THE SEA EMPRESS OIL SPILL: ENVIRONMENTAL IMPACT AND RECOVERY

Prof. Ron Edwards
Chairman Sea Empress Environmental Evaluation Committee
8 Maesmawr Close, Talybont-on-Usk, Brecon Powys LD3 7JG. U.K.

Dr. Ian White
Managing Director
The International Tanker Owners
Pollution Federation Limited
Staple Hall, Stonehouse Court, 87-90 Houndsditch, London EC3A 7AX U.K.

ABSTRACT

72.000 tonnes of light crude oil were released from the Sea Empress at the entrance to Milford Haven, South Wales over a 7 day period in February 1996, in an area of exceptional environmental value for wildlife, tourism and natural beauty. Natural factors (time of year, wind direction) coupled with effective clean-up at sea (through chemical dispersion) and on shore, minimised environmental impact. Nevertheless, there were adverse effects on fisheries, wildlife – particularly overwintering birds, tourism and amenity. (Human health studies have not been completed). Recovery, although not complete, has been encouraging although some wildlife populations remain depleted and further monitoring is needed, including of fish stocks.

The U.K. Government has responded to recommendations by the Sea Empress Environmental Evaluation Committee (SEEEC), agreeing to continued monitoring and research, as well as reviews of aspects of operational response and clean-up and to the need for national and local contingency plans for impact assessment.

INTRODUCTION

When the Sea Empress went aground within a kilometre of the shore at the entrance to Milford Haven in South West Wales (Figure 1) on 15 February 1996, and particularly after a week of attempted salvage during which about 72,000 tonnes of crude oil were released, a prognosis of the severest environmental damage was widely accepted. For this was an area of unrivalled coastal and marine resources in the U.K., the location of its only Coastal National Park, with 35 designated Sites of Special Scientific Interest, two National Nature Reserves and one of only three U.K. marine Nature Reserves: sites within the area had also received special European status, particularly to conserve rare and vulnerable bird species. Furthermore the area had an important tourist industry, principally dependent on its natural beauty, wildlife, and clean beaches.

To reinforce the drama of an impending disaster, TV and press cameras had a cliff platform adjacent to the drifting vessel during the prolonged period of oil loss.

Now, three years later, we are able to analyse the extent of the initial environmental damage and subsequent recovery as a result of numerous and detailed investigations, and to identify organisational changes which should reduce such damage and provide a sounder basis for damage assessment in the future. These aspects are described in the Report of the Sea Empress Environmental Evaluation Committee (Sea Empress Environmental Evaluation Committee Final Report, 1998) and the Proceedings of the Sea Empress Oil Spill Conference (Edwards, R, and Sime, H, in press). The former, primarily for the U.K. Government, has received a response broadly accepting the report's recommendations. Independent investigations and reviews on other aspects of the spill, particularly operational responses and salvage are in progress.

MAJOR FACTORS REDUCING IMPACTS

Environmental impacts of the spill were far less severe than was initially anticipated principally because:

(1) the spill occurred in February at a time of low environmental use and vulnerability: tourists were few, several species of sea-birds had not returned to the area to nest, many marine fish species were either inactive or had migrated to off-shore waters for the winter, and salmon and sea-trout were not in shallow coastal waters or migrating through the estuaries of the area.
(2) Winds were blowing from the northerly quadrant for most of the period of the spill and when most oil was released (63,000 tonnes: 87%) so carrying it away from the coast: such northerly winds are unusual in this area, particularly in February, occurring on average, only 15% of the time. Only during the first phase of the spill, when 9.000 tonnes were lost, was oil driven on shore and, again a week after the recovery of the vessel, when the wind direction changed and residual oil was driven along the South Wales coast and into Carmarthen Bay with its tourist beaches and concentrations of overwintering sea-birds (particularly the Common scoter).
(3) about 40% of the light crude oil from the Forties field evaporated and was blown away from the shore. The maximum recorded atmospheric concentration of on-shore hydrocarbons, 4 km from the spill area, was 9 p.p.m.: this compares with 50 p.p.m. at which some protective action is advised for outdoor workers.
(4) although mechanical recovery of oil at sea was hampered by high winds (>15 knots) during much of the recovery period and removed only 1 - 2% of the oil, the application of chemical dispersants by air was very successful and, in addition to natural dispersion (28%), resulted in at least a further 17,000 tonnes (24%) of the oil being chemically dispersed.
(5) in consequence of evaporation and natural and chemically induced dispersion at sea, only 3,700 – 5,300 tonnes of oil (5 – 7%) reached the shore – although this extended over a 200 km length and was transformed into 11,000 – 16,000 tonnes of emulsion. An effective clean-up operation, giving priority to amenity beaches and the general removal of bulk oil from accessible shores, initially involved about 1,000 workers. Within six weeks amenity beaches were visibly clean and available for tourist use, and it is estimated that by this time only about 500 tonnes of oil remained on shorelines. Some clean-up operations were however continued for 18 months, in part to provide a rapid response when localised pockets of oil were exposed on beaches or released from off-shore sediments during storms.

