ECOLOGICAL, ECONOMIC AND SOCIAL COSTS OF MARINE/COASTAL SPILLS OF FUEL OILS (REFINERY RESIDUALS)

Photo: Adala Leiro, Clean-up operations, Prestige spill, San Vincente beach, Bay of Biscay, 2002

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Introduction

For several centuries Northern hemisphere maritime trading nations have dreamed of, and struggled to discover, sea routes through the Arctic ocean in order to generate greater connectivity, and shorter, cheaper journeys, between the trading ports of Europe, north America, Asia and Russia. Such dreams have been thwarted, by both seasonal and permanent icing of the polar seas, and the major difficulties of navigating sub-polar seas in the context of icebergs and extreme weather conditions.

There is now, however, a broad scientific consensus that both permanent and seasonal sea ice cover in polar and sub-polar seas are steadily reducing in response to climate change. This factor, coupled with the growing demands of maritime trade for shorter, quicker and less expensive sea routes around the northern hemisphere is generating a significant increase in vessel traffic through Arctic and sub-polar seas.

In 2009, the Arctic Council's Arctic Marine Shipping Assessment report estimated that approximately 3,000 ships operated in truly Arctic waters, while another 3,000 were annually using the North Pacific Great Circle Route, roughly adjacent to the Aleutian and Kuril islands. The report stated that: "natural resource development and regional trade are the key drivers of increased Arctic marine activity." Thus it is no surprise that fishing vessels, oil/gas/mineral carriers, community supply ships and cruise ships represent the bulk of such traffic through the Arctic and sub-polar seas.

In September of 2009, two German cargo ships completed the first commercial passage from South Korea to the Netherlands via the Northern Sea Route, along the Arctic north coast of Russia. This route is generally considered less difficult than the North West Passage, which transits through the Canadian Arctic Archipelago.

According to a 2014 report issued by the Arctic Institute (a Washington based think tank) 71 ships carried 1.35 million tons of goods through the Northern Sea Route route in 2013. That was up from 46 vessels with 1.26 million tons of cargo in 2012. In total, 41 vessels traveled the full length of the Arctic shipping lane (Asia to Europe), and of those, 30 ships carried cargo, the report said. Most of the remainder of the new traffic through the Northern Sea Route was one-way shipments of fossil fuels from Northern Europe to Asia, or was between Russian ports.

Since the first crossing of the North West Passage by Amundsen in 1906, on average, less than 1 ship every ten years had completed the full passage until 1969, when the oil tanker SS Manhattan, refitted with an ice-breaker bow, crossed the Passage from east to west, and then returned east. That trip resulted in ten transits being recorded that summer, as four icebreakers escorted the oil tanker. The number of completed trips through the Arctic Ocean increased in the late 1970s, mostly due to the availability of icebreakers and other ships capable of navigating in difficult northern waters.

A record number of vessels (30) transited the North West Passage in 2012. In 2013, for the first time, a large bulk carrier (coal) transited the North West Passage. Only 17 vessels managed the full North West Passage in 2014, due to a short and cold summer.

In 2014, in the context of increasing traffic volume in what are considered to be some of the most significant high risk areas for global shipping, the International Maritime Organization (IMO) adopted the Polar Code. The Polar Code is widely regarded as a positive step towards protection of polar marine environments and will enter into force on January 1st 2017. However there is an emerging body of concern that the Code has failed to address the fact that refinery residual fuel oil spills (Heavy Fuel Oils [HFO] and Medium Fuel Oils [MFO]) are widely identified as the major risk posed by shipping to Arctic environments and wildlife and that, although fuel oil use and carriage in the Antarctic has been banned, those same fuels are permitted in the Arctic.

This report offers a brief review of the behavior and fate of both HFO and MFO spills in polar, sub-polar and similar cold water marine environments. The report also offers a brief review of the impacts of such spills and the relative "costing" of some of the impact parameters of such spills.

1 Medium and Heavy Fuel Oil: generic features and characteristics

1:1 MFO & HFO are a complex group of hydrocarbon products often referred to as "refinery residuals" because they consist of the highly viscous and tarry residues of the crude oil refining process from which the "lighter" more volatile components (e.g.petrol, diesel) have been distilled off.

1:2 Refinery residues consist of "heavy" compounds that are less prone to evaporation and distillation. By their nature and definition such compounds are less prone to degradation in the environment and are thus recognised as environmentally persistent.

1:3 MFOs and HFOs are NOT a chemically uniform product and their components are present in varying percentages that are dependent on the crude oil from which the residuals have been derived. Residual heavy compounds include bitumen, asphaltenes and long chain poly aromatic hydrocarbons (petrogenic PAHS). Waxes derived from the cleaning of crude oil storage tanks are also often added to refinery residuals. Mineral pollutants such as sulphur and heavy metals (vanadium, nickel etc), derived from the base load crude oil, may also be present in relatively high quantities. Such residues are then blended with a small amount of "lighter" fuels in order to reduce their viscosity and improve handling and pumping.

1:4 Thus the characteristics of MFOs and HFOs will depend on the baseline properties of the crude oil(s) from which the residuals are derived as well as the nature of any other products (including diesel) added in order to improve pumping/flow, handling and combustion. [Ref 1]

1:5 Because they are refinery residuals, MFOs and HFOs are relatively cheap and are much favoured as a marine fuel, especially for larger vessels such as tankers, bulk carriers and container ships.

