and luxuriant in 1996 and the eelgrass flowered in profusion. In Angle Bay, where the population occurs in three discrete areas, there was some physical damage to two of the eelgrass beds during the initial bulk oil removal. This resulted in deep wheel ruts into which oil had been introduced by the wheels of clean-up vehicles. Eelgrass in undamaged parts of the two affected beds, and in the third bed, flourished in 1996 and flowered in profusion[10]. Early indications from the 1997 survey indicate little overall change in the populations at all three locations, although there was no sign of recovery in areas damaged by vehicles in Angle Bay.

Factors such as timing of the spill (which occurred before the growth period had commenced), and possibly a reduction in grazing pressure on the grass resulting from a depletion of the invertebrates that feed on it, are thought to have been contributory to the apparent lack of damage as a result of exposure to oil. Monitoring is continuing.

Monitoring of the eelgrass populations will be continued until 2001, to determine whether or not any medium or long-term impacts of oil can be detected, and to monitor the recovery of the two sub-populations in Angle Bay that sustained physical damage during the clean-up operations.

5.8 AGRICULTURE

Agriculture plays an important role in the economy of south-west Wales - particularly potato and vegetable growing, dairy, beef and sheep farming. There was natural concern following the spill that some oil may have blown ashore and may have affected crops or livestock. As described in §5.2, the Welsh Office Agriculture Department, as a precautionary measure, sampled grass at sites round the coast and inland on 24 to 26 February 1996 (*figure 5.1*), with five sites resampled on 8 March. The samples were analysed for total PAH which were found to be elevated (up to 3,500 µg/kg wet wt) along the coast round St Ann's Head, Castlemartin and Skomer, but considerably lower inland (generally below 500 µg/kg).

Two samples of cauliflower were also taken from near the coast on 24 February. These showed tolerably low levels of total PAH (1,100 and 1,250 µg/kg wet wt). As a further precautionary measure, since a flock of sheep had been grazing in an area near some of the grass samples showing elevated PAHs, three sheep were slaughtered and samples of liver, muscle, fat and kidney were analysed for PAHs and *n*-alkanes. The PAH concentration of the various tissues were all less than 100 µg/kg (with only the fat containing PAHs in excess of 20 µg/kg). These concentrations were typical of what might be found in such tissues under normal circumstances. The *n*-alkane concentrations were similar in tissues from reference sheep which had been analysed as part of a separate MAFF project, and the types of *n*-alkanes present were also characteristic of those normally present in tissue, with none that would indicate the presence of crude oil. There was therefore no evidence that these sheep had been contaminated with oil from the spill.

Based on these results, together with general investigations and discussions with farmers, MAFF's Food Safety Directorate advised that the oil spill had not resulted in any risk to the human food chain from agricultural produce. The Welsh Office Agriculture Department provided advice on request to any farmers concerned about the effects from the spill.

In the light of the evidence available that the impact on agriculture was minimal, further resources were not committed to additional work in this area.

REFERENCES

1 Ritchie, W & O'Sullivan, M., 1994. *The Environmental Impact of the Wreck of the Braer.* The Scottish Office.

2 Evans, 00., 1997. *Effects of Oil and the Clean-up of Oil from the Sea Empress on the Nationally Rare and Scarce Vascular Plants of Pembrokeshire.* Draft Final Report by CCW in house.

3 Orange, A., 1997. *Monitoring of Lichen Communities at Stackpole* Warren NNR. Final Report by National Museum of Wales.

4 Wolseley, P. and James, P., 1997. *Report of Resurvey of Lichen Quadrats on Skomer Island.* Draft Final Report by the Natural History Museum.

5 Hale, A., 1997. Teloschistes flavicans (The Golden-hair lichen) at Manorbier, South Pembrokeshire. A report on its condition following the *Sea Empress* Oil Spill. Internal CCW Report.

6 Baker, J.M., 1976 Ecological changes in Milford Haven during its history as an oil port. In: Baker, J.M. (Ed.)*Marine Ecology and Oil Pollution.* Applied Science.

7 Baker, J.M., 1971. Successive Spillages. In: Cowell, E.B.*The Ecological Effects of Oil Pollution on Littoral Communities.* London: Institute of Petroleum.

8 Bell, S.A., Radford, G.L. and Rossall, M.J., 1997. *Damage Assessment Survey of Saltmarsh Affected by the Sea Empress Oil Spillage.* Interim Report by Institute of Terrestrial Ecology.

9 Howard, S., Baker, J.M. & Hiscock, K. 1989. The Effects of Upright Oil and Dispersants on Seagrasses in Milford Haven. In: Dicks, B. *Ecological Impacts of the Oil Industry.* London: Institute of Petroleum

10 Hodges, J.E. & Howe, M.J. 1997. *Milford Haven Waterway Monitoring of Eelgrass, Zostera angustifolia,following the Sea Empress Oil Spill.* Interim report by Pembrokeshire Coast National Park Authority.

6 Mammals

6.1 INTRODUCTION

Although there was no evidence of any immediate impact on mammals resulting from the oil spill, a number of species were considered to be potentially at risk. These included:

- grey seals;
- cetaceans – particularly harbour porpoises and bottlenose dolphins;
- otters feeding on the shore or in the sea;
- greater horseshoe bats hibernating in caves where oil vapour may have penetrated.

In many cases it was difficult to collect comprehensive data: mammals are generally mobile, sensitive to disturbance and less abundant than other types of animal; and the level of exposure to oil can only be measured directly if dead animals (such as stranded seals) are found. Nevertheless, several projects were carried out, taking advantage of monitoring data collected in the region over many years.

There are a number of potential risks to aquatic mammals from oil. Under conditions of close contact, some components of freshly spilled crude oil may cause damage to nervous tissue, liver and genetic material. Breakdown products (metabolites) of some PAHs are also known to be cancer-inducing. The build-up of hydrocarbons in animal tissue is not usually a problem because small doses ingested or absorbed are generally broken down by well-developed enzyme systems. Heavy contamination by oil of the pelt or coat of mammals such as otters (and perhaps seal pups) which rely on a layer of trapped air for insulation can lead to hypothermia or drowning, and the oil may be ingested during grooming. Mammals which rely on blubber for insulation – such as dolphins, porpoises and adult seals – are not at risk in this way. As fish also have enzyme systems which break down hydrocarbons rapidly (see §3.4.2), they are unlikely to be a major source of oil-related hydrocarbons. Clean-up activity is unlikely to have any impact on mammals, although excessive disturbance of mothers and pups on seal pupping beaches by shore clean-up teams can lead to abandonment.

6.2 GREY SEALS

About 5,000 grey seals (*Halichoerus grypus*) – around 4% of the UK grey seal population – live around the west Wales coast. They have been monitored extensively over many years. The seals breed, moult and rest on the islands and coast to the north and west of Milford Haven, including Skomer, Ramsey, the St David's Peninsula and north towards Cardigan. Seals can also be seen in inshore waters around the south Pembrokeshire coast and in Milford Haven waterway throughout the year, and some breeding ("pupping") occurs on the south coast [1].

Seals "pup" and then mate on remote beaches and in sea caves during the autumn, and adult seals moult during the winter, spending long periods ashore at a few, traditionally-used moulting beaches. The seals disperse widely during spring and summer. The *Sea Empress* oil spill occurred at the end of the 1995/96 winter moulting period, well after the 1995 pupping season.

Grey Seal (M Baines)

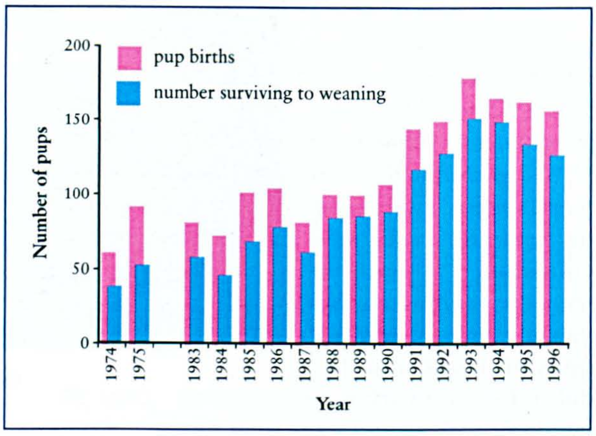
On 29 February there were around 160 seals on two Skomer beaches, of which 32 were described as completely stained and 27 as lightly oiled[2]. Seals were seen swimming in sheen, oil and emulsion without showing distressed behaviour or any obvious signs of illness, and they did not seem to try to avoid the oil. Over 20 moulting seals were recorded at Ramsey Island sites. Two were seen swimming in sheen, but there were no reports of any being oiled[3]. 120 moulting adults were present at a moulting site in north Pembrokeshire until the end of February but none were recorded as oiled. The seal sites on Lundy Island were not contaminated, and out of the 35 seals observed there, only one may have been slightly oiled[4]. The seabird surveillance flights between 21 February and 7 March 1996 recorded 16 seals at sea, with all but six of these well away from any oil contamination.

Seals normally begin to disperse in the spring – by 1 March there were only 38 seals remaining on Skomer – and so further direct monitoring was difficult. However, over the summer there was no increase (compared with previous years) in the number of live or dead seals stranded on the coast in the region, nor were there any reports of oiled seals.

Post mortems on six stranded dead seals collected in the autumn of 1996 showed they died of normal injuries or disease. Samples of muscle, liver and blubber from two animals (one pup, one adult) contained only very low levels of total hydrocarbons and PAHs, similar to levels found in seals and fish from uncontaminated locations[5]. None of the four and five ring PAHs (some of which can be metabolised to form carcinogens) were detected.

Most of the pupping sites which had been contaminated by oil were clean before the pupping season began. CCW monitors the success of pupping at key sites annually, and in 1996 two extra sites in north Pembrokeshire were added to the programme. Two rapid whole coast surveys of North Pembrokeshire were also carried out by the Wildlife Trust West Wales. Pup production at all sites was either very similar to recent years or followed established trends. Survival was average over all, and slightly higher than average on Skomer.

Figure 6.1 - Seal pup production and survival on Skomer Island, 1983-1996



Pups with oil or tar spots on their white coats are recorded each year. The incidence was no higher than previous years on Skomer, Ramsey and north Pembrokshire, and was recorded as lower than usual at some sites on Skomer. Only very few, up to about ten pups annually, are born on the Castlemartin peninsula. Residual surface oil was still present on some rock surfaces in this area during the autumn and several slightly oiled pups were recorded at Elegug Stacks.

Every pupping season, a proportion of young pups die from natural causes or are separated from their mothers. Some become stranded on the mainland coast. Despite pup survival being average, a higher than usual number of live and dead pups were reported stranded in 1996, and this was investigated carefully in case it was related to the oil spill. However, post mortem examinations and blood and tissue samples taken from dead pups gave no indication of raised hydrocarbon levels or any unusual effects that might be related to the oil. It is likely that the high numbers of reported strandings resulted from two factors: storms and greater public awareness. Unusually prolonged storms related to hurricane Lily (25 to 29 October 1996) washed many pups away from the beaches where they were born - one marked pup was observed, alive, over 66 km away - leaving the most exposed sites devoid of pups. Live pups were unusually seen stranded high on ledges outside caves. Following the storms, higher than usual numbers of stranded pups were also reported in other parts of Britain, including Scotland and Cornwall. In Pembrokeshire, public concern following the spill almost certainly increased the proportion of strandings which were reported.

During autumn 1996 there were several media reports that a herpes virus infection was partly responsible for the numbers of stranded pups. The herpes virus is widespread in UK seal populations and does not normally cause significant illness. The herpes virus was present in some of the pups taken into care, but veterinary opinion was that the infections were likely to have developed as a result of separation, stress and starvation which would have reduced the resistance of the pups to the virus.

There is no evidence to suggest that the spill had any short to medium term impact of any consequence on the grey seal population of west Wales. However, had the *Sea Empress* spill occurred during the pupping season it is possible that some seal pups could have been killed or otherwise adversely affected.

6.3 CETACEANS

There is little evidence that cetaceans (dolphin, whale and porpoise) have been killed in previous oil spills and, in the case of the *Sea Empress*, there is no evidence of any cetacean deaths. Nevertheless, records of sightings, as well as of live and dead strandings, were used to check for any change in distribution or abundance.

Between 1990 and 1996 the five most frequently recorded species around the west Wales coast – including live sightings and strandings – were harbour porpoises (*Phocoena phocoena*), bottlenose dolphins (*Tursiops truncatus*), common dolphins (*Delphinus delphis*), Risso's dolphins (*Grampus griseus*) and minke whales (*Balaenoptera acutorostrata*). Harbour porpoises and bottlenose dolphins were assessed as being the most at risk because of their permanent residence in the area[6].

During the two months following the spill, there were 32 cetacean sightings in the area (30 of harbour porpoises and two of bottlenose dolphins) and there appeared to be no change in the rate or distribution of sightings of these two species at coastal study sites compared with other years[6].

A review of the Natural History Museum's records of live and dead strandings of cetaceans between 1991 and 1996 around the coasts of north Cornwall, north Devon and west Wales, plus additional records for the south and south-east coast of Ireland, showed no increase in the rate of strandings for any cetacean species, either immediately following the oil spill or during the subsequent 18 months[7].

6.4 OTTERS

Otters are widespread throughout Pembrokeshire, and records suggest that they now visit estuaries and coasts more frequently than several years ago when populations were lower. Where freshwater streams flow into the sea, otters feed on both marine and freshwater organisms. Volunteers surveyed the coast and estuaries during the oil spill and found no evidence of the presence of otters or of any adverse effect of the spill.

6.5 GREATER HORSESHOE BATS

Greater horseshoe bats (*Rhinolophus ferrumequinum*) have declined substantially in Britain during this century and are now only found in south-west England and three nursery roosts in west and south Wales. 10% to 20% of the Pembrokeshire population hibernate in two adjacent sea caves on the Castlemartin coast, and there was concern that these caves may have been oiled and that the bats may have been affected by oil vapour.

The caves were visited on 26 February, 9 March and 23 March 1996 at a time when around 60 greater horseshoe bats were hibernating[8]. Oil had not penetrated the main cave though it did reach the entrance of the other cave (in which there were no bats at the time of the survey). Exposure of the bats to oil or vapour was therefore minimal and no obvious detrimental effects were observed. Monitoring in 1996 of the regular summer roosts around Milford Haven waterway indicated no abnormalities in roost attendance or the number of bats.

6.6 CONCLUSIONS

There was no evidence of any adverse impact on mammals resulting from the *Sea Empress* oil spill. However, had circumstances been different (for example, had the spill occurred during the seal pupping season), the outcome may not have been as fortunate, and in any future oil spill, local wildlife contingency plans (see §8.4.2) will need to provide clear guidelines on the rescue and rehabilitation of oiled mammals. The *Sea Empress* incident has also confirmed the value of monitoring such mammals. Key populations of mammals will continue to be monitored.

REFERENCES

1 Baines M.E, Earl S.J, Pierpoint C.J.L, and Poole, J. 1995.The west Wales grey seal census. Report to CCW.

2 Poole, J. 1997. Grey Seal Breeding Census: Skomer Island 1996, CCW Report No. 191.

3 Ian Bullock, RSPB pers. comm.

4 Munro, C. 1996. The Lundy littoral Survey 11th to 15th March 1996. A report to English Nature.

5 Law, J. CEFAS Unpublished data.

6 Baines M.E, Pierpoint C.J.L, and Earl S.J. 1997, A Cetacean Sightings Database for Wales and an Evaluation of Impacts on Cetaceans from the *Sea Empress* oil spill. Report to CCW.

7 Penrose, R. 1997. *Sea Empress* Oil Spill - West Wales review of marine mammal strandings from the west Wales coast 1991 – 1996. Report to CCW.

8 McOwat, T.P. 1997. Survey of the Castlemartin bat cave following the grounding of the *Sea Empress* February – March 1996. Report to CCW.

7 Birds

7.1 INTRODUCTION

The south-west Wales coast, islands and inshore waters are of outstanding international importance for their breeding seabirds, wintering sea-duck and wintering waterfowl.

The region supports about half a million breeding seabirds, including half of the world population of Manx shearwaters, the third largest population of gannets in the world, and more than 40,000 auks (guillemots, razorbills and puffins)[1,2,3,4]. Many areas have been designated as Special Protection Areas (for populations of international importance) or Sites of Special Scientific Interest *(figure 7.1)*. Two further Special Protection Areas are designated for their chough populations.

During winter more than 40,000 waterfowl visit the region, including 30% to 40% of the UK's common scoter wintering population[5,6]. Small numbers of three species of diver also regularly winter offshore.

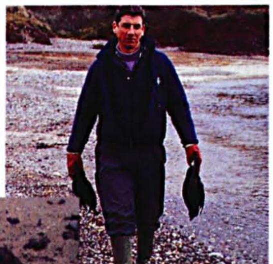
The immediate priorities following the oil spill were to set up a co-ordinated programme to collect and count all the dead and live oiled birds coming ashore (see §7.2), and to monitor the bird populations at risk out at sea and along the coastline[7,8]. This information was computerised and provided daily to the Joint Response Centre (JRC), statutory agencies and non-governmental organisations. Monitoring focused on three main groups of birds:

- **sea-ducks, primarily the common scoters** wintering in Carmarthen Bay and St Brides Bay (§7.3);
- **seabirds at their breeding colonies and feeding at sea**, which were surveyed from the ground, by air and by boat in late February and March (§7.5 - 7.15); and
- **the waders, wildfowl and gulls** feeding and roosting within Milford Haven waterway and the Daugleddau Estuary and at other coastal sites, which were counted daily until 25 February and then weekly until the end of March (§7.16 - 7.17).

After the emergency phase was over and SEEEC was established, longer term studies were commissioned to try to assess the full impact of the spill on these bird populations (see *Appendix C*). As well as carrying out counts of several species, samples of eggs and blood were checked for hydrocarbon content and corpses of oiled birds were examined in detail to learn more about the birds and how they had died. Some of the projects will run for several years to monitor possible longer term impacts.

7.2 OILED BIRDS

Immediately following the grounding, arrangements were put in place to collect oiled birds - both live and dead - along the whole coastline from Ceredigion in the north to West Glamorgan in the south-east, plus Lundy Island, the coasts of north Devon and Cornwall, and south-east Ireland. Protocols were agreed for how the birds



Collecting oiled birds (PCNPA)

Oiled bird (M Baines)

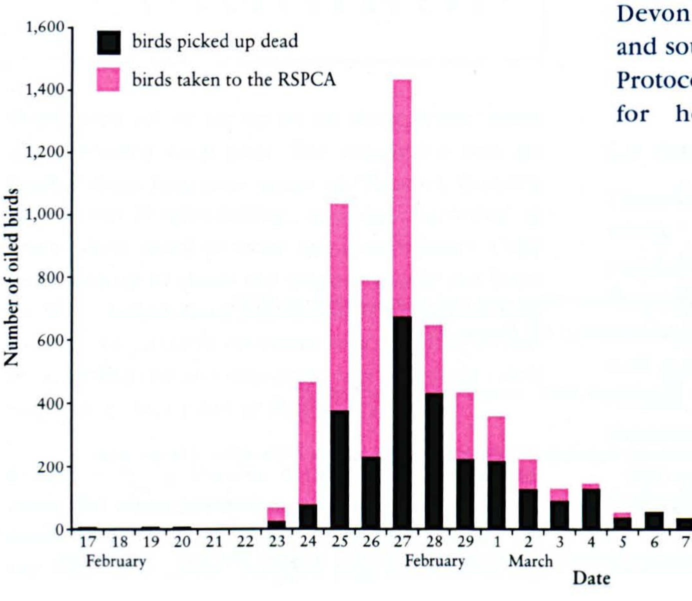
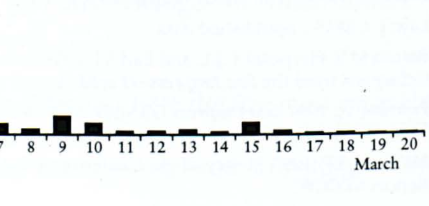



Fig 7.2 Histogram showing when oiled birds came ashore

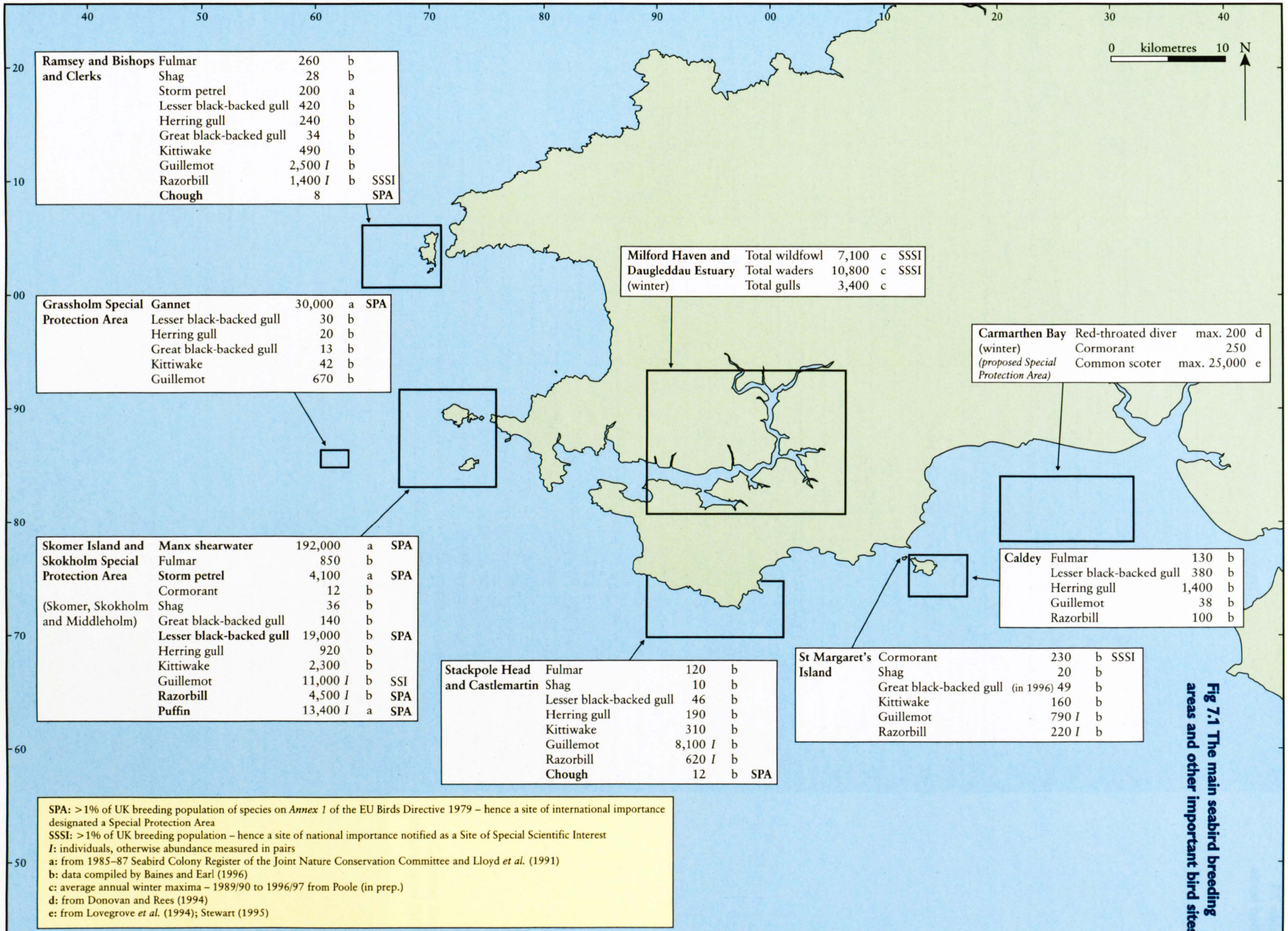


Fig 7.1 The main seabird breeding areas and other important bird sites

Table 7.1
Oiled birds

Species	Found dead							Taken to cleaning centres	Total
	Pembs	Carms	W Glam	Cards	Lundy etc	SE Ireland	Total dead		
Common scoter	540	791	450	5	1	56	1843	2753	4596
Velvet scoter	1						1	3	4
Red-throated diver	31	3	5		1	1	41	40	81
Black-throated diver			1				1	1	2
Great northern diver	2		1				3	5	8
Guillemot	798	27	38	1	44	196	1104	487	1591
Razorbill	192	12	9	17	9	73	312	29	341
Puffin							0	1	1
Auk species	4						4	0	4
Cormorant	7		1	1			9	1	10
Shag	12				1	2	15	12	27
Gannet	2		1		1	9	13	0	13
Herring gull	8	1	1			12	22	27	49
Black-headed gull	4		5	1			10	1	11
Common gull	2						2	0	2
Gull species	3						3	0	3
Kittiwake			1				1	6	7
Fulmar	1						1	1	2
Manx shearwater	1						1		1
Mute swan	2						2	23	25
Shelduck	1	1					2	1	3
Mallard	1						1	13*	14
Pintail	1						1	0	1
Scaup							0	2	2
Eider							0	9	9
Red-breasted merganser							0	1	1
Oystercatcher	15	1	3				17	13	32
Lapwing							0	1	1
Snipe							0	1	1
Curlew	2						2	0	2
Turnstone			1				1	0	1
Great crested grebe	1						1	2	3
Red-necked grebe							0	3	3
Grebe species	1						1	0	1
Grey heron	1		1				2	1	3
Buzzard							0	1	1
Peregrine							0	1	1
Feral pigeon							0	1	1
Carrion crow	2						0	0	2
Jackdaw	1						1	0	1
Unidentified/others**	61					13	74	1	75
TOTAL	**1697**	**836**	**518**	**25**	**57**	**362**	**3495**	**3428**	**6935**

Pembs: Collected from Pembrokeshire beaches
Carm: Collected from Carmarthenshire beaches
W Glam: Collected from West Glamorgan beaches
Cards: Collected from Cardiganshire beaches
Lundy etc.: Collected from Lundy, plus north Devon and Cornwall
SE Ireland: Found on beaches between Wexford and Cork

Taken to cleaning centres: Birds taken for treatment, including those that died in care. These figures have been excluded from the totals for the counties.

* includes 12 ducklings ** these remain unidentified but most were probably auks and scoters

would be collected and what would be done with the corpses. Details of all the birds were recorded, and the live birds were taken to the bird cleaning centres (see §8.2). Dead birds from the beaches or which died in the cleaning centres were frozen for further investigation[9].

The first oiled birds were reported on 17 February. By 1 June 1996, when recording stopped, nearly 7,000 birds of some 36 species had been collected dead or alive *(table 7.1)*. Fewer than 50 dead birds - mainly auks and gannets - were reported during the summer, including some unoiled birds unlikely to be connected with the *Sea Empress*. A few came ashore during April and May, but these were mostly birds which had died some time before. Around 85% of the birds recorded came ashore between 24 February and 4 March 1996 *(figure 7.2)*.

Most of the oiled birds were found along the south Pembrokeshire and Carmarthenshire coastline (*table 7.1*). The worst hit species was the common scoter (*Melanitta nigra*) which made up two thirds of the birds recorded: 4,600 were collected, mostly around Carmarthen Bay. Most of the rest of the birds collected were auks, mainly guillemots (*Uria aalge*). Two thirds of these came ashore along the south coast of Pembrokeshire between Linney Head and Tenby, close to the important seabird colonies at Elegug Stacks, Stackpole Head and St Margaret's Island. In contrast, only 155 dead oiled seabirds - mostly auks - were found on the mainland near to the main seabird islands of Skomer, Skokholm and Ramsey.

More than 300 live and dead seabirds (almost all of them auks) were collected on Lundy Island and in north Devon and Cornwall. Some oiled birds eventually reached south-east Ireland, between Wexford and Cork, where 360 were reported dead from mid-March onwards, again mostly guillemots[10,11].

Because only a small proportion of oiled birds reach the shore - dead or alive - it is likely that the total number of birds killed will be substantially higher than the totals given, perhaps several-fold. The exception to this may be the scoters in Carmarthen Bay, which, due to their location (and onshore winds during the worst period of oiling in Carmarthen Bay), were much more likely to have washed ashore when oiled.

7.2.1 Corpse drift experiment

In order to get a better idea of the proportion of dead seabirds which are recovered on shore, a number of oiled corpses (mostly guillemots) were neck-tagged and returned to the sea off south Pembrokeshire in four lines parallel to the shore. Beaches along the coast were then monitored for these corpses coming ashore[12]. 238 corpses were released in early March, but only 12 were eventually recovered - all in south-east Ireland - between 15 March and 7 May[11]. Whilst this experiment implies a very low recovery rate for birds carried towards Ireland, care needs to be taken in interpreting these results as winds and currents were likely to have differed from those during the spill.