ENVIRONMENTAL IMPACTS

The favourable natural factors and effectiveness of the clean-up operations greatly reduced the impact of the spill on the environmental and economic resources of the area. The following is a brief overview of the findings of the numerous post-spill studies and monitoring programmes, some of which are still on-going.

(a) HUMAN HEALTH

The health study by the Health Authority has not been completed although a preliminary report was published soon after the spill suggesting some possible short-term adverse conditions within the local communities including nausea, headaches and skin irritations: dermatological problems also occurred in beach-workers not wearing adequate protective clothing (Lyons. R. et al, 1996). Effects were minimised by the seaward dispersal of volatile hydrocarbons. Plant crops and animal products from coastal farms were declared safe for human consumption soon after the spill following hydrocarbon analysis.

(b) TOURISM

The tourist industry is important to the area, contributing about £160 million per year (about 20% of GDP), and there was considerable anxiety about the anticipated damage caused by the spill and the associated high media exposure. However, in large part due to the success and speed of the clean-up operation and the 'loyalty' of those visiting the area, the impact in 1996 was modest. No reliable data are available for 1997 or 1998 to assess whether recovery is yet complete (pers. comm: Wales Tourist Board).

(c) COMMERCIAL FISHERIES

The area, under the local control of the South Wales Sea Fisheries Committee, has a wide variety of commercially exploited species of fin–fish, crustaceans and molluscs. Although the fisheries are small when compared with total U.K. landings, they are important to the local economy and several

species are exported to mainland Europe and the Far East.

Soon after the spill, concentrations of hydrocarbons in seawater were elevated above background over a substantial area, although in the eastern part of the Bristol Channel contamination from sources other than the Sea Empress were involved. Levels were also particularly elevated in molluscs, but less so in crustaceans and some fin–fish. A closure order, preventing both commercial and recreational fishing (and the collection of edible sea-weeds), was issued over the affected area after the initial spill and was followed by a further order relating to the catching of salmon and sea trout in the rivers within the zone. These orders covered an area of 2,100 km^2 (Figure 1) and replaced an earlier voluntary suspension of fishing by the local fishermen. The orders were precautionary and did not imply damage to stocks but were served to protect the reputation of the local fishing industry and to prevent the sales of fish which could potentially be unpalatable or unsafe to eat.

The orders, kept under review through sea-water and tissue analysis, and by the use of a trained taste panel, were lifted progressively, starting with all fin–fish (including salmon and sea-trout) within about 3 months of the spill and followed by crustaceans and some molluscs (cockles and whelks) within eight months. Concentrations of hydrocarbons in mussels persisted for a much longer period and, although not exploited commercially, a ban remained in the most contaminated area until September 1997. Contamination of edible inter-tidal sea-weeds was mostly on the surface rather than through tissue absorption but, because of residual traces of hydrocarbons, the ban remained until June 1997.

No mortalities of commercial fin-fish, crustaceans or molluscs, which might be attributable to the oil spill, were recorded. Furthermore there is no evidence that spawning of these species was damaged in 1996 or subsequent years, although confirmation of the successful spawning and recruitment of some species must remain uncertain until juveniles reach commercially exploitable size (i.e. for lobsters, the year 2000). With respect to sea-bass, the single most important marine fish in the affected area, spawning was poor in 1996 and the 0-group fish resulting from the spawning were mostly distributed on the south side of the Bristol Channel and away from the South Wales coast. However, it seems likely that these features were related to natural factors, particularly weather conditions during and after the spawning period rather than the oil spill. In 1997 and 1998 mild winters led to excellent recruitment of sea-bass and high commercial catches are expected, beginning in 2001.