1:6 In the case of a marine spill of MFO and/or HFO, a specific understanding of the chemical constituents of any spilled fuel oil will almost always require detailed analysis of spill samples and CAN NOT be based solely on the trade definition or nomenclature of the subject oil.

1:7 Trade definition and product nomenclature of Fuel Oils is itself a source of considerable confusion across the globe. Fuel oils are variously defined as Bunker A, B or C; Fuel Oil No 2,3 or 6; MFO or HFO.

1:8 The Bunker A –C scale is roughly equivalent to the ASTM (American Society of Testing & Materials) fuel oil scale, however the French classification uses a reverse numbering system to the ASTM scale and caused confusion in the early phase of both the Erika and the Tanio spills. Early reports for both spills correctly stated that the oil involved was No 2 Fuel oil by the French classification (HFO), which is very different from the No 2 Fuel oil (diesel) on the ASTM scale.

1:9 For the purposes of this report the fuel oils under discussion will be identified as Bunker C/HFO, or Bunker B/MFO.

2 Environmental characteristics of spilled HFO and MFO

2:1 Behavior and long term fate of oil spilled into marine/coastal environments is directly related to the type of oil involved. Most liquid hydrocarbons are characterised by the tendency of the oil to spread into a slick over the water surface. However Bunker C/HFO, Bunker B/MFO and some heavy crudes, with a high viscosity and a pour point higher than the ambient water temperature, are the exception and have a strong tendency to solidify rapidly and form tar lumps in marine waters.

2:2 The high degree of viscosity of Bunker C HFO/Bunker and Bunker B/MFO is more pronounced in cold waters and exacerbated by cold winter temperatures. This means that both oils do not readily disperse or naturally degrade and are thus environmentally highly persistent in such environments.

2:3 Due to its deficiency of "lighter" compounds there may be no sea surface sheen to aid detection of HFO/MFO spills from aerial observations.

2:4 The high specific gravity of both HFO and MFO means that they are characterised by low buoyancy and may NOT float on the sea surface. Weathering and other processes may cause the viscosity to increase and render it more solid and less buoyant. The negative buoyancy (sinking) of HFO/MFO has been reported on many occasions as a result of a number of factors including:

a it's initial very high viscosity
b reducing salinity of coastal waters (glacial ice melt, fluvial inputs in estuarine areas)
c degradation/weathering of lighter fractions out of the spilled fuel oil
d AD-sorbtion onto the outer surface of sediment particles suspended in the water column, this is of particular relevance in the near shore zone where suspended sediment loading is likely to be higher than in the open ocean.**[Ref 2]**

2:5 The longer term fate of such sunken oil is multiple and complex, but includes the likely burial/incorporation beneath fresh sediments in near shore waters or stranding by waves and high tides along the intertidal zone. **[Ref 2]**

2:6 However, sunken/submerged oil does not always remained submerged. In the case of the THUNTANK spill in the Baltic Sea (Dec' 1986), the cargo of spilled fuel oil was denser than the surrounding water and sank. But, as the water temperature increased through the subsequent summer the oil became more liquid and buoyant, re-floated and was washed ashore during rough weather. Repeated shoreline oiling re-occurred near the spill site in the summers of 1987,1989, 1990 and 1991.

2:7 A similar phenomenon was observed during the Erika spill when oil stranded on the coast became mixed with sediment in the surf zone, sank to the seabed and was subsequently carried into shallow waters close to the coast by tides and wave action. A series of storms later transported the submerged oil back onto the coastline and beaches, many of which had been previously cleaned. It was additionally noted that as ambient water temperatures increased during the summer, much of the oil became more fluid and worked loose from the sand, stones, sea weed and other debris to which it had been attached. **[Ref 1]**

2:8 MFO and HFO are well reported to undergo water in oil emulsification when spilled into marine environments. In the case of the Erika spill, storm conditions and vigorous wave action generated the production of highly viscous “chocolate mousse” water in oil emulsion that was deduced to have a life span stability of at least 3 days under the ambient conditions of the Bay of Biscay. It was noted however, that under lower temperature conditions or incorporation into beach sediments, the life span of such emulsions might be prolonged for several weeks.

2:9 Many workers have observed that water in oil emulsions, derived from MFOs, HFOs and “heavy” crudes, occurred much sooner under winter conditions (sub-polar and polar air & water temperatures) where oil viscosities are increased by exposure to lower temperatures and in the presence of sea ice. **[Ref 3]**

2:10 MFO and HFO can cause damage to intertidal organisms due to smothering or displacement from shoreline substrates. Both MFO and HFO contain a range of toxic compounds, but generally have a lower proportion of short lived environmentally acutely toxic, aromatic hydrocarbons than “lighter” fuel oils.

2:11 By contrast, because the short lived (acutely toxic) aromatic hydrocarbons have been distilled off, both MFO and HFO contain a higher proportion of the longer lived, very environmentally persistent, less acutely toxic, hydrocarbon compounds (including the petrogenic PAHs) than most other oils. Such long lived compounds are as bio-available as the short lived acutely toxic compounds and present a significant long term, chronic biological threat to marine life. **[Ref 4]**

Case studies of fuel oil spills

3 Prestige oil spill, Spain/France 2002

3:1 On 13th November 2002, the tanker Prestige carrying a cargo of 77,000 tonnes of HFO suffered hull damage in heavy seas off northern Spain. She developed a severe list, began to drift towards the Spanish coast and was eventually taken in tow by salvage tugs. It is reported that the Prestige requested shelter in a "Safe Haven" port, but was refused and ordered out of territorial waters by the authorities of France, Spain and Portugal. Following the denial of Safe Haven salvors had no option but to tow the vessel out to sea and away from the coast. Six days later (19th November) the vessel broke in two some 170 miles/250 kms, north west of the Spanish coast. The two sections of the hull sank some hours later in waters about two miles deep.

