Science Series
Aquatic Environment Monitoring Report **no. 61**

Environmental monitoring conducted in Lyme Bay following the grounding of *MSC Napoli* in January 2007, with an assessment of impact

Cefas

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Contents

Executive summary

Robin Law

On 18th January 2007 the container ship *MSC Napoli*, outward bound from Europe to South Africa in heavy weather, began to take in water through cracks in the engine room walls. The crew abandoned ship and were airlifted to safety, and two emergency towing vessels maintained on station in the Western Approaches by the French and UK governments took her in tow. This decision was taken prior to the formal establishment of the Environment Group, but various members were consulted. The intention was to tow her to Portland Harbour on the south coast of the UK as a place of refuge where problems with the ship and her cargo could be tackled in safety. It was considered that to have allowed to the ship to sink in deep water would lead to a serious risk of chronic pollution with little or no ability to intervene. On the morning of the 20th January the ship suffered a serious structural failure and she was beached in Lyme Bay, off Branscombe in Devon, to prevent her from sinking. The ship was carrying 2,318 containers, 159 of which contained more than 1,600 tonnes of chemicals classified as dangerous goods by the International Maritime Organisation and around 4,000 tonnes of oil as fuel. A salvage operation was begun with the aim of removing the oil and cargo from the ship. A number of bodies (Defra, Marine and Fisheries Agency, Environment Agency, Cefas, Health Protection Agency, Natural England, Devon and Dorset Councils, the International Tanker Owners Pollution Federation) assisted the Maritime and Coastguard Agency in devising an appropriate response. As a quantity of oil and approximately 100 containers had been lost during and immediately following the grounding of the *MSC Napoli*, it was also decided to design and implement a monitoring programme in Lyme Bay in order to assess any environmental impact and to protect the human food chain.

Following an investigation by the Marine Accident Investgation Branch of the Department for Transport, it was concluded that faulty vessel design led to the structural failures. For more detail see NAIB (2008).

The cargo carried by the *MSC Napoli* was very diverse, including many non-hazardous goods (cars, gearboxes, paper, personal effects etc) and a wide variety of hazardous materials (including chemicals, solvents, personal care products and pesticides). Of particular concern were the pesticides lamda-cyhalothrin, profenofos, glyphosate, carbendazim, propaquizafop, and dibutyltin oxide and a broad range of other chemical products.

The monitoring programme which was developed and which is reported here was therefore based on three main assumptions:

1. oil has been lost and may affect the local environment and so hydrocarbons should be monitored.
2. during the salvage operation any of the chemicals aboard may be lost and monitoring for those compounds may be necessary in water, sediments and biota.
3. as Lyme Bay is of major nature conservation importance there will be a need to assess the damage to the local flora and fauna.

Initially, the Environment Agency augmented their routine water quality monitoring programme around Lyme Bay, both by adding additional stations to improve the data coverage and by implementing a screening procedure for chemicals in the water samples using coupled gas chromatography-mass spectrometry. In addition, Defra funded the Plymouth Marine Laboratory to undertake a survey of the waters across Lyme Bay at various distances from shore (along the 10m, 20m and 40m depth contours) to assess the levels of hydrocarbon contamination in subsurface waters and the surface microlayer. Also, Cefas and the Marine and Fisheries Agency instigated a programme of sampling commercial shellfish (crabs, scallops and mussels) from Lyme Bay and Portland Harbour. These were analysed for polycyclic aromatic hydrocarbons, toxic components of oil which can affect the human foodchain and whose concentrations may require fishery closures to be put in place. Natural England organised necropsies of a proportion of the oiled seabirds which was conducted by members of the British Trust for Ornithology to establish species affected and their condition prior to oiling, and Cefas conducted analyses of oil from the feathers of a number of birds in order to confirm that the oil was from the *MSC Napoli*. In preparation for analysis of any of the chemicals aboard the vessel if lost, Cefas and the Environment Agency collected sediment samples from around the shoreline of Lyme Bay and from the Fleet and Portland Harbour, and the Plymouth Marine Laboratory also collected surface sediment samples from all the stations of the cruise mentioned above. All of these sediment samples were stored frozen at –20°C in order that they could provide baseline data against which any future contamination by any of the chemicals could be assessed. In addition, the University of Plymouth deployed biological effects monitoring at a number of beach locations in Lyme Bay under an EU-funded programme called FACE-IT (Fast Advanced Cellular and Ecosystems Information Technologies).

Both the Plymouth Marine Laboratory (seawater) and Cefas (shellfish) studies showed elevated concentrations of PAH only in the area immediately outside the exclusion zone established around *MSC Napoli*. None of the shellfish showed PAH concentrations higher than the Food Standards Agency's guideline values (10 μg kg^{-1} wet weight for benzo[*a*]pyrene and 15 μg kg^{-1} wet weight for benz[*a*]anthracene and dibenz[*a,h*]anthracene) and so no fishery closures were imposed. Studies undertaken by the University of Plymouth showed limited sublethal biological effects in limpets from Branscombe, close to the *MSC Napoli*. Benthic surveys undertaken on behalf of Natural England found evidence of damage to the benthic environment surrounding the *MSC Napoli*, but it could not be established that this was a result of the grounding of the vessel. Oil spilled from the *MSC Napoli* resulted in over 3,000 seabird casualties. Necropsies of approximately 10% of these (306 birds) were undertaken in order to assess the impact on populations of seabirds affected. Of these, 168 were guillemots and 104 razorbills (55% and 34%, respectively). Of the guillemots that could be aged, 77% were adults, 20% were young adults and only 3% were sub-adults. The effects of the removal of breeding adults will probably impact on the southern populations that breed in Iceland, the Færoes, Britain, Ireland and France. Further funding may be sought to assess these impacts. Analysis of solvent swabs from oiled feathers from 13 birds was undertaken at Cefas, and fingerprinting studies confirmed that the oil on 12 of the feathers was fuel oil from the *MSC Napoli*. Some additional work on oiled birds was undertaken by the Veterinary Laboratories Agency. Five guillemots and three razorbills were studied and the gross findings indicated oil ingestion. See http://www.defra.gov.uk/corporate/vla/science/documents/science-end-survrep-qtlyw0107.pdf. Samples of seawater from the holds and engine room of the *MSC Napoli* were screened for chemicals by the Environment Agency and toxicity tested by Cefas against an alga and a crustacean. These studies showed low concentrations of chemicals and toxicity initially, which reduced in the holds as container of cargo were removed. Some residual toxicity remained in samples from the engine room, which was open to the sea, probably due to small leaks of oil from pipework. By the time all of the water was pumped out of the ship so that she could be refloated the level of toxicity was very low, so there was no concern regarding potential toxic impacts.

Overall, the impact of the *MSC Napoli* incident, as established during this monitoring programme, was less than initially feared from the first study of the hazardous goods manifest listing the chemicals and their quantities carried by the ship. Most of the oil fuels aboard were safely transhipped and removed and no dangerous goods containers were lost into the sea. The concentrations of chemicals that were released to the water environment during the incident were considered to represent a low risk of toxic impacts. The sensitive areas of Chesil Beach and the Fleet were not significantly impacted. The quantity of oil lost from the vessel to the sea off both the French and UK coasts was estimated by the Maritime and Coastguard Agency to be only ca. 300 tonnes. All of the containers remaining aboard following the grounding were transferred to Portland Port for processing and onward transfer, recycling or disposal of both containers and contents.

Background to the incident *Robin Law*

On Thursday 18th January 2007, the 62,000 tonne container ship *MSC Napoli* was en route from Antwerp to South Africa. The ship was 45 miles off the Cornish coast in international waters when she suffered flooding of the engine room during force 8 gales with 12m swells. The 26 crew abandoned ship and were rescued by helicopter. Both French and British emergency towing vessels arrived on scene. In accordance with the Anglo-French Joint Maritime Contingency Plan (Mancheplan), the British and French authorities then made an on-scene assessment of the condition of the vessel. The ship was carrying 2,318 containers, 159 of which contained more than 1,600 tonnes of chemicals classified as dangerous goods by the International Maritime Organisation. It was considered that to allow the vessel to sink in deep water would lead to a serious risk of chronic pollution with little or no ability to intervene and, accordingly, the decision was taken to tow the ship to port. Of the ports available, Portland Harbour was selected as the most appropriate destination considering both the steaming distance involved and the facilities available. The route to Portland was also considered to be the towing direction least likely to further damage the ship in the bad weather still prevailing.

A number of containers and a quantity of oil (estimated at ca. 150 tonnes) were lost during the initial flooding and abandonment of the vessel. The trajectory of the oil is shown in Figure 1. During the period 25 – 28 January 2007, patches of oil and soiled biscuit packets came ashore along a stretch of the beaches of North Brittany, France, between Perros-Guirec and Carantec. On the 28th January, surveys undertaken by CEDRE showed > 10,000 biscuit packets on the beach of Porz Billiec alone (Beau, 2007a & b). Local communes organised beach cleaning by manual means.

Figure 1. Predicted trajectory of oil lost during the initial stages of the incident (courtesy of CEDRE).

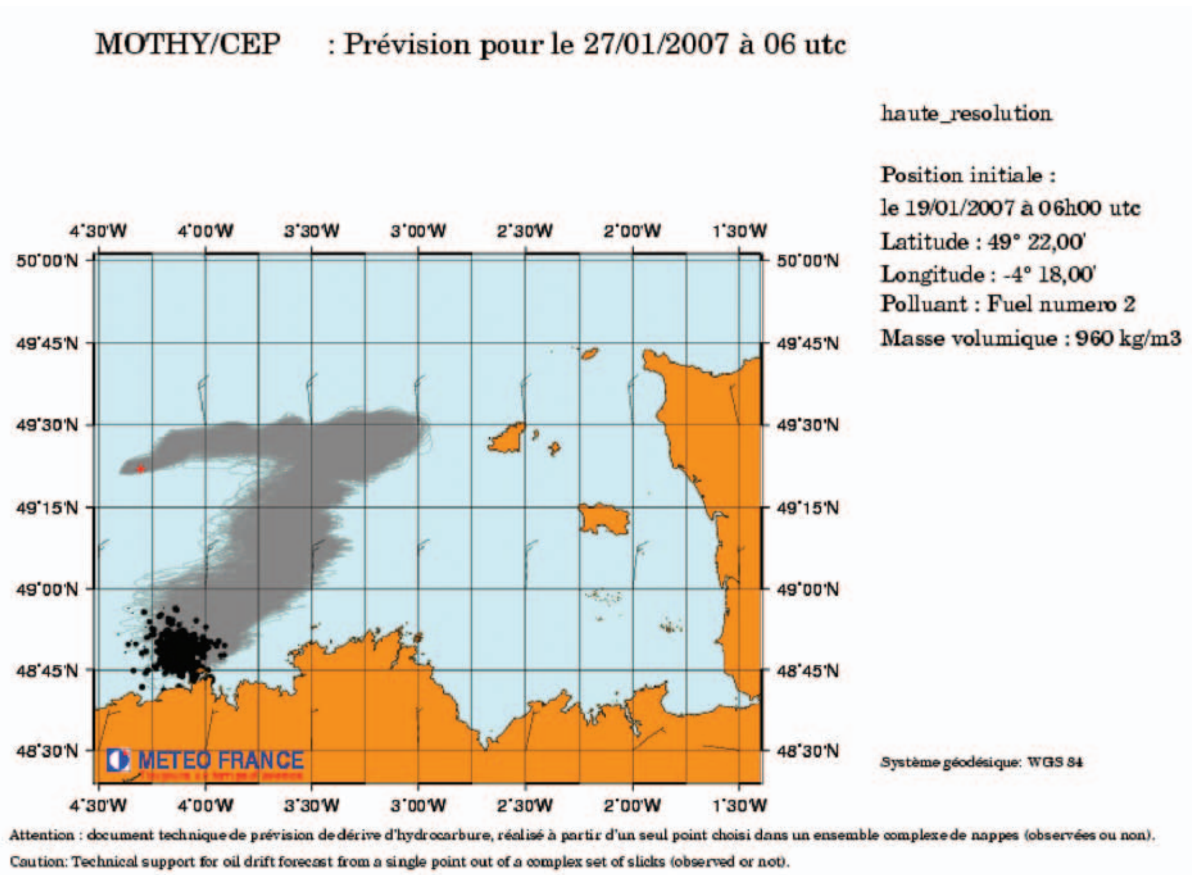
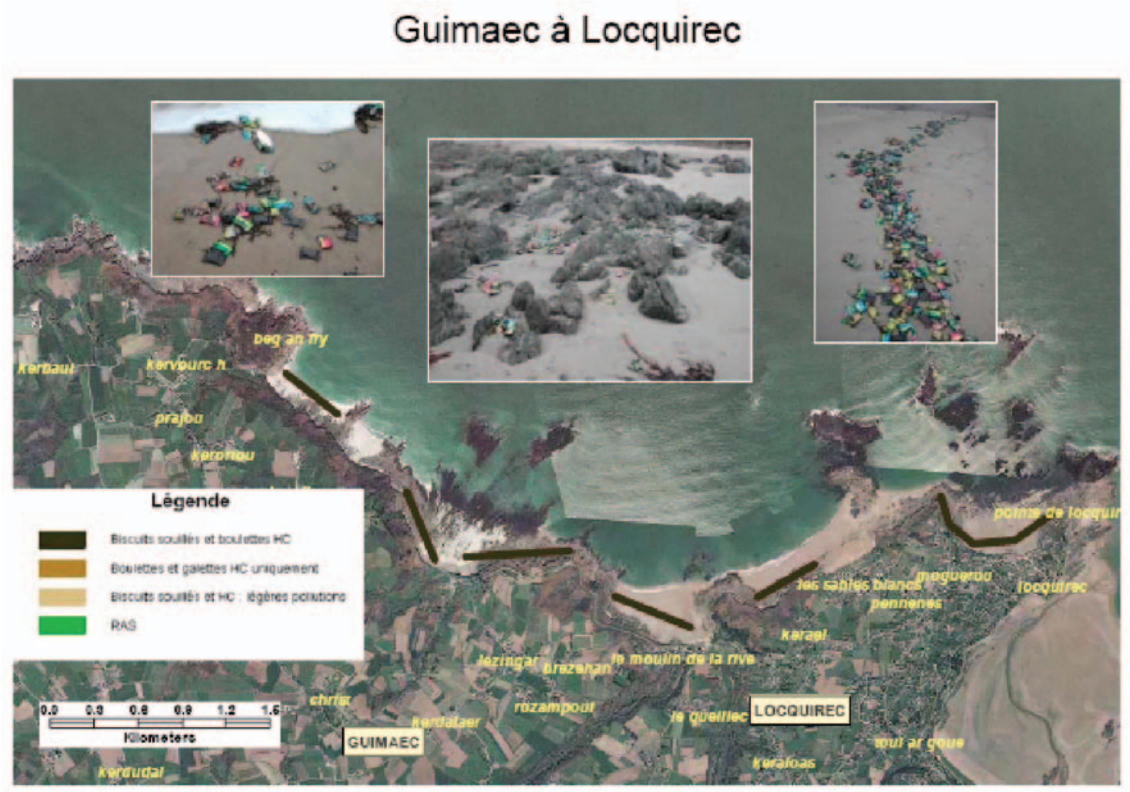