There is no evidence from the analysis of catch statistics that salmon were affected by the spill although catches of sea-trout (expressed as catch per unit effort) in the major river of the affected coastline, the Tywi, were low in 1996, particularly during the early part of the summer, when compared with neighbouring coastal rivers. Further time-series data are required to confirm the significance of this low catch. However, there was a reduction on the number of fishing licences and angler visits to the area during 1996 with a consequent decline in income. The effects were seemingly temporary with a recovery of angling activity in 1997 to that expected. No effects on fish stocks, through surveys of fry and parr densities, can be attributed to the oil spill but the spill reinforces the need for more effective census data of migrating adults by the installation of acoustic counters.

Landings of the most important crustaceans (edible and spider crabs, lobsters), expressed in both tonnes and as catch per unit effort, are shown in Figure 2. Whilst total landings of these species decreased in 1996 as a consequence of closure orders restricting the season, catches per unit effort showed no consistent decline and, in 1997, they were the highest they had been for lobster and spider crabs since records began in 1976. It seems that restricted fishing in 1996 due to the closure orders facilitated further growth, a factor which contributed to the total landings (tonnes) in 1997, being 60% higher than in previous years.

The market for whelks, exported mostly to the Far East, is volatile and the fishery has expanded and been over-exploited in recent years making interpretation of catch data difficult. Nevertheless total catches remained

high in 1996 and 1997: in 1998 export opportunities decreased and fishing effort was greatly reduced. The total landings of cockles, despite the limited closure order in 1996, have shown no evidence of damage and, from the most important site in the area - Burry Inlet, the catches in 1997 were the highest since records began (Figure 3).

In the absence of major mortalities of fish, the possibility of sub-lethal and chronic effects was investigated using a variety of techniques.

(1) EROD levels, which can be used as an indication of the exposure of organisms to xenobiotic compounds, such as PAHs, were measured in the livers of two species of flat-fish three months after the spill. Whilst there was evidence of elevated EROD levels at some contaminated sites, many factors other than oil exposure could have contributed to the spatial pattern of EROD induction. In similar studies with sea-trout in autumn 1996, EROD activity in fish from rivers of the area was similar to that at control sites, suggesting no undue exposure to oil constituents.

(2) Crude oil components, particularly PAH, can cause changes to the immune systems of vertebrates which impair their ability to combat pathogens. Mussels from oiled sites and a reference site were tested 5 weeks after the spill and several aspects of the immune competence were severely impaired. Subsequent recovery occurred in parallel with decreasing tissue concentrations of hydrocarbons (and PAH) and about 12 weeks post-spill immune systems had generally recovered. However, several environmental factors influence immune systems and there is a strong annual cycle of activity. Furthermore, other pollutants can induce change and subsequent tests in the affected areas over a period of a year suggested that a later increase in combustion-derived inputs of high molecular-weight PAH induced an increase in tissue concentrations and changes in the immune system. Nevertheless, the lack of mortality and the recovery of immunocompetence illustrate the high resilience of mussels to pollution.

(3) It has been shown that PAH compounds can induce DNA adducts and that these adducts may give rise to genetic alterations which can result in neoplastic disease. Mussels from a reference site and with low levels of DNA adducts were transplanted to an oil exposed shore and after about 3 months levels of DNA adducts had increased substantially but further transplantation studies a year later showed no DNA adduct increase, suggesting recovery of the area from residual contamination of oil products. Studies with fish species (dab, plaice, shanny) similarly showed that high levels of DNA adducts were induced at the highly polluted sites soon after the spill but that effects did not persist into 1997 (except for the dab at a few sites where other sources of contamination unrelated to the spill may have been responsible). These studies indicated that for a few months post-spill, exposure to potentially mutagenic and carcinogenic compounds had occurred. However cellular repair mechanisms exist and it is difficult to assess the long term significance of these findings, particularly at the population level.