Scoters and divers

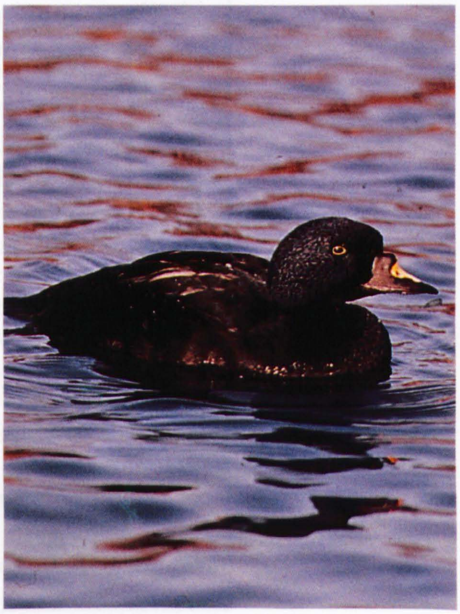
7.3 COMMON SCOTERS (*Melanitta nigra*)

Common scoters (a species of sea-duck) were particularly badly affected by the oil spill. There are estimated to be 1,600,000 common scoters worldwide, of which between 100,000 and 120,000 pairs breed in Europe, mainly in Scandinavia and Finland, the Baltic States, and Russia, with a few hundred pairs breeding in Iceland and the UK[13]. They spend the winter in the Baltic or North Sea, or further south along the Atlantic coast of Europe and North Africa[14], and around 40,000 visit the UK each year, staying at a small number of coastal sites.

Carmarthen Bay is the most important of these sites. Flocks are at their maximum here in August when the birds come to moult after breeding, and in late winter and spring when the wintering population is probably augmented by birds returning from other areas. The greatest numbers recorded here have been 25,000 birds in March 1974 and 17,650 birds in December 1994, though data are only available for short periods in the 1970s and 1990s[2,6,14]. As the bay is used as a staging area, there is probably a high turnover of birds passing through.

Like other sea-ducks, scoters spend much time on the surface of the water and dive to the sea bed for food, mostly bivalve molluscs. This leaves them particularly susceptible to oiling[13]. Before the oil reached Carmarthen Bay, therefore, the scoter flocks were counted so

Common Scoter
Melanitta nigra (RSPB)



that any impact could be assessed, using aerial transect counts between 20 and 22 February 1996 and systematic counts from fixed points along the coast from 18 February onwards. These showed there to be more than 8,000 common scoters in Carmarthen Bay, with a further 1,000 in St Brides Bay[15,16].

A large quantity of oil arrived in Carmarthen Bay on 22 February. The first oiled scoters were reported on beaches on 24 February, and by the beginning of March about half of the birds in the bay had come ashore oiled. Judging from where they came ashore, it appears that most came from the flock feeding within the western half of the bay between Saundersfoot and Pendine, although several hundred birds were recovered on the eastern side of the bay as well. Although generally only a small proportion of oiled seabirds are recovered following a spill, it is likely that a much higher proportion of the oiled scoters in Carmarthen Bay would have been washed ashore due to a combination of the location of the flock and the onshore winds during much of the period of worst oiling.

In total, 4,600 oiled scoters were collected from the beaches; 1,800 of these were dead and a further 1,700 died in the cleaning centres; the remaining 1,100 were eventually released (see §8.2.1). Only two other oil spills have killed more common scoters than this, and both were in Denmark in 1972: 10,000 birds in the Kattegat in March, and 7,000 birds in the Wadden Sea in December[17].

The scoter flocks were monitored throughout late winter and spring 1996. During the first ten days of March scoter numbers stayed low on the western side of the bay, but later in the month began to increase as more birds arrived in the area. By 17 March the total population had risen to 10,600 birds. Including the scoters which were oiled, this means that at least 15,000 scoters used the bay following the spill. Initially, many of the birds moved eastwards to nearby Rhossili Bay, an area usually little used by scoters, though many later returned to feed in previously oiled areas in Carmarthen Bay.

Numbers remained high in the area until late April when the flocks began to migrate, and by mid-May very few birds remained[15].

During the summer, the small breeding populations in Britain and Ireland were surveyed for any impact on numbers which might have resulted from the mortality of the Carmarthen Bay scoters. Around 100 fewer birds were counted (about 9% of the population)[18,19], but this difference might equally be explained by natural variability. The numbers breeding at the main Icelandic site (Lake Mývatn) were also reported to be similar to the previous year[20], and so it seems likely that the birds passing through Carmarthen Bay breed elsewhere, probably in Fennoscandia or around the Baltic.

Monitoring in Carmarthen Bay continued fortnightly through the summer and following winter until 1 April 1997, using land-based counts supplemented by several aerial counts during the autumn and winter. Far fewer scoters were recorded during the 1996/97 winter, with the highest count just 4,300 (on 25 November) (*figure 7.3*). This is 34% lower than the long-term mean and 10,000 birds fewer than the 1995/96 peak (including the oiled scoters).

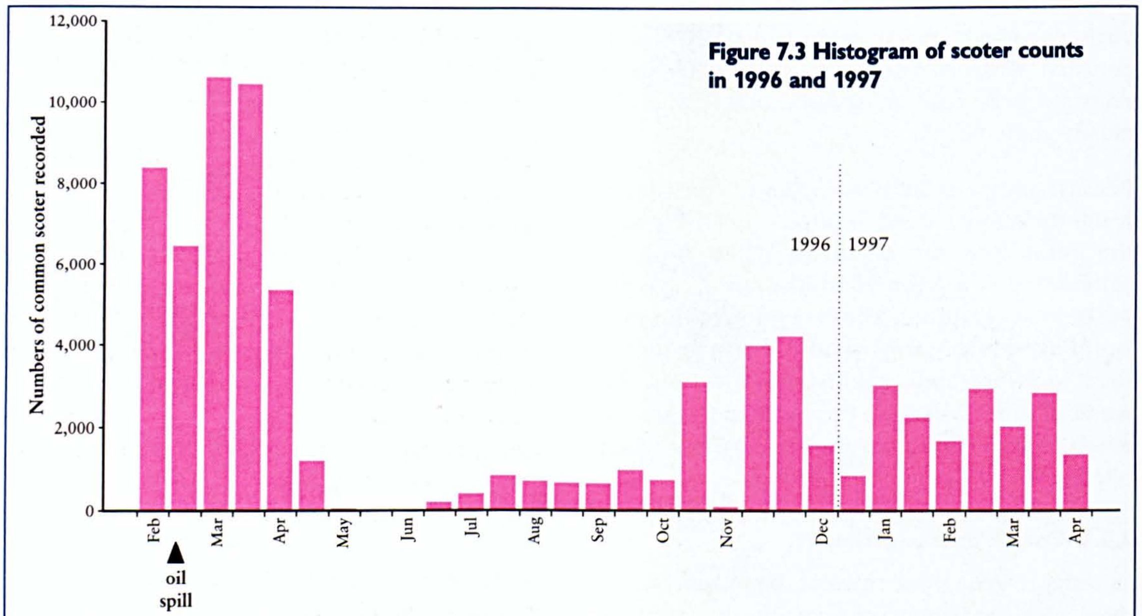


Figure 7.3 Histogram of scoter counts in 1996 and 1997

3,500 scoters are known to have died (see §7.2), but many more birds than this may have died as a result of the spill. There is, however, normally a high variability in flock sizes from year to year, and so it is difficult to draw any firm conclusions about the impact of the oil spill based on numbers observed during the 1996/97 winter.

The flocks were further offshore in the winter of 1996/97 than in previous years, suggesting a change in food supply - perhaps because some areas of Carmarthen Bay, particularly the intertidal region, had become unprofitable for foraging[15]. This might also explain the lower numbers of scoters observed.

The difficulty in drawing firm conclusions is a result of the limited knowledge that exists on scoter numbers, where they come from and their prey. Arrangements are already in place to monitor the Carmarthen Bay scoter flocks until 2001, and 750 of the scoters released after cleaning were ringed, so providing further useful information should these birds survive.

7.3.1 Examination of corpses

Nearly 2,400 scoter corpses - including birds which had died in the rehabilitation centres - were examined to investigate their body condition, cause of death, and their diet[14].

Most of the corpses were of adult males (2 years or older). Although there were few first year birds, their sex ratio was more balanced than that of adult birds.

	Male	Female
1st year:	5%	7%
adult:	65%	23%

Examining the corpses of oiled common scoters (N Straughan, WWT)

The higher number of males and the fact that the birds do not all migrate at the same time may have helped to reduce the overall long term impact of the *Sea Empress* spill on the scoter population. The larger pool of males - which normally occurs in the scoter population - should replace those which were killed, while most of the breeding females appear to pass through the area after February.

Most of the scoters were in full moult, which does not support previous reports in the literature that moulting finishes in December. Moulting leaves the scoters unable to fly and so at greater risk of contamination. The renewal of feathers is also energy-consuming, and so, while moulting, the birds need an increased quantity of good quality food.

7.3.2 Cause of death

More than 2,000 corpses were categorised according to how badly oiled they were and how much fat they had (a high level of fat is an indication of good body condition). For 600 of these, the date of collection from the beach was also known. Most of the birds were in poor body condition, and the proportions in the different oiling categories were:

- Heavily/completely oiled: 48% (half were encased in thick emulsion)
- Partially oiled: 32%
- No trace of oil: 20% (these had died after cleaning).

The heavily oiled birds tended to be those with the best body condition; only the most severely oiled had fat scores similar to those of healthy birds. On the other hand, the partially oiled birds were in poorer condition. This suggested that the more heavily oiled birds died rapidly while the less badly oiled birds survived longer but lost weight.

Further evidence for this came from the timing of when the birds were found. The first birds washed ashore had high scores for both oil and fat, but over the next six days the scores decreased as the birds became more emaciated. There were, however, subsequent peaks in both body condition and oil score on 3 and 10 March; these were probably due to re-oiling in the bay and the possible migration of fresh birds to the area, but not enough is known of the precise distribution and movement of both birds and oil at sea to confirm this suggestion.

Gross necropsy on 205 birds showed the main causes of death to be:

- haemorrhagic enteritis (diagnosed in 60% of the birds),
- pulmonary congestion/pneumonia (43%),
- pericarditis (16%), and
- drowning (14%).

Some birds suffered more than one of these conditions and a few birds had parasites.

Cause of death differed significantly between partially and heavily oiled birds. More of the heavily oiled birds died of drowning and pulmonary congestion/pneumonia, while the partially oiled birds died more often from causes related to oil ingestion: haemorrhagic enteritis (damage to the gut lining) and pericarditis (a secondary infection resulting from suppression of the immune system). The birds from the cleaning centres tended to have died from pericarditis, though this may be related to the initial level of oiling.

The conclusion from this work is that around half of the scoters died quickly after being smothered in oil, while half were less badly oiled and survived longer, perhaps up to a week, before dying from the effects of oil ingestion. It appears that these birds continued to feed - the proportion of birds with food items in the gizzard remained constant over the period - but failed to maintain body condition.

7.3.4 Diet

Previous studies from Britain and Europe have shown that scoters eat a wide variety of prey (43 types were recorded), with the dominant food changing according to season and location. Molluscs - bivalves in particular - were the most common items reported: the common mussel (*Mytilus edulis*) was most frequent, followed by the common cockle (*Cerastoderma edule*), Baltic tellin (*Macoma balthica*), striped venus (*Chamelea gallina*) and banded wedge shell (*Donax vittatus*).

Bivalve molluscs made up 97% of the prey items found in the *Sea Empress* birds examined, but some had taken gastropods, crabs, bristle worms, and, on one occasion, a fish - in all, a total of 28 taxa. The most important prey items were

- egg-shell razor (*Pharus legumen*) (58% of birds),
- common cockle (14%),
- banded wedge shell (14%),
- common mussel (11%) and
- nut shell (*Nucula nitidosa*) (8%).

Diet did not differ between the sexes and between different age classes (but only small sample sizes were available for first year birds).

It is surprising that egg-shell razors featured so prominently. Normally they would be hard for scoters to catch[21] as they are larger than most scoter prey and burrow rapidly as an escape response. It has been suggested[14] that the egg-shell razors left the sediments as a reaction to oil in the water and were therefore available to the scoters; they may even have been narcotised (see §3.8.4). A similar response to oil has been noted in other bivalves such as common cockles and pod razor shells *(Ensis siliqua)*[22]. Egg-shell razors have been reported in the common scoter diet on one previous occasion, also in Carmarthen Bay after an oil spill[23]. However, it is not known whether egg-shell razors are eaten by common scoters under normal conditions.

There was a strong relationship between diet, body condition and degree of oiling. The fatter, more heavily-oiled birds (which died quickly - see §7.3.2) fed more on egg-shell razors and less on common cockles than birds with lower oil and fat scores. This suggests that over time the scoters' diet changed from the razors to the cockles, but statistical analysis showed that this trend was related more closely to oil score and body condition rather than to date. This might be explained by birds in good body condition being able to feed in deeper water on the relatively large egg-shell razors, while birds in poor condition were forced to feed in shallower water on smaller cockles which provide less food for the effort used. Birds in poor body condition may also have been anaemic, further reducing their diving ability. However, a lack of detailed information on the distribution and availability of food species prevents any firm conclusions.

7.3.5 Conclusions

Common scoters moulting and wintering in Carmarthen Bay are clearly vulnerable to oil pollution and a large number died directly as a result of oiling following the *Sea Empress* spill. 3,500 scoters are known to have died, but peak numbers during the following winter were well below normal and 10,000 fewer than the peak in 1995/96. However, numbers normally fluctuate from year to year, and the change may be due, at least in part, to other factors. The studies of scoters also suggested that invertebrates which are important food items for these and other birds in Carmarthen Bay may have been affected by the oil. Many scoters were found to have eaten egg-shell razors, an unexpected prey, and feeding patterns in the bay the following year appear to have changed.

7.4 DIVERS (*Gavia stellata, G arctica, G immer*)

During autumn and winter, divers spend most of their time on the sea where they dive to forage for food; they can therefore be particularly vulnerable to oil pollution. More than 120 were killed after the *Amoco Cadiz* spill and 200 after the *Esso Bernica* in Shetland and related spills. The breeding locations of divers wintering off the British coast are poorly understood.

Diver species were amongst the earliest oiled bird casualties to be reported in the *Sea Empress* oil spill, and 81 red-throated divers (*Gavia stellata*), 8 great northern divers (*G immer*) and 2 black-throated divers (*G arctica*) were collected, mostly from beaches in south Pembrokeshire and in Carmarthen Bay. Although only about 1% of the casualties overall, these numbers may have been a very high proportion of the local wintering population at the time of the spill.

It is hard to estimate how many divers would have been in the area as they are not counted on an annual basis. Red-throated divers occur in small numbers around the west Wales coastline in winter, usually in sheltered bays or tide-races. They are regularly sighted within St Brides Bay and Carmarthen Bay, and there is thought to be a considerable turnover in their numbers off the Welsh coast during passage[2,3]. Occasionally, larger numbers are reported: 70 in 1980, and - exceptionally - 200 in 1993[2,33].

Usually only one or two black-throated divers are recorded around the west Wales coast in winter. Great northern divers are regular winter visitors and passage migrants, though again numbers are generally small; one or two occasionally appear in the Milford Haven waterway and the Daugleddau Estuary and up to six were recorded within Carmarthen Bay in February 1985[2]. The highest recent offshore count in Pembrokeshire was 43 in the Strumble Head tide-races in January 1991[3].

7.4.1 Examination of corpses

20 of the red-throated diver corpses were examined in detail. All were in winter plumage; 75% were adults and 75% were male (adult and juvenile).

The few identified diet items in the birds' guts were mainly small gadoid fish (cod family). Only one large, robust great northern diver had preened out and swallowed oiled feathers. This suggested that most of the birds had died rapidly before they had a chance to preen themselves. The corpses of three great northern divers were examined. Two were adult females in flightless moult but which had begun to moult into summer plumage; this is an important finding as these birds have not been recorded moulting in this region[24]. The other bird was a second year male in winter plumage. All three birds probably came from Greenland or Iceland. Both females had ingested Dublin Bay prawns (Nephrops norvegicus) which locally are only found at depths of more than 90m in the Celtic Deep south-west of Pembrokeshire[25].

Breeding Seabirds

7.5 SEABIRDS IN THE AREA AT THE TIME OF THE SPILL

The spill happened at around the time when many seabirds would be expected to return to the region for breeding. It was therefore important to establish quickly how many seabirds had returned to their colonies, and several surveys by air and sea were launched in the days following the grounding.

Several thousand auks and kittiwakes (*Rissa tridactyla*) were seen feeding over the Hats and Barrels reef near the Smalls, about 24 km west of Skomer, several days after the tanker grounded. On 22 February it was confirmed that most of the 30,000 pairs of gannets (*Morus bassanus*) had returned to Grassholm and were feeding to the west of the island well away from the oil. There were also large-scale arrivals of guillemots (*Uria aalge*) and razorbills (*Alca torda*) to colonies at Skomer, Skokholm, Ramsey and the Castlemartin coast on 23 February.

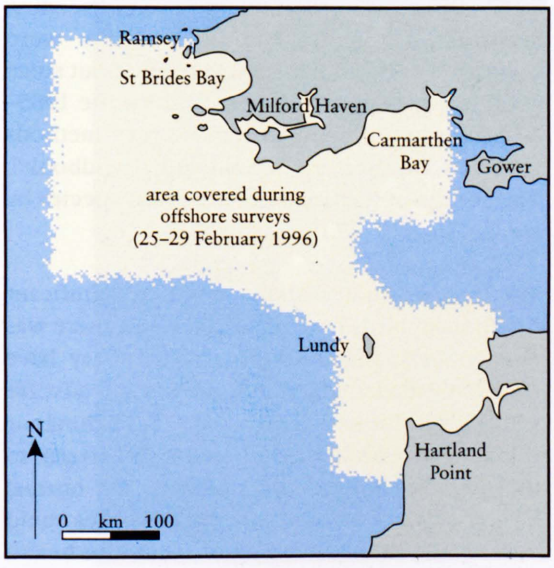


Figure 7.4 Map of area covered during offshore survey

Offshore boat surveys were conducted between 25 and 29 February. The surveys covered an area stretching from St David's peninsula to the Smalls in the north-west, to the north Devon coast and Barnstaple Bay and to the Gower coast in the east, a total sea area of 5,500 km^2 (see *figure 7.4*). In transects covering 230 km^2, 770 birds were counted giving a mean density of 3.4 birds/km^2. Assuming a fairly even seabird distribution, there could have been approximately 19,000 seabirds offshore in the whole area surveyed.

During the surveys, a total of 3,400 birds of 15 species were recorded. Gannets were the most numerous of the species seen, followed by guillemots, lesser black-backed gulls (*Larus fuscus*), fulmars (*Fulmarus glacialis*), herring gulls (*Larus argentatus*), kittiwakes and razorbills. More than 60% of the birds recorded were guillemots and razorbills. The Manx shearwater (*Puffinus puffinus*), storm petrel (*Hydrobates pelagicus*) and puffin (*Fratercula arctica*) populations had not returned to the area at the time of the spill.

These surveys were not designed to count oiled birds, but it was estimated that about 3% of all birds showed some degree of oiling. The highest degree of oiling was recorded to the south and south-east of Milford Haven, and the lowest to the south-west and west. However, there was no apparent relationship between the numbers of guillemots and razorbills recorded in coastal waters and the numbers recorded dead on adjacent coasts[11] .

7.6 MONITORING THE BREEDING COLONIES AND OTHER STUDIES

Between May and August 1996, and again in 1997, all the colonies of ten species of breeding seabird were monitored. The results were compared with similar surveys carried out since 1969 for Operation Seafarer[26] and for the 1985-87 Seabirds Colony Register[1]. Survey methods followed the Seabird Monitoring Handbook[27]. The results of these studies are given species by species in §7.7 - 7.15.

Monitoring studies show whether significant numbers of birds have been killed, but there was also concern that birds in the area may have suffered sub-lethal effects, ie having adverse effects on their performance or behaviour though not leading directly in the short-term to their death. For example, higher than normal levels of hydrocarbons in the birds' bodies could conceivably affect breeding or the future health of the birds and their offspring. Checks were therefore made on blood and egg samples; and breeding success studies were undertaken on several species of seabird, comparing results with previous annual studies on Skomer.

7.6.1 Blood analysis

Samples of blood were taken - under Home Office licence - from adult guillemots and razorbills, and from adult and nestling shags (*Phalacrocorax aristotelis*) from Skomer and Middleholm. For comparison, similar samples were taken on the Isle of May in Scotland.

The samples were analysed for signs of haemolytic anaemia. Seabirds exposed to PAHs can become severely anaemic[28], which can have a major impact on the efficiency of their foraging for food, particularly for diving species as it reduces the bird's oxygen-storing capacity and therefore the time it can spend underwater.

Whilst there were differences between the samples from Pembrokeshire and those from the Isle of May, including lower immature blood cell counts in the blood of Pembrokeshire birds, these findings do not suggest any physiological impairment resulting from the ingestion of oil. The oxygen-carrying capacity of blood from the south-west Wales shags and guillemots appeared to be greater than in the samples from Scotland. These results do not suggest any major sub-lethal effects resulting from the *Sea Empress* oil spill[28].

7.6.2 Egg analysis

Samples of seabird eggs were collected - under licence - during 1996 and analysed for PAH and *n*-paraffin residues[29] Samples included cormorant (*Phalacrocorax carbo*) eggs from St Margaret's Island; shag eggs from Middleholm and the Isle of May (a reference site); herring gull eggs from Caldey, Skomer and the Isle of May; and chough (*Pyrrhocorax pyrrhocorax*) eggs from south Pembrokeshire and Anglesey (another reference site). A sample of weathered oil from the *Sea Empress* was also analysed for the same chemicals as a comparison.

No *n*-paraffins were detected in any of the samples. Less than 1 µg/kg of PAHs were found in the eggs from both the reference and the Pembrokeshire sites, and there was no evidence that PAH levels were higher in the Pembrokeshire eggs. Indeed, the Isle of May shag eggs had slightly higher levels than the Pembrokeshire samples. The PAH profile in eggs from Pembrokeshire did not match particularly well with that of the weathered *Sea Empress* oil. It is likely that the PAH concentrations found in the eggs probably resulted from accumulation by birds of the low levels of PAHs which are widespread in the environment. However, only a small number of eggs were analysed, so the possibility is that patchy or relatively small scale elevations in PAH levels may not have been detected[29].

Although the PAH levels observed were probably not associated with the oil spill, they may still be a cause for concern as they were similar to or just below levels shown in experiments to have a toxic effect on embryos. However, little is known of the normal background PAH levels in seabird eggs and their effects[29].

7.6.3 Examination of corpses

More than 700 oiled seabird corpses were examined[24]. The birds were measured, food remains in the guts of 330 of the birds were analysed, and 230 corpses were examined pathologically to assess the cause of death.

Most of the birds were found to be in good condition but had died, due directly or indirectly to oiling. External oiling for almost all the birds examined was between 15% and 100%. The analysis of gut contents confirmed that the birds had been feeding normally; out of the 98 food items found, 70% were small gadoid fishes (from the cod family).

The empty stomachs of almost all of the auks and divers examined contained oil. Heavy oiling seems to have disabled the birds very quickly before the birds had a chance to preen themselves. Further findings from this study are given in the discussions of the different species which follow.

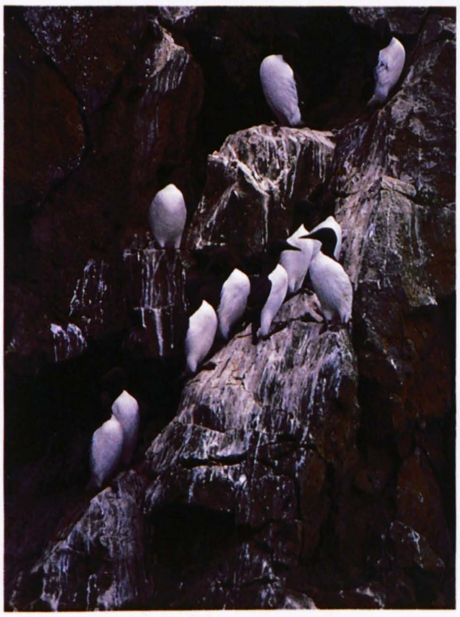
7.7 GUILLEMOTS (*Uria aalge*)

Guillemots are especially at risk of oiling because of their lifestyle. They spend much of their time on the surface of the sea - at some times of the year in large groups - and they feed by diving in pursuit of fish. Around 1,600 oiled guillemots were collected from beaches following the spill.

There are large numbers of guillemots in the region. In late winter the population includes birds returning to their breeding sites in the area as well as guillemots on their way northwards to other colonies. Around 26,000 guillemots were recorded in south-west Wales colonies in 1995; about 40% of these were on Skomer and 25% at Elegug Stacks, on the Castlemartin coast. The colonies have been regularly monitored over the last 30 years. There has been a trend of increasing numbers at most Welsh colonies since 1970, following earlier setbacks - most notably the "Irish Sea seabird wreck" resulting from a storm in the autumn of 1969 during which a large number of guillemots died (estimates vary between 15,000[30] and 35,000[31] deaths). In 1986 numbers in the Skomer colony fell by 5%, thought to be due to the *Bridgeness* oil spill the previous year[2]. Since then, the trend in south-west Wales until 1996 has been a steady annual population increase at most colonies at an average rate of about 8% per annum (*table 7.2*).

In 1996, 2,600 fewer breeding birds than 1995 were counted in the area affected by the spill (based on whole-colony count data - *see Box 7.1*), a decrease of 13%[4,32] (*table 7.2*). In contrast, colonies in north Pembrokeshire and Ceredigion increased in number; and even on Ramsey Island (at the northern end of the affected area) the upward trend continued with a 6% increase in whole-colony counts (7% in study plots)[4]. A similar increase in south Pembrokeshire and the islands, following the trend of recent years, would have resulted in around 1,200 more guillemots in the region in 1996.

The change was not uniform. On Skomer, numbers in study plots were the same as in 1995, the first season since 1990 with no increase[32]. On the other hand, numbers at all of the south Pembrokeshire colonies fell. At Elegug Stacks there was a significant decrease of 11% in the mean counts at the study plots (*table 7.3*).



Guillemots at Elegug Stacks, Castlemartin (M Baines)

Box 7.1 METHODS FOR COUNTING AUKS

Whole-colony counts: The total number of birds in a colony are counted from land or sea on one or more occasions in June. All the birds at the colony can vary from day to day, and counting can be difficult, so the counts may not always be an accurate estimate of the number of birds at the colony.

Study plot counts: Study plots are selected portions of a colony which are counted - from a good vantage point on land - five to ten times annually during the first three weeks of June. The mean study plot count provides the most statistically reliable method of showing year to year changes.

On Lundy, the study plot count showed 8% fewer birds in 1996 compared with 1995 (a decrease which was not statistically significant), while the whole-colony count was 27% lower than the previous count in 1992[33].

Some care is needed in interpreting the 1996 population figures. The breeding season at many British guillemot colonies was later than usual, and so counts made in early June may have been artificially low[33]. However, these counts do not take account of the number of non-breeding immature birds from other regions in the area at the time of the spill - an unknown number of which are likely to have been killed. Ringed birds amongst those washed ashore showed that at least some young birds from colonies as distant as south-west and south-east Scotland were affected by the spill (see §7.7.1 below).

Breeding success was monitored at three colonies in south and mid-Pembrokeshire and at one control site, Needle Rock, in north Pembrokeshire. Results at all the colonies were within the range recorded on Skomer during the period 1989 to 1996[4]. Studies of guillemots on Skomer showed that fewer two- and three-year-old birds survived in 1996 and 1997 compared with previous years[34].

Numbers substantially increased at most sites in 1997: overall, the whole-colony counts had increased by around 13% in south Pembrokeshire and the main seabird islands, although numbers on St Margaret's and Caldey Islands remained low. Bad weather in June 1997 probably reduced numbers in some colonies in north Pembrokeshire and Ceredigion exposed

Table 7.2 Whole-colony counts of guillemots at major colonies in south-west Wales.