Figure 2. Example of a survey map showing pollution of the northern French coast, with photographs of soiled biscuit packets stranded on the beach (courtesy of CEDRE).



The recovery operation led to the collection of 70 tons of waste in Finistère and possibly the same for the Cotes d'Armor. The cleaning operation was completed in June 2007. An example of a survey map is shown in Figure 2.

On the morning of Saturday 20th January the *MSC Napoli* was being towed past Lyme Bay when she suffered further serious structural failure and it was feared that she might sink before reaching Portland. In order to prevent this and to put her in a position which would allow the cargo and bunker fuels to be removed she was beached in Lyme Bay approximately 1 mile off Branscombe, Devon, during Saturday afternoon. The position of the *MSC Napoli* once beached was 50° 40.62′ N 03° 09.89′ W. A temporary exclusion zone of 500m radius was established around this position to prevent shipping hampering the salvage efforts, with a further 5 mile radius advisory zone whilst containers were in the water. Approximately 100 containers were lost into Lyme Bay during and immediately following the grounding. Of these, 76 came ashore in the local area and the remainder were presumed sunk in the vicinity.

Whilst in Lyme Bay, a further 150 tonnes of oil were lost. Some was dispersed using chemical oil dispersants approved by the Marine and Fisheries Agency and the remainder recovered from the beaches between Sidmouth and Chesil Cove. A large number of containers, contents and debris were recovered from local beaches by contractors and from the adjacent seabed using sonar surveys and divers.

Most of the ship's bunker fuels (diesel and heavy fuel oil IFO 380; totalling just under 4,000 tonnes) were removed by transfer to another vessel. Within about 4 months (by 17th May) all of the containers remaining aboard had also been removed and taken to Portland Port for disposal or recovery of both the cargo contained and the containers themselves. The ship was refloated on Monday 9th July, following the discharge of 58,000 tonnes of water from within the patched hull. She was then rebeached on Thursday 12th July following an inspection by divers which concluded that she was too badly damaged to be towed further without a serious risk of her breaking in two. On the 17th and 18th July, explosives were used to separate the vessel into two parts, the bow section floating and the stern section upright on the seabed. Following examination for invasive species by Cefas, the bow section was towed to the Harland and Wolff shipyard in Belfast for recycling, arriving in late August. Subsequently, plans were also made to cut up the stern section into pieces and take them away by barge for recycling. Work was proceeding and the accommodation block had been cut free and removed, when a serious storm upset the balance of the ship and she took on a 30°–40° degree list to starboard. This made the lightening of the stern section much more problematic, and plans are being revised with the intention of cutting up the remains of the wreck for recycling. Further salvage work is likely to begin in April 2008.

Rationale for the monitoring programme

Robin Law

The cargo carried by the *MSC Napoli* was very diverse, including many non-hazardous goods (cars, gearboxes, paper, personal effects etc) and a wide variety of hazardous materials (including chemicals, solvents, personal care products and pesticides). Of particular concern were the pesticides lamda-cyhalothrin, profenofos, glyphosate, carbendazim, propaquizafop, and dibutyltin oxide and a broad range of other chemical products.

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3. as Lyme Bay is of major nature conservation importance there will be a need to assess the damage to the local flora and fauna.

Computer modelling of the movement of spilled oil undertaken by Cefas indicated that oil was extremely unlikely to be transported to the west of 3° 20’ W (i.e. to the west of Budleigh Salterton). The area off the Rivers Exe and Teign and Tor Bay could therefore be considered as reference locations, albeit subject to some coastal pollutant inputs from domestic and industrial sources.

Initially, the Environment Agency augmented their routine water quality monitoring programme around Lyme Bay, both by adding additional stations to improve the data coverage and by implementing a screening procedure for chemicals in the water samples using coupled gas chromatography-mass spectrometry. In addition, Defra funded the Plymouth Marine Laboratory to undertake a survey of the waters across Lyme Bay at various distances from shore (along the 10m, 20m and 40m depth contours) to assess the levels of hydrocarbon contamination in subsurface waters and the surface microlayer. Also, Cefas and the Marine and Fisheries Agency instigated a programme of sampling commercial shellfish (crabs, scallops and mussels) from Lyme Bay and Portland Harbour. These were analysed for polycyclic aromatic hydrocarbons, toxic components of oil which can affect the human foodchain and whose concentrations may require fishery closures to be put in place. Natural England organised necropsies of a proportion of the oiled seabirds which was conducted by members of the British Trust for Ornithology to establish species affected and their condition prior to oiling, and Cefas conducted analyses of oil from the feathers of a number of birds in order to confirm that the oil was from the *MSC Napoli*. In preparation for analysis of any of the chemicals aboard the vessel if lost, Cefas and the Environment Agency collected sediment samples from around the shoreline of Lyme Bay and from the Fleet and Portland Harbour, and the Plymouth Marine Laboratory also collected surface sediment samples from all the stations of the cruise mentioned above. All of these sediment samples were stored frozen at –20°C in order that they could provide baseline data against which any future contamination by any of the chemicals could be assessed. In addition, the University of Plymouth deployed biological effects monitoring at a number of beach locations in Lyme Bay under an EU-funded programme called FACE-IT (Fast Advanced Cellular and Ecosystems Information Technologies).

Water quality monitoring undertaken by the Environment Agency

Giles Bryan, Peter Rose, Peter Jonas and Mark Kirby

In response to the grounding of the *MSC Napoli*, the Environment Agency undertook water quality monitoring and biota / sediment sample across Lyme Bay from 22nd January 2007. Monitoring was carried out to identify the risk presented to the water environment from the incident and is reported fully in Bryan *et al.*, 2008. This report can be obtained by contacting the Environment Agency National Customer Contact Centre on 08708 506506.

The risk presented by the ship reduced with time as the heavy fuel oil, diesel and containers were removed from the ship in a controlled way. Once all the oil tanks had been emptied, holds skimmed, and all the containers removed, the major risk to the environment had been significantly reduced. A small risk remained from oils that were still trapped in "difficult to access locations", from debris still in the holds, from containers that had not been located and removed from the sea bed, and finally from the ships structure itself.

Sampling

Samples of water, sediment and biota were collected from shore, beach and transect sites around and across Lyme Bay. Water samples were also collected by the Salvors from the seven holds and the engine room of the vessel itself. Biota and benthic sediment collections were not analysed but have been kept preserved deep frozen should the need arise to evaluate them further in the future.

The intensity of monitoring increased during the 2007 Bathing Waters season (May to September). Additional samples were collected at Directive monitoring sites on a monthly basis. A further detailed beach inspection was carried out in West Dorset / East Devon in July following the initial separation of bow and stern sections. Where oil deposits were found across the supra littoral fringe to the littoral zone, samples taken were generally identified as weathered heavy fuel oil. Water samples were analysed quantitatively for hydrocarbons and various compounds and GC-MS scans were carried out, qualitatively and semi-quantitatively identify the presence and concentration of other substances. Water quality samples from the ship's holds and engine room were also forwarded to Cefas for toxicological testing.

Results

Results from the laboratory analysis were forwarded to appropriate technical experts within the Environment Agency to assess the risk presented to the water environment. This primarily involved team members from Tidal Waters and from the Environment Agency Science Group, Chemicals Team. Water Quality results were also forwarded to Cefas and other stakeholders for their assessment.

The Environment Agency interpretation of risk to the water environment was carried out by reference to Environmental Quality Standards (EQS) (where these exist) or by reference to published ecotoxicity data where such data were available. EQS are set to protect aquatic life from either short term or long term exposure to a particular compound. The exposure duration was therefore considered during interpretation.

Cefas set up two established and internationally accepted bioassays to test the toxicity of the hold water samples. The first was with the marine harpacticoid copepod, *Tisbe battagliai*, as used in many previous monitoring studies (Kirby *et al.* 1998, Thomas *et al.* 1999). This is a 48 hour acute toxicity test conducted in 12 well cell plates. The second method was a 72 hour growth inhibition test conducted in 200 µl 96-well microplates using the marine diatom, *Skeletonema costatum*. The microplate assay was based on the standard guideline (ISO 10253) from the International Standards Organisation (ISO, 1995). Both assays were conducted at 20°C ±2. The use of the two assays in parallel provided quick results and coverage of two major taxonomic groups, crustacea and algae. The Environment Agency's interpretation of the data was then compared with Cefas toxicity results to draw a conclusion regarding the risk that water in the holds and engine room presented to the water environment at the time of sampling. This was then disseminated to stakeholders as appropriate.

Impact Assessment

Results of the analyses show a range of chemicals to have been identified. Hydrocarbons were occasionally present at elevated concentrations and occasionally observed on the beaches and surface waters of Lyme Bay. No 'exception' results were recorded on any beaches west of Sandy Bay in East Devon or in off-shore samples taken in a line from Portland to Tor Bay. Greatest concentrations were recorded in samples taken from the holds of the *MSC Napoli*. The greatest list of compounds identified from the beach samples was at Branscombe beach. This site was used to handle waste / debris from containers lost from the vessel and the closest beach to the grounded vessel.

Many compounds identified in the holds and engine room of the *MSC Napoli* were not recorded in costal water samples. Of the list of compounds that were recorded both in the vessel and coastal waters, the most ubiquitous were hydrocarbons and phthalates. Hydrocarbons, dibutyl tin compounds, xylene, sulphur and tetrachloroethylene were reported as present on the vessel; it is assumed the phthalates were also present. Ethylbenzene as a solvent / additive could have likewise been part of the cargo. Presence of dimethyl sulphide, a degradation product of phytoplankton, was not a surprise. Exotic chemicals used in fragrance precursors and local anaesthetic were recorded very infrequently and at very low concentrations.

