

The impact of the “*Sea Empress*” oil spill

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Abstract – The tanker “*Sea Empress*” grounded at the entrance to Milford Haven in February 1996, releasing 72 000 t of Forties blend crude oil and 480 t of heavy fuel oil into the waters of southwest Wales. An estimated 15 000 t of emulsified oil came ashore along 200 km of coastline. A fishery exclusion zone was established to protect consumers of fish and shellfish, and monitoring was instigated in order to establish the degree and spread of contamination. A wide range of further studies were conducted with the aim of assessing the overall impact of the spill. In this paper we report on the establishment and subsequent lifting of fishing restrictions and the results of the fish and shellfish monitoring programme. The application of a range of biological effects techniques which illustrated sublethal impacts is also described. In retrospect, the impact of the spill was much less than would have been expected from the quantity of oil spilled. This was due to the circumstances of the spill, which led to fresh crude oil, amenable to chemical dispersion, being released during each ebb tide and carried into deep water to the south of Milford Haven. This enabled the extensive dispersant spraying operation, which included the aerial application of 446 t of chemical oil dispersant in order to enhance the rate of natural dispersion of the oil. This reduced the impact of the spill by preventing an additional 57 000 to 110 000 t of emulsified oil from impacting the beaches.

Key words: Oil spill / “*Sea Empress*” / Fishery closure / Fish and shellfish monitoring / Chemical dispersion

Résumé – Conséquences de la marée noire du « *Sea Empress* ». Le pétrolier « *Sea Empress* » s'échoua à l'entrée de la baie de Milford Haven en février 1996, libérant 72 000 t de Forties (pétrole léger de la mer du Nord) et 480 t de fioul dans les eaux au sud-ouest du Pays de Galles. Environ 15 000 t de pétrole émulsionné vinrent s'échouer sur 200 km de littoral. Une zone d'exclusion de pêche fut établie pour protéger les consommateurs de poissons et fruits de mer, et une surveillance fut mise en place afin d'établir le degré de la contamination et sa diffusion. Une série d'études fut conduite dans le but d'évaluer l'impact global de la marée noire. Dans cet article, nous rendons compte de la mise en place et de la levée subséquente des restrictions de pêche, ainsi que des résultats du programme de contrôle des poissons et fruits de mer. L'application d'une gamme de techniques des effets biologiques, qui ont illustré des impacts sub-léthaux, est également décrite. Rétrospectivement, l'impact de la marée noire fut beaucoup moins conséquent que prévu au regard de la quantité de pétrole déversée. Ceci est lié aux circonstances de la marée noire, caractérisée par un déversement de pétrole brut léger frais, donc favorable à la dispersion chimique, se produisant à chaque marée descendante entraînant ainsi celui-ci vers des eaux profondes au sud de Milford Haven. Ceci a permis une opération intensive d'épandage de dispersants, notamment l'épandage aérien de 446 t de dispersants chimiques afin d'augmenter le taux de dispersion naturelle du pétrole. L'impact de la marée noire a ainsi été réduit, empêchant l'échouement additionnel de 57 000 à 110 000 t de pétrole émulsionné sur les plages.

1 Introduction

The tanker *Sea Empress* grounded on rocks at the entrance to Milford Haven whilst entering the port on 15 February 1996. During the next week 72 000 t of its cargo of 131 000 t of Forties blend crude oil and 480 t of fuel oil were spilt (SEEEC 1998). The coastline around south-west Wales is of exceptional conservation interest, and the area also supports a diverse fishery with extensive shellfish beds in some of the

estuarine areas (Gray 1995; Pawson et al. 2002). Following the spill, a monitoring programme for fish and shellfish in the area was initiated, and subsequently a fishery closure area was established as a precautionary measure to protect consumers. Within the monitoring programme concentrations of both hydrocarbons and polycyclic aromatic hydrocarbons (PAH) were determined in fish and shellfish tissues, and in edible seaweeds. Further details of the sampling programme and the analytical methods used are given elsewhere (Kelly and Law 1998; Law et al. 1998). Hydrocarbon analyses in waters and surface sediment sample were also conducted in order to understand the movement and distribution of the spilled oil.