Breeding colony	1987	1995	1996	1997	Average annual % change 1987-95	% change 1995-96	% change 1996-97
Mid & south Pembrokeshire - the area affected by the spill							
Skomer	6192	9995	9174	9721	+8	-8	+6
Middleholm	nc	183	212	214		+16	+1
Skokholm	292	684	509	613	+17	-26	+20
Elegug Stacks	3470	5928	4865	6091	+9	-18	+25
Stackpole Head to Elegug Stacks	1224	2149	2037	2284	+8	-5	+12
St Margaret Head	437	791	334	379	+10	-58	+13
Caldey	27	38	11	9	+5	-71	-8
Totals	11642	19768	17142	19311	+9	-13	+13
Ceredigion/North Pembrokeshire							
New Quay Head	2336	2062	2908	2744	-2	+41	-6
Ramsey	1740	2487	2640	2904	+5	+6	+9
Totals	4076	4549	5548	5648	+1.5	+22	+2

Table 7.3 Guillemot mean study plot totals at Skomer & Elegug Stacks

		1991	1992	1993	1994	1995	1996	1997
Skomer[32]	Mean totals	1911	1971	2220	2426	2664	2664	2838
	% change		+3.1	+12.6	+9.3	+9.8	0	+6.5
Elegug Stacks[33]	Mean totals	1646	1583	1806	1795	1764	1573	1908
	% change		-3.8	+14.1	-1.0	-1.7	-10.8	+21.3

Table 7.4 Selected razorbill whole-colony counts

Breeding colony	1987	1995	1996	1997	Average annual % change 1987-95	% change 1995-96	% change 1996-97
Mid & south Pembrokeshire - the area affected by the spill							
Skomer	2938	3393	**2934**	2931	+2	-13	0
Skokholm	702	891	**941**	1073	+3	+6	+14
Middleholm	nc	243	**253**	256	nc	+4	+1
Elegug Stacks	nc	418	**615**	656	nc	+47	+7
Stackpole Head to Elegug Stacks	117+	203	**206**	297	(+9)	+2	+44
St Margaret's	146	222	**100**	91	+7	-55	-9
Caldey	89	105	**16**	13	+2	-85	-19
Totals	**3992+**	**5475**	**5056**	**5317**	**(+5)**	**-8**	**+5**
Ceredigion/North Pembrokeshire							
New Quay Head	243	261	**314**	286	+0.9	+20	-9
Ramsey	800	1267	**1317**	1496	+7	+4	+12
Totals	1043	1528	**1631**	1755	+6	+7	+8

Table 7.5 Razorbill mean study plot totals at Skomer & Elegug Stacks 1991-1997

		1991	1992	1993	1994	1995	1996	1997
Skomer	Mean totals	692	705	721	833	886	**807**	905
	% change		+3.1	+2.3	+15.4	+6.3	**-9.0**	+12.2
Elegug Stacks	Mean totals	233	245	258	257	305	**327**	358
	% change		+5.2	+5.3	-0.4	+18.7	**+7.2**	+3.4

to northerly winds[35], and breeding success on Skomer in 1997 was also reduced by bad weather[34]. Several more seasons' data on breeding numbers and adult survival rates are needed before the full extent of the impact can be assessed.

7.7.1 Examination of corpses

504 corpses were examined examined[24] There was a high proportion of males, suggesting that these were birds returning early in the season to establish territories. 53% were summer plumage adult males probably already visiting Welsh or perhaps Irish nest sites. About 1% were "bridled head" guillemots; this low proportion indicated that the population involved was local to the Irish Sea, and this was supported by three ringed birds of which two (aged 23+ and 10+ years old) were local, and one (aged 16+) had been ringed in south-east Ireland. However, three more ringed birds showed that there had also been some non-breeding younger birds killed; two first year birds had been ringed on the Isle of May in south-east Scotland, and a second year bird was from Sanda Island in south-west Scotland.

More than 75% of food items in the stomachs of auks were small gadoids - *Trisopterus*, probably Norway Pout (*T esmarkii*) - and whiting (*Merlangius merlangus*).

7.8 RAZORBILLS *(Alca torda)*

Another auk species, razorbill, also featured highly amongst the birds coming ashore oiled: more than 340 were recorded. Internationally-important populations of these birds breed around south-west Wales, particularly on the islands of Skomer, Skokholm and Middleholm. There are also significant numbers on Ramsey and along parts of the Castlemartin coast. In total, there were between 7,500 and 8,000 razorbills in south-west Wales in 1995.

Like guillemots, razorbills were affected by the 1969 "Irish Sea seabird wreck". Since then their numbers have increased at most colonies in south-west Wales at a rate of approximately 5% *per annum*, and they have also colonised or re-colonised other sites[4].

Following the spill, there was an overall decrease of 7% in razorbills (ie approximately 420 fewer birds) compared with 1995 at the south and mid-Pembrokeshire colonies between Skomer and Caldey Island, according to whole-colony counts[35] (see *table 7.4*). There was considerable variation in the degree of change, with some

Razorbills (R Haycock, CCW)

colonies in the area even showing an increase in numbers. Provisional 1997 data showed an overall slight increase in the population in the area affected by the spill, but not at the sites which had been proportionately worst hit - Caldey and St Margaret's Island[35].

Razorbill breeding success was monitored at five study sites on Skomer in both 1996 and 1997. Overall breeding success was similar in both years and within the range recorded since these studies began in 1994[36].

Region	No. of colonies		No. of apparently occupied nests		% change 1994-1996
	1994	1996	1994	1996	
South Pembrokeshire	4	5	350	283	-19%
Cardigan Bay	11	9	315	254	-19%
North Wales	14	14	1626	1646	+1%
Total	29	28	2291	2182	-5%

Table 7.6 Regional totals for cormorants breeding in Wales[33,38]

	1991	1992	1993	1994	1995	1996	1997
No of apparently occupied nests	187	210	320	260	230	207	187

Table 7.7 Number of apparently occupied nests at St Margaret's Island[4,38]

7.8.1 Examination of corpses

172 razorbill corpses were examined[24]. Males outnumbered females at all ages and 30% were adult males. The adults were from one morphological population (based on wing and bill measurements and plumage) but the younger birds were more variable. The reproductive state was most advanced in the summer plumage adults (a sign that the birds were resident in the area and in breeding condition); these made up 46% of the total.

Three ringed birds were found in south-west Wales, all from colonies in south-east Ireland. One was in its 3rd year, the other two were aged 10+ and 13+ years. This supported observations from earlier oil spills, such as the *Christos Bitas*, that there are links between Irish and Welsh auk colonies in the southern Irish Sea[37].

7.9 PUFFINS (*Fratercula arctica*)

The islands of Skomer, Skokholm and Middleholm host the most important breeding population of puffins in Wales, currently about 13,000 birds (approximately 1.5% of the populations of this species within the European Union), making this of international importance.

Few puffins were in the area at the time of the spill and there were no indications that they were affected by it. Only two dead puffins were collected from the beaches, and both were unoiled and probably died as a result of normal winter mortality. The population is difficult to count accurately, but breeding success was reported to be good in 1996.

7.10 CORMORANTS (*Phalacrocorax carbo*)

The Welsh cormorant population is of national and international significance, and there was concern about the potential impact of the oil spill on cormorant colonies in south Wales[33]. During the spill, 10 oiled cormorants were collected from beaches.

Numbers of cormorants at breeding colonies were low in areas affected by the oil spill compared with levels recorded during 1994. A similar decline was observed in areas of west Wales not directly affected by the spill (see *table 7.6*). There was no firm evidence of an immediate impact, and the reduction in numbers of breeding pairs in 1996 may have been related to unusually cold spring weather[33,38].

Counts for the largest south west Wales colony - St Margaret's Island, near Tenby - are given in *table 7.7.* The number of apparently occupied nests decreased in 1996, but the breeding population has been declining annually since 1993. In 1996 this was still within the normal variability recorded over the last 30 years. Breeding success in 1996 at St Margaret's Island, Block House Stack (near Angle) and Green Scar (near Solva in mid-Pembrokeshire) was not significantly lower than at control areas (Dinas Island in north Pembrokeshire and Penderi in Ceredigion) or at colonies in south-west England and North Wales[4,38]

The numbers of cormorants breeding in most Welsh colonies in 1997 were comparable with those of 1996, but numbers at St. Margaret's Island declined further *(table 7.7)*; only in 1983 have fewer pairs been recorded. Breeding success was also lower at St Margaret's Island in 1997[39].

7.11 SHAGS *(Phalacrocorax aristotelis)*

The number of shags breeding around the south--west Wales coast has decreased since 1969. Shags are thought to be vulnerable to accidental entanglement in fishing gear[40], and this may have contributed to their overall decline[4]. 27 oiled shags were collected from beaches during the spill including two ringed birds, one from Middleholm and one from south-east Ireland.

There was a small but significant decrease in the populations of south Pembrokeshire, though the largest colony (on Middleholm) did not appear to have been affected (*table 7.8*). Count data in 1997 did not suggest that there had been any significant changes overall.

Table 7.8 Total numbers of occupied shag nests counted at selected areas in south-west Wales.

Colony/Area	1995	1996	1997
Cardigan Island	10	14	11
Ramsey/Bishops & Clerks	28	28	26
Middleholm	35	37	33
Castlemartin Coast	12	6	6
St Margaret's Island & Caldey	18	8	9

7.12 GANNETS (*Morus bassanus*)

The south-west Wales area hosts a major colony of 30,000 pairs of gannets on Grassholm[1], currently believed to be the third largest gannetry in the world.

In early 1996 there was a rapid increase (from 0.4% to 4.4%) in the proportion of Grassholm gannets which showed clear signs of oil contamination on their plumage; the timing suggested that oil from the *Sea Empress* spill was the most likely cause. Oil slicks did not reach Grassholm but there was concern that oil residues may have been carried to the colony on the birds' feathers or on oil-contaminated marine debris collected during nest--building, and that this might affect breeding success[41].

Gannets (E Bent)

Samples of nest material were therefore taken from Grassholm and a reference colony on St Kilda and were analysed for levels of PAH residues. The levels of PAHs from the single St Kilda sample appear to have been at the lower end of the range of levels recorded in the Grassholm samples [41]. However, the type of nest material collected by gannets at the two sites requires more detailed study before firm conclusions can be reached.

The colony was not counted in 1996, but studies (albeit of small samples) of gannet hatching success on Grassholm, showed no evidence that the oil had affected breeding performance at this internationally important site (*table 7.9*).

Table 7.9 Breeding success of gannets on Grassholm

	1993-95	1996	1997
No.of nests monitored	222-891	821	343
% with chicks	57-67%	71%	83%

7.13 GULLS

Nearly a fifth of the world population of a subspecies of lesser black-backed gull, *Larus fuscus graellsii*, breed in south-west Wales, with Britain's second largest colony on Skomer[4]. Around 5,000 pairs of herring gulls (*Larus argentatus*) breed in south-west Wales: the largest colony in the region is on Caldey Island[4]. Great black-backed gull (*Larus marinus*) are much less abundant than the other two species of gull and numbers in Wales are comparatively small[1].

Although oiled herring gulls were seen in Milford Haven waterway, at sea and along part of the coast during the spill, only 49 were collected from beaches. During summer 1996 a few dozen oil-stained herring gulls were seen at breeding colonies and coastal car parks in south Pembrokeshire. They seemed to be surviving well, preening or moulting out contaminated feathers. Count data showed no evidence of an impact to the gull species attributable to the spill. The number of nests of lesser black-backed gulls increased at most sites in the region in 1996; and, although the number of nests decreased on Skomer (from 15,500 to 14,400 nests); this was consistent with low breeding success following breeding failures in 1989 and 1990. Numbers of herring gull nests on Skomer and Skokholm decreased in 1996 for the third year in succession, but numbers increased at the most important site on Caldey Island and at other colonies monitored. Numbers of great black-backed gulls showed little change at most colonies[4,33].

7.14 KITTIWAKES *(Rissa tridactyla)*

A study of kittiwake breeding success was carried out in 1996[33,42]. The breeding success on Skomer (averaging 0.45 chicks per nest) was the lowest since 1986, and it had also declined at Elegug Stacks (0.2 chicks per nest) and St Margaret's Island (0 chicks). However, decreased breeding success started before the *Sea Empress* oil spill - also observed in south-west England and south-east Ireland - and there was no evidence to indicate that any changes in food availability or nest attendance patterns were caused directly or indirectly by oil from the *Sea Empress*. Provisional data for 1997 suggest that breeding success may be a little higher[35].

7.15 FULMARS (*Fulmarus glacialis*), MANX SHEARWATERS (*Puffinus puffinus*) and STORM PETRELS (*Hydrobates pelagicus*)

There were no indications of any significant effect on fulmars, Manx shearwaters or storm petrels. The Manx shearwaters and storm petrels populations had not returned to the area at the time of the spill. Some colonies of fulmars in the area affected by the oil spill decreased slightly in 1996 compared with 1995, though this was within the range of day-to-day variation in the number of non-breeding birds present at the colonies[4].

Wintering Waterfowl and Gulls

7.16 INITIAL COUNTS

During the winter, the Milford Haven waterway - and the Daugleddau Estuary which feeds into it - support large numbers of wildfowl, waders and gulls which have been monitored since 1982 through the Wetland Bird Survey[43]. Following the oil spill, systematic counting of birds in the main embayments was carried out on a daily basis up to 25 February and weekly thereafter to the end of March, recording the maximum number of birds of all species and the proportion oiled.

Figure 7.5 Bird counts within Milford Haven waterway and the Daugleddau Estuary

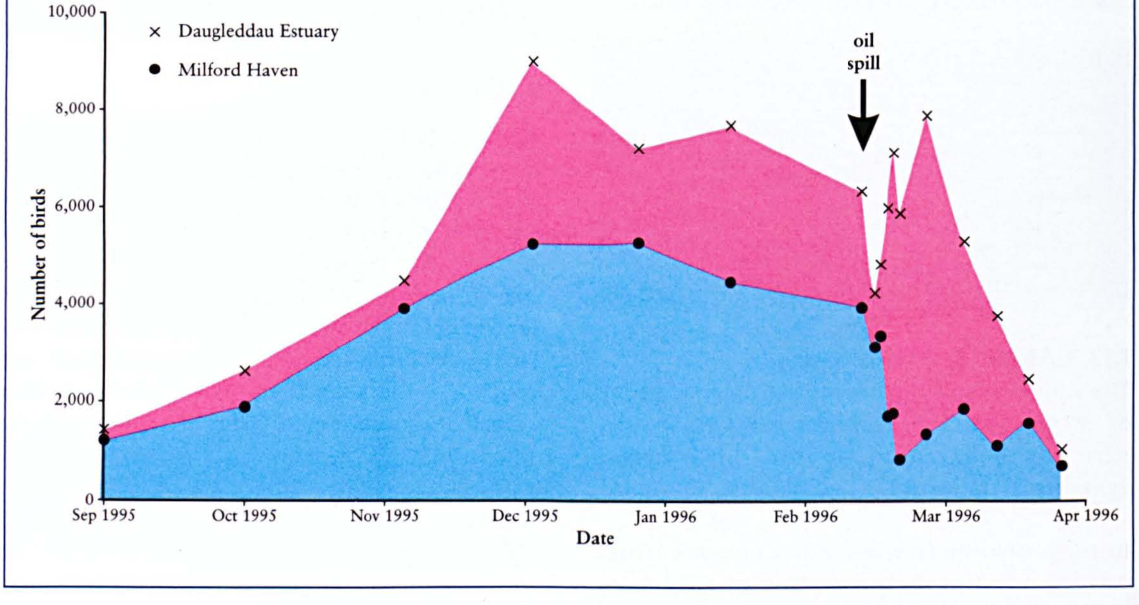


Table 7.10 - The days in February and March 1996 with the greatest proportion of oilded birds counted in the Milford Haven waterway and Daugleddau Estuary.

	22 February 1996			10 March 1996		
SPECIES	**No present**	**No oiled**	**% oiled**	**No present**	**No oiled**	**% oiled**
Red-throated diver	1	0	0	0	0	0
Little grebe	6	0	0	10	0	0
Great crested grebe	4	2	50	10	0	0
Red-necked grebe	2	1	50	0	0	0
Cormorant	44	4	9	38	0	0
Grey heron	7	0	0	19	0	0
Little egret	8	0	0	2	0	0
Mute swan	26	7	27	31	4	12
Canada goose	5	0	0	86	0	0
Shelduck	964	22	2	703	6	1
Wigeon	798	3	0.4	667	0	0
Teal	760	0	0	791	0	0
Mallard	131	0	0	49	0	0
Pintail	4	0	0	9	0	0
Shoveler	3	0	0	2	0	0
Tufted duck	0	0	0	1	0	0
Goldeneye	15	1	6	14	0	0
Eider	1	0	0	0	0	0
Red-breasted merganser	8	0	0	14	0	0
Moorhen	0	0	0	2	0	0
Total Wildfowl	**2787**	**40**	**1.4**	**2448**	**10**	**0.4**
Oystercatcher	369	86	23	90	23	25
Ringed plover	49	12	24	8	0	0
Grey plover	29	0	0	6	0	0
Lapwing	610	0	0	446	0	0
Knot	29	16	55	46	0	0
Snipe	0	0	0	53	0	0
Jack snipe	0	0	0	1	0	0
Ruff	0	0	0	1	0	0
Bar-throated godwit	5	0	0	2	0	0
Dunlin	3645	23	0.6	2981	0	0
Curlew	636	4	0.6	927	0	0
Spot redshank	0	0	0	1	0	0
Redshank	437	6	1.4	489	0	0
Greenshank	2	0	0	14	0	0
Turnstone	64	5	8	0	0	0
Total Waders	**5875**	**152**	**2.6**	**5293**	**23**	**0.4**
Black-headed gull	2283	473	20	1793	12	0.7
Common gull	124	65	52	100	0	0
Lesser black-backed gull	62	35	56	136	0	0
Herring gull	287	144	50	130	5	4
Great black-backed gull	5	1	20	21	0	0
Total Gulls	**2761**	**718**	**26**	**2180**	**17**	**0.8**
TOTAL BIRDS	**11423**	**910**	**8**	**9921**	**50**	**0.5**

On 18 February 1996 there were more than 12,000 waterfowl and gulls present within the Milford Haven waterway and Daugleddau Estuary[44]. The number of birds fell sharply throughout the estuary complex shortly after the tanker grounded and remained low in the worst-affected parts of the lower estuary (*figure 7.5*), though numbers generally increased again a few days later in the embayments above the Cleddau Bridge which had escaped significant oiling. By late February many species were beginning to leave the estuary on migration, but shelduck (*Tadorna tadorna*) and curlews (*Numenius arquata*) were still present in nationally important numbers.

Between 18 February and 3 March oiled birds of 27 species of waterfowl and gulls were observed. The highest proportion of oiled birds was seen on 22 February when around 8% of the 900 birds present were oiled - mainly gulls (including more than 50% of the common gulls *Larus canus*, herring gulls and lesser black-backed gulls), with some waders and wildfowl also affected (*table 7.10*). By 10 March there were far fewer birds in the area, of which less than 1% were oiled. The numbers of birds in the estuary and the proportion oiled continued to decrease during the rest of the month.

Although a great number of birds were seen to be oiled, few dead or live oiled birds were collected from the shore. This may have been because the oiling on their plumage was not severe enough to disable the birds or because the birds moved away from the area. Some oil-stained herring gulls were seen in summer 1996 and probably moulted out their oiled feathers (see §7.13).

Some important embayments in the area were heavily contaminated by oil, notably Angle Bay and Pembroke River. Contamination within some parts of Angle Bay continued to pose a threat to birds during summer 1996. These areas were monitored regularly and underwent a prolonged clean-up operation to remove surface and sub-surface oil.

7.17 MONITORING DURING THE WINTER OF 1996/97

To assess the impact on the waterfowl populations, four sites were chosen and counts were made at all states of the tide (following standard all-day count methodology[45]). A similar census had been undertaken in winter 1987/88[46]. The four sites chosen were:

- Angle Bay: heavily oiled following the spill, with mudflats between Angle Point and Sawdern Point further affected by secondary contamination coming from the oil stranded on the upper shore;
- Pembroke River: moderately oiled, particularly with heavy fuel oil on the upper shore and saltmarsh west of Bentlass, with some secondary contamination of mudflats and eelgrass beds;
- the Carew/Cresswell complex, effectively unoiled; and
- the confluence of the Eastern and Western Cleddau, again unoiled.

Nine species of bird were investigated in detail: shelduck, wigeon (*Anas penelope*), teal (*A crecca*), oystercatcher (*Haematopus ostralegus*), grey plover (*Pluvialis squatarola*), dunlin (*Calidris alpina*), bar-tailed godwit (*Limosa lapponica*), curlew and redshank (*Tringa totanus*). The study will continue for three years and will use Wetland Bird Survey counts made on the estuary over the last fifteen years.

A report on the first year's work found no firm evidence of any major impact of the oil spill on waterfowl numbers in the study areas or totals for the whole estuary[47]. There were changes in the feeding distributions and numbers of some species; this may have been due to the effects of oil though it may simply be due to natural fluctuations in population sizes. While numbers of oystercatchers, curlews and redshanks were lower on the two oiled sites, shelduck, wigeon and teal numbers had increased between 1987/88 and 1996/97. These three wildfowl species may have benefited from changes in the availability of food resulting from oil contamination[47], exploiting small but potentially numerous invertebrates such as some worms, (including *Capitella* spp and *Nematoda* spp) which are able to take advantage of disturbed ecosystems (see §4.13.2). Oystercatchers and curlews, on the other hand, tend to rely on larger food items such as mussels, cockles, *Arenicola* (lugworm) and *Hediste* (ragworm) which may have been reduced in numbers by oil contamination.

Wigeon and teal may also have exploited the eelgrass (*Zostera angustifolia*) at Pembroke River that has grown in abundance since the spill (see §5.7)[48]. However, they were not seen feeding at the eelgrass beds in Angle Bay. Another possible food source could be *Enteromorpha* or *Ulva*, both of which were abundant in 1996/97 (see §4.3.2).

A separate study gave no indication that the oil spill had any adverse effects on the resident shelduck breeding population within the estuary complex. The numbers of broods in 1996 and 1997 were high compared with 1995 and earlier observations[49,50].

7.18 CONCLUSIONS

The impact of the spill differed markedly between bird species. This was shown clearly by the records of oiled birds collected from the beaches following the spill: over 90% of these were from just three species - common scoter, guillemot and razorbill. These birds spend much time on the surface of the water and dive to feed, leaving them vulnerable to oiling. The same is true for the diver species wintering in the area, and it has been estimated that the number of oiled divers coming ashore was a very high proportion of the birds which would have been in the region at the time of the spill. In contrast, although many oiled gulls were seen at sea and within Milford Haven waterway, very few dead gulls were found on beaches and numbers increased at most breeding colonies. Oiled herring gulls were seen surviving in the summer 1996 and it is likely that many of the oiled birds were robust enough to survive the oiling.

The wintering population of common scoters in Carmarthen Bay was badly affected by the oil spill, and 3,500 scoters are known to have died. 1997 counts showed about 10,000 fewer birds visiting Carmarthen Bay than the 1996 peak, but this may, in part, be a result of other factors as populations fluctuate considerably from year to year. The population will be monitored until 2001. If this important population of scoters is to be protected in future, it is important to fill in the many gaps in our knowledge revealed by these studies. Work is necessary to establish where the birds breed, the abundance and distribution of the species they eat in Carmarthen Bay and the possible effects of pollution and commercial exploitation of shellfish on the food-chain in the bay.

Monitoring of the breeding seabird populations confirmed the impact on guillemots and razorbills. Instead of the increase in numbers of guillemots seen in nearby areas, in 1996 there were 2,600 fewer guillemots counted at the breeding colonies than in 1995, and 420 fewer razorbills (decreases of 13% and 7% respectively). These counts may under-estimate the number of non-breeding birds which may have been killed, including birds from other regions which had been passing through the affected area: ringed birds collected from the beaches provided evidence that at least some of these had been killed.

A number of important species appeared to have avoided any significant impact. Puffins, Manx shearwaters and storm petrels were away from the region at the time of the spill, and the oil did not reach Grassholm Island with its important gannet population. For other species of seabirds, monitoring data did not show any obvious trends which could be related to the spill. There was a significant decrease in the small shag populations along the south Pembrokeshire coast, but local decreases in some populations of other species were in line with trends established before the spill or with similar decreases observed outside the affected area. Studies provided no clear evidence of effects on breeding success of several species. However, further monitoring will be needed to confirm that there has not been an effect on a particular year-class and to check the recovery of impacted species. It is therefore important that the breeding seabird monitoring programme continues and that the colony register database is maintained. To provide better baseline information for any future incident, it would be beneficial to improve knowledge of the distribution and seasonal variation in population numbers close to important seabird areas.

Examination of seabird and scoter corpses showed that the birds died directly from the oil. The seabirds in particular appeared to have been feeding normally and had died quickly. Studies provided no evidence of sub-lethal effects such as anaemia or increased PAHs in eggs, and there was no evidence of birds dying through effects on the food chain - which is in line with the results of the marine studies which found little impact on fish (including sand eels, an important prey species). Studies of the scoters, on the other hand, suggested that egg-razor shells in Carmarthen Bay had been affected by the oil and had, as a result, become available to the scoters. So far they have only been recorded in scoter diet after oil spills, and it is not known whether they are eaten under normal conditions.

The programme of bird studies following the *Sea Empress* oil spill has provided one of the first examples in the UK where a full range of studies - including immediate and long term monitoring, and the collection and analysis of corpses and live birds - has been successfully integrated.

The essential points which enabled this work to take place included:

- The existence of good baseline survey data and previous regular monitoring, using standard methods.
- Ringing studies, which provided information on the likely origins of populations of particular species.
- Co-ordinated ground and air--based surveillance, covering a wide geographical area.
- Good record-keeping - though, despite the considerable effort devoted to trying to maintain compatible records for live and dead birds collected from beaches, the largenumber of birds meant that full information was not recorded for every bird.
- Computerisation of bird data and the use of electronic communication.

The availability of experienced volunteers together with trained professional wardens, rangers and ecologists proved crucial. The air-based work, in particular, required experienced observers. Many people were seconded to *Sea Empress* operations for specific tasks. Without the immediate availability of these personnel and such a swift organisational response it would have been difficult to collect the detailed information required daily by the JRC.

Based on lessons learnt following the *Sea Empress* spill, future plans might include:

- Plans for seabird surveys by boat and aircraft to start immediately; these should be designed to study the relationship between seabird distribution, the spread of oil and seabird mortality;
- Protocols for minimising disturbance to roosting,feeding and nesting birds and for avoiding sensitiveseabird and waterfowl and safe areas with aircraft flights;
- Protocols for making the most efficient use of volunteers;
- Access to survey military areas;
- A strategy for collecting and recording complete details for all live and dead beached birds; this should include the necessary standard recording proformas, maps and charts and the appropriate computing and communication technology;
- A protocol for the collection and storage for frozen seabird corpses;
- A protocol for licensing corpse drift studies;
- Integration of corpse drift experiments with oil spill computer modelling.

REFERENCES

1 Lloyd, C., Tasker, M.L. & Partridge, K. 1991. *The status of seabirds in Britain & Ireland*. Poyser, London.

2 Lovegrove, R.R., Williams, G.A. & Williams, I.T. 1994. *Birds in Wales*. Poyser, London.

3 Donovan, J.W. & Rees, G. Rees. 1994. *Birds of Pembrokeshire: Status and Atlas of Pembrokeshire Birds*. Dyfed Wildlife Trust.

4 Baines, M.E. & Earl, S.J. 1996. Breeding seabird of south-west Wales, 1996, following the grounding of the *Sea Empress*, ruary 1996. Dyfed Wildlife Trust Report to SEEEC.

5 Poole, A. In prep.. Milford Haven and Cleddau Estuary wetland bird survey 1996–1997 Report prepared for MHWEMSG on behalf of the Wildlife Trust West Wales and the Pembrokeshire Ornithological Research Committee.

6 Stewart, B. 1995. Survey of common scoter *Melanitta nigra* in Carmarthen Bay 1994/5. Report to The Countryside Council for Wales, Aberystwyth.

7 *Sea Empress* Environmental Evaluation Committee 1996. Initial Report, July 1996.*Sea Empress* Environmental Evaluation Committee, Cardiff.

8 Parr, S. J., Haycock, R. J. & Smith, M. E. 1997. The impact of the *Sea Empress* on birds of the Pembrokeshire coast and islands. International Oil spill conference.Improving environmental protection. Progress, challenges, responsibilities. American Petroleum Institute publication, no. 4651, Washington DC, US

9 Howlett, P. 1996. Report on sorting of casualties from the *"Sea Empress"* oil spill, received at the National Museum and Gallery, Cardiff. Report to Countryside Council for Wales.

10 Hurley, J. 1996. The March '96 oil incident. Wexford, SWC Promotions.

11 Colombe, S.V., Reid, J.B. & Webb, A.. 1996. Seabird studies off south-west Wales and south-east Ireland following the *Sea Empress* incident at Milford Haven,February 1996. Joint Nature Conservation Committee Report No. 225.

12 Thomas, D. 1996. Pembrokeshire beached birds surveys. Unpublished report to CCW.

13 Hagemeijer, EJM & Blair, MJ (Editors). 1997. *The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance.* T&AD Poyser, London

14 Hughes, B., Stewart, B., Brown, M. & Hearn, R. 1997. Theeffect of the *Sea Empress* oil spill on wintering common scoter *Melanitta nigra* in Carmarthen Bay, Pembrokeshire. Wildfowl and Wetlands Trust Report to SEEEC.

15 Stewart, B. Bullock, I, Haycock, R J. & Hughes, B. 1997. Land-based and air-based monitoring of common scoters in Carmarthen Bay, 1996-1997. Wildfowl and Wetlands Trust Report to SEEEC.

16 Bullock, I. & Williams, I. 1997. Aerial survey of thewintering scoter in Carmarthen and Cardigan Bays.RSPB. Draft Report to SEEEC.

17 Joensen, A.H. & Hansen, E.B. 1972. Oil pollution and seabirds in Denmark. Dan. Rev. Game Biol. 10 (5):1-31.

18 Underhill, M.C. & Hughes, B. 1996. The status of breeding common scoter *Melanitta nigra nigra* in Britain and Ireland in 1996: the effect of the *Sea Empress* oil spill. Wildfowl and Wetlands Trust Report to SEEEC.

19 Delany, S. & Gittings, T. 1996. Survey of common scoters at known Irish breeding sites, May 1996. Unpublished report, BirdWatch Ireland, Dublin.