3:2 The spilled oil drifted for extended periods under the influence of winds and currents. Oil first came ashore along 200 km of the Galician coast (Nov' 16th & 17th), before the ship had sunk. Subsequently, in response to shifting wind directions, the majority of the oil stranded along the north coast of Spain and the Biscay coast of France as far north as Brittany. It was estimated that between 1,900kms and 3,000kms of Portuguese, Spanish and French coastline were oiled.

3:3 After the initial clean-up was complete, it was estimated that approximately 63,000 tonnes (around 80%) of the HFO cargo were spilled from the Prestige. However this was later significantly revised upward.

Photo: Prestige break-up off Spanish coast

3:4 Safe haven / port of refuge issues: One of the major causes for the very widespread marine and coastal oiling impacts, and the subsequent wildlife mortality, was the decision of the Spanish (in the first instant), and subsequently, the French and Portuguese governments, to refuse Safe Haven and force the captain of the Prestige to take the vessel into offshore waters where she sank and spilled her cargo of HFO.

3:5 Since the Prestige spill, the European Commission, with the support of the IMO, EMSA and others has initiated a series of proposals for the identification and use of European Safe Havens/Ports of Refuge where damaged vessels may seek safety and shelter in an environment where offloading of hazardous and polluting cargo may be facilitated and repairs may be possible. The proposals urge coastal nations to identify such Safe Havens within their jurisdiction, to consult with local/regional authorities and to consider the stockpiling of relevant response equipment adjacent to such sites.

3:6 Such a policy is plainly highly relevant to the very exposed and extreme Arctic and sub-polar sea routes, but as of yet there appears to be little sign of such an initiative along the Arctic or near Arctic shipping routes and no Safe Havens have been formally identified in Arctic or sub-Arctic waters.

3:7 Response effort at sea: A major offshore clean-up was initiated to prevent pollution of coastlines. Vessels from 10 countries were involved in attempts to collect Prestige oil from the sea surface before it reached the coast. Over 1,000 fishing boats also took part in attempts to recover sea-surface oil from more sheltered coastal waters. However this effort was largely unsuccessful due to the severe autumnal weather in the post spill period, which severely restricted any at-sea activity. The at-sea clean-up was further hampered by the rapid emulsification of the spilled HFO due to a combination of heavy weather and autumnal/winter sea temperatures which exacerbated the natural tendency of HFO to form mousse emulsions. Collection of HFO and emulsion was additionally restricted due to the inability of most vessels (which lacked the ability to heat the oil and increase its viscosity) to efficiently discharge/unload the oil collected from the sea surface. Despite these issues it was estimated that approximately 50,000 tonnes of oily waste was collected by at-sea recovery.

3:8 Despite the at-sea attempts to collect spilled oil and wide spread booming of estuaries, Rias and other sensitive areas, extensive coastal contamination of all representative ecological and habitat types occurred.

3:9 Response effort on shoreline: Spanish shorelines were cleaned (largely manually), by a work force of over 5,000 military, local government personnel, contractors and volunteers. The process was slow, especially on rocky coasts. Re-oiling of previously cleaned areas was a frequent problem. On the Biscay coasts of France much of the oiling was in the form of tar balls and similar material, which was somewhat easier to collect. It was estimated that approximately 141,000 tonnes of oily waste was collected from Spanish shorelines, and 18,300 tonnes from French shorelines.

Photo: Voluntary helpers in Prestige clean-up operations

3:10 The total volume of collected oily waste (both at-sea and shoreline) was approximately 209,300 tonnes, equal to 3 times the volume of the entire cargo of the Prestige. [Ref 5]

3:11 Such evidence points to the extreme difficulty and problematical nature of oil spill clean-up waste which inevitably incorporates a large quantity of oiled materials which are not related to the spill (for example flotsam and jetsam, organic material). Collection, temporary storage, handling, transport and disposal of such material is an extremely expensive sector of oil spill response. Separation/ extraction of oil from such waste is also highly expensive and the relevant facilities are not always locally, or even regionally, available.

3:12 During early 2004 it was reported that the sunken halves of the Prestige were still leaking oil. The Spanish authorities decided to remove the remaining oil and work commenced in May 2004. The Spanish government reported that this work was completed by September 2004, that 13,000 tonnes of HFO had been recovered from the wreck and that the vessel had been made safe by applying bio-remediation to the remaining oil trapped within the wrecks.

3:13 However, in March 2006, new oil slicks were detected near the wreck of the Prestige, which investigators found to match the type of oil the Prestige carried. A study released in December 2006, led by José Luis De Pablos from Madrid's Centre for Energetic and Environmental Research, concluded that 16,000 to 23,000 tons of oil remained in the wreck, as opposed to the 700 to 1300 tons previously claimed by the Spanish government; that bioremediation of the remaining oil had failed; and that bacteria corroding the hull could, in the future, produce a rupture and quickly release much of the remaining oil and create another catastrophic spill.