Cefas toxicity testing showed that hold water quality generally improved through the incident as oils and containers were removed. There were certain periods of time when a deterioration occurred, potentially as a result of disturbance of containers, breach of containers or potentially resulting from work carried out to patch hull of the *MSC Napoli*. This may have resulted in reduced dilution potential and increasing chemical contamination.

A general assessment of the impact of large scale release of hold water as a plume, or as investigated by Cefas as a large instantaneous release of the entire hold material concluded that this would not have a significant environmental impact. The primary reason for this was the generally low toxicity of the hold and engine room water samples and the large dilution that would result when released into the surrounding waters.

The primary conclusion from both Cefas and Environment Agency during and after the incident was that concentration of chemicals that were released to the water environment during the incident presented a LOW RISK. The risk to birds, from landing on oiled water was, however, higher but was outside the scope of the Environment Agency report.

Lyme Bay survey undertaken by the Plymouth Marine Laboratory

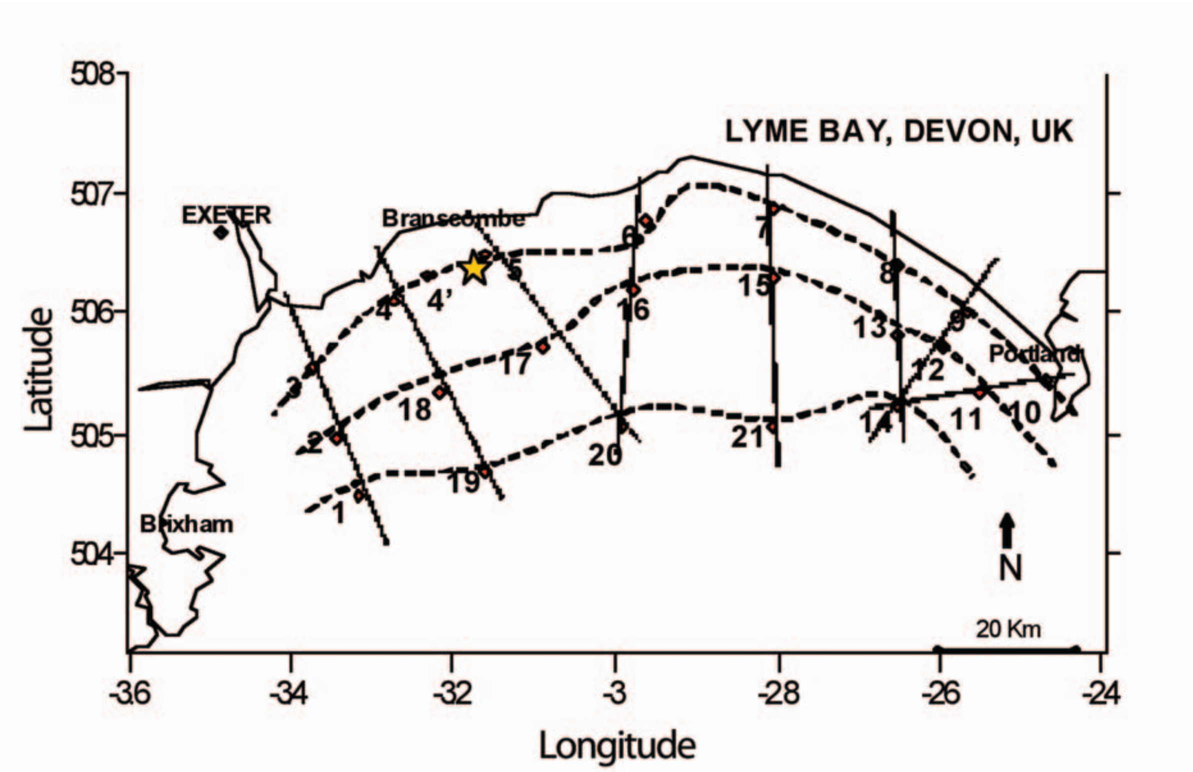
Carlos Guitart, Trish Frickers, James Readman and Robin Law

Once oil had been spilled in Lyme Bay following the grounding of *MSC Napoli* it became necessary to conduct a survey aimed at assessing the degree of contamination and its spread. The Environment Agency were analysing water samples taken from the coast, but it was decided to supplement this by mounting a dedicated cruise. This was conducted by scientists from the Plymouth Marine Laboratory on 30-31 January 2007. A series of samples of subsurface water and of the sea surface microlayer were taken at sites across the whole of Lyme Bay, approximately along the 10 m, 20 m and 40 m depth contours (Figure 3). In addition, samples of surface sediment were taken and stored frozen at –20 °C as baseline samples, in case sediment monitoring was to be conducted at a later stage. Samples from the sea surface microlayer were obtained using a surface slick sampler (Guitart *et al.*, 2004), and the subsurface water samples were obtained at 2 meters depth with 2.5 litre Winchester amber glass bottles using a custom-made stainless steel and Teflon sampling device (Kelly *et al.*, 2000; Law *et al.*, 1988).

Methods

The unfiltered seawater samples were extracted by liquid-liquid extraction with dichloromethane. For 2.5 litre samples of subsurface seawater (SSW), a triple extraction was used with 2 x 50ml and finally 1 x 25ml. For the 0.5 litre samples of the sea surface microlayer (SML), 2 x 25 ml and 1 x 15ml of dichloromethane were used. Surrogate solutions were made up for 1-octadecene, acenaphthene-d_{10}, phenanthrene-d_{10} and chrysene-d_{12} at a concentration of 5 ng/µl in methanol. All of the samples were spiked with 50 µl of each surrogate solution to yield a final concentration of 100 ng/l and 500 ng/l of each compound for the 2.5 l (SSW) and 0.5 l (SML) samples, respectively. Samples were extracted, reduced in volume down to 50 ml using a rotary evaporator, dried with anhydrous sodium sulphate, and transferred to vials to provide a final volume of 500 µl. Triphenylamine (50 µl) was also added as an internal standard. The fuel oil sample from the original oil spill was directly weighed and dissolved in dichloromethane and subsequent dilutions were made prior to analysis by coupled gas chromatography-mass

Figure 3. Coastal and offshore sampling locations in Lyme Bay surveyed in January 2007.



spectrometry (GC-MS) with a programmable temperature vapourising (PTV) injector.

GC-MS analyses were performed using an Agilent 6890 gas chromatograph interfaced with an Agilent 5973N mass spectrometer fitted with an inert source. Instrumental control, data acquisition and quantification were performed using Agilent ChemStation software. A capillary column HP-MS 5 (5% diphenyl / 95% dimethylsiloxane; 30 m x 0.25 mm id, 0.25 µm film thickness) was used to resolve the target analytes. A large volume injection (LVI) technique was used to inject 20 µl of extract using a PTV injector. Liquid CO_2 was used to cool down and stabilise the inlet at the injection temperature of 40°C. Solvent vent mode was used, with a vent flow of 200 ml/min for 0.20 minutes. The splitless purge time was 0.80 minutes ramping the inlet to 280°C at 650°C/min. The helium carrier flow was maintained at 1 ml/min. The oven temperature program was 1.05 minutes at 40°C, 4.20°C/min to 235°C, 3.60°C/min to 310°C and held at 310°C for 3.69 minutes, to provide a total run time of 72 minutes. The transfer line temperature was set at 280°C.

MS operating conditions were optimised by the autotuning software. The SCAN/SIM synchronous facility was used both to screen the extracts for non-target compounds and to quantify target PAH compounds, respectively. EI mass spectra were acquired at 70 eV and were monitored from 50 - 450 Daltons in the SCAN mode. A SIM programme was established to acquire signals for characteristic fragments for the target PAH and alkylated-PAH. The ion source and quadrupole analyser temperatures were held at 230°C and 150°C, respectively.

Results and Discussion

Data obtained from the survey have been summarised by Readman *et al*. (2007) and described in detail by Guitart *et al*. (2008). Results indicated localised oil contamination from the *MSC Napoli*, primarily in the form of a surface slick with low-level contamination extending throughout an area of approximately 15 km radius from the wreck (Figure 4). Further away from the wreck, PAH levels throughout Lyme Bay were generally typical of those associated with unpolluted marine environments, with low levels of pyrolytically derived PAHs. Screening by PTV-GC-MS did not reveal the presence of any other chemical contaminants listed on the *MSC Napoli* cargo inventory resulting from spillage.

ΣPAH concentrations (the sum of the PAH determined; see Guitart *et al*., (2008, including the supporting information) ranged from 0.7 to 31 ng/l in the SSW samples, with the highest concentration observed at station 5, closest to the *MSC Napoli*. In the SML samples, ΣPAH concentrations ranged from 0.7 to 5,707 ng/l, with the highest concentration also at station 5. Enrichment factors (EF) in the SML

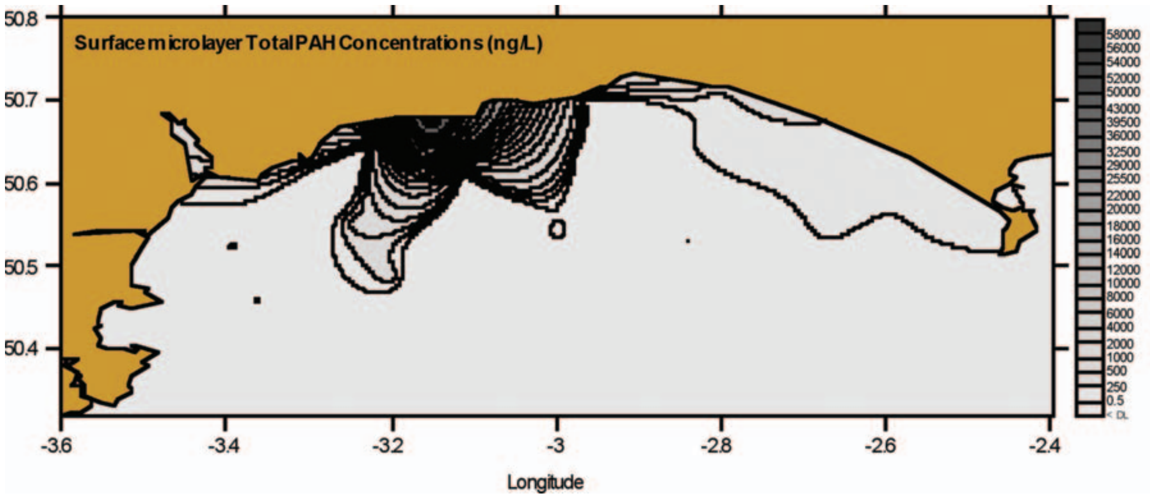
($EF = C_{SML}/C_{SSW}$) were calculated and, in the vicinity of the ship, approached 2000, declining with increasing distance from the vessel. The greatest of these factors represents approximately a 1000-fold enrichment over typical coastal SML enrichments and reflected clear (though localised) petrogenic contamination due to the oil released from the ship.

Figure 5a shows a chromatogram of the aliphatic fraction of the *MSC Napoli* heavy fuel oil (IFO 380). Chemical compositions of heavy fuel oils can vary widely as they are produced largely to physical rather than chemical criteria, often blending residual oils with diesel fuels or other lighter fuels. This results in a bimodal distribution of *n*-alkanes which is characteristic of such heavy fuel oils (Figure 5a). The first mode is centered at C_{14} with the second around C_{20}. In contrast, Figure 5b shows the aliphatic profile for the extract from the sample taken in the SML near the wreck where an oil sheen was visible. The distribution includes an unresolved complex mixture (UCM) that is characteristic of lubricating oils (lube oil) together with resolved *n*-alkanes in the C_{14}-C_{26} range, indicating a mixture with a lighter oil (such as diesel). Associated with the UCM is the presence of biomarkers (terpanes and steranes) which is a characteristic of lubricating oils such as transmission or hydraulic oil. Profiles of terpanes (m/z = 191) and steranes (m/z = 217) from the SML station 5 extract were clearly different to the profiles obtained for the fuel oil, in which terpane concentrations were very low and steranes were not detected (Guitart *et al*., 2008). From the analyses, the contaminated microlayer samples can therefore be linked to three sources of hydrocarbons: heavy fuel oil, lubricating oil and a lighter oil. The source of the contamination is more likely, therefore, to be the engine room/bilge water of the wreck, washed out through the fractured hull and containing engine and hydraulic oils.