20 A Einarsson, *pers comm*

21 Fish, J.D. & Fish, S. 1989. *A students guide to the seashore.* Unwin Hayman, London.

22 Law, R.J., Kelly, C.A., Graham, K.L. & Woodward, R.J. 1997.Hydrocarbons and PAH in fish and shellfish from south west Wales following the *Sea Empress* oil spill. Pp. 205-211 In: *Proc. 1997 International Oil Spill conference, Fort Lauderdale, Florida, April 7-10 1997.* American Petroleum Institute Publ. No. 4651, Washington.

23 Moyse, J. & Thomas, D.K. 1977. Sea duck of Carmarthen Bay. In: (Nelson Smith, A ., Ed.) *Problems of a small estuary.* Quadrant Press Ltd, Swansea. 5:3/1-13.

24 Weir, D.N, Kinder, A., Kitchener, R.Y., McGowan, R.Y.,McOrist, S. & Zonfrillo, B. 1997. Population structure, pathology and diet of samples of diver and auk casualties of the *Sea Empress* oil spill. Report by the National Museums of Scotland and University of Edinburgh to SEEEC.

25 Mackie, A.S.Y., Oliver, G., Ivor, P., Ivor, E. & Rees, S. 1995.Benthic biodiversity in the southern Irish Sea. Studies in marine biodiversity and systematics from the National Museum of Wales. BIOMOR Report No. 1.

26 Cramp, S. Bourne, W.R.P. & Saunders, D. 1974. *The seabirds of Britain & Ireland.* Collins, London.

27 Walsh, P.M., Halley, D.J., Harris, M.P., del Nevo, A., Sim,I.M.W. & Tasker, M.L. 1995. *Seabird Monitoring Handbook for Britain & Ireland.* JNCC/RSPB/ITE/Seabird Group, Peterborough.

28 Monaghan, P. & Turner, C.M.R. 1997. Analysis of blood samples following the *Sea Empress* Oil Spill. University of Glasgow Report to SEEEC.

29 Shore, F. R., Wright, J. 1997. Polycyclic AromaticHydrocarbon and n-Paraffin residues in seabird eggs after the grounding of the *Sea Empress.* Institute of Terrestrial Ecology (Natural Environmental Research Council) Report to SEEEC

30 Holdgate, M.W. 1971. The seabird wreck of 1969 in the Irish Sea. NERC Report.

31 Saunders, D.R. 1976. *A Brief Guide to Birds of Pembrokeshire.* H.G. Walters. (Tenby).

32 Poole, J. & Smith, S. 1996. Seabird Monitoring on Skomer Island in 1996. A Report from the Dyfed Wildlife Trust to the JNCC.

33 Thompson K. R., Brindley E. & Heubeck, M. 1997. Seabird numbers and breeding success in Britain and Ireland, 1996. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No. 21).

34 Birkhead, T.R. 1997. Skomer guillemot studies, 1997. University of Sheffield Report to the Countryside Council for Wales.

35 Baines, M.E. & Earl, S.J. In prep. Breeding seabird of south-west Wales, 1997 Report.

36 Poole, J. 1997. Razorbill breeding success on Skomer Island, 1997. Report to the Countryside Council for Wales, from the Wildlife Trust, West Wales.

37 Evans, S. B. 1979. Oil pollution of west Wales by the *Christos Bitas*, 12 October to 20 November 1978. Nature Conservancy Council, Dyfed/Powys Regional Report No.DP79/1 (unpublished).

38 Sellers, R.M. & Hughes, B. 1996. Status and breedingof cormorants *Phalacrocorax carbo* in Wales in 1996:The effect of the *Sea Empress* Oil Spill. Wildfowl & Wetlands Trust Report to SEEEC.

39 Newson, S., Hughes, B. & Sellers, R.M. 1997. Status and breeding success of cormorants Phalacrocorax carbo in Wales in 1997. Report to SEEEC

40 Thomas, D. 1992. Marine wildlife and net fisheries around Wales. Unpublished Report by the Royal Society for the Protection of Birds and the Countryside Council for Wales.

41 Colombe, S.V. & Santillo, D. In prep Grassholm gannets nest material studies

42 Hamer, K.C. & Turner, V. 1997. Productivity and nest attendance patterns of kittiwakes on Skomer following the *Sea Empress* oil spill. University of Durham, Dept. OfBiological Sciences, Report to SEEEC, Dyfed Wildlife Trust and the Countryside Council for Wales.

43 Waters, R.J & Cranswick, P.A, 1993. The Wetland Bird Survey 1992-93: Wildfowl & Wader counts. BTO/WWT/RSPB/JNCC, Slimbridge.

44 Poole, A. 1996. Milford Haven and Cleddau Estuary wetland bird survey 1995-1996. Report prepared for the Milford Haven Waterway Environmental Monitoring Steering Group on behalf of the Dyfed Wildlife Trust and the Pembrokeshire Ornithological Research Committee.

45 Clarke, N.A. 1990. Distribution Studies of waders and shelduck in the Severn Estuary. Report to U.K. Department of Energy's Re-newable Energy Research and Development Programme (ETSU TID 4076).

46 Prys-Jones, R. 1989. Abundance and distribution of wildfowl and waders on the Cleddau Estuary (Milford Haven). BTO Research Report. Thetford.

47 Armitage, M.J.S., Burton, N.H.K. & Rehfisch, M.M. 1997. The Abundance and distribution of waterfowl within Milford Haven after the *Sea Empress* oil spill. Year 1 Final Report to SEEEC.

48 Hodges, J. E. & Howe, M. 1997. Milford Haven waterway monitoring of Eel grass *Zostera angustifolia*, following the *Sea Empress* oil spill. Interim Report (1996) to SEEEC.

49 Hodges, J. E. 1997. Daugleddau Estuary & Milford Haven Waterway Annual shelduck survey. Unpublished Report for 1996, Pembrokeshire Coast National Park.Hodges, J. E. In prep. Daugleddau Estuary & Milford Haven Waterway Annual shelduck survey 1997 report.

8 Oiled Bird Cleaning and Rehabilitation

8.1 INTRODUCTION

Birds are often the most obvious casualties of oil pollution, providing the principal focus for a concerned public and the media. The sight of oiled birds raises strong feelings, and there is natural concern for the welfare of any live casualties. Following the grounding of the *Sea Empress*, about 7,000 oiled seabirds came ashore around south-west Wales, Lundy and south-east Ireland, and about half of these were still alive. A major rescue operation was mounted to clean and rehabilitate these birds. ("Rehabilitation" is defined differently by different organisations. In this chapter, the term is used to describe cleaned birds which have successfully returned to living in the wild for a significant period of time.)

Guillemot at the RSPCA wildlife hospital in West Hatch (C Seddon, RSPCA)

The consequences for birds of oil pollution are well documented. Less clear, however, is the effectiveness of the bird cleaning operations which follow the spills. The cleaning is generally carried out for the welfare of the individual birds rather than for conservation reasons: for common species, the number of birds cleaned is generally small compared with population sizes. However, recent studies from the USA have cast doubt on whether - for some species of birds - cleaning is in their best interest, suggesting that a very large proportion die soon after release[1]. This view has not gained universal acceptance, and it is likely that there will continue to be a strong public demand for bird cleaning following future spills. The rescue of oiled birds attracts great public support, and this may benefit wildlife conservation and animal welfare indirectly.

Two studies were commissioned. The first study, by Professor RB Clark, reviewed the bird cleaning operation and made recommendations for its future[2]. The second study, by the British Trust for Ornithology (BTO), used data on guillemots - which have been the most common casualties of oil spills in the UK - to calculate survival rates for this species after cleaning[3]. This chapter describes the bird cleaning operation following the *Sea Empress* spill, and draws conclusions from these two studies.

8.2 THE BIRD CLEANING OPERATION

The local oil spill contingency plan identifies the Royal Society for the Prevention of Cruelty to Animals (RSPCA) as the body responsible for co-ordinating the rescue and treatment of live birds in the region, and shortly after the grounding of the *Sea Empress* an RSPCA officer joined the Joint Response Centre (JRC) Environment Team. A number of independent organisations and individuals also mobilised resources.

Several holding centres were set up where birds collected from the beaches could be held and given first aid treatment before being taken to established cleaning centres. To cope with the expected large number of birds being received, an emergency holding and cleaning centre was also set up by RSPCA in premises made available by the District Council at Steynton outside Milford Haven.

Over three weeks, the emergency centre received more than 3,100 oiled birds of 20 different species. About 2,600 of these were common scoter and 420 were guillemots. The next most common species was the red-throated diver (35 birds). Almost all the birds arrived between 24 February and 2 March, with more than 750 being received on 27 February. Around 300 further birds were taken directly to other cleaning centres.

The JRC tried to ensure that all birds taken to the established bird hospitals were properly recorded, though a number of birds are known to have been taken away from the area for cleaning by independent groups. The RSPCA played an important role in obtaining this information for the JRC. Despite these efforts, insufficient details were recorded for many of the birds about the beaches where they were collected.

Given the enormity of the task, the collection of birds, first aid and transportation generally worked well. However, there were some problems. The number of birds at the cleaning centre at Steynton exceeded capacity and staff were diverted from cleaning and rehabilitation tasks to administer first aid to incoming birds. There was a need for additional space, facilities to hold birds for longer periods and more appropriately-trained staff and volunteers.

Birds were cleaned at several small centres in south-west Wales as well as at Steynton, but the principal cleaning centre was the RSPCA Wildlife Hospital at West Hatch, Somerset, which received nearly 2,300 birds for treatment. Smaller numbers of birds were transferred to other RSPCA and independent centres throughout the UK. The bird cleaning process is described in *Box 8.1*.

Although it would normally be desirable to release cleaned birds at the location where they were first collected, this involved the risk that the birds might have been re-oiled. Cardigan Bay was proposed as a release site for scoters as this is an important scoter wintering area which had not been affected by the spill; but this proved impractical, due to the travelling time involved, for all but the relatively small number of birds cleaned in Wales. Birds cleaned in the RSPCA were therefore released at selected sites near their respective cleaning centres.

The oil spill generated an immense amount of good will. Offers of help came from all over the world in a variety of forms, particularly by people volunteering to assist in the cleaning centres - though many people also donated items and money to aid the rescue effort, and many volunteers contributed considerable time and effort to collecting birds from beaches. Over 4,000 people contacted the RSPCA to volunteer assistance.

Apart from Steynton, all the cleaning centres used only trained staff or long-term, trained volunteers for cleaning and treating birds. Steynton made use of volunteers, but many were completely untrained and inexperienced and much effort was required to assess their relevant skills and then to train them. Unfortunately, not all the newly-recruited volunteers proved to be reliable and it was never certain how many would appear for duty or whether they would be prepared to undertake the necessary routine tasks.

Not all the public concern proved beneficial to the birds. Some well-intentioned but uninformed members of the public are known to have removed birds from the beaches and attempted to care for them without proper facilities, and people attempting inexpertly to collect birds were observed disturbing unaffected birds which then became oiled.

Box 8.1 THE CLEANING PROCESS

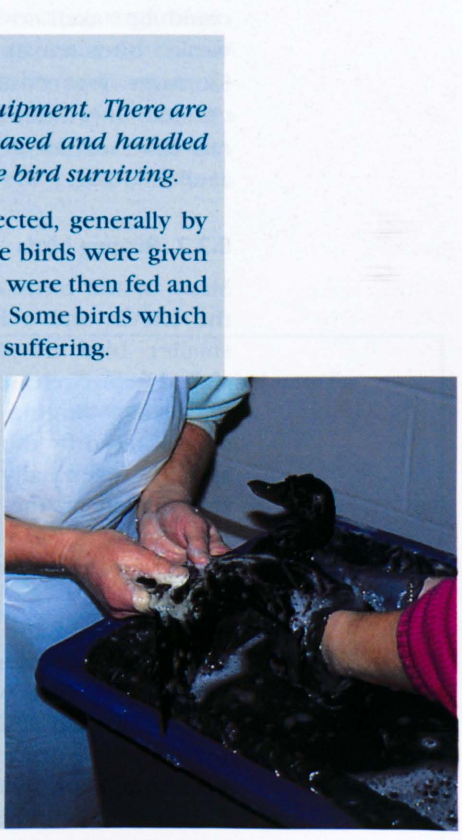
Note: Handling and cleaning oiled birds requires expertise and appropriate equipment. There are health and safety risks for those handling the birds; and if the birds are chased and handled inexpertly, they can be harmed or caused undue stress, with little chance of the bird surviving.

Beaches were patrolled for oiled birds, and any that came ashore were collected, generally by trained inspectors or volunteers, and taken to one of the holding centres. The birds were given fluids and charcoal, or an alternative, to absorb any oil they had swallowed, and were then fed and looked after until they were sufficiently strong for transfer to a cleaning centre. Some birds which were clearly going to die were killed humanely to prevent further unnecessary suffering.

Once the birds had regained strength and been transferred to cleaning centres, they could be washed. Hot water and washing-up liquid were used to clean the oil from the feathers, and a hot water shower was used to rinse the birds.

When undertaken by trained and experienced personnel with the right equipment this left the bird's plumage water-repellent, a process which could take around 30 to 45 minutes per bird.

The birds were rested overnight in a clean room and then transferred the following morning to areas with specially constructed pools where they could preen and adjust their plumage. The birds were carefully assessed over a number of days or weeks to ensure that their plumage was fully water-repellent, and they were finally checked by a vet or wildlife manager before being judged fit for release[4].



Scoter being cleaned (I Bullock)

8.2.1 Success rate

The birds arrived at the holding centres in a range of conditions, with some of them in a very weak state. Inevitably, many died before they could be taken to a cleaning centre, and others died after arrival at the cleaning centre. Most of the corpses were held by CCW for subsequent analysis (see §7.2).

From the available records it was estimated that about 60% of the birds which had been taken from holding centres to cleaning centres were cleaned and released. The different cleaning centres had different success rates, due in part to the fitness of the birds on arrival at the centres. *Table 8.1* shows the number of birds cleaned and released at RSPCA West Hatch, the cleaning centre which received the greatest number of birds. The table shows the wide range of cleaning success between species, the mute swan being particularly resilient to the cleaning process and species such as the red-throated diver and eider having a poor survival rate. Only birds judged fit to travel could be taken to the cleaning centres; the weaker birds remained at the holding centre at Steynton where many were cleaned. Inevitably the success rate here was lower, estimated at about 30%.

Sign on beach
(E Bent)

8.2.2 Ringing birds

Many of the birds cleaned by the RSPCA and a few of the smaller bird hospitals were ringed before release under the national ringing scheme administered by the BTO. This should eventually provide information on the survival of these birds in the wild as they are re-captured or found dead.

Around 60% of the guillemots and common scoters released were ringed. This was a lower proportion than desired, due in part to a lack of availability of rings and people qualified to do the ringing at the cleaning centres or release sites, and also to a reluctance at a few centres to allow birds to be ringed at all.

In total, more than 1,000 birds of 18 species were ringed, including 750 scoters and 220 guillemots. This was the largest number of scoters ever to have been individually marked in Britain and Ireland. According to the most recent published information there have only been about 50 scoters ringed in the wild and only about 6 ringed scoters have been recovered in Britain and Ireland[5]. Provided these birds are recaptured, this operation should provide an important opportunity for understanding better

Releasing shag and scoters
(C Seddon, RSPCA)

Table 8.1 Release rate for birds received at RSPCA West Hatch, Somerset[2].

Species	Admitted	Released	% released
Common scoter	1778	1088	61 %
Guillemot	399	250	63 %
Red-throated diver	43	19	44 %
Razorbill	28	17	61 %
Mute swan	14	14	100 %
Eider	7	2	29 %
Shag	8	4	50 %
Herring gull	6	4	67 %
Kittiwake	2	2	100 %
Red-necked grebe	2	2	100 %
Great northern diver	2	1	50 %
Great crested grebe	1	1	100 %
Heron	1	1	100 %
Red-breasted merganser	1	1	100 %
Velvet scoter	1	1	100 %
Total	2293	1407	61 %

the survival after cleaning of this little-studied species. A small number of guillemots were fitted with coloured rings so that they would be easily identified if they returned to any of the breeding colonies under observation.

8.3 THE SURVIVAL OF CLEANED GUILLEMOTS

Recent work in the USA has shown that birds of several species (guillemots, Western grebes, velvet scoters and surf scoters) which were released after cleaning survived for a very short time[1]. In that study, oiled guillemots which had been cleaned survived an average of only 39 days (range 1-919 days) after release, while unoiled guillemots were found to survive an average of 763 days (range 1-9,259 days). This called into question whether cleaning oiled birds of these species was in the interest of the welfare of individual birds or whether it was kinder to kill them humanely to relieve their suffering after collection.

A study was commissioned to examine the records held by the BTO of guillemots which have been ringed in the UK[3]. The aims were:

- To calculate the survival rates of oiled, cleaned and released guillemots.
- To compare these with the natural survival rates of guillemots which have not been oiled.
- To examine critically the quality of the available data and make recommendations for future improvements.

Guillemots were chosen because in the UK they are the most commonly oiled species of bird. Over 188,000 healthy and unoiled guillemots have been ringed at colonies around the coasts of Britain and Ireland[6]. The database of ringed birds which have been recovered holds details of over 300 guillemots which were cleaned, ringed and released between 1918 and 1995 (132 before 1985 and 177 from 1985 onwards). The survival rates of the birds ringed since 1985 - when a standard process of ringing after cleaning was adopted - were compared with 2,700 recaptured guillemots ringed over the same period which were unoiled and had therefore not been through the cleaning process and which were used to estimate natural survival rates.

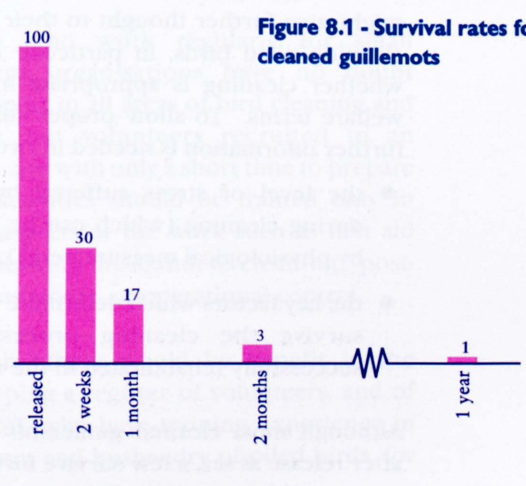
The study showed that a large proportion of the oiled and cleaned guillemots died soon after release, with more than 70% of the birds dying within 14 days. For every 100 cleaned guillemots released, 17 birds survived the first month following release, 3 were alive after the second month and only one had survived a year after release (*figure 8.1*). However, for those very few birds which do survive beyond two months the prospects of long term survival increased, and a small number of birds probably returned to colonies.

It is recognised that the database of ringed birds is relatively small. To improve the robustness of the conclusions, more information is needed and it is essential that all birds cleaned in future are ringed before release.

These results show clearly that the cleaning of guillemots is irrelevant for the conservation of populations of this species. Despite continuing losses of seabirds through oil pollution and the seemingly poor success of rehabilitating oiled birds, most guillemot populations in the north Atlantic have steadily increased during the last several decades. In terms of the welfare of the individual birds, it is vital that more is known about stress imposed by the collection, transport and cleaning in order to judge whether the process is justifiable in animal welfare terms.

However, the results for guillemots do not necessarily apply to other species. Some larger birds - such as mute swans - survive well after cleaning, but for most species rehabilitation rates are not known. For less common species there may be a stronger conservation argument for trying to rehabilitate as many birds as possible. For example, a sizeable proportion of the UK's wintering population of common scoter (10-15%) was affected by the *Sea Empress* spill, and 1,000 scoters were released after cleaning.

Figure 8.1 - Survival rates for cleaned guillemots



8.4 REVIEW OF BIRD CLEANING FOLLOWING THE *SEA EMPRESS* SPILL

Despite substantial doubts about the value of cleaning at least some species of oiled birds, it is likely that bird rescue operations will continue for the time being. It is important that these operations are managed and carried out as effectively as possible, and a wide-ranging review of bird cleaning - with particular reference to the operation following the Sea *Empress* spill - was commissioned[2].

This considered the benefits derived from bird cleaning (taking into account the guillemot survival study); the central management of the operation, including its structure and its integration with other aspects of the clean-up response; the management of the various treatment centres; and the procedures followed during treatment. The review was based on interviews with representatives of a wide range of organisations, along with the published literature on the subject and informal reports.

After consideration of this review and the guillemot survival study, several areas were identified where it appeared that the RSPCA and its counterparts in Scotland and Northern Ireland may be able to enhance the effective role it has in responding to incidents of this nature. The committee felt - and this was reflected in part through discussions with the RSPCA - that there was merit in the RSPCA giving further consideration to issues relating to information, planning and management, cleaning procedures and the role of staff and volunteers. The committee's suggestions which follow refer to the RSPCA, but it is expected that in Scotland and Northern Ireland the RSPCA counterparts may wish to consider similar action.

8.4.1 Information requirements

The RSPCA and other welfare organisations might give further thought to their reasons for cleaning oiled birds, in particular considering whether cleaning is appropriate in individual welfare terms. To allow proper consideration, further information is needed in two areas:

- the level of stress suffered by the birds during cleaning (which can be determined by physiological measurements), and
- the key factors which determine which birds survive the cleaning process and are successfully rehabilitated in the wild.

Although most cleaned guillemots die rapidly after release at sea, a few survive for a long time; and certain species (such as swans) appear to be successfully treated and rehabilitated. Establishing the factors which lead to successful rehabilitation may help to improve the effectiveness of cleaning procedures and help guide decisions as to which birds should pass through the cleaning process and which birds, with no realistic chance of survival, should be humanely killed to prevent unnecessary suffering.

The committee believes that it is vital that basic information is collected on the state of collected oiled birds, that each individual bird is tracked through the cleaning process, and that birds are ringed prior to release so that an assessment can be made of which individuals stand the greatest chance of long term survival. Guidelines on the information to be collected should be produced as part of the contingency planning process.

There is merit in establishing a national ringing and recovery database. The use of coloured rings on cleaned birds would increase detection rates at breeding colonies, improving the monitoring of breeding performance.

8.4.2 Planning and management

Oil spills resulting in large numbers of bird casualties are unpredictable events and some improvisation of bird rescue is an inevitable consequence. Although no organisation has statutory responsibility for wildlife rescue, the RSPCA is the only national organisation with the capability of undertaking this task. Since it will inevitably be heavily involved in any future emergency, it should be encouraged - in conjunction with other relevant organisations - to prepare a national contingency plan which supports the local oil spill contingency plans for the rescue of oiled birds and other wildlife.

However, in any oil spill that affects birds, numerous small local organisations and wildlife hospitals will play a vital supporting role. Regional groupings of such organisations, similar to the South West Oiled Seabird Group in the south-west of England, would complement the RSPCA regional organisation. It would be beneficial for the regional groups to forge strong links with the RSPCA and to formulate contingency plans for the transfer of oiled birds in the event of an oil spill with large numbers of bird casualties.

The RSPCA regional staff might be encouraged to ensure that bird cleaning and animal welfare centres in their area have adequate basic facilities. A national register of independent centres with the capacity to treat oiled birds could be compiled, listing their facilities, capabilities and experience; (and the RSPCA might consider the possibility of some form of accreditation scheme for independent hospitals and welfare centres). The RSPCA might also consider publishing a newsletter for these centres (and perhaps other wildlife hospitals) to improve co-operation and to encourage the use of best practices.

In the event of an oil spill, costs of bird rescue and treatment may be recoverable through claims against the vessel's insurers or other funds. There might be advantages to the claimants if legitimate claims for compensation by small groups (properly documented for insurance purposes) were brought together and presented as part of a more general bird rescue claim, perhaps with one organisation acting on behalf of the independent groups that collaborated with it.

8.4.3 Cleaning procedures

Cleaning procedures and bird husbandry are, at their best, professionally carried out, though this should not preclude a search for further improvements. The techniques currently in use in this country are clearly capable of achieving a high success rate (in terms of the proportion of birds which are released) with certain species. Different species have different requirements for cleaning and husbandry, and it is important that the protocols published by RSPCA and other bodies continue to reflect this.

Guillemot and black-throated diver after cleaning (W Telegraph)

Further consideration might be given to the criteria used for the selection of birds with reasonable chance of survival and fit to be cleaned, recognising the differences between species, with all groups involved in treating oiled birds being informed of the results.

Cleaning agents need to be evaluated through established tests, rather than by *ad hoc* experimental arrangements during rescue and cleaning operations. The washing-up liquids currently used were not formulated for cleaning oiled birds; if the manufacturers change the formulation, this could require the revision of protocols on cleaning.

During the spill, Elf Petroleum brought into the area a bird cleaning machine for assessment and use during the emergency. Although developed for use on beaches, this machine was eventually housed at the Elf Refinery where it was used to clean about 70 birds. The machine washes and rinses the bird very rapidly, though the process appears to be stressful to the birds. Further evaluation of the Elf bird cleaning machine is required before it can be recommended for widespread use.

8.4.5 Staff and volunteers

Particularly when large numbers of birds are oiled, rescue and treatment requires a large number of helpers, and numerous volunteers are likely to be available. Most are untrained and it is impractical to attempt to train them in bird husbandry in an emergency situation, as happened at Steynton.

The RSPCA might wish to consider training a number of its own staff and volunteers in the various tasks associated with oiled bird rescue and treatment. A system of certification, following training, might be considered, similar to the licence scheme for bird ringers operated by the BTO.

Volunteers who work regularly for small independent organisations have no doubt become expert in all areas of bird cleaning and husbandry, but volunteers recruited in an emergency and with only a short time to prepare for work activities should be trained only in particular aspects of the work such as first aid and pre-cleaning husbandry, cleaning, post-cleaning husbandry, or operational control.

Furthermore, there would be benefit in the RSPCA keeping a register of volunteers, and of its own staff, who have training experience in the treatment and husbandry of oiled birds, for possible assistance in future rescue attempts. Since volunteers came to south-west Wales from many parts of the country following the *Sea Empress* oil spill and would presumably be prepared to go elsewhere in the country if needed, this register would be valuable as a national inventory.

As in other spills, the rescue of oiled birds from the beaches following the grounding of the *Sea Empress* was hampered by the activities of a number of well-meaning but untrained people whose efforts were sometimes misguided. There might be advantage in mounting a publicity campaign to inform the general public that the rescue and treatment of oiled birds is a matter best left to those with training and experience, with consideration given to restricting beach access where feasible.

REFERENCES

1 Sharp, B.E. 1996. Post-release survival of oiled cleanedseabirds in North America. Ibis, 138:222-228.

2 Clark, R.B., Evans, S.M. & Palmer N. 1997. Review of the effectiveness of, and management procedures for, the rehabilitation (treatment, cleaning and release) of oiled birds with reference to the *Sea Empress* oil spill. Unpublished report prepared for SEEEC.

3 Wernham, C.V., Peach, W.J. & Browne, S. 1997. Survival rates of rehabilitated guillemots. Unpublished report prepared for SEEEC.

4 Research Unit on the Rehabilitation of Oiled Seabird (RUROS), 1972. Recommended treatment of oiled seabirds. RUROS, Newcastle-upon-Tyne.

5 Mead, C.J. & Clark, J.A. 1993. Report on Bird Ringing in Britain and Ireland for 1991. Journal for the British Trust for Ornithology Ringing Scheme Ringing & Migration, Volume 14 - Part 1.

6 Clark, J.A., Adams, S.Y., Peach, W.J. and Simons, J.R. 1996. Report on Bird Ringing in Britain and Ireland for 1994. Journal for the British Trust for Ornithology Ringing Scheme Ringing & Migration, Volume 17 - Part 1.

9 Amenity and Archaeology

9.1 INTRODUCTION

Major oil spills have significant consequences in terms of their impact on human beings which can extend beyond the local community that is directly affected. This chapter brings together results from several studies on the environment which are more directly related to people than most of those described elsewhere in this report.

Coastal footpath overlooking Barrafundle Bay (PCC)

SEEEC was asked to consider amenity as part of its assessment of environmental impact. Amenity - aspects of the local environment which local residents and visitors use and enjoy - is difficult to assess as it involves people's values, perceptions and behaviour. Further difficulties arise because of the lack of tried and tested methodology and inadequate baseline data. A number of different approaches were taken. These included investigations of the effect of the spill on visitors to the region (both the numbers of tourists and their perceptions of the spill) and on recreational fishing (see section §9.2.2), and the development of a new methodology for quantifying the aesthetic impact of oil on amenity beaches. There are some important archaeological sites on the Pembrokeshire coast, and these were surveyed for possible damage by the oil.

Oil at Tenby, 28th February 1996 (H Prosser)

9.2 AMENITY

South-west Wales offers a wide range of opportunities for public enjoyment, including traditional beach activities, water sports, sea-cliff climbing, walking, angling, natural history (such as bird-watching) and field studies.