(4) Lug worms and amphipods were introduced to sediment collected 5 weeks after the spill from 10 sites within Milford Haven and a reference site, and their mortality assessed after 10 days. There was no evidence of enhanced mortality at Milford Haven sites although the feeding rate of lugworms at all Milford Haven sites was less than 50% of that at the reference site. Further studies need to be conducted to establish whether factors other than oil pollution of the sediments were responsible for the reduced feeding rate.

(5) ‘Scope for growth’ measurements were conducted on mussels at several sites within and beyond the fishery closure area, ‘scope for growth’ being a measure of physiological fitness in response to stress, such as PAH contamination. Results suggested impairment at some heavily polluted sites soon after the spill but recovery by October 1996. As with other physiological tests, responses are not specific to oil contamination and other environmental factors may well have contributed to the observed impairment.

(d) OTHER MARINE IMPACTS

Whilst there was no evidence of mass mortalities of commercial fin-fish or crustaceans, large numbers of dead or moribund bivalve molluscs (including cockles from a non-commercially-exploited area)., starfish and heart-urchins were washed ashore, initially in areas near the grounding and

affected by bulk oil, and later in Carmarthen Bay. Although such standings can occur naturally, the extent of the phenomenon and the high tissue concentrations of hydrocarbons in stranded animals suggests that these were associated with the oil spill. Amphipods, generally regarded as sensitive to oil pollution, also disappeared from areas of the sea-bed. An extensive diving survey of the rocky sea-bed in July 1997 recorded that at most sites the communities had recovered and were in good condition although near the grounding site, amphipods and other small crustaceans were still sparse. A further survey within the Skomer Marine Nature Reserve also showed a decline in small crustaceans where there were elevated hydrocarbon levels in sediments.

Within Milford Haven waterway benthic samples were taken at 36 sites in October 1996 to compare with a similar pre-spill survey in October 1993. Further samples at fewer sites were taken in March-April 1996 and 1997. Despite elevated concentrations of hydrocarbons in sediments after the spill the biological effects were seemingly limited to an absence of amphipods at many sites in the lower reaches of the waterway.

Phyto-and zoo-plankton in the Milford Haven waterway and surrounding coastal waters were studied in a series of surveys but no effects of the spill were observed with the exception of the following

- an absence of barnacle larvae in Spring 1996 (but subsequent good settlement suggested that sampling time missed the planktonic stage)
- marked reduction on copepod egg viability in the Milford Haven waterway in April 1996 but complete recovery by November 1996.

(e) SHORELINE IMPACTS

Rocky shores dominate the coastline which was contaminated although sandy stretches are important and widely used by tourists. The existence of pre-spill data, from surveys which had been conducted at some sites only 6 months before the spill, made the assessment of impact fairly reliable. The mortality of limpets and other herbivorous gastropods was patchy, being particularly prevalent in areas of fresh oil contamination near the spill. Whilst this mortality contributed to the green flush (mostly Enteromorpha) on some rocky shores, natural factors operating in 1996 caused this phenomenon to be more general. The settlement of fucoid sea-weeds was also prolific in areas of gastropod mortality. The settlement of planktonic larvae in the winter of 1996-7 was good and with the unusually fast growth of the smaller population in 1996, grazing increased and substantially reduced the extent of the green flush in 1997. In severely impacted areas, limpet densities had increased to around 400 per m^2.

In most areas, barnacles survived and a good larval settlement in 1996 almost restored their distribution to pre-spill densities. Few other rocky-shore species were adversely affected and good recruitment in 1996 (e.g. sea-slater) increased densities substantially. Of those species living in crevices, Laminarian holdfasts and algal turf, several were decimated in heavily contaminated areas, particularly amphipods, polychaete worms and brittlestars and temporarily replaced by opportunistic species. However, surveys in March 1997 revealed a general recovery of this crevice, holdfast and algal-turf fauna and it has been suggested that these communities could be used more extensively for monitoring purposes.

Of particular conservation importance was the cushion starfish (Asterina phylactica) for not only is it comparatively rare but the species type-specimen was taken from rock-pools in West Angle Bay, one of the shores most badly polluted by bulk oil. The pre-spill population on this shore was about 150 but its reduction to only 13 subsequent to the spill caused concern, particularly as it had been previously thought that reproduction of the species required cross-fertilisation – a major problem for a widely-dispersed, fairly sedentary animal. Despite the absence of a major predator of cushion-star eggs in 1996, the shrimp Palaemon elegans, recovery was slow. Only 5 cushion stars were found in June 1997 but all had egg masses. From one egg mass, incubated in the laboratory, 50 juveniles were released. In June 1998 there were 45 cushion stars, most with eggs or in a reproductive state (pers. comm Robin Crump). It seems that recovery of this fragile species is virtually complete and knowledge of its reproductive biology has been advanced.