4 Prestige treatment and environmental impacts

4:1 Recovered wastes consisted of a mixture of oil, mousse emulsion, water, sand, pebbles, algae, plastic and wood, other flotsam and jetsam, oiled marine life in addition to oiled tools, protective clothing and clean-up associated wastes (brushes, cloths). Storage and treatment of Prestige oiled wastes within the Galician region was greatly facilitated by the proximity of the Galician Centre for the Treatment of Industrial wastes near La Coruna. Others sectors of the north Spanish coast and the Biscay coast of France are equally well supported by regional waste treatment plants.

4:2 As of 2008, the amount of waste collected and processed through the Galician treatment centre was estimated at 170,000 tonnes. In common with other Fuel Oil spills, this is nearly 4 times the volume of the total cargo of HFO carried by the Prestige. It was further estimated that the HFO content of the waste amounted to approximately 43,000 tonnes (i.e. that 34,000 tonnes of HFO was NOT recovered and remained in the environment.) [Ref 6]

4:3 Wildlife impacts on birds: The Prestige oil spill occurred in an area favoured by many northern sea birds during the over-wintering period, which congregate in large agglomerations in Iberian waters. Due to the large surface area covered by Prestige spilled oil slicks, many birds were impacted.

4:4 Over 23,000 dead seabirds were recovered during shoreline clean-up, but on the basis of studies related to other spills, workers have calculated that the total mortality of seabirds would have been between 150,000 and 250,000 because most corpses do not come ashore. Typically the worst affected species were diving birds such as guillemots, razorbills puffins and gannets.

Analysis of recovered leg rings confirmed that a high proportion of guillemots and puffins were from UK west coast colonies from South Wales up to the Western Isles of Scotland (declines in pop' numbers at such colonies were recorded for several years after the spill).

4:5 Another species suffering high mortality was the regional resident population of European Shag, a species defined as locally "endangered". A strong female skew in mortalities was attributed to the fact that male birds had already left for the breeding sites while females remained in the over-wintering area. Several hundred females were killed by the spill resulting in a detectable (11%) reduction in the regional breeding population
[Ref 7]:

4:6 Wildlife impacts on sea mammals: It has been estimated that the total number of cetaceans, other sea mammals and sea turtles directly or indirectly impacted by spilled Prestige oil was between 707 and 914 individuals. "Direct" impacts were categorised as anything from observed contact with oil through to death by oiling, while "indirect" impacts ranged from re-location (being forced to seek alternative feeding/habitation sites in order to avoid contact with the oil and the clean-up activity and in search of fish stocks which had also been forced to re-locate).

4:7 During the post-spill shoreline clean-up process, a relatively large number of sea mammals and other non-fish/non bird species were recovered dead from the shorelines of Galicia. 124 cetaceans of 11 species (including dolphins, porpoises and a whale), 90 sea turtles of two species, four grey seals and three otters were recovered. This was noted to be a much higher number of mortality strandings than the historical average for the time of year, it was also noted that only about 14% of (at-sea) cetacean mortalities were likely to be stranded on the Galician coast in a normal year. It may thus be concluded that the actual mortality of sea mammals and turtles was probably much higher than the recorded level of coastal mortality during the Prestige spill clean-up.

4:8 Autopsies proved the presence of Prestige spilled HFO in both digestive and respiratory tracts of those animals investigated. Autopsies demonstrated that death was caused by the effects of the spilled oil in 100% of (3) otters, 60% of 90 sea turtles, 66% of 4 seals and 3% of cetaceans

4:9 Data on sea mammal and turtle strandings from the rest of the north coast of Spain and the Biscay coast of France is lacking and (to date) I have been unable to find a comprehensive and reliable estimate. However, in the context of the detailed results of coastal surveys on the Galician coast, it is seems legitimate to assume that there would have been an additional number of such strandings, across the species range, along the north coast of Spain and the Biscay coasts of France, and that autopsy might have demonstrated spilled oil as the causative agent for mortality. **[Ref 8]**

4:10 Wildlife impacts on invertebrates: In common with most other oil spills, the overall/generalised impact of the Prestige spill on shoreline, intertidal and sub-tidal invertebrates has been poorly studied and quantified. This data gap becomes more acute with chronological distance from the spill and is a specific outcome of what may be interpreted as a "respond quickly and leave fast" policy on the part of response agency, oil company and national government. In the vast majority of marine oil spills response action and any spill related research are closed within two or three years of the initiation of the response and funding is wound down.

4:11 Bivalve molluscs are consensually agreed to accumulate petroleum hydrocarbons faster and to higher concentrations than other species. Thus bivalves are particularly important in the food chain as they are likely to transfer hydrocarbons to marine and coastal bivalve predators such as walrus, otters, bears and humans.

4:12 In the case of the Prestige spill there appears to be a general consensus among regional residents and users of the affected coast that intertidal shellfish, marine worms, small crustaceans and shoreline amphipods were severely impacted by the Prestige oil spill. Such scientific studies that were undertaken have tended to focus on commercially valuable species, thus there is a dearth of data for amphipods and non-commercial species of crabs, urchins, starfish and fin fish.