The oil spill directly affected the amenity of the area in a number of ways. All the main amenity beaches in south Pembrokeshire, and most of the rocky coast in between, were oiled. For several weeks, oil was visible on the surface of the sea around the coast and there were public concerns over bathing water quality. Beaches in St Brides Bay were also affected (though not to the same extent), as was most of the Haven. The worst impacted beaches could not be used until after the bulk oil had been removed, and the sight and smell of oil around the coastline was, for a time, unpleasant. For safety reasons, parts of the Coast Path (a National Trail) were closed for short periods during clean-up operations involving cranes and other heavy machinery, and climbers were advised not to use two of the best climbing areas in Pembrokeshire - Stennis Ford and Huntsman's Leap, Castlemartin. Many local people in particular felt a deep sense of violation and helplessness.

Cleaning the main amenity beaches in time for the Easter holiday period (5 to 8 April - about seven weeks after the spill) was considered a high priority, and, through a massive effort by all concerned, this was achieved. Water quality was measured regularly from May 1996 at beaches designated under the EC Bathing Waters Directive. All the water samples met the standards of the directive (which include the absence of a film of oil on the water surface), and the levels of total hydrocarbon in samples were considerably lower than the stringent "Guideline" standard set by the directive. Pembrokeshire County Council announced on 21 May 1996 that levels of contaminants in sea water were within safe limits for bathing.

9.2.1 Aesthetic Impact

It is clear that the public considers oil to be objectionable, but standard methodology does not exist for assessing objectively the likely aesthetic impact of oil on shorelines and for tracking medium to long term recovery[1]. Standards also do not exist against which to compare the results of such assessments, which would allow those involved with clean-up to determine objectively whether shorelines had returned to an acceptable condition in terms of public perception and aesthetic quality. It was decided to attempt the development of an appropriate methodology.

An oil scoring system was designed to reflect the likely aesthetic impact of different levels and types of oiling (see *Box 9.1*). This was tested in two survey programmes carried out by professional surveying teams in late 1996 and spring 1997, calculating oil scores for 32 shorelines. The robustness of the scoring system is still being evaluated, but preliminary indications suggested that the oil scores were useful in identifying subtle changes in shoreline oiling.

The detailed survey work showed at least some oil on most beaches (including beaches not oiled during the *Sea Empress* spill), though the oil scores were frequently low. However, in a separate questionnaire survey (see §9.2.3) during the summer of 1996, relatively few visitors to Pembrokeshire reported seeing evidence of oil on beaches, thereby suggesting that a low level of oiling - ie low oil scores - may be tolerated by many people.

9.2.2 Recreational fishing

Recreational fishing is popular in the seas around Pembrokeshire, and south-west Wales has a number of fine angling rivers with salmon and sea trout which attract many visitors. The fishery closure order (see §3.3) covered sport as well as commercial fishing and included salmon and sea trout in the rivers flowing into the closure area. The ban came into force on 19 March 1996 (the day before the season started) and was lifted for salmon and sea trout on 3 May 1996 and for other fish on 21 May.

Although it did not appear that salmon and sea trout were affected by the spill (see §3.4.1),

Box 9.1 SHORELINE AESTHETICS[8]

Aesthetic impact is subjective, but a scoring system was developed by estimating the likely impact that different levels and types of oiling would have on members of the public using a beach. The scoring took into consideration visual impact, odour and the risk of people becoming oiled. For example, fresh oil on the beach or an oil slick in the "paddle zone" would receive a high score, while sheen related to subsurface oil would be given a low score. The scoring was also related to the degree of oiling within each type of contamination.

Each individual survey started at the most obvious public access point to a stretch of shoreline, and the surveys were conducted along a series of transects radiating from this point (on the basis that people will generally go to the nearest suitable position relative to the access point). Photographs were taken of each access point and transect.

The methodology was tested and refined in two programmes of surveys (in November 1996 to January 1997, and March to April 1997). During each programme, aesthetic impact scores were calculated for 32 beaches. Only seven of the beaches showed no oil on either survey (including some beaches which had been oiled following the *Sea Empress* spill), though the oil scores for many of the others were low (ie there was little oiling observed). For twelve beaches, the oil score improved by the second survey, while on twelve others the score deteriorated. Samples showed that at least some of the oiling was unrelated to the *Sea Empress*. These results demonstrated that the methodology was able to detect subtle changes in the level and distribution of shoreline oiling and possible aesthetic impact, which should prove useful to those concerned with maintaining the cleanliness of beaches. The methodology should be further tested and developed as circumstances allow.

there was concern that the oil spill may have affected the amenity value of the river fisheries for longer than just the closure period, for example through potential anglers deciding not to fish in the area. A survey was therefore conducted of anglers who had fished the rivers in 1995, to establish whether or not there had been any impact on angling behaviour that could be attributed to the oil spill rather than other factors which affect angler choice[2]. Details are given in §3.6.1. The proportion of anglers visiting south-west Wales fell significantly in 1996 compared with 1995, and regular anglers made fewer visits. Fewer anglers bought licences, and a higher proportion of licences were for coarse fish and non-migratory trout, particularly early in the season and soon after the oil spill. The study concluded that the oil spill had an influence in the change in behaviour but was no more influential than the increase in licence fees.

9.2.3 Visitor perceptions and behaviour

A study was commissioned to assess how visitors perceived the impact of the oil spill on the amenity of the Pembrokeshire coast. This was based on a questionnaire survey of around 1,300 visitors during the summer of 1996[3].

The results from the questionnaire are summarised in *Box 9.2.* The study's overall conclusions were:

- Although there was a high awareness of the *Sea Empress* oil spill and its geographical impact amongst the respondents, this had not significantly affected their decision to come to Pembrokeshire for a holiday.
- Few of those questioned had seen any visible evidence of oil on the shorelines.
- Visitors did not change their activities or the way in which they used the shorelines because of the oil spill.
- There was a clear perception among those questioned that the effects on wildlife and the natural environment had been substantial.
- 93% of those visitors surveyed confirmed that they would probably or definitely return to Pembrokeshire within the next three years.

Box 9.2 ASSESSING PERCEPTION OF THE *SEA EMPRESS* INCIDENT IN VISITORS TO PEMBROKESHIRE IN 1996: SURVEY RESULTS

The overwhelming majority (88%) of the 1,316 people interviewed were staying away from home on holiday, mainly in Pembrokeshire. 24% of the holiday visitors were from Wales, 72% from other parts of the UK and 4% were from overseas. 89% of the day visitors interviewed were from Wales, whilst the remainder had travelled from England.

There was a very high level of awareness of the *Sea Empress* incident. When asked whether they recalled seeing, hearing or reading about a major (unspecified) incident which occurred earlier in the year, 96% referred spontaneously to some aspects of the *Sea Empress* oil spill. Predictably, awareness was highest amongst residents of Wales (98%), although the majority (69%) of overseas visitors also displayed awareness. A further 2% of all the respondents who had not exhibited any spontaneous awareness of the *Sea Empress* oil spill were able to recall the incident when prompted about it, wheras the remaining 2% reported no knowledge at all of the *Sea Empress* incident.

The vast majority of those who were aware of the *Sea Empress* incident (83%) said that it had not affected in any way their decision to take their day trip or holiday in Pembrokeshire. Although this figure is encouraging, it does not show the extent to which others may have been dissuaded from coming to the area.

Of the respondents who were aware of the *Sea Empress* incident, 40% thought that some of the Pembrokeshire coast had been affected, 36% thought that most of the coast had been affected and 10% thought that all the coast had been affected. When shown a map of west Wales divided into 6 coastal zones, respondents demonstrated a good awareness of the areas most affected by the spill.

Just over three-quarters (76%) said that they had not seen any effects of the oil spill, but about one in five (21%) claimed they had seen effects and the remaining 3% did not know. Only about one in ten claimed seeing physical evidence of the pollution. Almost two-thirds (62%) thought that the natural environment and wildlife had been greatly affected. 39% of all respondents believed that public enjoyment had not been affected at all; but 11% believed that it had been affected a lot.

However, the survey included only those visitors who, in spite of the oil spill, had still come to Pembrokeshire, so further research was commissioned from the Wales Tourist Board to assess the impact of the spill on potential as well as actual visitors (see section §9.2.4).

According to available statistical and anecdotal evidence, 1995 was a strong year of growth for tourism within south-west Wales, and further growth was expected in 1996. Any downturn resulting from the *Sea Empress* incident in 1996 arguably should therefore be compared with the

BOX 9.3 SOURCES OF INFORMATION ON TOURIST IMPACTS

1 Wales Tourist Board: Wales Visitor Survey 1996. Carried out to provide a profile on peak season visitors to Wales.

2 Wales Tourist Board: Pembrokeshire Brochure Enquiries. Main objective: To determine the extent to which the Sea Empress incident may have reduced the conversion rate of brochure enquiries to actual bookings in 1996.

3 Wales Tourist Board: Hotel Occupancy Survey: Long-running monthly measure of demand based on a sample of hotels in Wales.

UK Tourism Survey (the 4 national Tourist Boards): Continuous measure of the volume, value and characteristics of staying tourism by UK residents.

5 Wales Tourist Board: Survey of visitors to attractions. rovided information on annual visitor attendance at tourist attractions in Wales.

6 International Passenger Survey (National Office of Statistics): Provided a continuous measure of the volume and characteristics of international tourism to and from Great Britain.

7 UK Day Visits Survey (the 4 national Tourist Boards and others): Provided a measure of the volume, value and characteristics of leisure day trips from home taken by UK residents.

8 Wales Tourist Board: Visitors to Tourist Information Centres.

9.2.4 Tourism

It is estimated that tourism contributed about £160 million to the Pembrokeshire economy in 1995. Approximately 1 million trips and 5 million bed-nights were spent in the county[4]. The tourism industry relies heavily on the quality of Pembrokeshire's environment and its coastline, and the opportunities that it offers for open air recreation and leisure. A detailed analysis of all the information available (*Box 9.3*) was carried out to assess the impact - if any - of the oil spill on the tourism industry[5], but this analysis showed no consistent or measurable trends in tourism performance in 1996.

Tenby beach in summer 1996 (E Bent)

predicted increase expected for 1996 rather than the 1995 baseline level.

In any year performance varies significantly between individual tourism operators due to a complex mix of factors. Some businesses would therefore have been expected to perform better in 1996 than in 1995 and others to have fared worse, and the degree to which the *Sea Empress* incident affected performance in 1996 was unlikely to have been uniform throughout the industry. Those operators who were in a position to invest additional funds on marketing immediately following the incident, for example, were most likely to have limited any adverse impact to their businesses.

The diverse range of factors which influence the choice of holiday destination meant it was not possible to isolate impacts on tourism due specifically to the *Sea Empress* incident. However, there was some evidence from the response to follow-up questionnaires sent to those who had previously requested brochures to suggest that for one in five of those who actively considered Pembrokeshire as a prospective holiday destination in 1996, the *Sea Empress* incident was a significant reason leading them to decide against this.

The hotel sector in south-west Wales appears to have performed less well than other sectors of the industry in 1996. On the basis of available statistics, turnover in the commercial service sector could have suffered a downturn equivalent to £2m in Pembrokeshire. However, the number of visitors from other parts of the United Kingdom - who comprise the core market for visitors staying in Pembrokeshire - and the amount they spent appear to have increased in overall terms in 1996 compared with the previous year. This suggests that most of this growth would have been generated in the self-catering and caravan and camping sectors, and by people visiting friends and relatives. The number of visitors to tourist attractions increased slightly in 1996, while visitors to Tourist Information Centres decreased.

The spill had a significant effect on the environmental education activities at the Field Studies Council centres at Dale and Orielton. Between them, the two centres accommodate over 5,000 sixth-form and university students a year, specialising in marine ecology and coastal geography courses. During the first five weeks of the spill, it was difficult to teach on most of the rocky shores in south Pembrokeshire because of contamination by oil, though all-in-one suits donated by Texaco made it possible for students and staff to visit these shores. Although by late summer most of the exposed shores on the outer coast had cleaned up, some heavily contaminated sheltered shores within the Milford Haven waterway remained unusable. One of the best teaching shores in Wales in West Angle suffered severe ecological disruption as a result of the spill, but it is now undoubtedly the best place in Britain to teach students about the ecological effects of an oil spill and natural recovery processes.

9.2.6 The overall economic impact

Determining the overall impact of the *Sea Empress* oil spill on the economy of south-west Wales is complex and outside the scope of this report. This would need to take into consideration effects on tourism and fishing, knock-on effects to related industries and the service sector in the region, the costs of the clean-up operation, and money brought into the area through compensation payments. An early attempt to carry out such an analysis was made by Cardiff Business School under commission from Pembrokeshire County Council, the Welsh Development Agency and the West Wales Training and Enterprise Council[6]. This study highlighted the difficulty of separating out specific impacts directly attributable to the *Sea Empress* from the many other variables affecting the economy, but predicted that the spill might have a substantial immediate effect on the local economy, particularly on the tourism and fishing sectors.

9.3 ARCHAEOLOGY

The Pembrokeshire coast is important for its marine archaeology. Archaeological features of particular interest include extensive submerged forests (eg at Marros, Amroth and Newgale), medieval fish traps (at Giltar and Tenby), and wrecks on the open coast and in Milford Haven.

Archaeological features are vulnerable to oil spills in a number of ways:

- Contamination of the surface can lead to disfigurement and (in extreme cases) can obscure key features, rendering interpretation difficult;
- Heavy surface contamination can, in certain circumstances, alter the surface characteristics of some materials such as wood or peat deposits;
- The removal of oil from a shore can cause accidental damage.

A study of all sites at risk was therefore carried out in autumn 1996[7]. Comparisons were made with pre-spill data contained in the Regional Archaeological Sites and Monuments Record, augmented by the National Maritime archaeological database kept by the Royal Commission on Ancient and Historic Monuments.

The study concluded that, with the exception of some staining on the wreck of *HMS Tormentor* (near Manorbier), there was little evidence of contamination of archaeological features by oil. The study also concluded that no damage had been sustained as a result of clean-up activities.

9.4 CONCLUSIONS

The amenity value of south-west Wales - particularly the beaches - was directly affected by the oil, but the effects were temporary and amenity, in the main, had returned to normal within a few weeks. In some cases, however, perceptions of the impact on amenity remained for longer and this probably contributed to the decrease in sales of fishing licences and a reduction in the number of visitors staying in hotels. The predicted major impact on tourism does not, however, seemed to have occurred.

A methodology has been developed for tracking changes in the level of aesthetic impact of oil on beaches. This may prove useful to authorities charged with keeping beaches clean, particularly if it is established what level of aesthetic impact the public are prepared to tolerate.

REFERENCES

1 Bent, E. J. and M. C. Thomas, 1996. The aesthetic impact of oil on beaches. Development of aesthetic criteria, with recommendations for monitoring. Report to the Environment Agency.

2 Simpson, D., 1997. Report to the Environment Agency on *Sea Empress* Amenity Impact Survey.

3 Owen, R. Elwyn, (Beaufort Research) 1996. The *Sea Empress* oil spill – A survey of visitor perceptions. Report to CCW.

4 Webb, S, Wales Tourist Board, *pers comm*

5 Wales Tourist Board, 1997. An approach to estimating the impact of the *Sea Empress* incident on Tourism flows to Pembrokeshire during 1996.

6 Bryan, J. *et al*, 1996. The economic consequences of the *Sea Empress* spillage

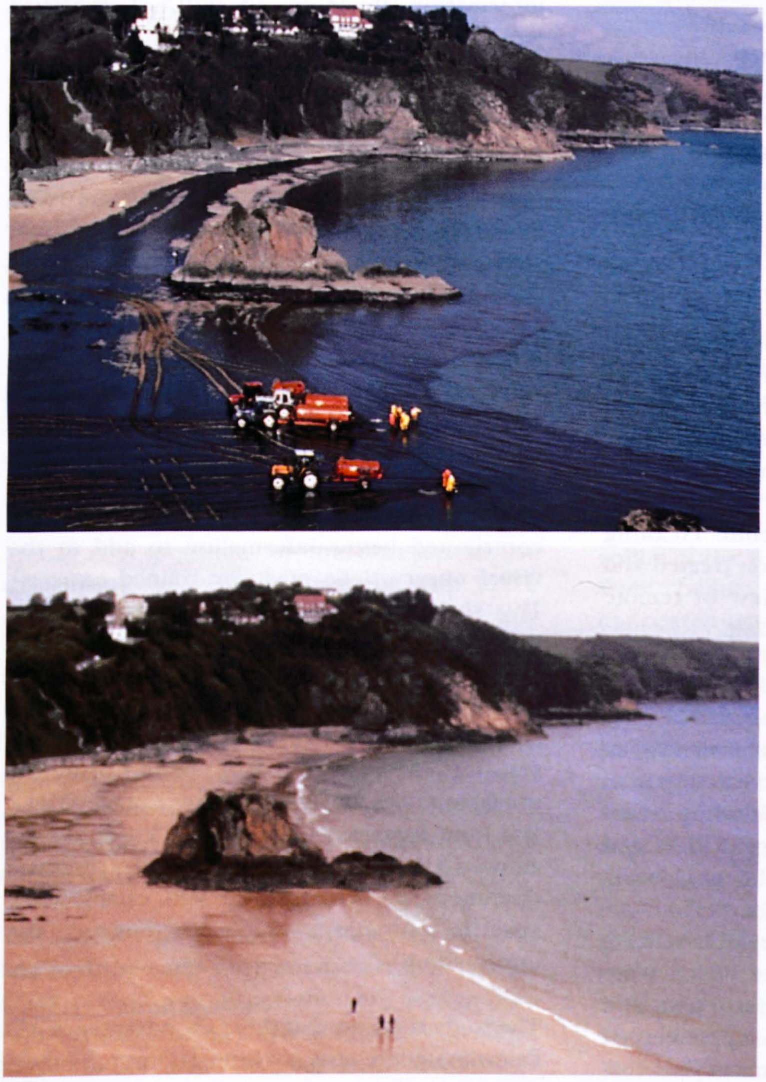
7 James, H. The *Sea Empress* Oil Spill: Archaeological Assessment of Effects on Intertidal and Shoreline features. Cambria Archaeology, 1997.

8 Bent, E. J. and P. Brown, 1997. The aesthetic impact of oil On shorelines. Report on two survey programmes undertaken on West Wales shorelines 1996-1997. Report to the Environment Agency.

10 The Clean-up Operation

10.1 INTRODUCTION

The *Sea Empress* clean-up operations were wide-ranging and included dispersant spraying and mechanical recovery of oil at sea, the use of protective booms, and the use of mechanical recovery, trenching, beach-washing, chemical dispersants and sorbents on the shoreline. At the height of the response, more than 50 vessels, 19 aircraft and 25 organisations were directly involved, with 250 staff working on the response at sea and 950 working on the shoreline. The clean-up operation began within hours of the *Sea Empress* running aground, and 18 months later there was still a small team working on shoreline clean-up. The total cost of the operation over that time was approximately £23m. The clean-up response has been described in a detailed report by the Marine Pollution Control Unit[1], and an overview of the operation was given in §2.3.



Tenby North beach before and after clean-up (before Easter) (ITOPF)

This chapter reviews the clean-up operation from two standpoints: the effectiveness of the procedures and techniques, and how the actions taken during the response affected the overall environmental impact. The chapter considers in turn the different aspects of the clean-up operation: monitoring the oil at sea; the dispersant operation at sea; mechanical recovery of oil from the sea surface; the use of protective booms; the shoreline clean-up; and the effectiveness of the national and local contingency plans and of the organisational structure.

10.1.1 Studies

SEEEC was asked by the Government to undertake a rigorous examination of the clean-up operation, procedures and techniques. A company with no involvement in the clean-up operation was selected in November 1996 to carry out this assessment and was asked:

- to examine the technical and operational response to the oil spill including the disposal of waste oil and debris – taking account of environmental impacts, oil weathering processes and cost-effectiveness;
- to report on the effectiveness of the emergency response by the Joint Response Centre (JRC) – including its constituent parts – and the Marine Response Centre (MRC); and
- to recommend possible improvements to techniques and procedures for clean-up response and waste disposal.

Many of the conclusions drawn by SEEEC in this chapter are based on the analysis carried out during that study.

The assessment was based on personal interviews and discussions with staff from key organisations involved in the response, and on a review of records and documents held by these organisations. A questionnaire was sent to more than 150 individuals directly involved in the response or representing organisations which may have been affected by the spill and clean-up. Views on the media arrangements during the incident were obtained from representatives of the media.

The effectiveness of the shoreline clean-up was assessed in detail on six beaches representing the range of shorelines affected by the spill. For each beach, the oil impacts, the accuracy of prediction of oil movement, the environmental impacts of clean-up and public interest considerations which may have affected the choice of clean-up options were studied from records, interviews and site inspections.

Monitoring of the dispersant operation at the time of the spill and several special studies allowed assessments to be made of the effectiveness and environmental impacts for different aspects of the clean-up operation. The studies included an analysis of the environmental effects of shoreline cleaning techniques and of the fate of oil on treated and untreated shorelines, plus a review of remote sensing and a trial of bioremediation.

10.2 MONITORING THE OIL

Monitoring the location of surface oil was an essential part of the clean-up at sea response. Several methods were used, including aerial surveillance, remote sensing (see §10.3) and ground surveys.

MPCU used two aircraft with remote-sensing equipment to make observations which were relayed by radio, transcribed into text and converted into situation reports supplemented by maps and charts. It has been accepted that the timeliness and accuracies of these reports might have been improved, and MPCU are examining the possibility of transmitting remote sensing data directly, and also the development of geographical information system (GIS) facilities to produce computer-generated maps and charts as an aid to information exchange, press briefings and record-keeping.

The approach adopted for coastline surveys used a variety of techniques and, with the benefit of hind-sight, the coordination achieved was not always perfect. The use of helicopters instead of fixed-wing aircraft helped the detailed surveillances of polluted shorelines and, when an environmental observer was also present, helped co-ordination of that aspect of the response. Other lessons learnt were to adopt standard reporting procedures and to link aerial observations with land based ones for validation purposes.

10.3 REMOTE SENSING

Remote sensing technology can be used in an aircraft (or, in some cases, a satellite) to provide information about an oil spill. Techniques include using radar, infra-red or ultra-violet radiation – or the analysis of visible light – to detect the position and extent of oil at sea. Remote sensing can also provide an indication of the relative thickness of oil, and radar can be used at night to provide information on the extent of oiling. Visual observation from surveillance planes was the main method for identifying the position and extent of the surface slicks, complemented by remote sensing methods for night-time observations and for detecting the types of oil.

A study was commissioned to review whether the use of remote sensing technology could have contributed better information to add to the visual observations made by trained experts[2]. This showed that remote sensing would have improved the consistency of interpretation of the extent of oiling and would have provided a permanent, verifiable record of oil at sea and along the shoreline. If the detailed remote sensing information had been promptly available to the Marine Response Centre (MRC) and Joint Response Centre (JRC) it would have allowed a more refined targeting of the response operations, particularly if the MRC established a specific function for distributing the information.

The study suggests that there are advantages in a co-ordinated remote sensing strategy to meet the needs of the operational response and also to provide information for environmental impact assessment. This includes a dedicated remote sensing aircraft (during the *Sea Empress* spill remote sensing aircraft were used to direct the dispersant spraying operation which meant that little remote sensing data was collected during the incident), a helicopter equipped with video to record shoreline oiling, and the incorporation of information on the position of the aircraft into the remote sensing data. The remote sensing aircraft would be controlled by one operational group within the MRC.

Satellite radar data can provide information over a much greater area than aircraft remote sensing, but interpretation of the images is very difficult except in areas well away from land. Detailed information on wind speed on the sea surface is essential, and without this only tentative conclusions can be drawn. It seems likely that current satellite-based radar systems will not replace visual observations and remote sensing from aircraft in the near future.

10.4 THE DISPERSANT OPERATION AT SEA

In the UK, when it is considered necessary to respond actively to a spill at sea, the use of dispersants is often the primary method of response. Dispersants cause oil to mix into the water column as small droplets (see §2.7.1), thereby breaking up or reducing the size of slicks and removing the oil from the surface. The purpose of this is to minimise the amount of oil stranding on beaches and to reduce the direct risk to seabirds and sea mammals. Dispersion, however, increases the exposure of marine organisms to the oil. This can be of particular concern in shallow water where the oil does not dilute to the same degree and organisms on the seabed may be exposed to potentially harmful concentrations of oil.

MPCU is responsible for the decision to use dispersants, subject to agreement with MAFF and statutory countryside agencies and any restrictions that are imposed. In the UK, dispersants are not used in water depths of less than 20 metres, or within 1 nautical mile of the 20 metre depth contour, without specific approval. In this incident the rule was relaxed after consultation to allow spraying beyond 1 km from the coastline in areas where there was a high water exchange.

The *Sea Empress* grounded within the 1 km limit and so dispersants were not used at first, though small quantities of dispersant were used in tests on 17 and 18 February. On 18 February the wind veered to the north, carrying the oil southwards away from the coast. Between 18 and 22 February, 442 tonnes of dispersant were applied (*table 10.1*), and, in addition, six tonnes of demulsifier were used on 18 February to break down emulsion into oil which could then be dispersed. The dispersant was sprayed onto the areas of thickest oil by aircraft directed from above by a control aircraft; this allowed ribbons of oil as narrow as 10m to 20m to be sprayed effectively. Dispersants work most effectively on fresh oil before it has emulsified, and so the main target for the operation was the newly-released oil which leaked from the tanker at each low tide over the period (see §2.7.1). Once the surface slick of fresh oil had been successfully dispersed then a secondary target was the larger patches of more weathered oil further offshore.

Date	Dispersant (tonnes)	Demulsifier (tonnes)
16 Feb	2	2
17 Feb	2	2
18 Feb	29	6
19 Feb	57	
20 Feb	110	
21 Feb	179	
22 Feb	67	
TOTAL	446	8

Table 10.1: Application of dispersants and demulsifier at sea.

10.4.1 Monitoring the dispersant operation

It is not always possible to tell from aerial surveillance whether dispersants have been effective, so International Maritime Organization guidelines[3] recommend that subsurface oil concentrations should be measured during operations. The *Sea Empress* spill was the first major spill where monitoring from boats, of oil behaviour and water concentrations, was co-ordinated with the aerial dispersant application[4,5]. The test sprays on emulsion on 16 and 17 February showed the value of this: aerial surveillance judged the tests to be ineffective, but monitoring from boats showed that the first application of dispersant tended to break and disperse the emulsion over a period of 30 minutes to one hour and subsequent additions of dispersant increased the concentrations of dispersed oil in the water column. This was consistent with previous sea trials[6,7].

Section 2.7.2 described the results of monitoring of oil concentrations under fresh crude oil and oil on which dispersant had been sprayed.

10.4.2 Effectiveness of the dispersants

The monitoring conducted during the *Sea Empress* showed that the concentrations

Dispersant spraying (M Baines)

measured beneath oil dispersing naturally and where dispersants had been applied were comparable with concentrations measured during previous field trials with Forties Blend crude oil under generally similar wind conditions (14-20 knots). These field trials gave the following results for the first 30 minutes following treatment with dispersants[8,9,10]:

- Total dispersion following dispersant application: 22% (±6%)
- Natural dispersion in a control experiment: 6% (±3%)

Chemically-enhanced dispersion was therefore estimated in the case of this field trial to be 16% (±9%).

In *figure 2.9* it was estimated that 52% (±7%) of the *Sea Empress* oil dispersed over a period of days. A rough estimate of the possible split between natural dispersion and chemically-enhanced dispersion can be made, if it is assumed that the same ratios applied as were determined from the sea trial. On this basis the total dispersion figure can be broken into:

- Natural dispersion: 14% (±7%)
- Chemically-enhanced dispersion: 38% (±14%)

This would suggest that an additional 27,000 tonnes of the Forties Blend crude oil spilled from the *Sea Empress* was dispersed as a result of the dispersant spraying operation.

It needs to be recognised, however, that whilst these estimates of the split between natural and chemically-enhanced dispersion are the best available for any major oil spill, they are only indicative. Extrapolation from a sea trial involving a few tonnes of oil and measurements made over a short time period to a spill of the size of the *Sea Empress,* where conditions varied and various processes affected the rate of both natural and chemically-enhanced dispersion over a number of days, is inevitably imprecise. This high level of uncertainty over the estimates is evident from the size of the error ranges attached to the percentages.

Particular doubts have been expressed about the calculated percentage of the Forties Blend crude oil that dispersed naturally in the real spill conditions of the *Sea Empress*, with some commentators considering that the split between natural and chemically-enhanced dispersion may have been more equal[11]. (This would be broadly consistent with the lower end of the range for chemical dispersion (24% ie 38%-14%)). In support of this view it has been pointed out that an unknown quantity of oil escaped southwards during the night when no spraying was possible and that it is conceivable that a greater proportion of this oil may have dispersed naturally, especially as there were no reports of serious pollution from outside the main affected area. In addition, it was considered that natural dispersion may have been enhanced where slicks interacted with the shoreline.

Nevertheless, even on the basis of the lowest percentage of the calculated range (25% or 18,000 tonnes), each tonne of dispersant would appear to have resulted in around an extra 40 tonnes of oil being dispersed. This is an improvement by a factor of about two on the normally-accepted ratio of 1:20 dispersant to oil. This high level of effectiveness of the dispersant was probably due to a number of factors:

- Forties Blend crude oil is amenable to chemical dispersion;
- oil was released daily from the tanker and so the response could be targeted at relatively fresh crude oil throughout much of the dispersant operation; and
- the spray aircraft targeted the oil accurately, under the direction of surveillance aircraft controlling their operations.