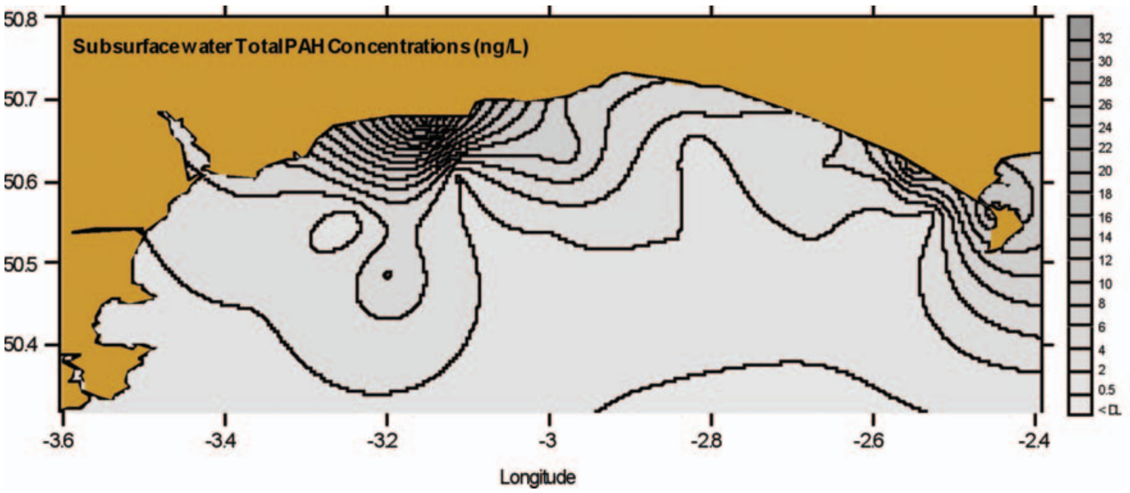
The PAH distribution patterns in the SML and the SSW samples also differed from those of the IFO380 oil. The heavy fuel oil sample was characterized by a high percentage of naphthalene and its alkylated homologues (> 60% of the total PAH) with phenanthrene and dibenzothiophene series comprising 18% and 12%, respectively (Guitart *et al*., 2008). It can be assumed from the spatial plots (Figure 4) that the elevated concentrations of total PAH in the sea surface microlayer close to the ship result from oils spilled from the *MSC Napoli*. Elevated concentrations at the same stations in the subsurface waters can be attributed to the dissolution of the lighter compounds from the surface slick (i.e. WAF). Fluoranthene/Pyrene ratios (Fl/Py) (Figures 6a and 6b),

Figure 4. Spatial plots of total PAH in Lyme Bay. a) concentrations (ng/L) in the sea surface microlayer (SML), b) concentrations (ng/L) in the subsurface water (SSW). Total PAH concentrations in the sea surface microlayer clearly depict the extent of the oil spill contamination.

a)



b)

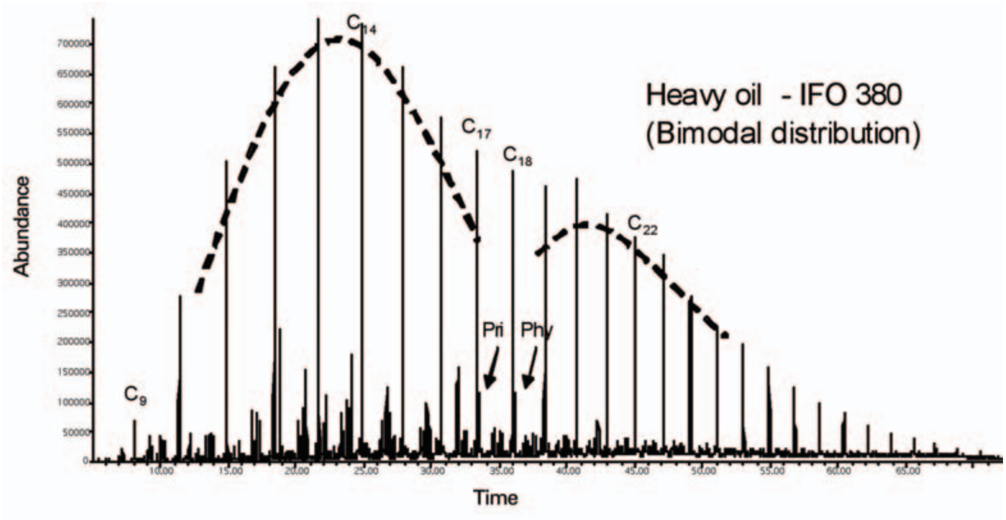


can differentiate between petrogenic (Fl/Py < 1) and pyrolytic (Fl/Py > 1) inputs. Beyond the localised area of the spill, PAH from pyrolytic sources were more dominant in the sub-surface waters, reflecting the general background contamination in the area. The petrogenic input due to the oil spill is, however, evident, especially in the surface microlayer in the vicinity of the *MSC Napoli*. This is shown to contaminate sub-surface waters close to the ship. Throughout the remainder of the bay, Fl/Py ratios are consistent with pyrolytic sources, with major inputs from the Exe estuary and Brixham harbour on the western side, and from Portland (i.e. runoff) on the eastern side. These are seen as patches with Fl/Py ratios > 1.

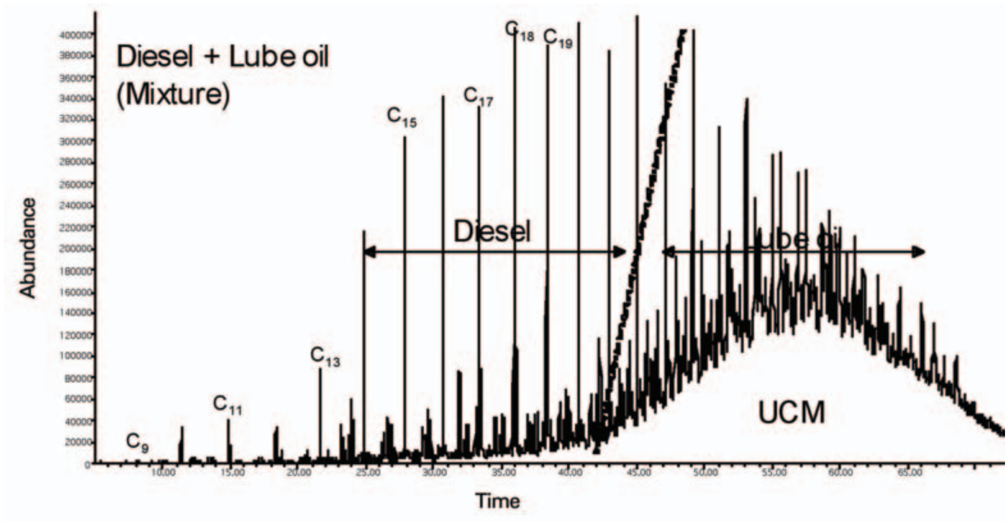
In summary, oil spilled from the *MSC Napoli* was primarily present as a localised surface sheen. From the analyses, the contaminated microlayer samples can be linked to three sources of hydrocarbons: heavy fuel oil, lubricating oil and a lighter oil.The source of the contamination was not, there-

Figure 5. a) GC-MS single ion chromatogram profile (m/z = 57) for aliphatic hydrocarbons in the *MSC Napoli* IFO380 heavy fuel oil and b) the sample taken in the sea surface microlayer at station 5 near the grounded vessel.

a)



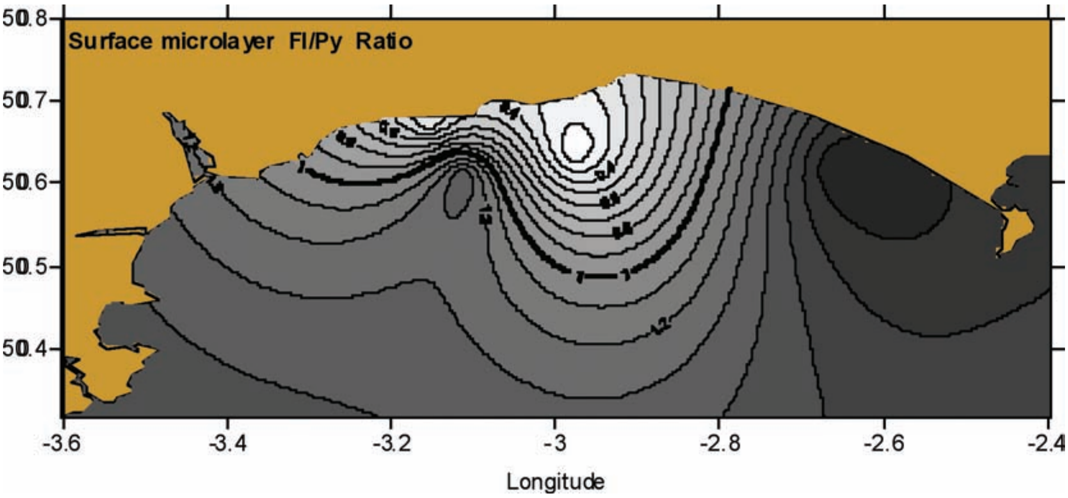
b)



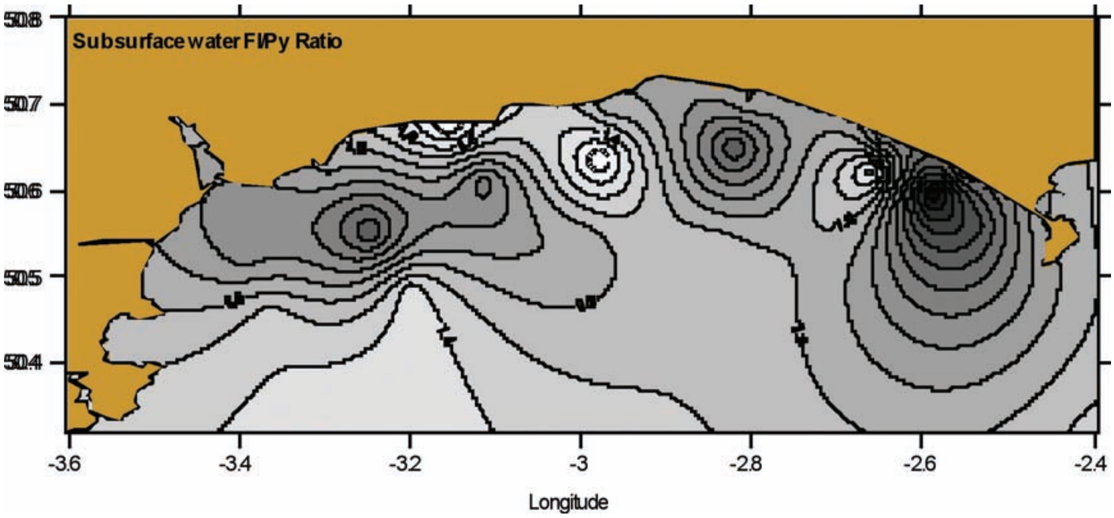
fore, only fuel oil and is more likely to have originated from the engine room/bilge water of the wreck, washed out through the fractured hull and containing engine and hydraulic oils. Transfer of PAH from the microlayer to the sub-surface water occurs to an extent, although spatially this appears more localised than surface microlayer contamination. Further away from the wreck, PAH levels throughout Lyme Bay were generally typical of those associated with unpolluted marine environments, with low levels of pyrolytically derived PAHs.