4:13 A few studies have shown that six months after the spill and clean-up campaign, invertebrate populations of the exposed sandy beaches of Galicia were significantly reduced. Furthermore, their abundance inversely related with the oil pollution gradient. The number of taxa was reduced but not the diversity values. The only clam on these sandy beaches was Donax. Before the spill and clean-up, it occurred in six beaches but afterwards, only in one. Upper beach, dry sand amphipod communities were particularly reduced due to both oil toxicity and extensive beach cleaning that also removed seaweed wrack. **[Ref 9]**

4:14 The health of mussels was studied through the investigation of hydrocarbon biomarkers. Thus, as a result of the Prestige oil spill, the study showed that the health of the mussels had been seriously affected. Signs of recovery were observed in 2004, in the samples from Galicia; and in 2005, in those from the Basque coast. However changes in the immune response were observed in mussels during the first years of the study and, although this had improved somewhat, the 2006 samples indicated that it still has not recovered the situation prior to the oil spill.

4:15 Apart from the mussels, their environment was also studied. In 2003 environmental conditions prejudicial (generating excess hydrocarbon tissue concentrations) to the health of mussels were recorded. In 2004 the first signs of recovery were noted but, on terminating the research in 2006, they still had not reached conditions of a healthy ecosystem. **[Ref 10]**

4:16 Mussels are filter feeders and thus particularly prone to accumulation of hydrocarbon particles suspended in the water column. Thus the research outcomes for mussels may be taken as an indicator of the likely impact on the range of other bivalve shellfish found across the Prestige spill impact area.

5 Prestige compensation payments

5:1 Costing the outcomes of the Prestige spill remains an incomplete exercise. The process currently involves settlement of multiple claims for damages and compensation to claimants in Spain, Portugal and France. There have already been a sequence of compensation awards followed by appeals which overturned the earlier awards. Criminal responsibility remained a debateable issue until early 2016.

5:2 In January 2016 the captain, the British insurer and the owner of the Prestige, were found guilty for one of Europe's worst environmental disasters, according to the Spanish Supreme Court. The court sentenced the tanker's captain to two years in prison, canceling an earlier ruling that he had no criminal responsibility. The captain was found guilty of recklessness and causing the accident and subsequent catastrophic environmental consequences.

Based on the court decision, Mare Shipping, the owner of the 81,000-dwt tanker, the mutual insurance company The London P&I Club, and the International Oil Pollution Compensation Funds (IOPC Funds) were also found liable for the disaster, however, the court said that their sentences will be established at a later date. The new ruling opens the door to damage claims against the captain and the insurer, The London Steamship Owners Mutual Insurance Association, with one prosecutor calling for more than 4 billion euros. However, it may well be the case that this ruling will be appealed.
[Ref 11]

5:3 A 2009 review of (then) current outstanding costs/compensation concluded that:

- **a** Total losses for the fishing industry of the northern Spanish and Basque coasts for the period 2002-2006= Euros 296.26 million
- **b** Total losses for the tourist industry (north Spain and Basque coasts) 2002-2006=Euros 718.78 million
- **c** "Extra costs" maritime transportation sector 2003:
  Galicia =Euros 0.8 million;
  north Spain= Euros 4.58 million
- **d** Shoreline cleaning 2002/2003:
  Galicia=Euros 387.43 million;
  north Spain coast 2001-2006= Euros 446.97 million
- **e** Public administration costs: (community support/compensation, pollution monitoring, research, "image restoration")
  Galicia=Euros 451.69 million
  North Spain coast= Euros 737.18 million

Total hypothetical costs = Euros 3,042 million [Ref 12]

N.B. Environmental damages remain un-quantified and the French and Portuguese claims are not included in this estimate.

5:4 It can be seen from the above paragraphs that, despite the 14 years since the spill, it is not yet possible to attempt a conclusive estimate of the final costs that will be awarded in the Prestige case. It is highly likely that the totality of compensation claims will not be settled for several years, thus it is currently **NOT** possible to calculate the relative costs of the Prestige spill.

6 Nakhodka, Sea of Japan 1997

6:1 On 2nd of January 1997 the Russian tanker Nakhodka (en route from Shanghai (China) to Petropavlosk (Russian Federation) with a cargo of 19,000 tonnes of Medium Fuel Oil (MFO), broke up in storm conditions and heavy seas around 110 kms north east of the Oki islands in the Sea of Japan. The tanker broke into two sections resulting in the immediate loss of around 6,200 tonnes of MFO.

6:2 The Sea of Japan is characterised by relatively extreme winter conditions. Winter monsoons, blowing from the north west, bring cold and dry conditions. The coldest months are January and February when winter sea temperatures sink to below 0 degrees C in the northern sector, which freezes for around 4 to 5 months of each year and may extend from October to June as continuous cover in Bays and floating patches in the open sea.

6:3 The southern sector of the Sea of Japan is generally less cold, but the winter monsoons also bring cold weather conditions and winter storms to this area. Sea surface temperatures (at the coast) for the southern sector average around 10 degrees C.

6:4 The stern section sank, containing around 10,000 tonnes of cargo and lay on the seabed at a depth of around 2,500 metres. This section continued to leak oil at a rate of between 3 to 15 tonnes per day.

6:5 The bow section drifted towards the coast of Honshu Island, Japan and eventually grounded on rocks 200 metres from shore near the port of Mikuni, Fukui prefecture. A "substantial amount of oil" (approximately 1,200 tonnes) was released, causing very heavy contamination of the adjacent coast. In late April, salvors hired by the Nakhodka's owners removed the bow section and associated debris for "scrapping".