10.4.3 Practical benefits of using dispersants

Without chemical dispersion, at least 18,000 tonnes of oil would have remained on the sea surface and may therefore have come ashore (in addition to the 3,700 to 5,300 tonnes estimated to have stranded (see §2.9.2). Had it not dispersed, much of this oil would have emulsified, increasing its volume by a factor of three to four (ie 54,000 to 72,000 tonnes of emulsion). The removal of bulk oil from the shoreline could have been much more difficult and could have taken considerably longer, with the increased likelihood of oil being buried or remobilised and contaminating other stretches of coast. There would have been additional problems of waste disposal, and it may not have been possible to clean the main amenity beaches in time for Easter.

Comparable figures for the cost-effectiveness of different aspects of the clean-up operation are difficult to establish since the basis of the charging arrangements varies depending, for example, on the nature and source of the particular equipment, material and manpower. The cost per tonne will also vary depending upon assumptions made regarding the quantities of oil dealt with. However, it has been estimated[12] that in the case of the *Sea Empress* the dispersant operation cost between £40 and £65 per tonne of oil dispersed (not allowing for the substantial costs to the UK government of maintaining the fleet of dispersant spraying aircraft on permanent standby), compared with around £2,000 per tonne of oil removed through mechanical recovery at sea and more than £9,000 per tonne of oil for shoreline clean-up, including the final polishing on the main amenity beaches. Whilst the actual figures can be disputed, they illustrate one of the benefits of the successful dispersant spraying operation in this particular case. It should not be assumed, however, that a similar range of figures would apply to other spills in UK waters or further afield.

10.4.4 Environmental advantages and disadvantages of dispersant use

Consideration of the merits and disadvantages of dispersant use should take account of the fact that, when oil is spilled in large quantities, there is no response which avoids adverse environmental effects. Even if it were possible to collect all the oil from the sea surface, its disposal would still present environmental problems.

Dispersants have frequently been criticised as being toxic. They are, however, far less toxic than they used to be, and it is a licensing requirement in the UK that dispersed oil with dispersant is no more toxic to marine organisms than dispersed oil alone. It has been suggested that some dispersants may contain endocrine-disrupting compounds which might affect fish and other organisms, but the dispersants used in the UK do not contain any chemicals of a similar structure to those known to have this effect. Dispersants rapidly become dilute and eventually biodegrade.

The main potential environmental impact of dispersant use at sea is that the oil is mixed through the water column, increasing the exposure of marine organisms to the oil – particularly in shallow water where it is possible for relatively high concentrations of oil to reach the seabed. When applied to oil shortly after its release, dispersion reduces the rate of loss of the evaporative (and more toxic) components of the oil which therefore mix temporarily into the water column.

Dispersant use during the *Sea Empress* incident may have contributed to the effects observed in the studies of marine impact described in Chapter 3. There seems to have been little impact on fish and most crustaceans, though large numbers of bivalve molluscs and other benthic species were stranded on beaches shortly after the spill, and studies have shown that amphipods have been killed in some areas (see §3.8). It is assumed that some of these effects were caused by chemically-dispersed oil. There is no evidence of birds or mammals being affected by oil in the water column.

In contrast, the use of dispersants can offer a number of important environmental advantages through reducing the amount of oil on the sea surface and the amount likely to come ashore. Laboratory evidence has suggested that the use of dispersants may also increase the rate of biodegradation at sea and reduce the adhesion of oil to sediment particles[13]. The estimates in §10.4.3 suggested that if dispersants had not been used during the *Sea Empress* incident, then there could have been three to five times the amount of surface oil. It is possible to speculate on the likely effects of this. Several thousand seabirds and common scoters are known to have died through direct exposure to surface oil (see §7.2), and it seems likely that many more would have come into contact with the oil had there been greater quantities on the sea surface. Although more oil coming ashore does not necessarily mean that a greater length of coast would be affected (the oil may just come ashore in greater quantities at the same sites), it is probable that some areas only lightly oiled would have been more heavily oiled and that there would have been considerably more problems with bulk oil lifted by tides contaminating nearby stretches of shoreline. Cleaning of the shoreline – both natural and as part of the response – is likely to have taken longer. Some of the effects noted in Chapter 4 appeared to be related to the degree of oiling, so it seems reasonable to assume that the impact on the shoreline was reduced by the use of dispersants.

10.4.5 Overall conclusion on the dispersant operation

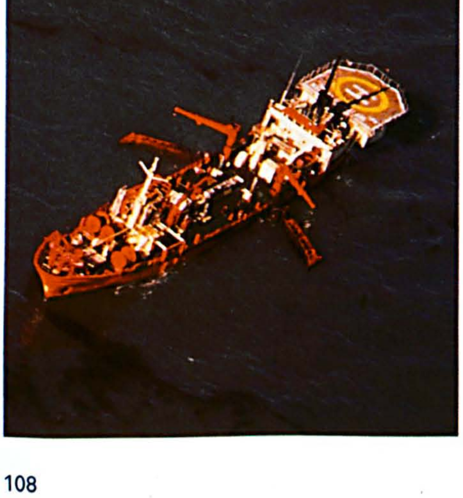
In the case of the *Sea Empress*, it appears that the use of dispersants was, overall, of benefit to the environment. It seems clear, from observations and the evidence provided, that the dispersant operation was vindicated in shortening the time that oil remained on the sea surface, and in significantly reducing the amount of oil which could have reached the shoreline and its impact on seabirds and the coastal environment and resources. The aerial application of dispersants was controlled and monitored effectively. There was little over-application of dispersant, and no evidence that there was substantial over-spray outside the target area, or that dispersant spray was deposited on-shore. Effective targeting was ensured by the use of a control aircraft flying above the spray aircraft. Monitoring of oil concentrations in the water column helped in maximising the effectiveness of the spraying strategies by showing that the dispersant was having an effect even on emulsified oil.

10.5 MECHANICAL RECOVERY OF OIL AT SEA

Mechanical recovery of oil from the sea surface allows the oil to be disposed of in a controlled way and so is the best environmental option. However, it is particularly difficult to recover oil from the sea surface as the open sea presents a harsh working environment for the recovery equipment and wave motion causes the oil to fragment and spread over a wide area. The method therefore only works well in calm conditions and good weather and is often restricted to sheltered areas. The upper limit in wind speed for effective recovery operations is about 15 knots, and this was exceeded for much of the period of the response at sea, but the period of calm weather from the end of February until early March allowed mechanical recovery to take place. A review of past oil spills shows that rarely has more than 10% of the total amount of oil spilt been recovered from the surface of the open sea[14].

During the recovery operation, between late February and early March, 24 vessels were deployed on mechanical recovery. Recovery of oil from the water surface began at first light on the day following the grounding (16 February) using two small recovery vessels which operated within the Haven. Two larger vessels able to work outside the Haven arrived from Liverpool Bay on 21 February and these were joined by four further vessels from France and the Netherlands supplied under the Bonn Agreement, a framework for co-operation between North Sea member countries. The oil recov-ery vessels worked mainly within the Haven or in the inshore waters of Carmarthen Bay in the Tenby area. These areas were too close to the shore for using dispersants and were relatively sheltered, which helped to minimise the difficulty of recovering the oil.

Mechanical recovery of fragmented oil slicks (see also photo in §2.6.1) (ITOPF)



When the oil moved to waters in Carmarthen Bay too shallow for the oil recovery vessels to reach, small fishing vessels, working in pairs, were used to "cut out" areas of emulsion using a boom, towing the emulsion slowly out to deeper water where the larger vessels could use their recovery systems. A similar system using inflatable boats was used close to shore around some of the sensitive seabird areas at Skomer and Stack Rocks. This technique proved very successful and could usefully be included in future guidelines on oil spill response.

Around 7,500 tonnes of oil and water mixtures were recovered from the sea and discharged to the Texaco refinery. Overall, 1-2% of the total quantity of oil spilled was recovered at sea.

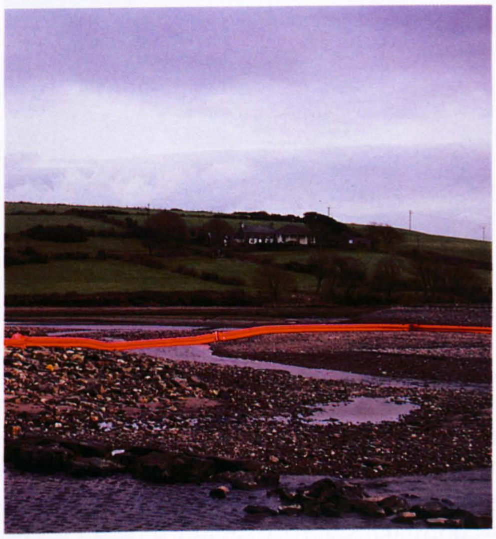
Concern has been expressed that recovery operations started late. However, conditions in the initial days would not have allowed much oil to have been recovered. Even if large specialised recovery vessels had been available shortly after the spill it is doubtful that oil recovery could have exceeded 5% of that spilled[15]. Greater environmental benefit might have been achieved by better targeting of recovery operations on sea areas adjacent to the most sensitive coastlines. MPCU now consider that the mobilisation of recovery vessels should be given the same priority as the aerial spraying, provided that weather forecasts are favourable.

The engagement of the French and Dutch vessels was considered justifiable based on the assessment of the situation at the time, but the engagement of further large recovery vessels after this date would not have been justified, given the decreasing volume of oil and emulsion. Higher volume skimmers than those held by MPCU are available, but would have required additional offshore support craft and a reception tanker. These additional resources could not have been mobilised quickly enough to make a significant contribution to oil recovery. In contrast, oil recovery from shallow waters would have been improved by bringing in additional belt skimmers from other parts of the UK such as Sullom Voe Terminal. It would be of benefit if MPCU's review of arrangements for locating recovery vessels included assets held by oil companies at refineries and terminals.

10.6 USE OF BOOMS

Booms can be used in some circumstances to protect stretches of shoreline, but they are only useful for shoreline features such as small harbours and inlets. They are not effective on coastlines in open sea areas or with high tidal ranges or strong currents.

While there was surface oil at sea, booms were used at sites which had been identified as sensitive and suitable for booming, and which had been surveyed during contingency planning. Once the oil had stranded, booms were also used around Tenby Harbour to minimise the spread of oil to other stretches of coastline.



Boom at the Gann (E Bent)

The deployment of booms at pre-planned sites such as the Neyland Marina and elsewhere was effective, and other sites were considered by the JRC. The Dyfed County Council's local oil spill contingency plan gave information on pre-identified sites for booms but did not list areas where booms were not considered feasible, and there were some unrealistic expectations of their effectiveness. In practice, booming was effective only within some of the more sheltered areas of Milford Haven. Consideration could be given in oil spill contingency plans to the identification of areas not amenable to the use of booms.

10.7 THE SHORELINE CLEAN-UP

10.7.1 The removal of bulk oil

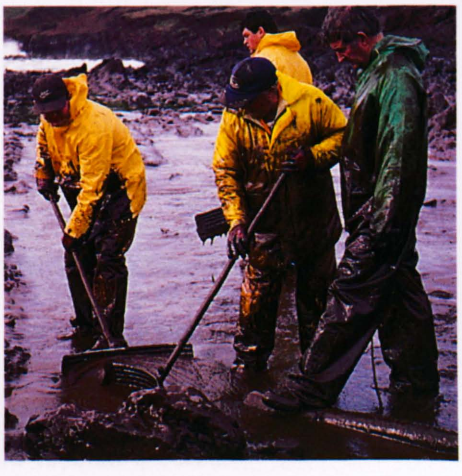
Around 11,000 to 16,000 tonnes of emulsion came ashore along 200 km of coastline (see §2.9.2), requiring a major clean-up operation lasting many months. The worst affected areas were West Angle Bay to Linney Head, western Carmarthen Bay and the southern shore of Milford Haven waterway.

The initial priorities were the removal of bulk oil from accessible sites (except for a number of sites which were left to clean naturally for comparative purposes) and cleaning up Tenby and Saundersfoot beaches in time to allow public access by the Easter holidays. The removal of the bulk oil reduced the risk of re-contamination of a cleaned beach by oil brought by the tide from neighbouring areas, and final cleaning was deferred until bulk removal was completed.

Trenches at Saundersfoot, 28 February 1996 (E Bent)

A number of techniques were involved including the use of suction equipment, excavators, absorbent material, flushing with water at low pressure, and the manual use of shovels and scrapers. JCB vehicles were used to dig trenches to trap oil, particularly on the main amenity beaches; but in order to minimise environmental damage on more sensitive shorelines, the use of heavy machinery and intrusive clean-up techniques was avoided wherever possible.

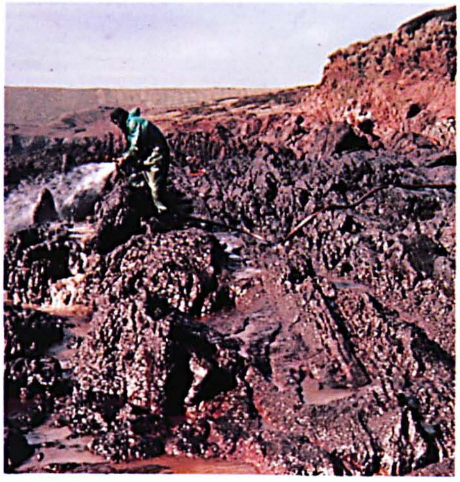
There might have been advantage in having a mobile team skilled in sea access operations to remove bulk oil from beaches with difficult land access. Potential problems which can be encountered if bulk oil is not removed immediately were demonstrated at Skrinkle Haven. The difficulty of access and conflicting reports about the state of the beach meant that the bulk oil was not removed quickly. The oil became buried under sand, hiding the severity of the oiling from the response teams, and was reworked by the tide. Over the following 18 months, deposits of oil and oily sand were intermittently deposited on the shoreline. This led to an extended programme of beach clean-up and the need for daily surveys. Diving surveys carried out in the spring of 1997 showed that the sediments off Skrinkle Haven were still oiled to a significant extent.



Bulk oil removal using suction equipment and scrapers at Manorbier (PCNPA)

10.7.2 Cleaning the residual oil and remaining bulk oil

Most of the bulk oil was removed from amenity beaches by mid-March 1996. The operation then turned to cleaning the residual oil as well as trying to tackle bulk oil along inaccessible stretches of coast. Again, several techniques were used, chosen according to the type of shoreline material, the type of oil, the extent of contamination, the degree of exposure of the area to wave action and particular environmental considerations. These techniques included manual scraping and digging, cleaning with absorbent material, the removal of oiled sand and other beach material, low and high pressure washing with water, washing cobbles or shingle in pits or cement mixers, and surf washing.



High-volume water flushing to displace oil on rocky shoreline, between Wiseman's Bridge and Amroth (ITOPF)

Some areas were left to clean naturally. It was the general policy of the JRC that rocky shores outside the main amenity areas, inaccessible cobble and boulder shores, mudflats and saltmarshes should be excluded from the clean-up operation. For saltmarshes in particular, studies at previous oil spills have shown that physical damage during clean-up can cause longer term problems than the oil[16].

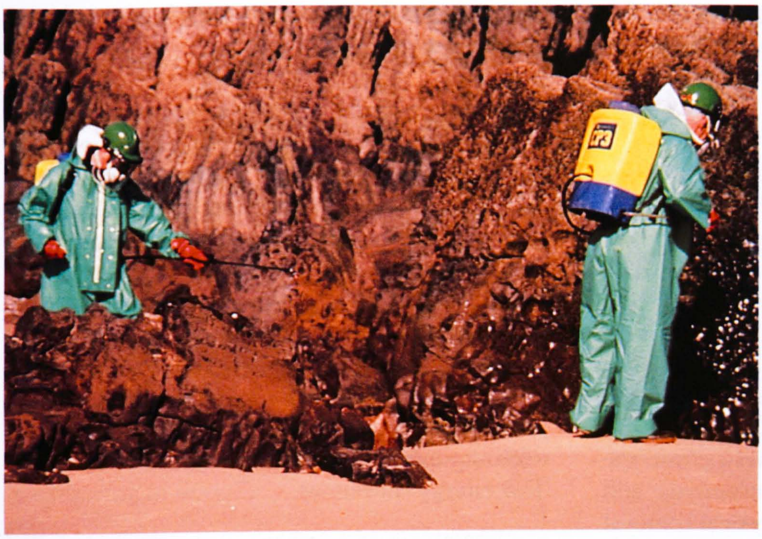
The main amenity beaches were sufficiently clean by Easter for tourists to use them, and effort was then directed to the more challenging beaches where access and the nature of beach material presented problems. By September 1996 a combination of the clean-up response and natural clean-up had reduced the quantity of oil on the shoreline to an estimated 500 tonnes (see §2.9.3).

The mobility of beach material caused difficulties: at times up to 2 or 3 metres depth of sand or gravel could be deposited on a beach or removed with one tide, thereby covering or uncovering oil. Oil also became trapped in inaccessible places such as deep crevices and under large boulders. Trapped or covered oil caused a number of problems throughout the remainder of the year, particularly when bad weather or tides caused the movement of beach material and led to this oil being lifted and recontaminating cleaned areas of shoreline. There were many examples of this during the storms in October 1996. Recontamination also occurred when emulsion broke down into liquid oil in hot weather over the summer. Tar balls, mainly resulting from oil which had combined with sediment as it was washed from beaches, came ashore frequently at many sites. All these incidents were dealt with rapidly by small teams reporting to the JRC which remained in operation until September 1997. All clean-up activities were brought to a close by the beginning of October 1997, although a final survey was proposed for spring 1998 to establish the need for removing any remaining deposits of oil exposed during the 1997/98 winter.

Final cleaning of a sandy beach, Saundersfoot (ITOPF)

10.7.3 Use of dispersants onshore

With the agreement of the Environment Team in the JRC, dispersants were used to remove weathered oil from rock faces at those sites most accessible to the tourists using amenity beaches on the south Pembrokeshire coast. A total of 12 tonnes of dispersant was used. Tests were carried out on two beaches with different dispersants and cleaning agents to determine which were the most effective at removing the residual oil. The dispersants were applied before high tide, and the subsequent concentrations of oil in the water were monitored carefully. The dispersed oil concentrations were found to be relatively low (3,000 µg/l at maximum, and more typically less than 1,000 µg/l) and also very localised (typically affecting areas about 20 m across).



Controlled use of dispersant for cleaning rocks on amenity beach, Tenby (ITOPF)

10.7.4 Surf washing

Cobble beaches are notoriously difficult to clean if the oil penetrates into the beach. Oiled cobbles were cleaned in pits and cement mixers but another approach which was found to work well in some circumstances was "surf washing"[17,18]. It was noted that oil had often not adhered tightly to shore material due to a natural interaction between the oil droplets and minute mineral particles in the water, a process known as "clay-oil flocculation"[19,17]. This reduced the adhesiveness of the oil and promoted dispersion of the oil by preventing the droplets from coalescing. At Amroth and Marros, oiled cobbles were taken from the high water mark down the beach at low water to where they would be washed naturally by the surf and where the processes of tidal washing, abrasion by sand particles and clay-oil flocculation contributed to the cleaning process. The oiling of the cobbles decreased at each tidal cycle so that by the fifth day there was no longer significant oiling in the cobble zone[18].

10.7.5 Fate of oil on treated and untreated beaches

The environmental benefits of removing oil from shorelines are not always clear. Shorelines where the bulk oil has been removed recover naturally over a period of time, and further response efforts may even slow down the natural clean up processes. A study was therefore carried out to quantify the effect of clean-up on oil levels of treated shorelines compared with untreated shorelines of a similar degree of oiling and wave exposure. This used new analytical techniques (based on chemical biomarkers) to quantify the processes affecting the oil.

The oil levels and the fate of residual oil were studied at five sites (Horse Neck, Kilroom and Mun Sands, Pwllcrochan, Kilpaison, and Coppet Hall) which represented different degrees of wave exposure, sediment texture, severity of oiling and clean-up history[20]. Each site except Horse Neck included areas which had been cleaned and areas which had been left to clean naturally for comparison. (Clean-up at Pwllcrochan was not completed until March 1997.)

By September 1996, the first monitoring point of this study, the cleaned sites generally had less oil

Natural clean-up at a monitoring site (Frainslake Beach), 2 March and 22 May 1996 (S Howells, CCW) cover than the leave-alone sites; but by the end of the monitoring period - June 1997 - there was little difference in oil cover between the cleaned and leave-alone sites.

The rate of oil removal by natural processes appeared to be most strongly related to the degree of exposure to wave action and to beach type. The exposed sandy beaches (Coppet Hall, Kilroom and Mun Sands) were clean at an early stage in the monitoring programme, with physical removal apparently the dominant process. Oil still remained in June 1997 on the more sheltered coarse sediments (Kilpaison and Pwllcrochan) where oil had penetrated into the cobbles or had formed asphalt pavements, and here both biodegradation and physical removal had occurred. Oil also remained on the upper part of the rocky shores (at Horse Neck and also on rocks at Pwllcrochan and Kilpaison). Oil biodegradation was an important process on these low energy, porous (and therefore largely aerobic) shorelines, accounting for between 40% and 85% of the residual oil. In each case the indigenous population of micro-organisms was capable of biodegrading a wide range of hydrocarbons. Physical processes were therefore removing increasingly biodegraded oil from the beaches.

These results suggested that, on exposed sandy shores, oil removal by physical processes was rapid, and so the main environmental benefits of clean-up was to prevent contamination of the nearshore environment or nearby shorelines from oil lifted from the beach. On sheltered, largely aerobic beaches, oil biodegradation was an important process.

10.7.6 Bioremediation

Bioremediation - a clean-up technique which involves setting appropriate conditions to encourage the natural breakdown of oil by micro-organisms - was not used following the *Sea Empress* spill as part of the clean-up operation. However, the opportunity was taken to establish an experimental plot at Bulwell Bay in Milford Haven waterway[21]. Bioremediation techniques were used in Alaska following the *Exxon Valdez* incident[22,23,24].

Micro-organisms which break down oil are widespread in the natural environment, especially in shore areas where there are frequent inputs of oil, such as Milford Haven waterway, but the breakdown of oil can be limited by factors such as temperature and the availability of nutrients such as nitrogen and phosphorus. Adding nutrients can stimulate microbial activity, thereby promoting biodegradation[25].

The experiment involved comparing two different nutrient treatments - one applied weekly and the other in a slow-release form - with an untreated site over several weeks. Both increased the rate of biodegradation of a mixture of heavy fuel oil and Forties Blend crude, and the methods were equally effective. The treatments had no measurable effect on the nutrient content of the seawater in the area and there were no detectable toxic effects. The slow release method may prove a cost-effective technique for enhancing the natural recovery of low energy shorelines.

10.7.7 Termination of clean-up

The continuation of the JRC 18 months after the incident has led to questioning of the criteria for determining both the termination of its own activity and arrangements for deciding when clean-up should cease at individual sites. The decision to terminate clean-up is influenced by a number of factors including environmental and amenity priorities, political and media pressures, economic concerns and the consideration of diminishing returns. Although there has been a desire to remove all traces of oil from the local environment, the level of cleanliness to aim for should be related to the use of the area, its capacity for natural clean-up and the ability of damaged ecosystems to recover. The one complicating factor which lengthened the clean-up period was the exposure of oil when storms moved beach sediments. With limited exceptions the Pembrokeshire coastline did not have significant amounts of contamination by summer 1997 and probably did not require the JRC for co-ordination of clean-up operations, and this could have been left, within clear guidelines, to the local authority.

It is suggested that clean-up objectives and criteria for success be clearly defined at the outset of the response. The JRC needs clear objectives for the clean-up operation, criteria to monitor progress and guidelines for when a co-ordinated response to clean-up should be terminated. Criteria of cleanliness should be agreed for those resources of greatest importance. The strategy set by the JRC in late April 1996 "to combine effective management of resources with sensible economy and prompt action to meet the expectations of local residents" probably placed undue reliance on amenity criteria.

10.7.8 Overall performance of shoreline clean-up

The on-shore clean-up techniques were generally successful in meeting the agreed priorities. There were instances of over-cleaning and cases where final clean-up could have been left to natural processes, but these were minor in the overall scale of the incident. Differences between the views of the organisations and authorities involved did not materially detract from the efficiency of the clean-up response. There was some over-application of chemical dispersants at Tenby and Skrinkle Haven, and the excessive use of absorbents at some sites. In some instances, stone washing seemed to be excessive compared with leaving natural weathering to occur[26].

10.8 ENVIRONMENTAL EFFECTS OF SHORELINE CLEAN-UP

Management of clean-up activities ensured that environmental and conservation considerations were given a high priority and damage to shoreline communities was limited and mostly temporary, even in amenity areas. Clean-up activities on rocky shores were largely restricted to upper shore rocks adjacent to amenity beaches and other areas with accessible pooled oil. Many areas were left to clean naturally (see §10.7.5); these included mudflats and saltmarshes which are especially susceptible to clean-up damage.

Table 10.2 Observed consequences of clean-up activity carried out on rocky shores

Clean-up technique	Main study sites	Observed worst case effects
Dispersant spraying followed by scrubbing	Manorbier, Monkstone Beach.	Reduced densities of typical invertebrate populations compared with uncleaned areas. In particular there was a loss or failure of recruitment of juvenile limpets at a Manorbier site where dispersants were used. In 1997 there was successful recruitment, so any effect was limited to one year. Loss of the lichen *Arthropyrenia halodytes* from barnacle cases. This was still evident in autumn 1997.
Dispersant spraying followed by scrubbing and high pressure washing.	Tenby (Paragon); St. Catherines Island; Gosker Rock.	Stripping of all invertebrates and algae, including surface biofilms, resulting in the delayed resettlement of algae and a different pattern of recolonisation by invertebrates, particularly barnacles and edible winkles. Limpet numbers remained low in Autumn 1997.
Wiping of rock with releasing agents	Manorbier, Skrinkle Haven, Church Doors	These agents were used only at points of public access where the biota was sparse. No effects due to cleaning were observed.
High pressure washing only.	West Angle Bay; St Catherine's Island.	Stripping of algae, winkles, mussels, barnacles and lichens. Recovery at the boat pool, West Angle Bay delayed, effects still apparent in Autumn 1997.
Lower pressure washing only.	Tenby Harbour (old) wall.	Removal of some winkles only. Rapid recovery.
Deluge and trenching in boulder/shingle shores.	Popton beach, Angle Bay.	Washing out of fine sediment, detritus and invertebrates. Physical destabilisation of substrata resulting in enhanced erosion.
Removal, cleaning and replacement of beach material	Freshwater West, West Angle Bay North Cove)	No obvious effects at Freshwater West. The biota of such a wave-exposed boulder and cobble shore would have been naturally sparse and transitory. Some evidence of physical destabilisation of beach material at West Angle Bay, with the temporary loss of large quantities of detritus and invertebrates.
Manual wiping with rags, scraping and mopping up	Angle Bay; Skrinkle Haven	Spreading of oil splashes on lichen colonies and removal of brittle foliose species.
Indirect damage	Angle Bay, Popton Beach, Llanreath, Pwllcrochan, Freshwater West	Persistent deep tyre tracks and ruts damaged some sheltered shoreline shingle habitats, with disturbance to populations of amphipods, crabs and insect larvae. Observations in Autumn 1997 support the view that the shingle has been destabilised in places. Similar activity on exposed shores, such as Freshwater West, did not have any lasting impact.
Construction of access routes to shores	Popton beach, Freshwater West, Angle Bay, Swanlake, Drinkham Bay and Lyndsway Bay	Temporary construction of ramps and scaffolding caused slight short term damage to cliff vegetation. The track built down to Popton resulted in the removal of an area of bracken and gorse but would limit any impact of any future incident requiring access. The temporary tracks onto Freshwater West were no longer visible in 1997, whilst the area around the sides of Angle Bay retained the signs of disturbance of sediments in some places with continuing reductions in the fauna.

A study was carried out to assess the environmental impact of clean-up activities, in particular on rocky shores, looking in detail at the different techniques used[27]. Some of the results are summarised in *table 10.2* (previous page).

The shoreline clean-up techniques used were correct in principle[28], though there were minor problems. For example, there were instances of damage from heavy machinery on edges of mudflats, (eg at Angle Bay - §5.7), and at many accessible sandy beaches trenches dug for the mechanical recovery of oil were not lined or marked, leading to further incorporation of oil into the sand. In some instances, the oil was not removed before the incoming tide, resulting in longer-lasting contamination.

High pressure washing of upper and middle shore rocks at Tenby, the West Angle Bay boat pool and some other sites stripped barnacles, mussels, limpets, algae and lichens from rocks. Although barnacles and mussels returned quickly, impacts on fucoid algae and limpet populations were still evident during the summer of 1997 and lichen colonies will take many years to recover. A series of experiments to assess the advantages and disadvantages of high pressure washing of oil-covered lichens on upper shore rocks is being carried out at two sites in Milford Haven waterway. This long term study will monitor recovery rates on adjacent washed and unwashed rock surfaces[29]. It is certainly clear that where pressure washing is required to remove oil from rocky shores, the pressure should be kept to the minimum necessary.