Figure 6. a) Spatial plot of Fl/Py ratios in Lyme Bay. The SML shows an important petrogenic input associated with the oil spill from the *MSC Napoli* superimposed on a generally pyrolitic background across the bay. b) The Fl/Py ratios indicate other sources of PAH contamination (e.g. from estuaries, harbours, runoff, atmospheric deposition etc) rather than the oil spill.

a)



b)



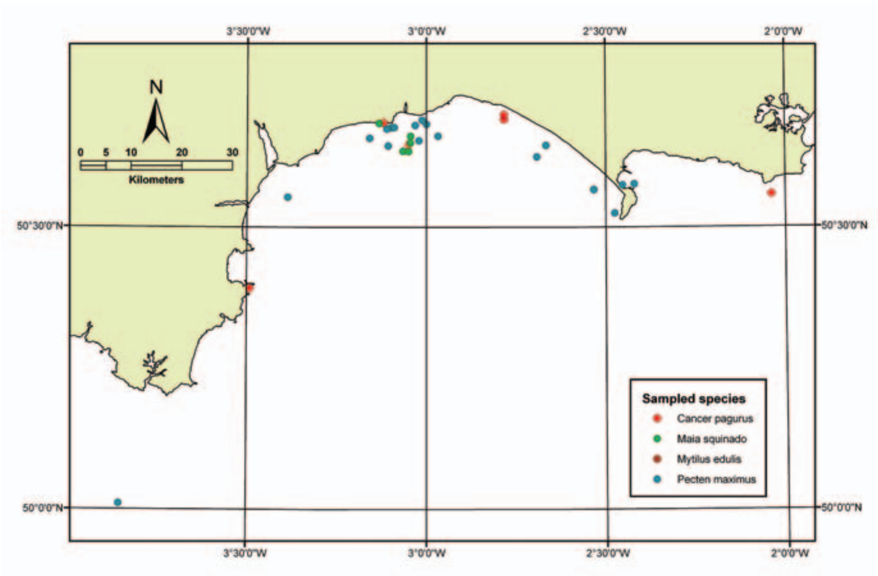
Commercial fish and shellfish monitoring undertaken by Cefas

Carole Kelly, Kerry Baker, Myriam Lunn, Philip Mellor and Robin Law

As spills of oil occurred soon after the grounding of *MSC Napoli*, it was important to assess any potential impacts on the human food chain and the local benthos. It was decided to instigate a monitoring programme using commercial shellfish from the area of Lyme Bay, as this would address both concerns. Oils contain toxic components known as polycyclic aromatic hydrocarbons (PAH). All of these have acute toxic effects and some of the larger PAH are potential human carcinogens, and so of particular concern for human consumption. As PAH occur naturally in oils and are produced by a large number of industrial and domestic activities, there is usually a low level of contamination in shellfish from all UK locations. In order to protect the human food chain, the UK Food Standards Agency has established guideline values for three of the carcinogenic PAH: 10 µg kg^{-1} wet weight for benzo[*a*]pyrene and 15 µg kg^{-1} wet weight for each of benz[*a*]anthracene and dibenz[*a,h*]anthracene. Exceeding any of these values following a spill may trigger fishery closures in order to prevent excessively contaminated shellfish being consumed. Samples of commercial shellfish (edible and spider crabs, mussels and scallops) from Lyme Bay and Portland Harbour were collected by fishing boats or, in the case of farmed mussels in Portland Harbour, by divers. They were frozen at –20°C and transferred to Burnham on Crouch by courier, then stored frozen prior to analysis. Sixty-four samples collected between 24th January and 22nd May 2007 were analysed. Total hydrocarbon and PAH analysis for a suite of parent PAH and their alkylated derivatives were conducted using well-established protocols (Kelly *et al.*, 2000). These involved alkaline saponification of tissues, solvent extraction, clean-up of the extracts on alumina, total hydrocarbon determination by ultraviolet fluorescence spectrometry and final determination using GC-MS. Analytical quality control involved the analysis of blanks and laboratory reference materials within each sample batch and the use of control charts. Sampling locations from which shellfish were collected are shown in Figure 7, and a summary of the PAH data is given in Table 1. The full dataset is presented as electronic supplementary information relating to Kelly *et al.* (in press), linked by the Laboratory Sample Numbers (LSNs) for the individual samples in Table 1.

In 1995-97, we undertook a survey of PAH concentrations from commercial shellfish beds around England and Wales. No scallops were analysed but, in mussels, summed PAH concentrations ranged from 40 to 11,500 µg kg^{-1} wet weight. The concentrations observed in Lyme Bay in 2007 are at the lower end of this range, although the earlier samples were exposed only to diffuse pollution and local point sources. Following the oil spill from the *Sea Empress* in Wales in

Figure 7. Locations in Lyme Bay from which shellfish samples were collected.
Summed PAH concentrations ranged from 7 to 568 µg kg^{-1} wet weight, with the highest concentration observed in scallops collected off Branscombe Beach in March. Concentrations in scallops and in one sample of mussels were somewhat higher than those in crabs, but only samples collected very close to the wreck (but outside the 500m exclusion zone) showed signs of contamination from the spilled oil. Even in these samples, concentrations were only slightly elevated relative to the general background.



1996, in which 72,000 tonnes of crude oil were lost, mussels from many sites within the fishery closure area showed summed PAH concentrations above 1,000 μg kg^{-1} wet weight and the highest concentrations observed, within Milford Haven, were > 100,000 μg kg^{-1} wet weight (Law and Kelly, 2004). Also within Milford Haven itself, summed PAH concentrations within the range 100 to 2,450 μg kg^{-1} wet weight were found in samples of edible crabs, velvet crabs and lobsters sampled during the 3 months following the spill (Law and Kelly, 2004). The concentrations observed in crabs from Lyme Bay in 2007 were lower than those seen during the *Sea Empress* incident.

The UK Food Standards Agency guideline values were not exceeded, and the three PAH for which these were set were not detected in any of the crab tissue samples. High molecular weight PAH are of low solubility and, in contrast to filter feeding animals such as mussels which accumulate PAH from their diet, crabs and finfish absorb PAH primarily from the water column via their gills. Therefore they mainly absorb low molecular weight PAH such as naphthalenes and phenanthrenes, as was observed following the *Sea Empress* spill mentioned earlier (Law and Kelly, 2004). These compounds are acutely toxic, but do not have any carcinogenic potential. In consequence, the toxic equivalent concentrations (a means of summarising carcinogenic potential across a range of PAH compounds) observed in crabs (BaPE values; calculated as in Law *et al.*, 2002) were 0.2 μg kg^{-1} benzo[*a*]pyrene equivalents or lower. In the single sample of mussels a BaPE value of 2.1 μg kg^{-1} benzo[*a*]pyrene equivalents and, in scallops, BaPE values ranged from 1.7 to 16.7 μg kg^{-1} benzo[*a*]pyrene equivalents. In the commercial shellfish survey of 1995-97 referred to above, the BaPE values in mussels ranged from 2.3 to 109 μg kg^{-1} benzo[*a*]pyrene equivalents as a result of general background contamination. In summary, the elevation of PAH concentrations in shellfish as a result of oil lost from the *MSC Napoli* was both modest and localised.

Table 1. Total hydrocarbon and summed PAH concentrations in shellfish from Lyme Bay (mg kg^{-1} wet weight Forties crude oil equivalents and µg kg^{-1} wet weight, respectively).

LSN	Species	Tissue	Date	Location	THC	∑ PAH
2007/00824	Edible crab	Hepatopancreas	24.01.07	off Branscombe Beach	9.0	17
2007/00825	Edible crab	Claw/body meat	24.01.07	off Branscombe Beach	1.6	8
2007/00822	Edible crab	Hepatopancreas	24.01.07	off West Bay	5.0	26
2007/00823	Edible crab	Claw/body meat	24.01.07	off West Bay	1.2	9
2007/00783	Edible crab	Hepatopancreas	24.01.07	off Portland, east end Lyme Bay	8.1	22
2007/00784	Edible crab	Claw/body meat	24.01.07	off Portland, east end Lyme Bay	1.4	7
2007/00952	Edible crab	Claw/body meat	31.01.07	off Portland, east end Lyme Bay	1.4	8
2007/00953	Edible crab	Hepatopancreas	31.01.07	off Portland, east end Lyme Bay	23	24
2007/01002	Edible crab	Claw/body meat	09.02.07	off Brixham	0.9	12
2007/01003	Edible crab	Hepatopancreas	09.02.07	off Brixham	3.2	ND
2007/01014	Edible crab	Claw/body meat	12.02.07	off Branscombe Beach	1.2	15
2007/01015	Edible crab	Hepatopancreas	12.02.07	off Branscombe Beach	5.5	36
2007/01020	Edible crab	Claw/body meat	13.02.07	off Brixham	1.1	11
2007/01021	Edible crab	Hepatopancreas	13.02.07	off Brixham	6.4	19
2007/01062	Edible crab	Claw/body meat	13.02.07	off West Bay	1.2	10
2007/01063	Edible crab	Hepatopancreas	13.02.07	off West Bay	5.4	16
2007/01191	Edible crab	Claw/body meat	22.02.07	off Portland, east end Lyme Bay	1.8	14
2007/01192	Edible crab	Hepatopancreas	22.02.07	off Portland, east end Lyme Bay	2.9	12
2007/01420	Edible crab	Claw/body meat	21.02.07	off Seaton	1.5	12
2007/01421	Edible crab	Hepatopancreas	21.02.07	off Seaton	9.8	29
2007/01426	Edible crab	Claw/body meat	17.02.07	off Seaton	1.2	16
2007/01427	Edible crab	Hepatopancreas	17.02.07	off Seaton	3.0	18
2007/01528	Edible crab	Claw/body meat	05.03.07	off Seaton	1.5	28
2007/01529	Edible crab	Hepatopancreas	05.03.07	off Seaton	1.8	ND
2007/01576	Edible crab	Claw/body meat	09.03.07	centre of Lyme Bay	1.4	18
2007/01575	Edible crab	Hepatopancreas	09.03.07	centre of Lyme Bay	14	ND
2007/02238	Edible crab	Claw/body meat	25.04.07	off Portland, east end Lyme Bay	1.2	9
2007/02239	Edible crab	Hepatopancreas	25.04.07	off Portland, east end Lyme Bay	1.4	12
2007/02948	Edible crab	Claw/body meat	22.05.07	off Branscombe Beach	1.5	13
2007/02949	Edible crab	Hepatopancreas	22.05.07	off Branscombe Beach	18	79
2007/02953	Edible crab	Claw/body meat	16.05.07	off Branscombe Beach	2.2	14
2007/02954	Edible crab	Hepatopancreas	16.05.07	off Branscombe Beach	16	48
2007/01434	Spider crab	Body meat	17.02.07	off Axmouth	2.2	13
2007/01433	Spider crab	Hepatopancreas	17.02.07	off Axmouth	2.9	33
2007/01524	Spider crab	Hepatopancreas	02.03.07	off Axmouth	1.6	ND
2007/01525	Spider crab	Body meat	02.03.07	off Axmouth	2.1	30
2007/02957	Spider crab	Body meat	16.05.07	off Branscombe Beach	2.3	14
2007/02958	Spider crab	Hepatopancreas	16.05.07	off Branscombe Beach	48	69
2007/01108	Mussel	Whole tissue	31.01.07	Portland Harbour	8.0	79
2007/00745	Scallop	Viscera	24.01.07	off Portland, east end Lyme Bay	8.6	ND

Table 1 continued. Total hydrocarbon and summed PAH concentrations in shellfish from Lyme Bay (mg kg^{-1} wet weight Forties crude oil equivalents and µg kg^{-1} wet weight, respectively).