Whilst there was initial bleaching of coralline red algae, associated with the death of surface cell layers, monitoring in 1996 and 1997 showed that most algae shed these layers and continued to grow.

On sedimentary shores, where extensive pre-spill surveys had been carried out in 1994, the major impact was the disappearance or decrease in numbers of amphipods and other crustaceans, and polychaete worms and their temporary replacement in 1996 by opportunistic worm species. However, surveys in 1997 suggested substantial recovery of the pre-spill fauna.

Although saltmarshes are not extensive in the area, they occur within the Milford Haven waterway and, of the maritime vegetation types, they were the most directly impacted, particularly by heavy fuel oil. Subsequent recovery has been variable, with some species (e.g. sea purslane) recovering well and others showing continued die-back (e.g. saltmarsh rush): monitoring of these saltmarshes is continuing.

(f) BIRDS AND MAMMALS

Although the area contaminated by the oil spill is one of the most important U.K. coastal locations for birds, many migrants had not returned to nest and so a major impact was avoided. Nevertheless several species are resident throughout the year or are wintering migrants and these were severely affected, about 7,000 oiled birds being collected on shore and an unknown number dying at sea. Of the 7,000, about half were still alive and most were released again after careful cleaning procedures. However, there is evidence that for at least one species commonly oiled, the guillemot (representing 23% of those collected after the Sea Empress), most birds die soon after release.

But by far the most abundant casualty (66% of collections) was a sea-duck, the common scoter (Melanitta nigra), a migrant for which Carmarthen Bay is the most important U.K. wintering site. The Bay contained about 8,000 scoters when oil arrived there on 22 February and of these the majority were washed ashore or died at sea. Further migrants subsequently used the Bay, up to a peak of 15,000, but its suitability as a feeding ground is doubtful since detailed studies suggested that some bivalve populations on which scoter normally fed were severely reduced and others, the behaviour of which changed following contamination by oil, became more accessible (e.g. razor shells) but probably toxic when ingested. One year later, in the winter of 1996-7 the maximum scoter count in Carmarthen Bay was about 4,300 with few birds using the usual shallow feeding areas. The highest scoter count in the winter of 1997-8 was also greatly reduced (6,700) suggesting that recovery was likely to be prolonged.

Detailed counts of nesting sea-birds and breeding-success had been conducted at intervals from 1969, with which post-spill data could be compared. Physiological measurements were also made on selected species to assess the possible development of haemolytic anaemia and eggs were analysed for PAH and n-paraffin residues but no adverse results were recorded. Census data at nesting sites in and adjacent to the affected area also suggested that, with the exception of guillemots and razorbills, bird populations and nesting success were not appreciably reduced. However, numbers of guillemots and razorbills decreased in the affected area by 13 and 7% respectively in 1996 and, whilst recovery has occurred at several nesting sites, the colony counts at two have remained consistently at less than 50% of pre-spill values.

The area is important for sea-mammals, particularly grey-seals (about 4% of U.K. population) which use the beaches of the coast and islands as nurseries, and for small cetaceans., which are frequently sighted. Fortunately the main nursery areas for seals are to the north west of the oil-affected area and the birth and pup rearing season is in the autumn. Dispersion was underway when the spill occurred. Cetacean sightings before and after the spill (harbour porpoises and bottleneck dolphins) suggested no change in the frequency or distribution of their occurrence

(g) OTHER IMPACTS

There were short-term impacts on amenity, particularly access to coastal paths, during the clean-up process and industries within the Haven are reputed to have experienced short-term interruptions in cooling water supplies.

There was a more profound attitudinal change in the local population towards the risks associated with the transport of oil and

associated products. Despite the very high unemployment rate for the area (11.5%) and earlier indications of support, the planning authority rejected planned developments at the local power station in relation to the import and use of a bitumen based product, developments which were crucial to the power station's future operation. It is difficult to assess for how long this change in attitude will persist, particularly during a period of further job losses.