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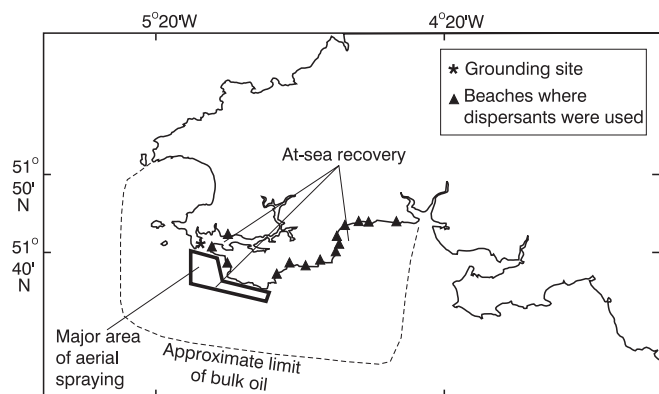


Fig. 1. The coast of southwest Wales affected by oil spilled from the *Sea Empress*. The dotted line indicates the outer limit of bulk oil contamination. The figure also indicates the main area of aerial dispersant spraying, beaches on which dispersants were applied, and the main areas of at-sea recovery.

2 Response activities

2.1 At-sea recovery

In theory, the most attractive response to an oil spill from an environmental protection standpoint is the recovery of the oil whilst it is still at sea. However, despite the availability of a wide range of booms and skimmers, they all suffer logistical and performance limitations in the turbulent sea conditions which often prevail around the UK. During the *Sea Empress* incident, wind speeds above 30 knots prevented at-sea recovery operations for much of the initial stages of the spill. In all, eight oil recovery vessels and twenty small support vessels were deployed, both within Milford Haven and outside, recovering *ca.* 3% of the spilled oil (approximately 4000 t of water-in-oil emulsion) (Lunel et al. 1995; MPCU 1996). The main areas of at-sea recovery are indicated in Figure 1.

2.2 Aerial dispersant spraying at sea

In total, 446 t of chemical dispersants were sprayed onto spilled oil from aircraft, mostly between the 18th and 22nd February. Figure 1 shows the major areas of dispersant use in relation to the spread of bulk oil from the spill (MPCU 1998). Most of the oil spilled from the *Sea Empress* was lost as the tide ebbed, so that fresh oil amenable to spraying was initially carried to the south and away from Milford Haven. For this reason most of the aerial spraying took place over the deeper waters off Milford Haven. Tidal flows in the region are amongst the strongest on the European Shelf, and typical tidal excursions west of Milford Haven are of the order of 20 km during spring tides. Dispersed oil was taken first to the west and then to the north, through St. Bride's Bay and beyond St. David's Head and into the Irish Sea. Chemically dispersed oil forms very small droplets, which are very amenable to bacterial degradation. It has been estimated that the successful application of dispersants in this incident prevented an additional 57 000 to 110 000 t of emulsion coming ashore in South Wales, in addition to the 11 000 to 16 000 t which in the event led to the contamination of 200 km of coastline (SEEEC 1998).

Concentrations of oil below the chemically dispersed slick (determined by flow-through fluorescence spectrometry) were initially found to be in the range 1 to 10 mg L⁻¹, but were rapidly diluted to <1 mg L⁻¹ (Lunel et al. 1995).

Fine sediment areas throughout the western Bristol Channel and off the coast of West Wales were sampled in case naturally dispersed oil was being transported to sediment sinks, as was observed south of Shetland following the *Braer* spill (Davies et al. 1997). Analysis of the sediments yielded low hydrocarbon concentrations and confirmed that this process was not a factor following the *Sea Empress* spill (SEEEC 1998).