LSN	Species	Tissue	Date	Location	THC	∑ PAH
2007/00758	Scallop	Gonad	24.01.07	off Portland, east end Lyme Bay	8.6	112
2007/00759	Scallop	Muscle	24.01.07	off Portland, east end Lyme Bay	2.1	24
2007/00768	Scallop	Muscle	24.01.07	off Salcombe	2.7	31
2007/00767	Scallop	Gonad	24.01.07	off Salcombe	9.2	ND
2007/00769	Scallop	Viscera	24.01.07	off Salcombe	8.6	ND
2007/00793	Scallop	Muscle	25.01.07	off Branscombe, 2 miles ENE of *MSC Napoli*	6.4	77
2007/00802	Scallop	Muscle	25.01.07	off Abbotsbury	2.5	29
2007/00781	Scallop	Muscle	25.01.07	off Axmouth	3.4	77
2007/00812	Scallop	Muscle	24.01.07	off Lyme Regis	3.3	32
2007/00940	Scallop	Whole tissue	30.01.07	off Abbotsbury	8.9	124
2007/00947	Scallop	Whole tissue	31.01.07	off Portland, east end Lyme Bay	5.7	106
2007/00969	Scallop	Whole tissue	08.02.07	off Axmouth, 5.1 miles ESE of *MSC Napoli*	15	162
2007/00970	Scallop	Whole tissue	08.02.07	off Beer, 2 miles E of *MSC Napoli*	26	ND
2007/01179	Scallop	Whole tissue	22.02.07	Portland Harbour	7.3	95
2007/01186	Scallop	Whole tissue	22.02.07	off Portland, east end Lyme Bay	6.4	107
2007/01415	Scallop	Whole tissue	26.02.07	off Beer	17	229
2007/01526	Scallop	Whole tissue	05.03.07	off Teignmouth	5.2	83
2007/01527	Scallop	Whole tissue	13.03.07	off Branscombe Beach	37	568
2007/01583	Scallop	Whole tissue	09.03.07	off Portland Bill	5.2	61
2007/01590	Scallop	Whole tissue	09.03.07	Portland Harbour	6.3	70
2007/02233	Scallop	Whole tissue	25.04.07	off Portland, east end Lyme Bay	3.8	32
2007/02875	Scallop	Whole tissue	19.04.07	off Charton Bay, 6.1 miles ENE of *MSC Napoli*	13	96
2007/02885	Scallop	Whole tissue	19.04.07	off Branscombe, 0.7 miles S of *MSC Napoli*	14	93
2007/02896	Scallop	Whole tissue	19.04.07	off Charton Bay, 5.75 miles E of *MSC Napoli*	19	139

Seabird necropsies and oil profiling

Steve Benn (compiler)

A major aspect of Natural England's response was to identify the rationale (including justification) and methods for dead seabird collection, collation, transport, storage, analyses (necropsy) and data capture. Consideration was also required for further storage and eventual disposal of the dead oiled birds. Paid contractors and trained members of non-governmental and voluntary conservation organisations (e.g. RSPCA, RSPB and DWT) collected live and dead oiled birds. Live birds were processed at various RSPCA centres in the south and midlands. Bird carcases were stored at pre-arranged sites. The carcases were transported from the collection points by contractors and delivered to the Natural England office at Wareham where they were stored in a mobile freezer prior to relocation to the Cefas laboratory at Weymouth for necropsy by the British Trust for Ornithology (BTO).

The BTO conducted analyses of the oiled bird carcasses to determine impact upon populations of seabirds affected. A summary of the findings are provided here and the full report may be found at the following web address;

http://www.naturalengland.org.uk/planning/coasts-seas/default.htm

Methods

Where possible, all birds were assigned to species or family level, aged where applicable on plumage, and scored according to the percentage of the plumage that was oiled according to van Franeker & Meijboom (2002). For guillemot *Uria aalge* and razorbill *Alca torda*, standard measurements were taken to determine age and sex of birds, and to assess their broad geographic origin. Including wing length (maximum chord; Svensson 1992). Wing length in both auk species increases with latitude, so this gives some indication as to the natal origin of individuals involved in the spill. The guillemots were additionally assigned a score as to the state of moult on the head (white-headed, moulting or brownheaded), and noted the presence/absence of white tips on the greater underwing coverts. In order to age the guillemots, the following classes were established:

- Birds with an obvious "bursa of Fabricius" were classed as juveniles (first-years)
- Birds with a fully brown head, or moulting into this plumage, were classed as subadults/adults. This follows work by Nevins & Carter (2003) that states that adults and older sub-adults moult into alternate (summer) plumage through the winter (October to February) whilst first-year birds do not moult until May or later.
- Degree of ossification of the supra orbital ridge (SOR). This ridge, which is located at the edge of the salt gland depression, is cartilaginous or non-existent in the youngest birds (SOR=1), and ossifies with age, forming a thickened ridge in the oldest individuals (SOR=7). The scoring for the supraorbital ridge used here was taken from Nevins & Carter (2003). Birds with a well-ossified skull (SOR=5) were classed as sub-adults/adults and those with a fully ossified skull (SOR=6 or 7) were classed as adults (Soldaat, 2007).
- Males with testis width of greater than 2.5 mm and female with an ovarian follicle diameter greater than 1.5 mm were classed as adults, following work by Anker-Nilssen *et al.* (1988). These birds with wider testes or ovarian follicles had a high likelihood of past breeding activity.

For razorbill, the birds were classified into four age groups according to the structure of the bill after Anker-Nilssen *et al.* (1988), where juveniles = no white bands or grooves on bill, immatures = white band on bill but no grooves, sub-adults = white bands on bill and single groove, or adults = white band on bill and two grooves.

Internally for both auk species, the birds were examined for the presence or absence of a juvenile organ the "bursa of Fabricius", and the size of the sexual organs (diameter of largest ovarian follicle in females and width and length of the left testis in males) were recorded. From a sample of oiled and nonoiled auks, liver tissue and oiled feather samples were taken for future toxicological analyses. Following post-mortem, birds were refrozen and stored at the Natural England regional offices in Arne, Dorset.

Results

In total, 306 corpses were processed, although many of these were incomplete or very old and skeletal. Despite this, most could still be identified to species. The majority of birds were guillemot and razorbill, and numbers of each species are shown below in Table 2.

Table 2. Species list for dead collected birds.

Species name	Fresh corpses	Old corpses
Fulmar *Fulmarus glacialis*	1	3
Gannet *Morus bassanus*	0	4
Black-headed gull *Larus ridibundus*	1	0
Lesser black-backed gull *Larus fuscus*	0	1
Herring gull *Larus argentatus*	1	4
Great black-backed gull *Larus marinus*	0	2
Kittiwake *Rissa tridactyla*	1	2
Unidentified large gull	0	1
Guillemot *Uria aalge*	141	27
Razorbill *Alca torda*	82	22
Little auk *Alle alle*	0	1
Unidentified auk	12	0
Totals	**239**	**67**

Oiling

Many of the corpses were too decomposed or waterlogged to accurately assess the extent of oiling, but this was possible on 287 birds. Of these, 88 showed no external signs of oiling, with the remainder showing varying degrees of oiling. Samples of liver were taken from a selection of birds, both oiled and clean, for future toxicological analyses, and samples of oil were taken in the form of clipped oiled feathers from 13 of these birds.

Sex and age structure

Through internal examination of the sexual organs, it was possible to determine the sex of 142 birds. For razorbill, the ratio of male:female was 1:2.3 and for guillemot was 1:1.

It was possible to identify the majority of guillemots as sub-adults, adults or juveniles, although a sample of birds remained for which criteria were not conclusive to assign these to one or other age group, see Table 3. A majority of the birds aged were adults (77%), with 20% classed as subadult/adult and 3% as juvenile. Birds of unknown age (60 individuals) were more likely to be subadults or juveniles than adults, as they did not fall into any of the three adult criteria listed above (head moult, SOR, testis/ovary size), though this was unclear.

Table 3. Age classes of guillemots found following the *MSC Napoli* incident.

Age	Number (% of aged birds)
Juvenile	3 (3%)
Sub-adult/adult	22 (20%)
Adult	83 (77%)
Unknown	60
Total	**168**

For razorbill, the majority of birds were adults or sub-adults (82% of aged birds), whilst 18% were juveniles or immatures.

Comparing the sex of guillemots and razorbills in relation to age, in the latter there was a greater proportion of females in all ages classes. In guillemots, though, 63.6% of adults of known sex were male, whereas in all other age categories (including unknown) only 26.5% were male, see Table 4.

Table 4. Sex composition in relation to age of guillemots and razorbills found following the *MSC Napoli* incident.

		Male	Female	Unknown
Guillemot	Juvenile	1	1	1
	Subadult/adult	3	8	11
	Adult	35	20	28
	Unknown	5	16	39
Razorbill	Juvenile	2	3	11
	Immature	0	1	0
	Subadult	5	10	20
	Adult	9	19	15
	Unknown	0	4	5

Standard biometrics

Wing measurements (maximum chord) were taken from 142 guillemots and 96 razorbills. There was no significant difference in the mean wing length between the sexes in either species, although there was an age-related difference in wing length of razorbills, with juveniles tending to have shorter wings than sub-adults and adults.

The natal origin of guillemots and razorbills

A comparison between the wing length of guillemots from this study and wing measurements from breeding colonies and from the *Erika* and *Tricolor* oil spills was conducted. Colonies are ordered according to latitude, with an increase in wing length with latitude. This provides strong evidence that the majority of guillemots involved in the *MSC Napoli* incident were likely to have originated from colonies in the south of England, Wales or Ireland. This is supported by the fact that we found no birds of the 'bridled' form, which is more predominant in northern colonies (Birkhead 1984).

Barret *et al*. (1997) showed that there is also a strong clinal increase in wing length with latitude for razorbill. The mean wing length of 190.6 mm in this study shows that most birds are likely to have been of the *islandica* race (breeding in Iceland, the Faeroes, Britain, Ireland and France) and within this race are most likely to have been from a southerly population.

Ring recoveries

We have received details of 15 ringed birds involved in the *MSC Napoli* incident (13 guillemots and two razorbills). Individuals were all found along the coastline around Chesil Beach and reported in the days following the incident. These birds came from several breeding colonies where large numbers of birds are ringed, see Figure 8. These ring recoveries do indicate age and origin, though the distribution of ringing sites will be affected by ringing effort.

Great Saltee Island, Wexford, Ireland

- M51882 (razorbill) – ringed as a pullus in 1986
- X00795 (not oiled) – ringed as a pullus in 1991
- X46623 (not oiled) – ringed as a pullus in 1994
- X48821 (found in post-mortem sample) – ringed as a pullus in 1995
- R03773 – ringed as a pullus in 1999
- R11765 – ringed as a pullus in 2000
- R26407 – ringed as a pullus in 2001

Sanda Island, Strathclyde, Scotland

- T77986 – ringed as an adult in 1994
- X49978 – ringed as a pullus in 1998
- X36674 – ringed as a pullus in 2000

Skomer Island, Pembrokeshire, Wales

- X19947 – ringed as a pullus in 1995
- R07946 – ringed as a pullus in 2001

Other colonies

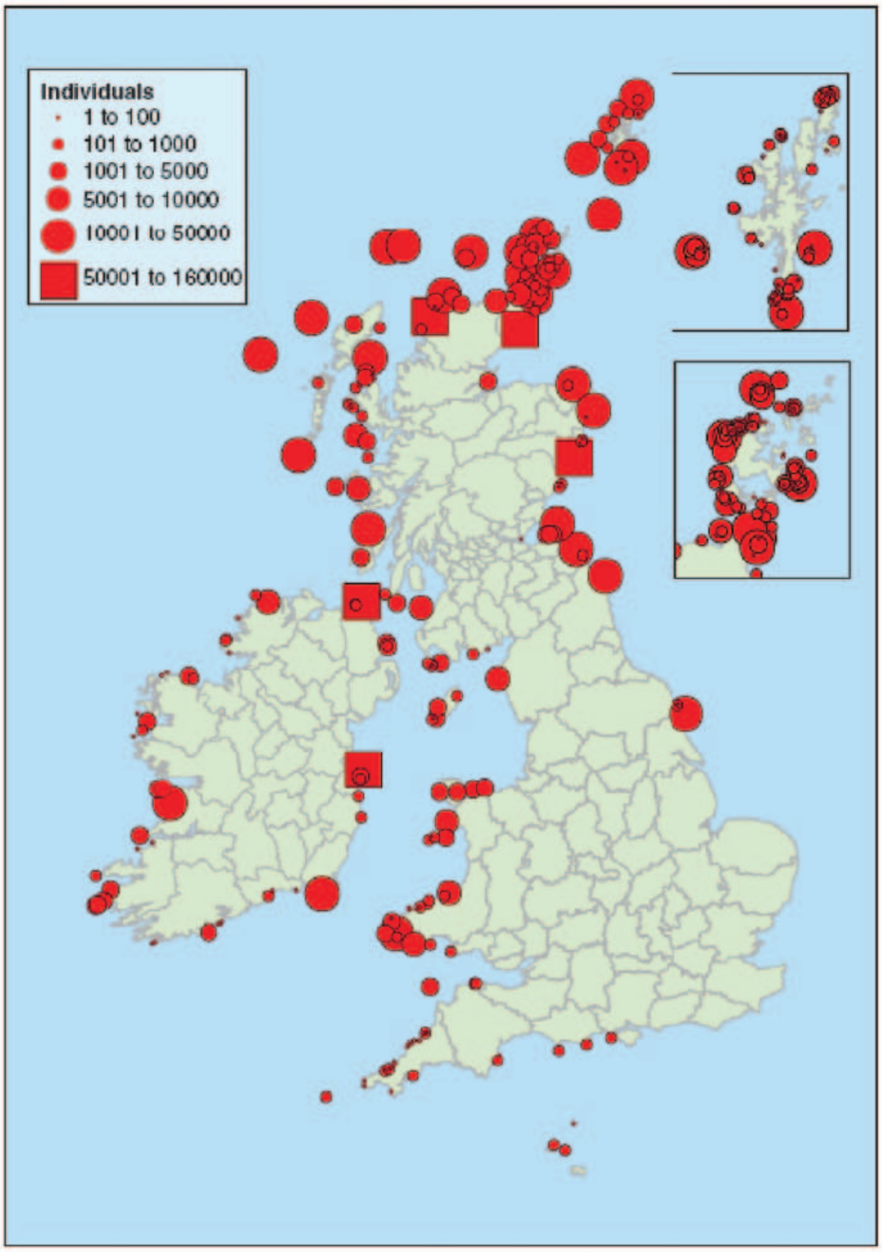
- T82747 – Ynys Gwylan Islands, Gwynedd, Wales, ringed as a pullus in 1998
- M96661 (razorbill, not oiled) – Fair Isle, Shetland, ringed as a pullus in 2002

Finally, (FRP) DA225561 was originally found following the Erika spill in December 1999. It was successfully rehabilitated, ringed and released off the Brittany peninsula in January 2000. It was subsequently found alive in Lyme Bay but later died in care.