GOVERNMENT RESPONSE TO SEEEC'S RECOMMENDATIONS

SEEEC'S recommendations were in two broad categories:

- Those specifically related to the Sea Empress spill and the area of South West Wales where environmental impacts occurred
- Those of national significance derived from Sea Empress experience

The former principally referred to the continued need for monitoring environmental resources and, with few changes, the Government agreed to the necessity for the further work programme.

The latter extended beyond the remit of this paper but of those related to environmental impact the most important were:

- the need for national and local contingency plans to include assessments of environmental impact so that responses to spills can be rapid, properly resourced and having prepared and validated procedures for chemical and biological monitoring, together with accurate models for predicting the behaviour and distribution of oil at sea and appropriate methods for describing oil distributions on shore.
- that the costs of properly-designed and government–approved environmental impact assessments that are in proportion to the severity of the pollution and predictable effects should be met by those responsible for the spill or by those bodies required to pay compensation, rather than from public funds.
- that research is required to provide further understanding of the sensitivity of some organisms, such as amphipods, and behavioural responses of others, such as razor-shells, which are important in marine food-chains.
- that further development of biological monitoring methods was necessary for coastal and shore-line habitats.

The Government was supportive of these proposals which were referred to the appropriate agencies for action or response.

BIOGRAPHY

Professor Ron Edwards CBE, an aquatic ecologist, was Head of the Applied Biology Department at the University of Wales in Cardiff for over 20 years. He recently retired as Board Member of the Environment Agency and was Chairman of the Sea Empress Environmental Evaluation Committee.

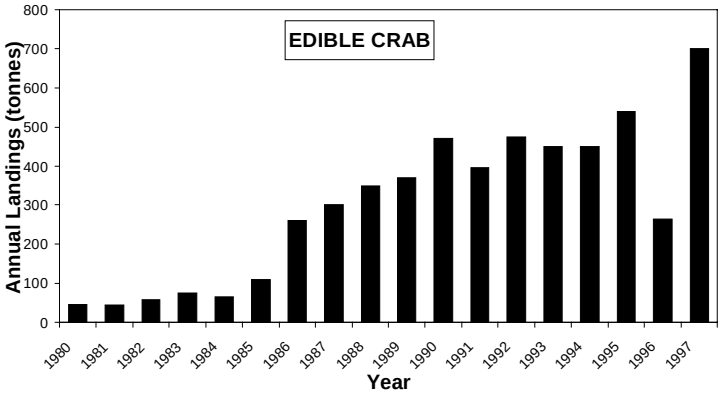
REFERENCES

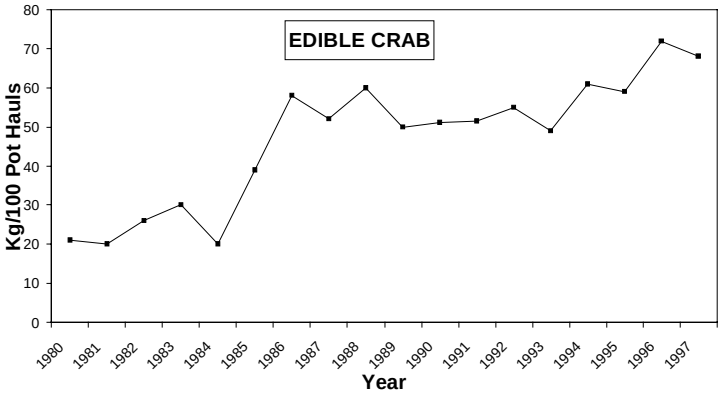
1. Sea Empress Environmental Evaluation Committee Final Report (1998) London. The Stationery Office , (ISBN 011 702156 3.)
2. Sea Empress Oil Spill Conference Proceedings (1998) Editors Edwards R W and Sime H
C.I.W.E.M. (in press).
3. Lyons, R et al (1996) Report to Dyfed Powys Health Authority on the acute effects of the Sea Empress Oil spill on the health of the South Pembrokeshire population 12pp.