2.3 Dispersant use on beaches

All of the beaches marked in Figure 1 were treated with oil dispersants, but the majority of the 12 t of dispersant used on beaches was applied to the amenity beaches around Tenby and at Skrinkle Haven. The dispersants were applied before high tide, and the resulting oil concentrations in seawater over the beaches were typically <1 mg L⁻¹ (maximum 3 mg L⁻¹) affecting areas *ca.* 20 m across. The main tourist beaches were sufficiently clean by Easter, nine weeks after the spill, to allow their use by visitors.

3 Controls on fishing activities

Local fishermen implemented a voluntary ban on fishing immediately after the grounding of the *Sea Empress*. As the tonnage of oil lost from the vessel increased it was clear that there was likely to be severe contamination of, and possible effects on, fish, shellfish and crustacean stocks in the affected area. Once the likely spread of the oil and the area within which fish and shellfish were likely to be contaminated could be predicted with some degree of certainty, controls were implemented under the 1985 Food and Environment Protection Act (FEPA). The restriction was a precautionary measure, intended to protect consumers from potential danger from eating contaminated seafood. The controls prohibited all commercial and casual collection of fish (including salmon and sea trout), shellfish (crabs, lobsters, cockles and mussels, etc.), and seaweeds. The total area affected covered about 810 square miles (2100 km²) of coastal waters from St. David's Head to Port Eynon Point, and included all the freshwater rivers and streams discharging into that area (Fig. 2).

4 Mortalities of fish and shellfish

There were no reports of mortalities of commercially-exploited crustaceans or fish (including salmon and sea trout) as a result of the oil spill. Fish are mobile and can move away if they find the conditions are unattractive to them. Also, at the time when oil concentrations in water were at their highest, crabs, lobsters and fish close to the shore would not have been actively feeding, whilst species such as crawfish, spider crabs and many fish would still have been in their winter feeding grounds away from the spill-affected area. Large

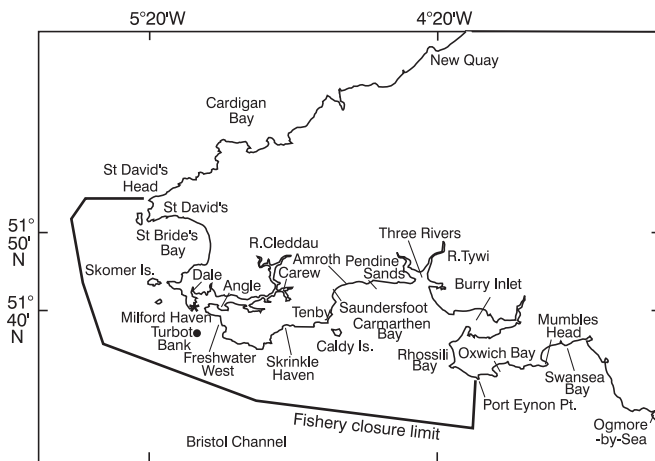


Fig. 2. The coast of southwest Wales affected by oil spilled from the *Sea Empress*. The line indicates the outer boundary of the fisheries closure area, and the star symbol marks the *Sea Empress* grounding site at St. Ann's Head.

numbers of dead or moribund shellfish (mostly bivalve molluscs) were however washed ashore during the weeks following the oil spill (SEEEC 1998), although none of these involved the major commercial stocks. The strandings involved a number of species (including cockles *Cerastoderma edule*; striped Venus *Chamelea gallina* and razorshells *Ensis siliqua*) and locations within the areas of bulk oil contamination (Rutt et al. 1998). Also, during April, 7–10 weeks after the start of the incident, many thousands of moribund specimens of the rayed trough shell (*Maetra stultorum*) were stranded along the beach at Rhossili Bay (on the eastern side of Carmarthen Bay, outside the zone of heavy bulk oil pollution). Studies of the seabed showed little impact resulting from the spill except for marked reductions in the abundance of amphipods (particularly *Ampelisca* spp., *Harpinia* spp., and Isaeidae) in some areas to the north of the grounding site (Levell et al. 1997; Rutt et al. 1998). In a previous survey conducted in October 1993, these taxa were distributed almost exclusively on the lower and middle parts of Milford Haven, and were absent from the majority of the same sites in October 1996. As the amphipods were situated within Milford Haven itself, it seems most likely that they were affected by naturally dispersed oil, driven into the water column by the turbulent conditions within the entrance to the Haven. Recovery of the amphipod fauna was evident in all reaches of Milford Haven by 1998, a pattern which generally continued during a later survey in 2000 (Nikitik and Robinson 2003).