6:6 Under the prevailing meteorology and sea state (which prevailed intermittently for several weeks) the spilled MFO formed a very stable and persistent water-in-oil emulsion (chocolate mousse). This emulsion proved resistant to both natural physical degradation and to "chemical breaking" by the use of solvents and dispersants.
The water-in-oil emulsification of the MFO caused an increase in volume of the oil by a factor of 4 to 5 as a result of the emulsion having a water content of up to 80%.

6:7 Persistence of the spilled MFO and the subsequent emulsion allowed it to travel great distances under the influence of winds and currents and to impact extensive areas of the Japanese west coast several hundred kms away from the scene of the original spills.

6:8 Although the most intensely impacted area of the coast was within 20 to 30 kms of the leak from the grounded bow section, all sources unanimously agree that the combined leaks from the original incident, the sunken stern section and the floating (later grounded) bow section distributed MFO and emulsion along a 1000 km stretch of coastline.

6:9 "Sadly, no studies of the long-term environmental impact assessments of residual heavy oil have been initiated in the wake of the spill. Such studies can contribute to formulation of measures to deal with future damage caused by heavy oil spills. Lesson: long-term research on the environmental impacts of oil spills must be conducted in Japan."

6:10 "The accident occurred during the winter season. This, combined with limitations on the monitoring of the direction and impact of the oil slick as it drifted, caused delays in the implementation of effective emergency response measures. Also, imprecise data used to computer simulate the oil slick led to a low level of simulation accuracy. Further complicating this situation is the fact that certain data, acquired from the area, could not be publicly disclosed due to the institutional constraints." **[Ref 13]**

7 Nakhodka spill response effort

7:1 More than 80 vessels belonging to Japanese government agencies and departments were engaged in oil recovery from the sea surface. Several hundred fishing boats were mobilised to collect oil manually. Helicopters were deployed to spray a limited amount of dispersant.

7:2 Shoreline clean-up was organised by local fishery associations, prefecture and municipal authorities. In the five most heavily oiled prefectures more than 500,000 man days were expended on shoreline clean-up. During the period of most intensive shoreline clean-up (end of Jan'/early Feb') weather conditions were very severe with almost continual strong winds, sleet and snow. Despite this most of the shoreline oil had been removed by the end of February.

Photo: Clean-up operations after the Nakhodka spill in Japan

By the end of May, all prefectures had declared that clean-up was completed, although there is some evidence to suggest that different areas had differing standards for identifying clean-up completion.

7:3 Unfortunately, no precise data on the environmental impacts of the Nakhodka spill appears to have been compiled. There are a few papers in the Marine Pollution Bulletin discussing the effects of bio-remediation on some intertidal shores, This Journal also published a short paper on the expected chronology of ongoing impacts on a small number of intertidal invertebrates (hypothesised that such impacts may last for 2 to 3 years). However none of these is relevant to the overall quantification of impacts, and no numerically detailed records have been found for oiled birds (dead or alive), or the range of free swimming and sessile marine species impacted by oil. Accordingly this parameter cannot be discussed in the context of the Nakhodka spill.

7:4 The total volume of spilled MFO can be calculated to be around 17,400 tonnes (initial spill = 6,200 tonnes+ sunk/leaking stern section containing 10,000 tonnes + oil lost from bow section after grounding around 1,200 tonnes). Precise definitions of the quantity of oil stranded on Japanese shorelines have not been offered. However ITOPF has estimated that "several hundreds of tonnes of emulsion stranded at various locations". **[Ref 14]**

7:5 Given that the emulsions were reported to be around 80% water, it may be concluded that the "several hundred tonnes of emulsion" would have contained only about 20% MFO. Thus ITOPFs estimate might, at best, account for no more than 200 tonnes of oil having reached the shoreline. It can be seen that the oil recovered from the environment represented only a minor fraction of the total spill volume.
It was noted that the high viscosity of the MFO and the emulsion created enormous problems with regard to the collection and disposal of oily waste collected from shorelines because, due to viscosity issues, an enormous volume of environmental material/debris became mixed with the oily waste during collection and removal action along the shoreline. The total quantity of heavily oiled waste has been estimated (by ITOPF) at around 50,000 tonnes (about 250 times greater than the volume of oil estimated to have reached the Japanese coastline). **[Ref 14]**

7:6 These heavily oiled wastes required transport (road, rail and sea) to industrial disposal facilities such as incineration plants, throughout Japan and initiated a costly and expensive operation. These facilities were often overwhelmed by the volume of incoming material, and long delays in receiving and processing the waste occurred In common with most other, post spill, clean-up processes such movements by rail, road and sea probably inevitably generated additional oiling problems along the chosen routes, though these are not reported. As a result roads, railways, loading depots and pre-transport storage facilities had to be frequently cleaned, the ships, truck and rail rolling stock also probably required repeat cleaning, though such action is not referenced in the final compensation claims.

7:7 Moderately oiled material was buried at industrial land fill sites, while lightly oiled material was buried at the “beach margins” or placed in the surf zone for what is known as “surf washing”. **[Ref 14]**

NB: It has been repeatedly reported that manual collection is generally more precisely targeted than mechanical collection, and returns much lower levels of oiled waste containing a higher percentage of oil and lower percentages of “debris” such as vegetation and flotsam.