Clipped oiled feathers from 13 of the collected birds were solvent extracted and the extracts fingerprinted by GC-MS at Cefas in Burnham on Crouch. The profiles of these oil samples were compared with chromatograms generated from authentic samples of the IFO380 heavy fuel oil from the bunker tanks of *MSC Napoli*. This provided confirmation that the oil on birds derived from the *MSC Napoli* (Law and Kelly, 2008).

The BTO conducted analyses of the oiled bird carcasses to determine impact upon populations of seabirds affected. In total 306 corpses were analysed. These consisted of ten species, the most common species being guillemots and razorbills. The analysis demonstrated that of the guillemots approximately 77% were adults and of the razorbills approximately 82% were either adult or sub-adults. This high concentration of mature birds can be expected to have a negative impact on the breeding population of both species. Further funding may be sought to assess these impacts. Historically, there has been a low survival rate of auk species (particularly guillemots) which have been rescued and released and which may therefore subsequently be washed up in the area. Collecting data on these birds is also important in determining the full environmental impact of the incident.

Figure 8. Distribution of guillemot colonies in Britain and Ireland, with colonies from which ringed birds recovered from the *MSC Napoli* oil spill originated highlighted. Reproduced from Mitchell *et al.* (2004), with permission from the Joint Nature Conservation Committee.



Benthic surveys in Lyme Bay

Steve Benn (compiler)

In the early stages of the incident, Natural England undertook to conduct a study to monitor the benthic ecology of the local area potentially impacted by the *MSC Napoli* grounding. This study involved the Devon Wildlife Trust as key partners, as they have an established history in monitoring the key species/habitats of nature conservation importance (i.e. pink sea fan) in the local area.

In the event, Natural England contracted two benthic surveys:

a) Marine Bio-images was contracted to use drop-down video to survey the seabed near the grounded vessel, with particular emphasis on the subtidal reef areas nearby, to assess whether significant impacts had occurred as a result of the grounded vessel.
b) Seasearch was also contracted to survey the seabed area close to the *MSC Napoli*, this time using divers.

This section provides an overview of both reports, for readers wanting to access the full reports, these are publicly available at the address below;

http://www.naturalengland.org.uk/planning/coasts-seas/default.htm

Video

Method

The area surrounding the *MSC Napoli* grounding was surveyed using a drop-down video system. This consisted of a Sony DV camcorder within a Gates underwater housing fitted with a wide-angle port, mounted in a custom-built stainless steel frame and connected to a surface colour monitor by a video umbilical. Video was reviewed in real time as the camera travelled across the seabed. The video was also recorded on to DV tape, for subsequent analysis and editing.

Video drop locations were selected at regular intervals, parallel to the shore, from approximately one nm east of the *MSC Napoli* to approximately one nm west of the *MSC Napoli* but keeping outside of the 500m exclusion zone. This process was then repeated approximately 500m further out, in slightly deeper water. A number of video drops were then conducted across the main reef areas within 2nm to the east of the *MSC Napoli*. These included the named reefs Beer Home Ground, Eastern Heads, West Tennants Reef, and Pinhay Settle.

The video survey was conducted from the 10m workboat Miss Pattie, working out of Lyme Regis.

Results

The Survey was undertaken between the 6th and 8th of August 2007. A total of 48 stations were surveyed. At each station, the video was allowed to drift close to the seabed for 2-5 minutes, to allow a reasonable amount of seabed to be observed. The time, location, depth and observations for each video drop can be provided on request.

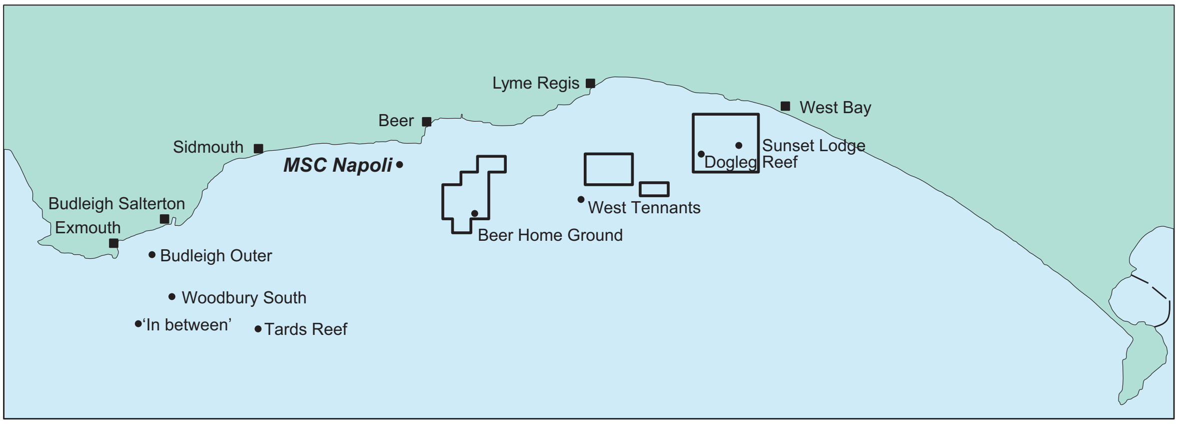
No obvious signs of contamination or physical damage from the *MSC Napoli* could be seen on any of the nearby reefs. Physical damage (numerous detached *Eunicella verrucosa* seafans) was noted on the West Tennants Reef; however this is most likely due to recent activity by mobile fishing gear, specifically scallop dredging, in the area. Given the distance from the *MSC Napoli*, and the lack of any observable debris in this area it is difficult to see how the grounding of the *MSC Napoli* could have caused this.

Some debris was observed on the seabed relatively close to the *MSC Napoli*, in approximately 10m water depth slightly to the east of the ship. This was in a relatively high energy area of cobbles, small boulders, algal turf and some erect sponges. No signs of physical damage due to mobile debris moving around could be detected on the video image.

Oiling of static fishing gear was also noted in this vicinity, with heavy oil coating pot floats. How recently this had occurred could not be ascertained, however it seems unlikely that fishermen would continue to handle oily gear for any length of time without either cleaning or replacing it given the inevitability of contaminating both boat and catch with oil.

Close to the ship (less than 1000m) the visibility deteriorated markedly. This was probably due to a combination of fine sediment seabed in this area (particularly in slightly deeper water) and the pumping out of the *MSC Napoli* bow section that was occurring throughout the survey period.

Figure 9. Map of Lyme Bay benthic survey area



Divers

Method

Seasearch was also contracted to survey the benthic area close to the grounded *MSC Napoli*, refer to Figure 9. This survey was carried out on 16th and 17th June 2007.

The surveys used established Seasearch volunteer survey methodologies involving different dive pairs completing general Seasearch Survey forms, or Seasearch Pink Sea Fan Survey forms with other divers taking photographs. This ensured that at least one survey form and one sea fan form was completed at each site. The survey team consisted of eight Seasearch surveyors. Information was recorded underwater using a slate and pencil with data being transferred to either survey or sea fan forms on return to the surface.

Seasearch Survey forms allowed collection of the following information:

- recorders divide the site into separate habitats and provide a description and qualitative information about seabed composition and features,
- Species are recorded in separate lists for each habitat using the SACFOR (Superabundant-abundant-common-frequent-occasional-rare) scale,
- Positions for each dive are recorded by GPS and dive times recorded,
- Depths are recorded by surveyors using dive computers, which also provide minimum temperature information, and,
- After the survey all depths are adjusted to chart datum, JNCC biotopes identified for each habitat and all of the data entered into the Marine Recorder database.

Pink Sea Fan forms allow collection of the following information:

- depth,
- habitat and density of sea fans at the site,
- detailed information about individual colonies comprising width, height, whether or not polyps extended, colour, condition (using a 1-5 scale),
- fouling species attached,
- fishing debris attached, and,
- presence of sea fan, sea slugs or anemones and their numbers.

Results

Habitat and species information

This section provides a summary of each site dived, for full details you are directed to the web site below. General locations of the dive sites are shown in Figure 9. Species lists for each site with abundances are provided in an appendix to the full report:

http://www.naturalengland.org.uk/planning/coasts-seas/default.htm

Site 1: Beer Home Ground (500 38.27'N 0030 02.79'W)

Habitat description

Smooth, flat mudstone bedrock at 20m below chart datum (bcd). Rock with thin covering of fine silt with sparse and damaged growth of sea fans and dead men's fingers. Small straight ledge (did not appear to be a natural feature) down to rock covered by small boulders, some obviously broken, cobbles and pebbles, again with a fine silt cover.

This site had the lowest number of species recorded during the survey weekend. Fauna was generally sparse with low, fast growing hydroids and bryozoans dominating. Amongst longer lived species pink sea fans were frequent, though a number were growing at an unnaturally flat angle with the sea bed and some were broken off at the base. King scallops were present in significant numbers.

This site has clearly been extensively dredged in the past. The flat surfaces are an un-natural feature and the preponderance of smaller species and damaged and bent sea fans are also the result of trawling. The site is currently within the voluntary closed zone for scalloping and the damage may well have been caused some time ago. There are numbers of small sea fans, dead men's fingers and potato crisp bryozoans all of which are signs of regeneration. However, overall, this is currently a highly degraded site.

Site 2: West Tennants Reef (500 38.80'N 0020 57.78'W)

Habitat description

An area of raised bedrock about 1.5m higher than the surrounding seabed and 21m bcd on its top. The rock had a flat plateau-like upper surface about 10m across with a length of at least 50m (the extent was not surveyed). There was a light cover of silt on the upper surfaces. The steep sides of the plateau had fissures and small overhangs inhabited by crabs and lobster. The lower surface surrounding the reef (23m bcd) had a mixture of small boulders, cobbles and pebbles lying on flat rock with a thicker covering of silt than on the rocky plateau.

The number and range of species recorded here was similar to Beer Home Ground. However the density of pink sea fans, soft corals and larger hydroids (especially antenna hydroid) was much higher. The raised rocky reef had a high density of pink sea fans with up to 5 colonies per square metre. Some sea fans were bent over or broken off. The lower surface had a considerable amount of broken fauna present. This included broken sea fans and many parchment worm tubes.

This site had both the highest density of sea fans of any of the sites surveyed in the bay and also the highest level of visible damage to the habitat. It was also surveyed in July 2006 and similar or worse conditions were recorded. The site has clearly suffered physical damage, but it seems unlikely that it has been in the last year. However it is not within the voluntary closed areas and could thus be dredged at any time. It may be that the height of the plateau above the surrounding seabed has provided a measure of protection.

Site 3: Dogleg Reef, West Bay, Dorset (500 40.76'N 0020 50.14'W)

Habitat description

The site comprised of a gently sloping silted rocky surface facing south-east. It was relatively smooth and featureless. At the upper end it was broken up into huge flat blocks of rock with vertical fissures between them. The rock is understood to be Blue Lias and is relatively soft and heavily bored with many small burrows in the surface, though it was not clear what the main boring organism is.