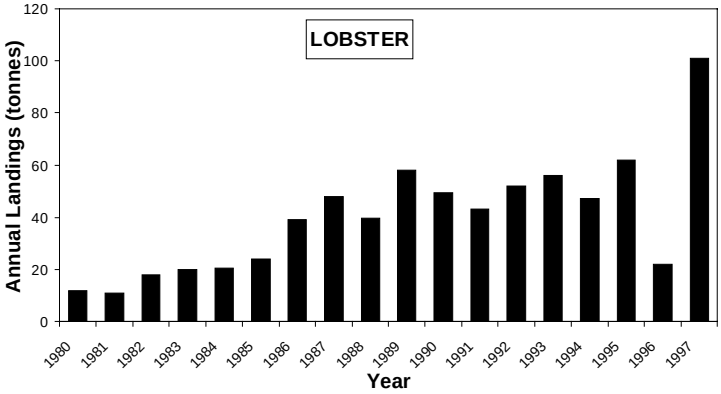
ACKNOWLEDGEMENTS

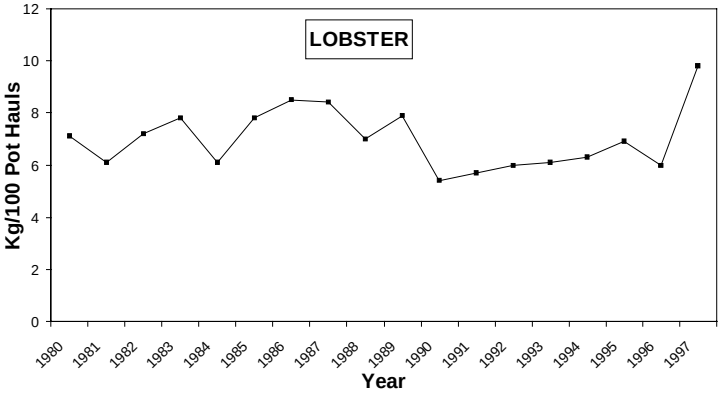
The authors wish to thank all those who contributed to the SEEEC Report and Conference Proceedings from which much of the information in this paper is drawn and to staff of the Countryside Council for Wales and the Sea Fisheries Committee for updating us on the most recent results of monitoring.