8 Nakhodka costs, losses and compensation

8:1 Japan has its own national Oil Pollution Compensation Law which incorporates the 1969 Civil Liability Convention, the 1971 Fund Convention and the 1992 Protocols to both Conventions.

8:2 The Nakhodka was flagged to the Russian Federation (RF). At the time of the spill, the RF was a party to the 1969 Civil Liability Convention and the 1971 Fund Convention but NOT to the 1992 Protocols to both Conventions. Thus the tanker owner’s limit of liability was governed by the 1969 Civil Liability Convention, which restricted any claim (through this Convention) to no more than about 2.3 million US dollars.
Additional compensation was available from the Oil Pollution Compensation Funds (IOPC: 1971 and 1992) up to a total amount of 192 million US dollars though this sum would include any compensation paid by the tanker owner. The time limit for the submission of claims against the ship owner, the ship’s P&I club (insurers) and the IOPC funds, is 3 years from the incident (i.e. Jan’ 2nd 2000) and all relevant claims were brought before the courts by that date.

8:3 The IOPC had already made a number of part payments for the assessed claims after estimating the total annual exposure of the funds, and set a % limit on payments due to an expected heavy claim rate for 1997 (a year in which a number of significant oil spills occurred). At the beginning of 2000, the agreed level of payment was 70% of total claim. Later in the year this was raised to 80% of the total claim. **[Ref 15]**

8:4 The final assessment of total Nakhodka claims was not completed until 2002, although the Japanese government had made loans available to those who participated in clean-up operations, pending payments from the combined funds available from the ship owner, the vessel’s P&I club (insurers) and the IOPC funds. **[Ref 15]**

8:5 The final compensation to the claimants was as follows:

Government ministries and agencies (shoreline and at sea)	US$ 17.6 million
Japanese Marine Disaster Prevention Centre (at sea clean-up)	US $ 116.4 million
Local Government / Prefectures (shoreline clean-up)	US$ 52.7 million
Fishery associations (clean-up and lost fishing income)	US$ 16.5 million
Tourism (318 individual claimants)	US$ 12.6 million
Others (undefined)	US$ 21.2 million
Ship Owners	US$ 7.2 million
Total Payments	US$ 244 million

[Ref 16]

N.B. In 2013 Euros were averaging 0.75 Euros per dollar, thus the total payout (in dollars) was 152.85 million dollars.

9 Erika, Bay of Biscay 1999

9:1 On 12 December 1999, the Maltese-registered tanker Erika (19 666 GT) broke in half, during storm conditions in the Bay of Biscay, some 60 nautical miles off the coast of Brittany, France. All members of the crew were rescued by the French maritime rescue services.

9:2 The tanker was carrying a cargo of 31,000 tonnes of Bunker C HFO, of which an estimated 20,000 tonnes were spilled. The bow section sank in about 100 metres of water. The stern section sank to a depth of 130 metres about ten nautical miles from the bow section. An estimated 6,400 tonnes of cargo remained in the bow section and a further 4 800 tonnes in the stern section.

Photo: The tanker Erika sank off the coast of Brittany in December 1999. Miles of shoreline were polluted by the oil spill. Credit Marine Nationale/French Navy, via Associated Press

9:3 The loss of the Erika occurred during a severe winter storm with accompanying very heavy seas. Average sea temperatures for December, in the central/northern sector of the Bay of Biscay, range from about 11 to 13 degrees

10 Erika environmental impact

10:1 Approximately 450 kms of shoreline were affected by oil. The coastal environments oiled included rocky coasts, “armored” coasts, sandy coasts, estuarine, tidal lagoon, salt marsh and “salting” environments. Both sub-tidal and inter-tidal oiling were recorded. As a result of the re-mobilization of sub and inter-tidal oil, repeat shoreline cleaning was necessary. Major kills of many sub tidal and inter tidal invertebrates and seabirds were recorded. Follow on studies indicated that Erika oil toxicity impacts were detectable in some invertebrate and shellfish communities several years after the spill. **[Ref 17]**

Photo: Erika spill: Impacts of HFO on diving birds: Gannet. Credit: Tim Deere-Jones

10:2 Economic impacts were severe as fin and shell fisheries were closed and the tourist trade and associated economic activity naturally suffered major short term, down turn. Impacts were most marked during the year 2000, though reported to a lesser extent in subsequent years. As is the case with all oil spills, social impacts have been less well recorded. Socio-psychological impacts of the economic impacts were not recorded or discussed.

10:3 Some health study was carried out to investigate the possible health impacts to beach cleaners of prolonged and repeated skin contact doses of oil acquired during clean-up operations and to investigate the possible impacts of prolonged and repeated inhalation doses of Volatile Organic Compounds (VOCs) in ambient beach air as a result of vaporisation during heavy duty (warm water and cold water) power hosing and the elevated temperatures due to sunny weather through the spring and summer of 2000.

10:4 This, and other studies, have noted that there was some evidence for health impacts as a result of spilled oil coming ashore and that although clean-up workers were specifically noted as receiving high exposures, non-worker members of the coastal population (including children, pregnant women, the aged and the ill) were also at risk of exposure and subsequent health impacts. **[Ref 18]**

11 Erika response operations

11:1 The Erika spill occurred during a major storm that had caused significant damage across France. French emergency responders and their equipment (emergency planners, local authority workers, fire brigades and the military) were fully employed in terrestrial storm response, recovery and repair work. As a result, when oil came ashore along the Biscay coast, much of the collection and management of shoreline stranded oily waste was initially conducted by volunteers, lacked coherence and suffered from weak management which generated secondary oiling of previously un-oiled supra-tidal areas and public roadways.