The smooth sloping rock surface was relatively sparsely covered in sessile fauna, though pink sea fans were common. Bryozoan crusts and chimney sponge, *Polymastia mamillaris*, were both common but whilst there was a good range of other sponges, hydroids, anemones, and sea squirts none were very numerous. The broken blocks had very little sessile fauna but were a habitat for fishes which were numerous and the fissures also provided a habitat for red tube worms, *Protula tubularia*.

The site had been previously dived in 2004, and no significant changes were noted. There was a number of sea fans detached and lying on the seabed. One intact colony had a plastic bag wrapped around it which was carefully removed, others had strings of squid eggs attached.

Of particular interest at this site was the presence of the snapping prawn, *Alpheus macrocheles*, a rarely recorded species.

Site 4: Sunset Ledge, West Bay, Dorset (500 41.08'N 0020 48.03'W)

Habitat description

The site comprised of an elongated rocky ridge running east-west with a 3m high vertical face on the northern side and a gently sloping face on the south side. The top of the reef had a depth of 15.5m bcd (the shallowest of the 4 sites surveyed) and the surrounding lower seabed to the north a depth of 22m bcd. The north-facing face (17.5-21.5m bcd) was overhanging in places and had many longitudinal fissures and crevices.

The upward facing surface of the ridge had a rich mixed faunal and flora turf characterised by dead men's fingers, sponges, anemones and low growing red seaweeds. The vertical/overhanging face had large numbers of anemones (especially the sandy creeplet, *Epizoanthus couchi*) and cup-corals (sunset, *Leptopsammia pruvoti*, and southern, *Caryophyllia inornata*) amongst sponges and bryozoans. The lower surface to the north of the ledge has a depth of 22m bcd. There were areas of exposed rock and boulders at the base of the wall. Away from the ledge the seabed consisted of poorly sorted sand and gravel ridges with occasional boulders and cobbles. Sea fans were present on this lower surface in small numbers.

The main feature of the site is the abundance of the nationally rare sunset cup-coral, *Leptopsammia pruvoti* and the southern cup-coral, *Caryophyllia inornata*. Lyme Bay is one of only five areas in the British Isles where the sunset cup-coral is known to occur. The others are Lundy, Isles of Scilly, Plymouth Drop Off and Sark (Channel Islands). The range of species recorded at this site was significantly higher than any other during the survey. It was also the one site with no evidence of recent or past damage from dredging activities. It is within one of the voluntary closed areas.

Pink Sea Fan records

Detailed records of sea fans were made at all four sites during the Seasearch survey and repeat previous records. The results are shown below in Table 5.

A comparison with previous records* (also collected by Seasearch staff but unrelated to the *MSC Napoli* incident) may be made at each site.

Table 5. Records of sea fans recorded in the Seasearch survey.

Site	Number recorded	Max width	Mean width	Max height	Mean height	Average condition	Abundance
Beer Home Ground	28	28	18.1	25	16.9	4.29	occasional
West Tennants							
(upper surface)	22	58	24.4	42	26.0	4.35	forest
West Tennants							
(lower surface)	9	45	21.3	32	19.4	3.00	occasional
Dogleg Reef	47	35	13.9	30	14.9	4.19	common
Sunset Ledge	14	40	18.9	30	15.5	3.5	occasional
Total	**120**	**58**	**17.9**	**42**	**17.8**	**4.07**	-

Beer Home Ground	Number recorded	Max width	Mean width	Max height	Mean height	Average condition	Abundance
June 2007	28	28	18.1	25	16.9	4.29	occasional
August 2004*	13	25	13.1	20	13.5	4.23	occasional

West Tennants	Number recorded	Max width	Mean width	Max height	Mean height	Average condition	Abundance
(upper surface) June 2007	22	58	24.4	42	26.0	4.35	forest
(lower surface) June 2007	9	45	21.3	32	19.4	3.00	occasional
July 2006*	24	50	24.0	20	13.5	3.42	common

Dogleg Reef	Number recorded	Max width	Mean width	Max height	Mean height	Average condition	Abundance
June 2007	47	35	13.9	30	14.9	4.19	common
August 2004*	7	41	21.6	25	18.1	4.29	forest

Sunset Ledge	Number recorded	Max width	Mean width	Max height	Mean height	Average condition	Abundance
June 2007	14	40	18.9	30	15.5	3.50	occasional
July 2006*	18	70	26.0	35	24.1	2.61	common

There are two main causes of declines in sea fan populations, benthic fishing and disease. Benthic fishing activities, scallop dredging in the case of Lyme Bay, lead to physical damage to sea fan colonies including breaking them off from the seabed and entanglement in fishing gear. There was ample evidence from Beer Home Ground, West Tennant's and Dogleg Reefs that such damage has been an issue at these sites. Broken sea fan colonies, in some cases still living, were photographed in 2006 and during this survey

Although both benthic surveys found evidence of damage to the benthic environment surrounding the *MSC Napoli*, neither survey was able to identify that this damage was caused by the *MSC Napoli* grounding. This is possibly due to size of area that needed to be covered and also because the immediate area, where it can be expected that most of the impact would be evident/obvious, was out of bounds due to the exclusion zone. However, we cannot assume that no damage has been caused, particularly when we consider the number of containers lost overboard, some of which were possibly dragging along the seabed for some considerable time before retrieval. Once the *MSC Napoli* has been fully removed there is an obvious need to undertake similar surveys at the exact location of the original grounding and also at the secondary site after the attempt to re-float the *MSC Napoli* and areas out to the boundaries of the original surveys.

Sublethal biological effects monitoring

Tamara Galloway

In collaboration with the Plymouth Marine Laboratory, scientists from the University of Plymouth (now at the University of Exeter) used combined biological effects monitoring techniques and chemical fingerprinting to undertake a rapid assessment of the impact of spilled oil and chemicals on the adjacent coastline. The aim of the study was to explore the relationship between contamination from the *MSC Napoli* and sublethal effects in the common limpet (*Patella vulgata*), a mollusc which inhabits the rocky shores around Lyme Bay. Limpets were chosen for study as they are grazers which occupy an important position in maintaining the ecosystem function of rocky shores. They are also considered highly vulnerable to the toxic effects of petroleum hydrocarbons. The biological effects testing regime selected in this study was chosen to monitor the sublethal effects of petroleum and included biomarkers of cellular function (cell viability, phagocytic index), oxidative stress (total antioxidant status, glutathione reductase activity) and genetic damage (Comet assay). A measure of exposure to organophosphorus insecticides (acetylcholinesterase activity) was also included as these were amongst the cargo of *MSC Napoli*. For this study, three locations within Lyme Bay were studied, and two reference sites in Cornwall and Devon were sampled for comparative purposes.

In the aftermath of the grounding, during January 2007, significant differences were evident in biomarker responses in limpets collected from the shoreline at Branscombe Beach, Lyme Bay and Chesil Cove, reflecting more stressful conditions at sites down-tide of the *MSC Napoli* compared with control sites. Although oil contamination appeared to be restricted to a surface slick in the vicinity of the wreck, biomarkers of cytotoxicity and immunotoxicity (cell viability and phagocytosis, respectively) were reduced in samples of common limpets from Branscombe beach, close to the wreck (Galloway *et al.*, in prep.).

A second collection of limpets and winkles was made during July, around the time when explosives were used to break the vessel into two parts. Ecotoxicological testing showed further impairment of cellular function in these animals, and chemical fingerprinting using GC-MS indicated that oil swabbed from their shells matched the IFO380 heavy fuel oil carried by the *MSC Napoli*. At this time, analysis of further samples of limpets using the Comet assay indicated that the proportion of DNA damage observed in limpets from Branscombe were significantly higher than in those from a reference site at Port Quin. The mean value was higher by approximately a factor of 4 times.

In conclusion, these results illustrate the value of combining biomarkers of sublethal effect with chemical analysis for determining which pollutants are responsible for biological degradation and which are not. The overall ecological impact on the biomass of limpets from impacted areas awaits confirmation.

Assessment of impact

Robin Law

Initial assessments of the dangerous goods manifest by Cefas identified the most hazardous chemicals and prioritised these for removal. In the event, because of the restricted space within and around the stacks of containers within the ship this proved impossible and the salvors proceeded downwards in each hold in turn. The stowage plan was coded, though, so that the salvors would know when particularly hazardous materials were being removed. From the viewpoint of aquatic toxicity, a pyrethroid insectide (lamda-cyhylothrin) represented the worst case. It was estimated that one drum of the pure compound carried the potential for acute toxicity within a 6km by 6km area in a water depth of 30m. In one container, 3.5 tonnes of the formulated insecticide was held in 16 drums, but the concentrations of the active ingredient were not given. Other pesticides present within the cargo included carbendazim, profenfos, propaquizafop, fluazifop-p-butyl and glyphosate. This last weedkiller was carried in four containers totalling 66.6 tonnes. Amongst the other chemicals carried were diphenylamine, dibutyl tin oxide, p-dichlorobenzene, isophoronediamine, phosphorus, solvent naphtha, tetrachloroethylene and xylenes. Such a mixture of dangerous goods is not by any means unusual on a medium- to large-size container ship. Overall, it was determined that there was a serious risk of major environmental damage if these chemicals and the oil were released into Lyme Bay, particularly as the prevailing winds and tidal currents would spread pollution along the coast to the east, towards Chesil Beach and the Fleet, considered the most vulnerable intertidal areas.

Of the 4,000 tonnes of oil on board the *MSC Napoli* when she first got into trouble, most was safely transhipped and removed and only around 150 tonnes of oil, mainly from the flooded engine room of *MSC Napoli*, was lost in Lyme Bay. Most of this oil rapidly came onshore and was removed by contractors retained by the owners and insurers of the vessel, along with most of the containers and their contents. No dangerous goods containers were lost into the sea, and they were all taken ashore safely in Portland Port where they could be emptied without risk of contamination of the sea. Containers which sank between being lost from the vessel and the beach were located by sonar surveys and divers and were recovered to shore.

Contamination of both the water column and shellfish in Lyme Bay due to oil lost from *MSC Napoli* was modest, localised and would not be expected to persist.

Lessons learnt

Robin Law

Standing Environment Groups proved their worth during the *MSC Napoli* incident, as the Environment Group formed to advise the responders worked together smoothly and effectively from their first meeting on 20th January 2007.

Toxicity testing of hold water proved to be a very effective means of assessing the threat posed by concentrations of a broad range of chemicals. This was the first incident in which this approach was used as a control measure. More detail can be found in Kirby *et. al.* (2008).

This was also the first incident in which a grounded container ship was unloaded to shore. It was fortunate that Portland Port was available for this purpose, with little traffic of its own, but was still a technically difficult and demanding operation. To repeat this for the largest container ships now at sea, more than three times the size of *MSC Napoli*, would be a vastly more difficult operation. This would greatly extend the timescale of the salvage operation and the scale of the environmental monitoring required for impact assessment.

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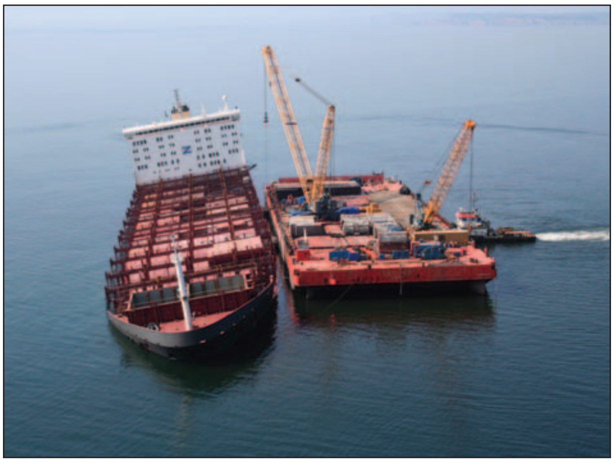
Photographs

MSC Napoli grounded in Lyme Bay, 20 January 2007

Booming around the *MSC Napoli*.

Transhipping oil from *MSC Napoli* to the *Forth Fisher*.



Removing containers from the *MSC Napoli*.

Protective boom in place at an estuary mouth.

Processing containers in the "hospital" at Portland Port.

Refloating the *MSC Napoli*.

The bow section of *MSC Napoli* arrives in Belfast for recycling.

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