Overall, the range of conspicuous species badly affected was very similar to those documented for two previous oil spills which occurred in the same general geographic area and with similar environmental conditions. Those spills involved the *Torrey Canyon* (Cornwall 1967) and the *Amoco Cadiz* (Brittany 1978).

5 Effects on fish and shellfish stocks and plankton

While there was no clear evidence of damage to commercial stocks of fish and shellfish, SEEEC has suggested in its

final report that further assessment may be necessary to establish whether breeding and recruitment of some species (e.g. bass, edible crabs, lobsters and whelks) was successful in 1996 after the spill (SEEEC 1998). Bass spawned in 1996 were found to be more abundant on the south side of the Bristol Channel than in South Wales nurseries, and particularly scarce within Milford Haven. Also, 0-group bass at sites along the coast of South Wales to the west of Swansea Bay were less likely to have attained the critical 60 mm overall length for survival through the first winter than those from nursery areas in North Devon and Cornwall. In 1997, however, there was no indication that 0-group bass were less abundant in any South Wales nursery, including Milford Haven, than on the south coast of the Bristol Channel (Lancaster et al. 1998). The late recruitment of 0-group bass in 1996 was attributed to lower water temperatures in February and March than in 1997 and 1998, and was not restricted to South Wales (Reynolds et al. 2003).

The herring stock within Milford Haven is also of particular interest as it represents a discrete stock. It was not possible to establish the success of spawning in 1996, but the presence of adult fish in spawning condition in 1997 suggests that there was no long-term effect (SEEEC 1998).

Data from the routine surveys conducted using the continuous plankton recorder in the Bristol Channel and adjacent offshore areas indicated that the *Sea Empress* oil spill had no dramatic effects on the plankton of the southern Irish Sea between February and October 1996. All of the common taxa showed normal levels of abundance, some taxa suggested in the literature to be susceptible to the effects of oil pollution showed no marked changes, and no striking changes were noted in the phytoplankton and zooplankton communities as a whole (Batten et al. 1998).

6 Contamination of fish and shellfish

6.1 Migratory fish (salmon and sea trout)

Levels of hydrocarbons in both liver and muscle of all finfish remained relatively low throughout the incident. The concentrations of PAH in salmon flesh (the summed concentrations of 19 individual PAH and groups (Σ PAH)) of 12 to $186 \mu\text{g kg}^{-1}$ wet weight) were much lower than those recorded following the *Braer* oil spill in Shetland in 1993, when concentrations of up to $14\,000 \mu\text{g kg}^{-1}$ were found in caged salmon 10 days after the grounding (Whittle et al. 1997). The majority of Σ PAH values in our study were actually within or below the range of reference values established for fish taken outside the area affected by that spill, but all of the fish analysed in our case were wild specimens as no farming takes place around south-west Wales. These salmon and sea trout had presumably spent little time in the affected area as they migrated into the rivers to spawn, and also would not have been actively feeding at that time.