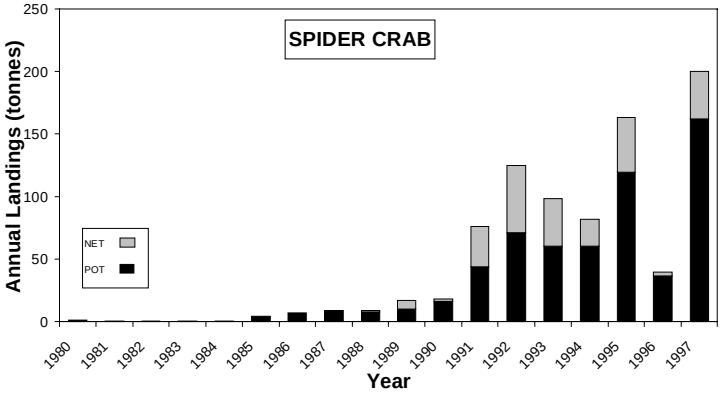
FIGURES

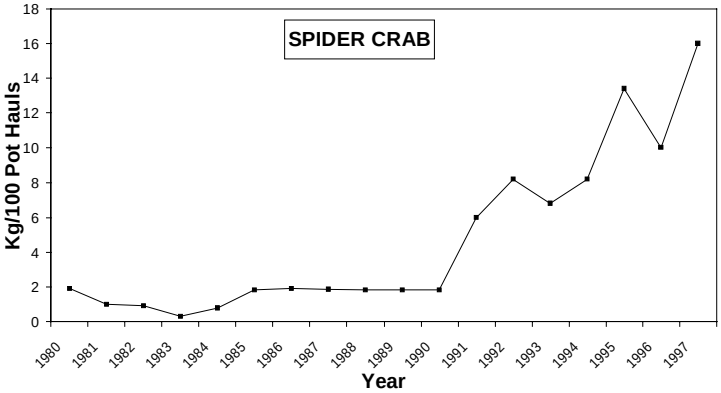

EDIBLE CRAB
Annual Landings (tonnes)
Year

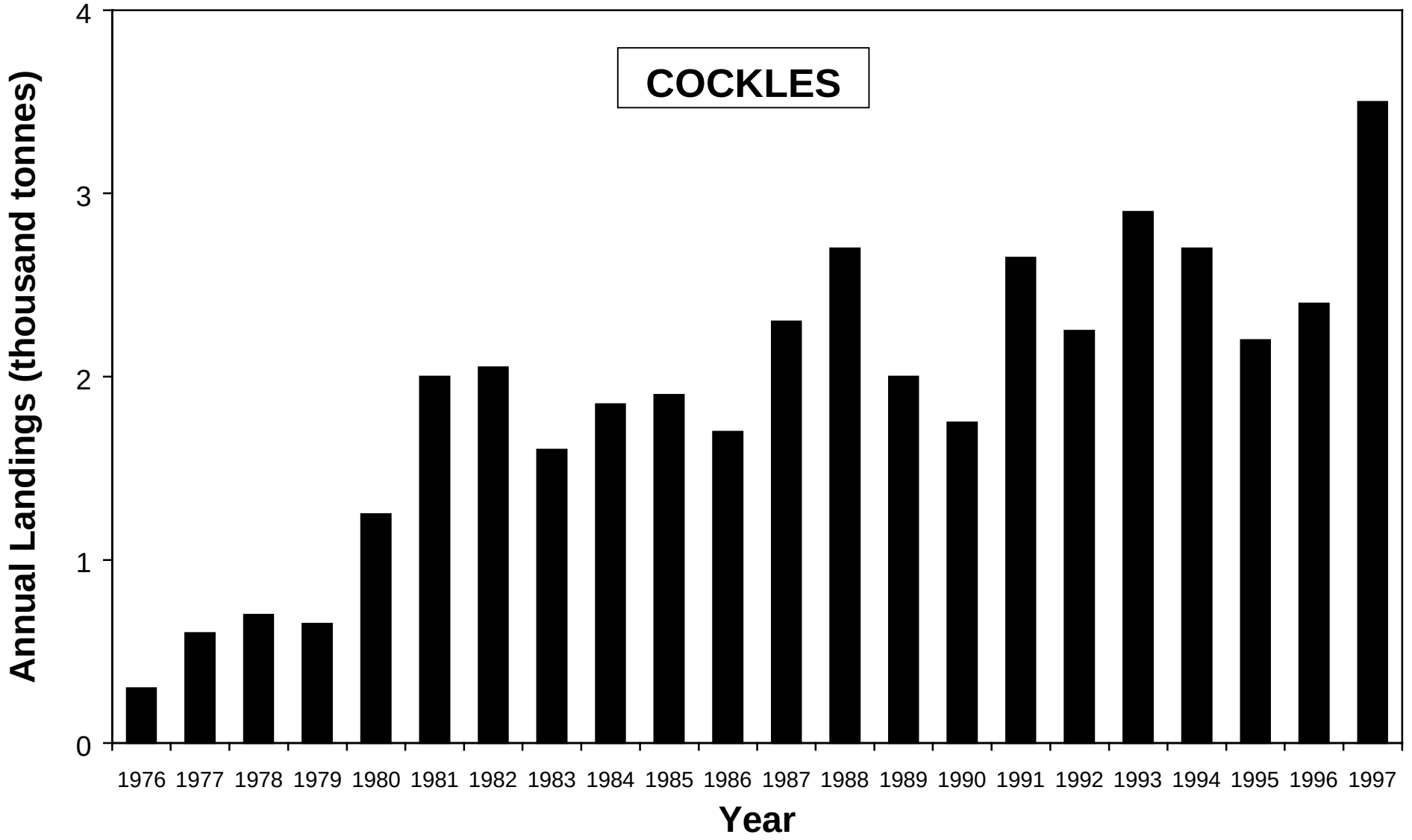

EDIBLE CRAB
Kg/100 Pot Hauls
Year


LOBSTER
Annual Landings (tonnes)
Year


LOBSTER
Kg/100 Pot Hauls
Year


SPIDER CRAB
NET
POT
Annual Landings (tonnes)
Year


SPIDER CRAB
Kg/100 Pot Hauls
Year


COCKLES
Annual Landings (thousand tonnes)
0
1
2
3
4
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997
Year