Oiled waste from Angle Bay, June 1996 (T Kirby)

Dispersants were mainly used to clean persistent oil encrustations from rock platforms and boulders around selected amenity beaches. Evidence from monitoring in these areas showed that barnacles and mussels re-colonised the cleaned rock quickly but suggested that the dispersant delayed the recolonisation of microscopic algal films. These algae are the primary colonisers on clean surfaces and are often the precursors to the settlement of other algae. The effect was limited to surfaces where the chemical had been directly applied and was mostly temporary; typical algae and animals had recolonised the rock surfaces by the spring of 1997. Spraying of dispersants on part of St Catherine's Island was also shown to have caused localised mortality of mussels (*Mytilus edulis*) and other shore biota on ledges where dispersant collected in pools. These mussels had previously survived persistent oiling[30]. It is obviously important to limit the use and take particular care in the application of dispersants.

Manual wiping of oiled rocks with rags helped to remove oil coatings in some amenity areas, but in a few places over-exuberant wiping spread the oil onto unoiled surfaces and lichen colonies.

10.9 DISPOSAL OF WASTE

The clean-up operation generated a large amount of oiled waste material including liquid waste (collected during the mechanical recovery at sea and during the bulk oil removal operation), oiled sand and oiled materials such as seaweed, beach debris, clean-up equipment and protective clothing.

The disposal of this waste presented a serious problem. After reviewing possible landfill sites in the early days of the incident, the JRC agreed to store oily wastes at landfarms and temporary holding areas, and to set up a Waste Disposal Group to find permanent disposal sites. Strictly, a waste management licence was required for the temporary holding areas, but this would have involved planning permission and a consultation process which was clearly impracticable. The Environment Agency therefore allowed the temporary storage under strict supervision.

Liquid waste amounted to about 20,000 tonnes and this was mainly taken for processing by Texaco, recovering 1,500 tonnes of oil. Solid waste amounted to 12,600 tonnes of which 4,800 tonnes was landfilled (at a site near Merthyr Tydfil 160 km away) and 7,800 tonnes (including the oiled sand) was taken to Texaco's landfarm, where conditions are maintained which promote the biodegradation of the oil by bacteria.

The ultimate fate of the disposed oil depended on the method of disposal. Much of the oil was reclaimed from the liquid waste. Landfarming uses the principles of bioremediation (see §10.7.6) to break down the oil, by adding nutrients; the waste is rotovated to ensure aerobic conditions. The material sent to the landfill site was not subjected to any pre-treatment; as conditions at the site are anaerobic, the oil is unlikely to degrade quickly, but absorption by other material in the landfill prevents the oil from becoming mobile. A small amount of oiled sand was used to make asphalt, and a further small amount was subjected experimentally to "thermal desorption", a process where the sand is heated to burn off the hydrocarbons, theoretically allowing it to be taken back to the beach - though the process leaves it sterile and changes its colour.

It was fortunate that the Texaco refinery was prepared to accept a large proportion of the waste, a situation which might not apply to spills in other locations. There is no regional or national contingency arrangement for the disposal of waste, although the problem had been considered by Dyfed Oil Pollution Advisory Group and research studies on the disposal of oil in sand dunes and dune grassland were under way.

In view of the unsatisfactory nature of current licensing arrangements applying to emergencies, the Environment Agency, MPCU and Local Authority Associations need, as a matter of urgency, to agree national waste disposal guidelines on:

- regulatory requirements for temporary storage;
- exemptions which may apply to emergency arrangements;
- Duty of Care obligations, particularly for waste transfer;
- preferred disposal routes for liquid and solid wastes; and
- availability of reprocessing and incinerator capacity.

10.10 THE EFFECTIVENESS OF THE PLANS AND ORGANISATION

10.10.1 National Contingency Plan and local plans

Since the *Torrey Canyon* incident in 1967, central government has taken statutory powers to reduce the risk of oil pollution at sea and has accepted responsibility for dealing with spillages which threaten the UK coastline. MPCU (part of the Coastguard Agency) was set up in 1978 to lead the government's emergency planning and response duties for spills. The National Contingency Plan sets out the organisational framework, principles and procedures to be implemented by organisations which cooperate in dealing with marine pollution. MPCU is responsible for maintaining the NCP for dealing with oil spills from ships at-sea, and for holding the UK stockpiles of response equipment.

For oil spills at sea, MPCU is directly responsible for response measures, but where marine oil spills come ashore, local authorities have accepted a voluntary responsibility to clean the shorelines. In this case, MPCU provides guidance to local authorities on contingency planning, and in the event of a major spill provides help in coordinating shoreline operations, particularly the selection of appropriate clean-up methods. The National Contingency Plan requires a JRC to be set up to integrate the on-shore response of central and local government.

At the time of the spill, Dyfed County Council was responsible for the local Oil Spill Plan which included the functions of the County, District and Borough Councils. The Plan covered arrangements for co-ordination between Districts/Boroughs, procedures for setting up a JRC and for providing administrative support. The Port of Milford Haven Anti-Pollution Plan (June 1992) also sets out actions to be taken by the Port Authority, the local authorities, and the oil company concerned where there is widespread pollution of the Haven.

Although the shoreline response is the responsibility of the local authorities, in the Milford Haven plan each of the local oil companies agreed to take responsibility for the clean-up of shoreline oiling arising from a tanker bringing oil to its refinery. Texaco therefore managed the shoreline response within Milford Haven waterway until the full scale of the spill became apparent.

10.10.2 Overall conclusion

The National Contingency Plan was basically sound. The Plan had been revised in December 1995 to reflect the lessons learned from the *Braer* incident in 1993. It was up-to-date in terms of factors to be covered and the roles and responsibilities of key participants. The speed with which command and control of the incident was set up provided sound evidence of the Plan's practicality; for example, the JRC was operating within 12 hours of the initial grounding of the *Sea Empress.* There were adequate resources for the aerial application of dispersants and the recovery of oil from the sea, and the equipment inventories for shoreline clean-up were appropriate for a national or international plan. The local organisations were more than adequately prepared for a local or regional response, and planning arrangements for a national response were adequate. The co-operation between key local participants on environmental and technical matters was commendable and made a significant contribution to the effective operation of the JRC. This had been helped by the participants training together on numerous occasions beforehand.

However, a number of points were identified where there could be improvements, and these are presented below.

10.10.3 Roles

The Plan could provide clearer recognition of the qualitatively different tasks facing the managers of the sea and onshore operations. The response at sea requires an authoritative, focused approach for the emergency and salvage stage, whereas the onshore clean-up operation requires an approach based on project management and consensus between groups.

There was some confusion amongst those taking part in the response over roles and who was in charge of operations. The role of the JRC and senior MPCU staff need to be defined more clearly in the Plan[31].

The MPCU Overall Commander - the Chief Executive of the Coastguard Agency - was based at Southampton, and so was remote from the scene of the incident and was unable to respond fully to the high level of media interest. The media expect open access to the most senior officer in the emergency response, particularly during the early stages of an incident. On balance, it is suggested that the Overall Commander and his support team should be located at the scene of the incident to act as the authoritative spokesman for MPCU and the Coastguard Agency. This would relieve operational staff of this burden at a time of high workload and stress. The Overall Commander would maintain the role of official contact for central government organisations, but would not have an operational response role.

There was considerable confusion over the role of the Joint Response Centre (JRC), which played no part in the operation at sea. MPCU therefore proposes changing the JRC's name to "Shoreline Response Centre" to clarify its role.

10.10.4 Organisation of the JRC

The incident occurred only six weeks before the district and county councils in the region were reorganised to form the unitary authorities of Pembrokeshire and Carmarthenshire. Senior local authority staff had to commit their time to this transition. This had only a slight effect on practical aspects of the clean-up to 1 April 1996, but the impending changes did weaken the management of the JRC during the early stages of the incident. Not having a chief officer from Dyfed County Council to chair or participate in the JRC Management Group resulted in resource deficiencies in the JRC, particularly for administrative support. This led to poor record-keeping and poor documentation, particularly in support of the settlement of financial claims. The lack of local authority resources contributed to the difficulties in managing the intense media interest during the early period of the incident. The inception of the new unitary authorities on 1 April 1996 improved matters, particularly in record-keeping and health and safety.

The chairmanship of the JRC Management Group was taken by the General Manager of Milford Haven Port Authority. Although this post would normally have been occupied by a senior local authority officer, the arrangement worked effectively; but there was a lack of appropriate senior effort at the strategic level for dealing with a long-running response. It is proposed that Chairmanship of the JRC should normally be taken by the chief executive of the local authority. This should help to release local authority resources for strategic planning and support activities.

Record-keeping in the JRC was inadequate, particularly in the early days of the response. Ordnance Survey maps overlaid with acetate sheets to show affected shorelines were updated daily, but the previous information was not archived. Many personal logs and records were not collated centrally and therefore may not have been considered in official reports on the incident. MPCU plans to devise standard forms and a computer Geographical Information System for use in future incidents. Dictaphones (and video cameras in some instances) would also facilitate record-keeping, particularly in the field. It would be beneficial if local authorities could provide staff and support facilities to the JRC for record-keeping, administrative support and media briefings.

The information flow between the JRC and the Marine Response Centre (MRC, responsible for the response at sea) was inadequate. There was a general view that the MRC was not providing the JRC with sufficient information on possible scenarios for oil movement and spreading, despite having a computer modelling system able to predict the movement of oil slicks. However, the quantities of oil lost were of such magnitude that any coastal defence measures based on predictive information would only have been minimally effective. Better provision of actual and predictive information on oil distribution could be provided for incidents with extensive shoreline impacts. There is a need for a liaison officer to operate at the MRC to provide the formal link with the JRC and to ensure efficient cross-flow of information as the incident progresses. If the MRC and JRC are not co-located, liaison officers would need to be appointed in both Centres.

Texaco took responsibility initially for onshore clean-up operations within Milford Haven waterway in line with the port's oil pollution contingency plan. There have been concerns expressed about the lack of co-ordination between the JRC and Texaco, though these appear unjustified. Oil Spill Response Ltd (OSRL) resources were deployed before the JRC started, and a staff member of OSRL joined the JRC on 17 February. Texaco was also represented on the JRC Co-ordinating Team when established. To avoid potential future conflict, the port's plan might be modified so that where the scale of an incident requires a multi-agency response, the oil company concerned will be released from its obligations under the plan and will work as directed by the JRC.

MPCU has recommended that a JRC manager is required to run the Centre and be supported by a transport co-ordinator and health and safety manager for large-scale incidents.

Unsatisfactory staffing arrangements meant that personnel were required to work long hours under stressful conditions. It is suggested that further attention be given to arrangements for the relief of personnel during long-running incidents. This was one of the published lessons from the *Braer* incident. There has been some criticism of the level of experience of key JRC participants, but the rarity of spills of this scale in the UK needs to be recognised as a contributing factor.

Local authorities have no statutory obligation to prepare contingency plans and to carry out shoreline clean-up, and this has been the subject of long-standing debate. In this incident, the councils in the region had prepared effective plans and a statutory obligation would have made little difference. The incident, however, demonstrated the importance of such plans, and there is much to be said for the planning and response being placed on a statutory basis to ensure that adequate resources are provided for effective contingency planning in the UK. Lord Donaldson's Inquiry following the *Braer* oil spill recom-mended that harbour and local authorities should have such a statutory duty, and the Merchant Shipping and Maritime Security Act 1997 includes an enabling power allowing local authorities to be given this role. There are, however, resource implications to this proposal which would need to be considered.

Concerns of the local authorities over expenditure or the recovery of costs did not constrain the clean-up effort either before or after reorganisation. Inadequate documentation to support claims to the International Oil Pollution Compensation (IOPC) Fund led to delays in reimbursing clean-up costs. Such delays may result in the authorities in future incidents being reluctant to commit voluntarily to the levels of expenditure necessary for effective clean-up. Local Authority Associations might seek guidance from the IOPC Fund on whether compensation could cover the costs of buying in commercial accounting services to maintain JRC financial records and to process claims.

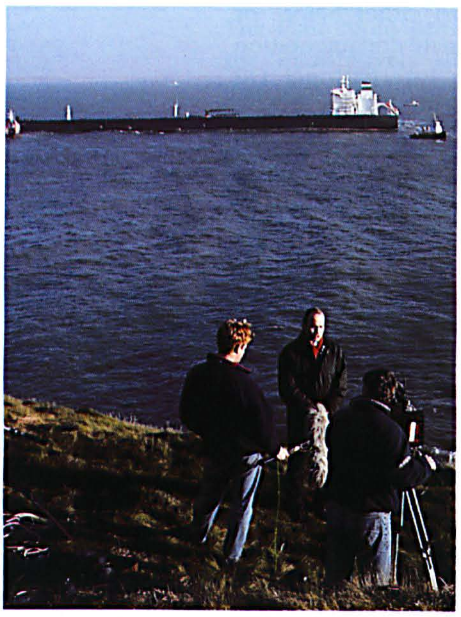
Communications facilities in the JRC were inadequate at the outset of the incident, and in future it would help JRCs to have a telephone switchboard to filter incoming calls. Access control at the JRC building was lax, resulting in non-essential personnel distracting staff from their heavy workload.

10.10.5 Beachmasters and workers

The UK Petroleum Industry Association (UKPIA) agreed to provide support for assisting and supervising clean-up operations. UKPIA representatives were appointed as beachmasters, and although the arrangement worked satisfactorily, site management varied in efficiency. Senior oil company staff are not necessarily the most suitable beachmasters. Job descriptions for beachmasters are being prepared by MPCU, and these need to indicate the required supervisory skills for contract labour.

Information flow between beachmasters and the JRC was confused in the early stages, with conflicting instructions from the JRC and inconsistencies in beach surveys as a result of differing interpretations of oil impacts. Better surveys – ie ones conducted according to standard guidelines – conducted by JRC technical and environmental staff would have helped to maintain consistency. A standardised approach to shoreline assessment using a trained Shoreline Clean-up and Assessment Team (SCAT) approach - such as used following the *Exxon Valdez* - would have been of benefit.

The clean-up workers were mainly sourced through short-term contracts with a significant number of previously unemployed personnel. Although there were a few instances of poor performance, overall there was no evidence that the clean-up was impeded.



Filming of the *Sea Empress* (E Bent)

10.10.6 Health and Safety

Several participants and observers noted the lack of attention to occupational health and safety issues during the early stages of shoreline clean-up. The Control of Substances Hazardous to Health (COSHH) Regulations 1994 require employers to assess health risks arising from hazardous substances and to consider the level of personal protective equipment necessary to control exposure adequately. Employees or their representatives must be informed of this assessment. Crude oil is classified as a hazardous substance requiring a COSHH assessment, but it was two to three weeks into the response before this assessment was carried out. The Management of Health and Safety at Work Regulations require risk assessments of site-specific hazards, but these assessments were only done intermittently until after local government reorganisation.

MPCU has recognised these deficiencies and has responded by issuing a Scientific, Technical and Operational Advice Note providing detailed guidance to local authorities. MPCU intends to maintain a central database of COSHH data for crude oils and refined products. Inclusion of existing information on dispersants and demulsifying agents would also be helpful.

However, this MPCU Note omits reference to the accepted practice of requiring all new workers to attend a safety induction briefing which would cover health and safety at work issues such as personal protective equipment, personal hygiene, first aid and accident-reporting procedures. A video on the main techniques for shoreline clean-up, the main risks involved, and the precautions required to avoid accidents would provide a valuable introduction for new clean-up workers and volunteers. Local authorities should make sure that their liability insurance policies cover the activities of workers and volunteers operating under instructions from the JRC. The JRC must ensure effective compliance with Health and Safety requirements including safety induction for the clean-up workforce.

10.10.7 Media Issues

Media interest in the days following the grounding was intense. The demands this can impose were amply demonstrated at the *Braer* oil spill in 1993, but this experience was not fully carried forward to the initial handling of the *Sea Empress* incident. Whilst there was generous recognition of the efforts of those involved, there was serious criticism of the way that the media and public relations were handled. Although procedures for handling media issues are documented in the relevant contingency plans, the facilities for the press team and media representatives were inadequate for this scale of incident.

The incident demonstrated that contingency plans and training need to emphasise that the media should be viewed positively. During the press conferences in the early days of the incident, information was difficult to obtain and appeared not to reflect the true gravity of the situation. Pressure of operational demands meant there was a failure to provide public reassurance through the presence of senior members of the Management Group at some media briefings.

At an operational level, information was not always passed consistently and promptly to the Press Office to enable the media to be kept up-to-date with developments. Presentation of graphical information on the distribution of oil at sea and on the shoreline was poor. Some organisations represented within the JRC issued press releases at variance with the Press Office releases. The editing of press releases needed better control to remove inaccuracies. Local media coverage should have been monitored more intensively to counteract false or misleading stories.

The net result was that the media lost confidence in the authority of the Press Office to provide accurate, timely information. It is suggested that the National Contingency Plan emphasises the positive value of meeting the media's needs and covers the resources required by all organisations participating in the JRC to meet those needs. In recognition of these deficiencies, MPCU is reviewing the procedures, resources and training which will form a national contingency plan for media relations. This should include the production of explanatory leaflets on the response to an oil spill, and the consequences and environmental benefits of the measures adopted.

10.11 CONCLUSION

Based on the detailed independent analysis carried out, the overall conclusion is that the clean-up response was in general well managed, planned and executed[31]. The marine response measures almost certainly considerably reduced the gross level of shoreline pollution - which nonetheless was substantial - and the use of dispersants at sea was vindicated by both a reduction in the impact on amenity and wildlife, giving an overall environmental benefit.

The inevitable environmental impacts onshore were not generally made worse by inappropriate or intrusive clean-up techniques, and, in the main, the techniques employed were successful in meeting the agreed priorities for shoreline clean-up. There were instances of over-cleaning and cases where the final clean-up could have been left to natural processes, but these instances were minor in the overall scale of the operations[32].

REFERENCES

1 MPCU (1996). The *Sea Empress* Incident, Milford Haven15 February 1996. A report by the Marine Pollution Control Unit, December 1996. The Coastguard Agency. 128 pp.

2 Davies L., Lunel T., Boxall S., Shimwell S., Byfield V., Gommenginger C., Gurney C., "Review of *Sea Empress* aerial/satellite images and optimisation of proceduresand interpretation", AEA Technology report to EA (SEEEC project P10), 1997.

3 IMO/UNEP guidelines on oil spill dispersant application,including environmental considerations. International Maritime Organisation, London, 1995.

4 Lunel T., Swannell R., Rusin J., Bailey N., Halliwell C., Davies L., Sommerville M., Dobie A., Mitchel D., McDonagh M., & Lee K. Monitoring of the effectiveness of response options during the *Sea Empress* incident: A key component of the successful counter-pollution response. Spill Science & Technology Bulletin., 99-112, Vol. 2, (Published in 1996) 1995.

5 Lunel T., Rusin J., Bailey N., Halliwell C., & Davies L. A successful at sea response to the *Sea Empress* spill. Proc. 1996 Arctic and Marine Oil Spill Programme (AMOP), 1499-1520, 1996c.

6 Lunel T. & Lewis A. The use of fluorometry and remote sensing to determine the effectiveness of demulsifier in sea trials. Proc. Emulsion Workshop, 1993.

7 Walker M. & Lunel T. Response to Oil Spills at Sea Using both Demulsifiers and Dispersants. Proc. 1995 AMOP,537-558, 1995

8 Walker M., McDonagh M., Albone D., Grigson S., Wilkinson A., & Baron G. Comparison of Observed and Predicted Changes to Oil after Spills. Proc. 1993 Oil Spill Conference, 389-393, 1993.

9 Lunel T., Davies L. & Brandvik P. Field Trials to Determine Dispersant Effectiveness at Sea. Proc. 1995 AMOP, 603-628, 1995.

10 Lunel T. & Davies L. Dispersant effectiveness in the field on fresh oils and emulsions. Proc. 1996 Arctic and Marine Oil Spill Programme (AMOP), 1355-1394, 1996.

11 Maritech Ltd., Independent assessment of clean-up operations, report to Welsh Office, 1997 (SEEEC project P1) Para. 10.5.1

12 Maritech Report, 1997 Para. 8.3

13 Swannell R., Daniel F., Croft B., Engelhardt M., Wison S., Mitchel D., & Lunel T. Influence of physical and chemical dispersion on the biodegradation of oil under simulated marine conditions. Proc. 1997 Arctic and Marine Oil Spill Programme (AMOP), 617-641, 1997.

14 ITOPF Containment and recovery of oil at sea. The International Tanker Owners Pollution Federation Ltd. Contract No. 23/91, 1991.

15 Maritech Report, 1997 Para. 8.4

16 Baker J. Net environmental benefit analysis for oil spill response. Proc. 1995 International Oil Spill Conference,611-614, 1995.

17 Bragg, J.R. and E. Owens, "Shoreline cleansing by interactions between oil and fine mineral particles", in *Proceedings of the 1995 International Oil Spill Conference,* American Petroleum Institute, Washington, D.C., pp. 219-227, 1995.

18 Lee K., Weise A., Lunel T. Marine Oil Spills: Enhanced biodegradation with mineral fine interaction. 4th International In Situ and On-site Bioremediation Symposium. New Orleans. April 1997b.

19 Bragg, J.R. and S.H. Yang, "Clay-oil flocculation and its role in natural cleansing in prince William Sound following the *Exxon Valdez* oil spill", in *Exxon Valdez* Oil Spill: Fate and Effects in Alaskan Waters, editors, P.G. Wells, J.N. Butler and J.S. Hughes, American Society forTesting and Materials, Philadelphia, Pennsylvania, pp.178- 214, 1995.

20 Swannell R., Mitchell D., Little D., Smith J., "The fate of oil on cleaned and uncleaned beaches following the *Sea Empress* Incident", AEA Technology report to EA (SEEEC project P2), 1997.

21 Swannell, R. Evaluation of Bioremediation Techniques", AEA Technology report to EA (SEEEC project P3), 1997.

22 Pritchard, P.H. and Costa, C.F. (1991). EPA's Alaska Oil Spill Bioremediation Project. Environmental Science and Technology 25: 372-379.

23 Bragg, J.R, Prince, R.C, Harner, E.J. and Atlas, R.M. (1994) Effectiveness of bioremediation for the *Exxon Valdex* oil spill. Nature 368 (6470): 413-418

24 Swannell, R.P.J., Lee K., and McDonagh, M. (1996). Field Evaluations of Marine Oil Spill Bioremediation. Microbiological Reviews 60: 342-365.

25 Swannell R., Mitchel D., Jones D., Willis A., Lee K., Lepo J., "An evaluation of bioremediation of oiled sediment buried within a mudflat environment. Proc. 1997 Arctic and Marine Oil Spill Programme (AMOP), 703-713, 1997.

26 Maritech Report, 1997 Para. 11.6.3

27 Little, A., Moore, J., Dyrynda PEJ in prep. Environmental impacts of shoreline clean-up following the *Sea Empress* oil spill. Report to CCW

28 Maritech Report, 1997 Para. 9.3

29 Crump, R.G., & Moore, J., 1997. Monitoring of upper intertidal lichens at Sawdern Point. A report to CCW from the Field Studies Council, Orielton Field Centre, Pembroke and OPRU, Neyland, UK 4pp.

30 Dyrynda P.E.J., "An appraisal of the early impacts of the *Sea Empress* oil spill on the shore ecology within south-west Wales." (report funded by The Wildlife Trusts and WWF – UK), 1996.

31 Maritech Report, 1997 Para. 15.2.6

32 Maritech Report, 1997 Para. 15.1

11 Conclusions and recommendations

11.1 INTRODUCTION

After reviewing the work commissioned by SEEEC to assess the environmental impact of the oil spill and the effectiveness of the clean-up operation, it remains to draw together the committee's principal conclusions, recorded in some detail in the preceding chapters, and to make recommendations including where it is considered that procedural improvements can be made which might have wider application.

11.2 CONCLUSIONS

11.2.1 Impacts and recovery

The main environmental impacts of the spill included:

- Large numbers of marine organisms were killed either as fresh oil came ashore (eg limpets and barnacles) or when raised levels of hydrocarbons in the water column affected bivalve molluscs and other sediment-dwelling species.
- Populations of amphipods (small crustaceans) disappeared from some areas and were severely depleted in others, both onshore and on the seabed near the site of the grounding.
- Several thousand oiled birds, many already dead, washed ashore, with the total number of birds killed likely to be far greater than this. The greatest impact was on birds which spend much of their time on the sea surface, particularly the common scoter, diver species, guillemots, razorbills and divers. Studies showed that there was a significant impact on breeding guillemots in particular.
- A significant decrease in the population of the rare cushion starfish *Asterina phylactica* in the rock pools of West Angle Bay, close to the site of the grounding, with numbers falling from more than 150 to 13 individuals.

In addition there was temporary damage to some algae, lichens and saltmarsh vegetation. Deaths amongst certain shoreline species left an imbalance in eco-systems, leading to temporary increases in other species, such as green algae where limpets had been killed and some species of polychaete worms in sediment shores. Concentrations of oil in bivalve molluscs, such as mussels, remained high for many months.

Many studies were commissioned to look for further impacts, both immediate and longer term. As well as checking for changes in population size and distribution of a variety of species, studies also focussed on sub-lethal effects and changes in breeding success. These studies concluded that:

- There appeared to have been no impacts on mammals.
- Although tissue concentrations of oil components increased temporarily in some fish species, most fish were only affected to a small degree, if at all, and very few died
- Several important populations of seabirds were not significantly affected, and there was no evidence of any effects on seabird breeding success.
- Rare plants in the area were not significantly affected.

The population sizes of many species fluctuate naturally from year to year. This, coupled with a lack of baseline data for some species or locations – or a lack of knowledge of other factors affecting the population – meant that the results of several studies were equivocal. These included impacts on some of the seabird populations such as cormorants and some animal species of the sediment shore. Future monitoring will also be needed to check that the 1996 year class of several species of marine animals – including the commercially-exploited crabs, lobsters, bass and whelks – was not impacted by the spill.

The main impacts all occurred at the time of the spill or shortly afterwards, and there appear to have been few major longer term effects. Indeed, several of the affected species seem to have substantially recovered. Guillemot and razorbill numbers have largely recovered, there has been good recruitment of many species along much of the affected shoreline; and there are signs that some of the amphipod species have become re-established in some areas. There do not seem to have been any longer term effects on the fisheries of the region which can be attributable to the spill, although continued observations on some stocks are needed to verify this conclusion. It is likely, however, that the imbalance in the eco-systems of the worst affected stretches of shoreline will recover slowly, based on past experience of oil spills, and there must be concern over the recovery of the internationally important population of common scoters, the rare cushion starfish and amphipod species in the few locations where they were still absent a year after the spill. Monitoring will continue to record their recovery and should establish whether there are longer-term effects, not yet apparent.

It appears that although a very large amount of oil was spilled in a particularly sensitive area, the impact was far less severe than many people had expected. This was due to a combination of factors – in particular, the time of the year, the type of oil, weather conditions at the time of the spill, the clean-up response and the natural resilience of many marine species.

Fish and mammals were able to avoid the worst of the oil, and any oil they may have absorbed probably broke down fairly rapidly through their efficient enzyme systems. Many species were able to survive a degree of oiling; for example, oiled gulls were seen alive many months after the spill, and at the time of the spill it was noted that some marine organisms had survived even heavy oiling. Many marine species are able to re-populate an area rapidly following a decrease in numbers, particularly where the eggs and juveniles go through a planktonic stage – ie they are carried by currents in the water and so can be brought to an affected area from nearby areas.

Although the rapid, large scale use of dispersants at sea probably increased the exposure to oil of animals on the sea bed – and may have contributed to the strandings of bivalve molluscs and other species and the decrease in amphipod populations in some areas – on balance it is likely that it was of benefit in reducing the overall environmental impact of the spill. The operation resulted in far less oil on the sea surface, which in turn reduced the risk to birds and the quantity that could come ashore. Learning from previous spills, the shoreline clean-up operation was carefully carried out to ensure the minimum environmental impact. The Environment Team in the Joint Response Centre (JRC) played an important role in the strategy for clean-up, advising on priorities and the choice of techniques. It was also fortunate that the direction of the wind during the spill resulted in relatively little oil reaching the important seabird sites at Skomer and Skokholm and none reaching Grassholm.

The timing of the spill was, in many respects, fortunate. Several important bird populations, including Manx shearwaters and puffins, had not yet returned to the region for breeding. Relatively few fish were in the area, several species being still out to sea for the winter, and feeding activity was at a seasonal low. Had the spill occurred later in the year, for example during the seal pupping season, the overall impact may have been quite different.

11.2.2 Amenity

The amenity value of south-west Wales – particularly the beaches – was directly affected by the oil, but the effects were temporary and amenity, in the main, had returned to normal within a few weeks. In some cases, however, perceptions of the impact on amenity remained for longer and this probably contributed to the decrease in sales of fishing licences and a reduction in the number of visitors staying in hotels.