6.2 Other finfish

All the species of finfish sampled exhibited low concentrations of both hydrocarbons and PAH (Σ PAH values

<100 $\mu\text{g kg}^{-1}$ wet weight in muscle tissue; Law and Klungsøyr 2000), and, as they were not significantly elevated over those seen outside the affected area, it was not possible to observe any trend with time. In all cases fish took up primarily low-molecular weight PAH compounds (predominantly naphthalenes), presumably mainly from the dissolved phase by diffusion across gill surfaces. These compounds are more water-soluble than the high-molecular weight PAH (including those with carcinogenic potential), and so would have occurred at higher concentrations in the dissolved phase. Fish muscle generally contains only very low concentrations of PAH as they have an effective mixed-function oxidase system which allows them to metabolise and excrete these compounds rapidly, and so the risk to consumers is minimised (Law and Hellou 1999). Some of the low-molecular weight PAH do carry the potential for taint, but tests by a trained panel did not find taint in any fish samples taken from Welsh waters throughout the incident.

6.3 Crustacea

Other than within Milford Haven itself, hydrocarbon concentrations in crustaceans also remained low and, as in the case of finfish, low-molecular weight PAH dominated. Figure 3 shows data from the GC/MS analysis of a lobster tail sample illustrating the predominance of naphthalenes. The Σ PAH concentration in this sample was 2450 $\mu\text{g kg}^{-1}$ wet weight, of which >95% was due to naphthalene and its C₁- to C₃-alkylated derivatives. Edible crabs, velvet crabs, spider crabs and lobsters were sampled across the closure area. Within Milford Haven Σ PAH concentrations within the range 100 to 2450 $\mu\text{g kg}^{-1}$ were found in samples of edible crabs, velvet crabs and lobsters sampled in the period February to April, and occasional concentrations in the lower part of the range were still evident in May and June in samples from heavily impacted sites (such as in Angle Bay, and close to the mouth of Milford Haven). These concentrations declined rapidly, and Σ PAH concentrations in edible tissues were well below 100 $\mu\text{g kg}^{-1}$ by the time restrictions were removed. As a prerequisite to lifting the closure order taint tests were conducted; no taint was detected, however, in samples of crabs and lobsters tested by the taste panel.

6.4 Whelks

Whelks sampled off Tenby on 25 February, when the first oil was beginning to come ashore in Carmarthen Bay, showed clear signs of contamination, with a Σ PAH concentration of 3800 $\mu\text{g kg}^{-1}$ wet weight. This contamination seems to have been very localised, however, as other samples collected from Carmarthen Bay around the same time yielded much lower values for both hydrocarbons and PAH. From the beginning of June onwards whelks taken across the whole area from Carmarthen Bay to the Isle of Lundy in the middle of the Bristol Channel yielded low concentrations, with all Σ PAH concentrations below 50 $\mu\text{g kg}^{-1}$. As for finfish and crustaceans low-molecular weight PAH predominated, and by this time no taint was evident. The closure order affecting whelks was not lifted, however, until somewhat later due to the concerns of fishermen about their export market potential, which necessitated more detailed coverage of the area exploited by the whelk fishermen.

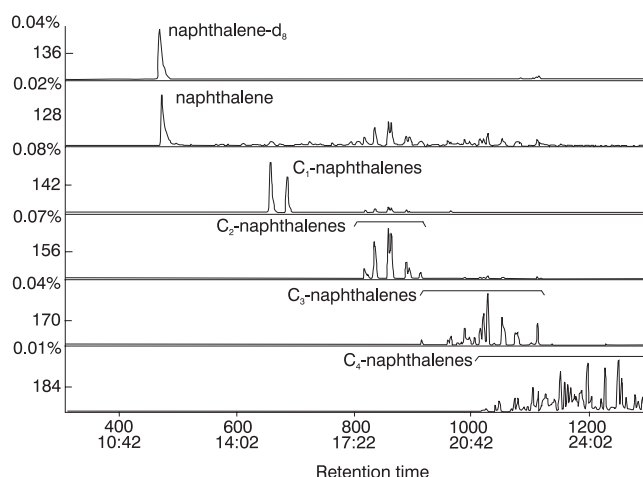


Fig. 3. Mass chromatograms of the extract from a lobster tail sample, collected on 22 February 1996 from Monk Haven, at the north end of Dale beach. Mass 136 represents the surrogate internal standard, naphthalene-d₈. Masses 128, 142, 156, 170 and 184 represent naphthalene and its C₁-, C₂-, C₃- and C₄-substituted derivatives respectively.

6.5 Bivalve molluscs

The main commercial fisheries for bivalve molluscs are for cockles and mussels in the Three Rivers and Burry Inlet areas off Carmarthen Bay, oysters (both native and Pacific) are reared at Carew (above Milford Haven), and scallops are also fished by boats from Milford Haven. All of these species were monitored routinely, and other species (e.g., clams, carpet shells, dogwhelks, periwinkles, razor shells, trough shells) were analysed either following stranding events, or to provide spatial coverage as available. Hydrocarbon concentrations in both cockles and mussels exposed to oil rose very rapidly, and to high concentrations. This was apparent in mussels sampled across the closure area in March 1996, from St. David's in the north to the Three Rivers area to the east, mostly in stocks which are not exploited commercially. At many of the sites within the closure area Σ PAH concentrations in mussels were well above 1000 $\mu\text{g kg}^{-1}$ wet weight.

Within the most heavily impacted area (between Milford Haven and Tenby) concentrations of PAH generally rose very rapidly and then declined steadily over the next four months. Very little oil seems to have entered the Burry Inlet, possibly as a result of the restricted entrance to the Loughor estuary. A small quantity of oil passed beyond the fishery closure area both to the east of Port Eynon, as shown by a small rise in PAH concentrations in mussels from Oxwich Bay around 35 days after the grounding, and oil also entered St. Bride's Bay, as reflected by uptake in mussels from Skomer Island. The slowest declines were seen in intertidal mussels on the south Pembrokeshire coast, particularly around Skrinkle Haven and Caldey Island where oil persisted subtidally to the end of 1996. The highest concentrations of PAH in mussel tissues were seen at sites within Milford Haven close to the spill site, with Σ PAH concentrations >100 000 $\mu\text{g kg}^{-1}$ wet weight being reached within about a week of the grounding. This reflected direct uptake of naturally dispersed oil droplets from the water column within a very short time after release

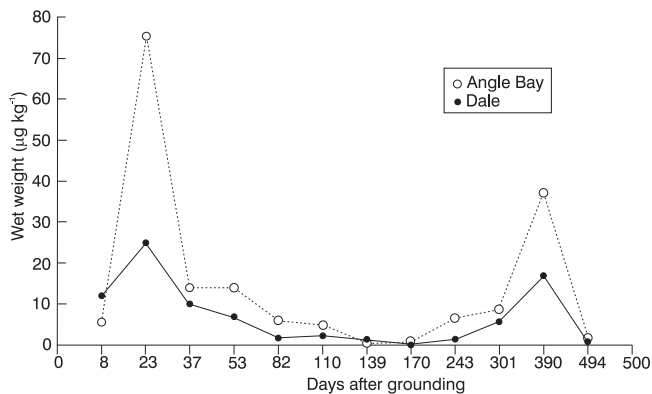


Fig. 4. Time-trends of concentrations of benzo[a]pyrene in whole tissue of mussels collected from Angle and Dale after the grounding of the *Sea Empress* ($\mu\text{g kg}^{-1}$ wet weight).

from the vessel (Law et al. 1999). As the concentrations of oil-derived PAH declined, a seasonal variation in the concentrations of the higher-MW (combustion derived) PAH became apparent, and was particularly marked in mussels from within Milford Haven. Concentrations of benzo[a]pyrene in mussels from Angle and Dale are shown in Figure 4. In both 1996 and 1997, concentrations reached a maximum in March, declining to close to zero in mid-summer. This seems to be related to larger combustion PAH inputs in winter, and to aspects of mussel physiology which are discussed elsewhere (Law et al. 1999). Similar seasonal cycles in PAH concentrations in mussels have also been observed in both Germany and the Shetland Islands (Jacob et al. 1997; Webster et al. 1997).