11.2.3 Bird cleaning and rehabilitation

More than 3,000 oiled birds were collected from beaches and taken for cleaning. A review of this process concluded that the operation had generally been well-managed, but suggested improvements for future operations. A detailed analysis of data on the survival of guillemots from previous oil cleanings showed, however, that when these birds are released after cleaning, almost all of them die very rapidly. This calls into question whether it is, from a bird welfare viewpoint, better to clean these birds or whether it might be kinder to kill them humanely to relieve their suffering. More information is needed on the amount of stress guillemots and other bird species undergo during cleaning and what factors determine more successful rehabilitation of cleaned birds into the wild.

11.2.4 Fate of the oil

An important issue to resolve was the long-term fate of the 72,000 tonnes of crude oil and 480 tonnes of heavy crude oil. About 40% evaporated soon after being spilled. This will have rapidly become very dilute in the atmosphere and then, over the course of subsequent days and weeks, will have been broken down by sunlight or deposited in extremely low concentrations over a very wide area. Around 52% of the oil dispersed into the water where almost all of it will eventually have been broken down by micro-organisms. Surveys at sea have suggested that this oil has not been deposited in sediments in significant quantities.

About 1-2% of the oil was collected from the sea surface and taken to a refinery and between 5% and 7% stranded on the shore. A year after the spill, well under 1% remained on the shore, with the rest either disposed of following the extensive clean-up operation, biodegraded or washed back into the sea where it dispersed or accumulated in sediments near the shore. It is clear from this analysis that only a very small proportion of the spilled oil remained in a form that could cause any longer term environmental problems.

11.2.5 The clean-up operation

Overall, the clean-up operation was well-managed, planned and executed. The marine response measures - particularly dispersant spraying operation - almost certainly considerably reduced the gross level of shoreline oiling and the inevitable environmental impacts of the spill were generally not made worse by the use of inappropriate or intrusive clean-up techniques. In the main, the techniques employed were successful in meeting the agreed priorities for shoreline clean-up - such as cleaning the main tourist beaches to a sufficient degree to allow their use by tourists at Easter just nine weeks after the spill. A number of improvements are suggested, which are contained in the recommendations which follow.

The application of dispersants at sea was monitored from boats during the operation and this provided useful information to assist those carrying out the response, as well as leading to a greater understanding of the fate of the oil.

11.2.6 The assessment programme

SEEEC commissioned a wide-ranging programme of studies, and although many of these showed no evidence of an impact related to the oil, it was nevertheless important that those studies were carried out. The studies were carefully chosen, and it is unlikely that additional ones would have revealed any further major environmental impacts.

Many of the studies benefited from the large amount of baseline data available on some species and sites within the region, but a number of gaps in the knowledge became apparent, regarding both the natural variability of some species within the area, and the mechanisms behind some of the observed phenomena (such as the mass strandings of some bivalves and the vulnerability of species such as amphipods). Impact assessments were also hindered in some cases by a lack of basic knowledge on some species, including, for example, the normal food of common scoters. One important body of information which was only partially available was the level of exposure to oil - including the amount of oil, the type and the time it remained - at the areas of shoreline studied. Detailed knowledge of this would have been of great help in making a full analysis of shoreline effects. It would also have been beneficial if several key studies could have started immediately following the spill. These observations relate to recommendations made with respect to impact assessment contingency planning which follow.

Some new techniques were developed during the assessment programme, including monitoring techniques for rock pools and the fauna of seaweed holdfasts, and a methodology for assessing the level of aesthetic impact of shoreline oiling. These may be of use at future spills.

11.3 RECOMMENDATIONS

SEEEC's recommendations fall into two broad categories:

- Those which are more specifically related to the *Sea Empress* spill and the area of south-west Wales where environmental impacts occurred. These mostly involve continued monitoring in circumstances where the full effects of the spill cannot yet be assessed.
- Those of national significance derived from the *Sea Empress* experience, which propose research and actions to improve response and assessment procedures wherever another major spill should occur in the UK.

Some of the recommendations relate to specific government agencies or other organisations. Where this is the case, the organisation is named at the end of the paragraph.

11.4 RECOMMENDATIONS OF LOCAL RELEVANCE

Our recommendations exclude the existing monitoring programmes, supported by the agencies and some voluntary bodies, which provide important baseline data for some wildlife species, particularly mammals and birds, which are of crucial value when a spill or other damaging event occurs. Additionally, agencies have already agreed to commission certain special projects - such as the monitoring of salt marsh vegetation (CCW), and of salmon and sea trout stocks (EA). These initiatives are important but are already in progress.

Proposals are made in the Marine Impacts chapter (§3.11) for the continuation of monitoring programmes for several commercial species of fish and shellfish - particularly of the herring population within Milford Haven waterway, and of edible crabs, lobsters, whelks and sea bass over a wider area - for it is still uncertain whether the 1996 (and possibly 1997) year class has been reduced by the spill. Whilst primarily of local relevance, the results could be of wider significance in relation to our understanding of the effects of oil spills on fisheries, given the quality of the baseline data available for some of these populations. There is also merit in continuing to survey the benthic populations of invertebrates in heavily impacted areas where mortalities of amphipods occurred. Decisions will no doubt need to be made by MAFF and others concerning the respective priorities of these monitoring programmes when funding is considered. (MAFF)

Similarly, several shoreline impacts were identified, but here the pattern of recovery seems to be under way and on a path described earlier for other oil spills. Nevertheless, some species - such as the cushion star *Asterina phylactica* - are of particular conservation importance and are still vulnerable; some priority needs to be afforded to the continued observation of these species. (CCW)

With respect to birds, because of the importance of the area for both over-wintering and breeding, baseline data are already extensive. Nevertheless, the availability of data needs to be reviewed and, with respect to the common scoter in particular, some further ongoing studies are advisable in view of the international importance of the over-wintering population in Carmarthen Bay. (CCW)

11.5 RECOMMENDATIONS OF NATIONAL RELEVANCE

11.5.1 Research

There were several effects seen following the *Sea Empress* spill which, although reported at previous spills, remain unexplained and require further investigation. Amongst these were the vulnerability of amphipods to oil pollution and the behaviour of several bivalve species, such as razor shells, in moving out of the sediments. As these animals are important in marine food chains and are therefore of ecological significance, it would be of interest to gain a better understanding of the exact cause of the observed effects and the reasons for the apparent sensitivity of certain marine species to low levels of oil, although devising appropriate experimental methodologies may prove challenging. (NERC)

There were also suggestions that certain intertidal and subtidal communities - in particular animal species in oarweed (*Laminaria*) holdfasts and algal turfs in rockpools - might prove useful for monitoring effects of oil. These deserve further consideration, as does the exploration of the opportunity of predictive modelling of pre-spill communities from the physical attributes of their environment, for many areas where spills might occur will not have pre-spill descriptions comparable with those of south-west Wales. This type of model has proved a valuable tool in measuring pollution stress in rivers by comparing communities exposed to pollution with those communities expected at these same sites without pollution. (EA, Countryside Agencies)

11.5.2 Bird cleaning and rehabilitation

Studies which SEEEC commissioned following the *Sea Empress* spill called into question its animal welfare value of oiled bird cleaning and rehabilitation - particularly for those species with high mortalities during cleaning or soon after release into the wild. In future oiling incidents, we propose further work to assess stress factors during cleaning and the development of better diagnostic tools for an early evaluation of the chance of survival of individual birds so that a more informed judgement can be made about whether such cleaning is continued. The factors related to successful cleaning and rehabilitation need to be investigated further to optimise prognosis and cleaning arrangements.

The study also concluded that there was a need for a wide-ranging national review of arrangements currently in place with particular respect to:

- planning and management
- cleaning procedures
- availability and training of staff and volunteers.

Although the RSPCA is a charity and not a statutory body and can therefore determine its own policy in this matter, SEEEC believes that such a review, initiated by the RSPCA, would be valuable and timely and would bring about a significant improvement in current arrangements. Furthermore (with its equivalent bodies in Scotland and Northern Ireland) it is the only organisation with the resources, skills, organisation and widespread support to carry it out. (RSPCA)

11.5.3 Closure orders for fisheries

Closure orders (ie Exclusion Orders issued under the Food and Environmental Protection Act 1985) prohibit fishing for named species in defined areas and are issued by specific government departments. Following the issue of such orders after the *Sea Empress* oil spill and also the subsequent lifting of these restrictions, there was widespread confusion both in the fishing community and amongst the general public about the basis of these orders. Although issued as precautionary measures to protect consumers from eating potentially contaminated fish and shellfish, they were sometimes interpreted as evidence - or likelihood - of damage to the actual stocks. In future the causation of such orders should be made clearer both when they are issued and when they are lifted. (WO,MAFF)

11.5.4 Clean-up assessment

Despite the considerable success of the clean-up procedures both at sea and on shore, we have several recommendations which, if followed, should lead to improvements. These are discussed fully in the Clean-up Operation chapter, §10.10, and include:

- the clearer definition of tasks allocated to specific managers within the response organisation;
- the need for the Overall Commander to be at the scene of a major incident to act as authoritative spokesman for the MPCU and Coastguard Agency;
- the need to rename the Joint Response Centre (JRC) to make clear its role solely in shoreline clean-up;
- preference for the appointment of a local authority chief officer to chair the JRC and the likely consequential improvement in administrative support and staffing levels;
- improved documentation and record keeping to assist the prompt preparation and payment of claims for compensation;
- the need to establish clear criteria for terminating shoreline clean-up at individual sites, recognising that natural clean-up processes also occur;
- the need to charge local authorities with the statutory obligation to prepare local contingency plans and to carry out shoreline clean-up provided adequate resources are made available. In this incident local plans had been prepared and their importance was demonstrated. Lord Donaldson's inquiry recommended that local authorities should have such a statutory duty although the Merchant Shipping and Maritime Security Act 1997 only provides enabling powers rather than a statutory duty to adopt this role.
- the importance of adherence to Health and Safety requirements for the clean-up workforce and of close attention to planning duty rosters to ensure that staff are not unduly stressed through working excessive hours;
- better provision of actual and predictive information on oil distributions, particularly where there are extensive shoreline impacts. Greater use should be made of IT facilities for preparing and archiving aerial surveillance maps with validation using standard reporting procedures. These standard procedures were not used in relation to the *Sea Empress* spill and it became clear that whilst their use might have been beneficial to the clean-up operation, their further development might also provide information useful in the assessment of ecological impacts.
- the need to respond to the media in a more positive and co-ordinated manner;
- the importance of developing emergency procedures and arrangements for the disposal of oily wastes at both national and local level. The current licensing arrangements applying to emergencies are unsatisfactory and need to be resolved urgently (within one year), initially through discussions between EA, MPCU and local authority associations.

Some of the above recommendations are matters which apply principally to the Coastguard Agency and, more specifically, to MPCU: these matters are already being considered by that agency in its current review of the national contingency plan. (MPCU)

It is for government to consider the need to charge local authorities with the statutory obligation to prepare local contingency plans and carry out shoreline clean-up (DETR).

11.5.5 Future arrangements for impact assessment

Although there are contingency plans at a national and local level for responding to oil spills, with the response action dependent on the scale of the spill and its overall impact, there are no comparable response plans for assessing environmental impacts. In consequence, during the early days after a spill, when the collection of environmental information is crucially important, reliance is placed on *ad hoc* arrangements. The ESGOSS Report (the equivalent to SEEEC's report following the *Braer* oil spill in Shetland), proposed that a liaison group be established as soon as possible at all spills posing a significant threat to the environment. In the case of the *Sea Empress* spill there were special factors which reduced the problem, not least the availability of local experts to gather information immediately after the spill took place and rapid action by particular agencies. Nevertheless, there were several examples of early uncoordinated responses. After a few weeks an Interim Technical Co-ordinating Group met to assess the monitoring activities of the main organisations and to ensure overlaps and gaps were minimised, and about six weeks after the spill SEEEC was established to carry these objectives forward. This was a commendably short period, but during those early weeks a more structured, co-ordinated approach, adopting clearly defined procedures and sampling and analytical protocols, and providing an assured funding base for its programme, would have proved highly beneficial.

It is recommended that emergency response plans are prepared at national level so that, whenever a serious spill occurs, an environmental Impact Assessment Group (IAG) is established to carry out the necessary monitoring and environmental measurements. The main objectives of the IAG would be to determine:

- concentrations of oil in the environment, particularly in sensitive species and habitats,
- and compare these with baseline data;
- the fate of oil over time;
- environmental effects (both short term and long term) of the spill and of clean-up responses, and to describe rates of recovery.

This group, although working closely with the JRC and co-operating over aspects of data collection and interpretation, must have clearly defined and separate objectives. Examples of where collaboration would seem sensible are:

- describing the type, position, extent and state of oil at sea and onshore;
- predicting the future track of oil slicks and areas of shoreline likely to become polluted;
- predicting the effects of anti-pollution measures on the fate of the oil at sea and onshore.

The IAG will need to focus on both the short term needs and longer term assessments. It would not normally be necessary to set up a special SEEEC-type structure. It is envisaged that a similar arrangement to the IAG would be established following incidents involving chemical pollution at sea and that this will be considered during the planning process.

In establishing priorities it will be necessary for the IAG to co-operate with the public health and food safety authorities as there is considerable overlap in the data needed (eg concentrations of contaminants in commercial fish species). The IAG should not, however, become involved with providing advice on public health matters.

It will also be necessary to review the availability of baseline environmental data for the UK shores and coastal areas and put in place suitable archiving arrangements. Standard sampling and analytical methods will also need adoption and validation. The desirability of establishing further monitoring systems should also be reviewed.

Concerning the responsibility for setting up and maintaining the IAG, the existing statutory duties (including emergency procedures in relation to pollution incidents) of the Environment Agency (and the Scottish Environment Protection Agency), together with its network of offices, scientific staff and facilities, makes it the preferred organisation for being charged with providing the lead in establishing the IAG and organising the environmental response to a major incident. However, other options for a lead agency should be explored. We envisage that other members of the IAG should include statutory countryside agencies, local authorities, and government departments with appropriate territorial and functional responsibilities.

The IAG has been described here as being a national entity but it is envisaged that within an overall national framework, with standard plans and procedures, local arrangements would be put in place with trained staff available in coastal regions. Membership of the group for any specified incident would be in part dependent on the environmental resources affected. It is expected that NGOs would participate as organisations carrying out specific tasks on impact assessment.

It is the committee's view that the costs of environmental impact assessments of the type undertaken by SEEEC (and proposed for the IAG) should be met by those responsible for the spill, or by those bodies which are required to pay compensation. However, we appreciate that such costs are currently only considered an admissible claim by the International Oil Spill Pollution Compensation (IOPC) Fund to the extent that the studies relate to damage that would fall within the definition of "pollution damage" in the relevant international conventions. These conventions were established to ensure that those who undertake reasonable clean-up measures or who suffer economic losses as a result of a spill of crude oil or heavy fuel oil from a tanker receive prompt and adequate compensation. The committee has no desire to see this primary objective impaired but it believes that further consideration should be given by the IOPC Fund to the possibility of funding properly designed and co-ordinated environmental impact assessments following major tanker spills that are in proportion to the severity of the pollution and predictable effects, and that take into account existing scientific knowledge.

Appendix

APPENDIX A
THE COMMITTEE

Chairman:
Professor Ron Edwards, CBE

Members:
Mr David Bedborough
Marine Pollution Control Unit

Mr Roy Bunce*
Department of Environment

Dr Alan Elliott
University of Wales, Bangor

Mr Arthur Hacking
ADAS (now retired)

Dr Charlie Pattinson
Environment Agency

Dr John Portmann
MAFF Directorate of Fisheries Research (now retired)

Dr Havard Prosser
Welsh Office

Mr David Seal
Pembrokeshire County Council

Dr Malcolm Smith
Countryside Council for Wales

Mr Nic Wheeler
Pembrokeshire Coast National Park Authority

Dr Ian White, OBE
International Tanker Owners Pollution Federation

Invited to meetings:
Mr Bob Macey
Welsh Office

Secretariat:
Dr Tim Kirby
Secretary to SEEEC

Miss Helen Jenkins
Assistant Secretary (August-December 1997)

Miss Sarah Norton
Assistant Secretary (up to August 1997)

***Roy Bunce** retired from the committee and was replaced by **Mr Mark Bendon**, DETR

Members of the Committee at Manorbier following a committee meeting, July 1996 (M Cavaney)

APPENDIX B

TASK GROUP 1: MARINE

Chairman:
Dr John Portmann

Secretary:
Mr Andrew Franklin
Centre for Environment, Fisheries and Aquaculture Science

Members:

Mr Blaise Bullimore
Countryside Council for Wales

Mr Phil Coates
South Wales Sea Fisheries Committee

Mrs Joan Edwards
The Wildlife Trusts

Mr Ceri Evans
Welsh Salmon and Trout Angling Association

Mr Robin Law
Centre for Environment, Fisheries and Aquaculture Science

Mr Paul Leonard
Ministry of Agriculture, Fisheries and Food

Dr Jon Moore
OPRU

Dr Charlie Pattinson
Environment Agency

Dr Havard Prosser
Welsh Office

Dr Mike Roberts
Department of the Environment, Transport and the Regions

Dr Ian White, OBE
International Tanker Owners Pollution Federation

Mr Mark Williams
Environment Agency

TASK GROUP 2: SHORELINE AND TERRESTRIAL

Chairman:
Dr Malcolm Smith
Countryside Council for Wales

Secretary:
Dr Mandy Richards
Countryside Council for Wales

Members:

Mr Mark Bendon
Department of Environment, Transport and the Regions

Dr Robin Crump
Field Studies Council

Miss Jennifer Dack
Countryside Council for Wales

Mr Jack Donovan
Wildlife Trust West Wales

Mr Steven Evans
Countryside Council for Wales

Mr Arthur Hacking

Mr Bob Haycock
Countryside Council for Wales

Miss Jane Hodges
Pembrokeshire Coast National Park Authority

Mr Roger Milne
Environment Agency

Dr Jon Moore
OPRU

Dr Norman Ratcliffe/Dr Ken Norris
Royal Society for the Protection of Birds

Dr Siân Pullen
World Wide Fund for Nature - UK

Mr David Seal
Pembrokeshire County Council

Mr Tim Thomas, MBE
Royal Society for the Prevention of Cruelty to Animals

Mr Steve Webb
Wales Tourist Board

Mr Nic Wheeler
Pembrokeshire Coast National Park Authority

Mr Mark Williams
Environment Agency

TASK GROUP 3:
POLLUTANT BEHAVIOUR

Chairman:
Dr Charlie Pattinson
Environment Agency

Secretary:
Mr Colin Strange
Environment Agency

Members:
Mr David Bedborough
Marine Pollution Control Unit

Miss Jennifer Dack
Countryside Council for Wales

Dr Alan Elliott
University of Wales, Bangor

Dr Rod Jones
Countryside Council for Wales

Dr David Little
Arthur D Little Ltd

Dr Tim Lunel
AEA NETCEN

Dr John Portmann

Dr Havard Prosser
Welsh Office

Dr Mike Roberts
Department of the Environment

Dr Richard Saull
Environment Agency

Dr Ian White, OBE
International Tanker Owners Pollution Federation

APPENDIX C

PROJECTS COMMISSIONED ON BEHALF OF SEEEC

The following projects were commissioned on behalf of SEEEC. In addition, the EA holds monitoring data on water quality and sediment hydrocarbon concentrations, and CEFAS has data on hydrocarbon levels in biota.
(Details on how to access project reports is given after the table.)

Project title	Work carried out by	Contracting organisation	SEEEC number
FATE OF OIL (Chapter 2)			
Benchmarking of the existing hydrocarbon data for the area affected by the *Sea Empress*	AD Little Ltd	EA	P4
Hydrocarbon data review and quality control	AD Little Ltd	EA	P5
Refinement of the estimated shoreline figure in the oil budget	AEA Technology/ AD Little Ltd	EA	P6
Hydrocarbons in the surface microlayer	Milford Haven	EA	P7
Sediment transport paths outside Milford Haven, in relation to long-term transport of *Sea Empress* oil	AD Little Ltd	EA	P8
Modelling the vapour cloud	CERC Ltd	EA	P9

Project title	Work carried out by	Contracting organisation	SEEEC number
MARINE IMPACTS (Chapter 3)			
Fish (excluding salmonids)			
Impact on the recruitment of bass in south-west England and Wales	University of Wales, Swansea/ CEFAS	MAFF	M1
Impact on herring stocks in Milford Haven	University of Wales, Swansea	MAFF	M2
Effect of oil on sandeel distribution and on bait-fish: the significance for predators	SWSFC	SWSFC	M3
Genetic and potentially carcinogenic damage in marine species produced by oil exposure	University of Wales, Swansea	MAFF/DETR	M6
Studies of DNA adduct formation	University of Wales, Swansea	MAFF/DETR	M7
Salmonids (Salmon and Sea Trout)			
Impact on the commercial and the recreational migratory salmonid fisheries in west Wales	EA	EA	M8
Impact on the amenity value of the migratory salmonid fishery	Marketing Focus Ltd	EA	M9
Accumulation and toxicity of oil by salmonids entering the sea as smolts during the spill aftermath	EA	EA	M10
Salmon - juveniles	EA	EA	M10B
Influence of crude oil and dispersants on salmonid migratory behaviour	CEFAS	MAFF	M11
Shellfish			
Analysis of lobster and crab fisheries and stock biometrics	SWSFC	SWSFC	M12
Effect of oil in whelk fishery in Carmarthen Bay	University of Wales, Swansea	MAFF	M13
Plankton			
Monitoring of phytoplankton within Milford Haven	EA	EA	M14
Impact on phytoplankton and zooplankton populations	Sir Alister Hardy Foundation	EA	M15
Subtidal sediment			
Macrobenthic survey of Milford Haven waterway	OPRU	EA / WO	M16
Subtidal benthic survey of Milford Haven, Carmarthen Bay and surrounding area	OPRU	EA / WO	M17
Sub-tidal rock			
Assessment of epi-benthic communities and species	Marine Seen and SubSea Survey	CCW	M20
Mid-channel rocks - establishment of permanent monitoring site	Marine Seen and SubSea Survey	CCW	M21

Project title	Work carried out by	Contracting organisation	SEEEC number
General			
Skomer Marine Nature Reserve - assessment of fauna of sub-tidal sediments	SubSea Survey	CCW	M23
Skomer Marine Nature Reserve - analysis of field data	Sue Gilbert	CCW	M23
SHORELINE IMPACTS (Chapter 4)			
Intertidal rocky shore studies			
Established rocky shore transects - Skomer	Field Studies Council – Orielton	CCW	ST1
Established rocky shore transects - Milford Haven	OPRU	CCW	ST2
Established rocky shore transects - Dale	Field Studies Council - Dale Fort	CCW	ST3
Established rocky shore transects - West Angle and Manorbier	Field Studies Council - Orielton	CCW	ST4
Assessment of heavily oiled rocky shores - biotope mapping	Marine Seen	CCW	ST5
Rock pool community monitoring	SubSea Survey	CCW	ST6
Impact on crustose coralline algae	Culverhouse Partners	CCW	ST7
Impact on *Laminaria spp* holdfast fauna	Plymouth Marine Laboratory	PML/ CCW	ST8
Paludinella littorina - impact monitoring	Malacological Services	CCW	ST9
Pembrokeshire Marine Species Atlas	SubSea Survey and exeGesIS	CCW	ST10
Monitoring of lichen quadrats - West Angle	Field Studies CounciL - Orielton	FSC	ST11
Monitoring of lichen quadrats - Sawdern Point	Field Studies Council - Orielton	FSC	ST12
Recruitment and reproductive potential of *Asterina phylactica*	Field Studies Council - Orielton	FSC	ST13
Rock pool fauna of West Angle Bay and Manorbier	Field Studies Council - Orielton	FSC	ST14
Limpet recruitment and age structure	Field Studies Council - Orielton	FSC	ST15
Impact on sensitive sessile communities	University of Swansea	CCW	ST16
Autecological studies of sensitive invertebrates - *Monodonta lineata*	Annette Little	CCW	ST17
Intertidal sediment shore studies			
Macrofauna of sediment shores - Milford Haven, Carmarthen Bay and bird feeding areas	SubSea Survey	CCW	ST18
Impact assessment of eelgrass *Zostera sp*	Pembrokeshire Coast National Park Authority	PCNPA	ST19
Strandline Fauna	University of Swansea	CCW	ST20
Impacts on Meiofauna	Heriot-Watt University	CCW	ST21

Project title	Work carried out by	Contracting organisation	SEEEC number
Combined intertidal, rocky and sediment shore studies			
Environmental impacts resulting from the clean-up	Annette Little	CCW	ST22
Summary of initial field observations	University of Swansea	WWF-UK/ The Wildlife Trusts	ST23
Role of benthic/sub-aerial algae	Dr. Elliot Shubert	CCW	ST24
MARITIME VEGETATION AND AGRICULTURE (Chapter 5)			
Terrestrial vegetation sampling and analysis	ADAS / SOAFED	WOAD / CCW	ST25
Terrestrial lichen impact monitoring - Skomer	Natural History Museum	CCW	ST26
Terrestrial lichen impact monitoring - Stackpole	National Museum of Wales	CCW	ST27
Terrestrial lichen impact monitoring - *Teloschistes flavicans*	Natural History Museum	CCW	ST28
Rare, maritime, higher plant monitoring	Countryside Council for Wales	CCW	ST29
Damage assessment survey of saltmarsh	Institute of Terrestrial Ecology	CCW	ST30
MAMMALS (Chapter 6)			
Greater horseshoe bat survey	Tom McOwat	CCW	ST31
Marine mammals - strandings records	Marine Environmental Monitoring	CCW	ST32
Marine mammals - live sightings database	Wildlife Trust West Wales	CCW	ST33
Grey seal pup production and monitoring studies	RSPB and Wildlife Trust	CCW	ST34
BIRDS (Chapter 7)			
Tagged birds - release and tracking	Channel Seabirds Research Group	CCW	ST35
Scoter - Bi-monthly counts (land-based and aerial)	Wildfowl and Wetlands Trust and RSPB	CCW	ST36
Scoter - repeat breeding survey	Wildfowl and Wetlands Trust	CCW	ST37
Scoter - biometrics and gut content analysis	Wildfowl and Wetlands Trust	CCW	ST38
Razorbill - survival monitoring	University of Sheffield	CCW	ST39
Cormorant - impact on breeding colonies	Wildfowl and Wetlands Trust	CCW	ST40
Seabirds - survey of breeding colonies, south west Wales	Wildlife Trust West Wales	CCW	ST41
Seabirds - analysis of blood samples	University of Glasgow	CCW	ST42
Seabirds - biometrics and gut content analysis	National Museums of Scotland	CCW	ST43
Gannets - oil contamination of nesting material	RSPB, CSRG, Greenpeace	Greenpeace/ CCW	ST44

Project title	Work carried out by	Contracting organisation	SEEEC number
Waders and waterfowl - counts of wintering flocks	British Trust for Ornithology	CCW	ST45
Kittiwakes - impact on birds on Skomer	University of Durham	WTWW	ST46
Analysis of egg samples	Institute of Terrestrial Ecology	CCW	ST47
OILED BIRD CLEANING AND REHABILITATION (Chapter 8)			
Guillemots - survival rates of rehabilitated birds	British Trust for Ornithology	CCW	ST48
Review of bird rehabilitation techniques and procedures	University of Newcastle	CCW	ST49
AMENITY AND ARCHAEOLOGY (Chapter 9)			
Amenity and public enjoyment assessment	Beaufort Research Ltd	CCW	ST50
Assessment of impact of oil on selected archaeological features	Dyfed Archaeological Trust	CCW	ST51
Aesthetic impact - review and refinement of criteria for oil pollution	Dr. Edward Bent	EA	ST52
Aesthetic impact - survey of impacted shorelines	Dr. Edward Bent	EA	ST53
CLEAN-UP (Chapter 10)			
A review of the effectiveness of the clean-up operation	Maritech Ltd	WO	P1
Evaluation of bioremediation techniques	AEA Technology	EA	P3
The fate of oil on cleaned and uncleaned beaches following the *Sea Empress* incident	AEA Technology/ AD Little/ OPRU	EA	P2
Review of aerial/satelite images and optimisation of procedures and interpretation	AEA Technology	EA	P10
Assessment of environmental impact of clean-up activities	Annette Little	CCW	ST54

ACCESS TO PROJECT REPORTS

A full set of reports will eventually be housed at the following libraries accessible to the public:

County Library, Haverfordwest, Pembrokeshire

Environment Agency, St Mellons, Cardiff

Countryside Council for Wales, Bangor

National Library of Wales, Aberystwyth

British Library, London

The reports commissioned by CCW will also be held in CCW offices in Mold, Aberystwyth and Cardiff, the Welsh Office library in Cardiff, the Scottish National Library in Edinburgh and the Joint Nature Conservancy Council library in Peterborough. It may be necessary to arrange in advance visits to some of these libraries.

Individual reports may be requested from the agencies which commissioned the work. There may be a charge to cover the cost of photocopying. Reports commissioned by MAFF should be requested from the organisation carrying out the work, *ie* the University of Wales Swansea or CEFAS.

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