7 Removal of fishery restrictions

The fishery restrictions were removed in stages as the results of the monitoring study showed that concentrations of hydrocarbons and PAH had declined to levels so low as to pose no further risk to consumers, and that the species involved were free of taint. These criteria were similar to those established after the *Braer* spill in Shetland in 1993 (Topping et al. 1997). Background data for PAH in tissues of commercial fish and shellfish taken off south-west Wales before the *Sea Empress* spill were sparse, and samples taken outside the closure area were also analysed within the monitoring programme in order to gather information on contamination resulting from other sources of oil and PAH within the area so as to aid interpretation. Subsequently, this lack has been addressed and baseline data have been gathered for PAH in commercial stocks of bivalve molluscs around England and Wales. Controls on fish and crustacea were removed relatively quickly (within 3 to 8 months respectively of the grounding), and the major intertidal cockle beds in the Burry Inlet and Three Rivers were also relatively lightly contaminated and reopened 4½ and 7 months respectively after the grounding. The restrictions covering intertidal mussels in the south-east of the closure area and oysters within Milford Haven were the last to be lifted, remaining in place for about 19 months until 12 September 1997. Selective restrictions have remained in place for long periods following earlier spills, for instance, seven years for Norway lobsters

(*Nephrops norvegicus*) and mussels off Shetland following the *Braer* oilspill in January 1993. This was a result of oil becoming entrained in subtidal sediments in the inner sounds and voes. Similar circumstances did not arise in the case of the *Sea Empress*, except around Skrinkle Haven and Caldey Island where oil persisted subtidally in sandy sediments until the end of 1996.

8 Biological effects studies

In the wake of the oil spill a number of biological effects techniques were deployed in order to assess exposure to PAH and the likely occurrence of sublethal effects. These involved the determination of EROD (ethoxyresorufin-O-deethylase) in fish, measurements of immune function, scope for growth and lysosomal stability in mussels, DNA-adducts in fish and transplanted mussels and the application of whole-sediment bioassays to samples from within the Milford Haven waterway. These studies are reported in detail elsewhere (Dyrynda et al. 1997, 2000; Fernley et al. 2000; Kirby et al. 1999; Law et al. 1998; Lyons et al. 1997). A variety of impacts were observed, but all were short-lived.

9 Conclusion

The effects of the *Sea Empress* spill on fisheries were less severe than could have been expected on the basis of the quantity of oil spilt. There were no reports of mortalities of commercially-exploited crustaceans or fish (including salmon and sea trout) as a result of the oil spill. In finfish and crustaceans, the levels of contamination were low. This may have been partly due to the fact that the spring of 1996 was colder than usual, and feeding activity may have been reduced at the time the oil was released. Most of the crabs and fish may also have been offshore at the time of the spill due to the season. Much higher tissue concentrations were seen in bivalve molluscs, both from within and outside Milford Haven. Mass strandings of a number of species occurred, apparently as a direct result of the oil spill. Major stocks exploited commercially, such as those of the Three Rivers and the Burry Inlet, were not affected in this way. Biological effects studies likewise demonstrated a variety of impacts on local fish and mussels, but all were short-lived.

There is little doubt that the aerial application of dispersants helped to reduce the impact of the *Sea Empress* spill on fisheries considerably by significantly reducing the amount of oil which reached the shoreline. Contamination by hydrocarbons and PAH persisted longest in mussels from the intertidal area to the east of Milford Haven (Freshwater West to Pendine Sands), and derived from bulk oil contamination of the shoreline. This is in line with observations at previous spills where contamination has persisted for years due to oil becoming trapped within sediments in low-energy coastal environments, resulting in recontamination when the oil is mobilised by storms or tides. The large-scale use of dispersants requires identification of the resources to be protected as part of a contingency plan and detailed (and rapid) consultation between government and nature conservation agencies before use, but can yield real environmental benefits.

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