11:2 Following eventual mobilization of the French POLMAR spill response teams, the initial removal of the bulk of the oil from shorelines was completed quite rapidly. However, considerable secondary cleaning was still required in many areas in 2000 due to repeat oiling (every tide basis) of shorelines. Operations to remove residual contamination began in spring 2001. By the summer tourist season of 2001, most of the secondary cleaning had been completed, apart from a small number of difficult sites in Loire Atlantique and the islands of Morbihan. Clean-up efforts continued at these sites through the autumn and most were declared complete by November 2001.

Photo: Erika spill: Citizen volunteers (note absence of protective gear). Credit Tim Deere-Jones

11:3 More than 250,000 tonnes of oily waste were collected from shorelines and temporarily stockpiled, this was more than 10 times greater than the volume of the original spilled oil. Total SA, the French oil company, engaged a contractor to deal with the disposal of the recovered waste and the operation was completed in December 2003.

11:4 Additional clean-up costs were generated by poor management of temporary, oily waste storage sites, which spilled oil into surrounding environments as a result of torn and leaking membrane linings, and in several cases a total lack of bunded enclosures for storing oily waste collected in tubs, drums and plastic bags which were subsequently over filled or burst and split. [Ref 19]

11:5 The French Government decided that the oil should be removed from the two sections of the wreck. The oil removal operations were funded by Total SA and carried out by an international consortium during the period June to September 2000. According to the operatives no significant quantities of oil escaped during the operations, although it was reported that small quantities of oil had been leaking steadily from the sunken sections since the original spill.

12 Erika spill compensation claims and payments

12:1 The process of compiling, agreeing and settling such claims has been complex, prolonged and fraught with dispute and involved many legal hearings, criminal investigation, disputes between "responsible parties" and appeals to higher courts.

12:2 Criminal proceedings were undertaken against the master of the Erika, representatives of the ship owners and management company, the ship's Classification Society and the TOTAL oil company (nominal owners of the spilled oil and charterers of the Erika) French civilian and naval personnel responsible for shipping and "coast guarding" activities were also investigated in order to establish their degree of responsibility for the incident.

12:3 In June 2008 French courts found that the following 4 parties (ship owners representative, president of the ship's management company, the Classification Society and TOTAL SA oil) were criminally liable for the offence of causing pollution. Subsequent court proceedings, including Court of Appeal, confirmed the decision. Various agreements were then formalized between the guilty parties with regard to payment of claims that were awarded, by the final hearing of the French Court of Appeal.

Material damage (costs of clean-up etc.)	165.4 million Euros
Moral damage (loss of equipment, damage to reputation brand image and natural heritage)	34.1 million Euros
Pure environmental damage	4.3 million Euros
Total payouts	203.8 million Euros

[Ref 20]

13 Selendang Ayu, Unalaska Island 2004

13:1 In December 2004, the Malaysian bulk carrier Selendang Ayu (39,775 GT; built1998) suffered engine failure whilst en-route from Seattle, USA to the People's Republic of China. Despite the best efforts of the crew, the vessel drifted for about 2 to 3 days and eventually ran aground several hundred yards off shore of Skan Bay, Unalaska Island, Alaska.

13:2 Shortly after the grounding, on December 8th, the vessel broke in two as a result of the severe weather (winds in excess of 60 mph and wave heights exceeding 35 ft). Six crew members died whilst being lifted from the ship by helicopter.

13:3 At the time of the incident, the vessel was carrying approximately 1,548 tonnes of Bunker B MFO, 60 tonnes of marine diesel oil (MDO) and an un-quantified volume of mixed lubricating oils.. Lightering operations conducted by heavy-lift helicopter removed around 407 tonnes of Bunker B from the vessel.

13:4 The remaining 1,200 tonnes of Bunker B/MFO and MDO, and the entire cargo of 60,000 tonnes of soya beans were lost to sea. **[Ref 21]**

13:5 Winter weather conditions severely restricted any significant shoreline or at-sea clean-up response. Such work was not begun until the following spring. **[Ref 22]**

13:6 It is reported that over 86 miles(138 kms) of the Unalaska island coast were oiled by the Selendang Ayu spill.

Photo: Selendang Ayu sinking in Alaska

14 Selendang Ayu environmental impacts

14:1 State of Alaska, US wildlife Agencies and ITOPF reports refer to the following impacts of the Selendang Ayu spill. The spill occurred within the Alaska National Wildlife Refuge, which is also an International Biosphere Reserve.

14:2 Spilled oil was transported, via winds and currents, resulting in impacts to water column habitats, birds, marine mammals, and the initial oiling of approximately 86 miles of shoreline habitats. In addition to impacting water column and shoreline habitats, oil was also transported to inter- and sub-tidal sediment habitats including sand, shingle and rocky beaches, vegetated shorelines, estuarine and freshwater habitats (driven there by heavy seas and onshore storm force winds). **[Ref 23]**

14:3 It is reported that the prevailing temperatures and sea conditions included strong winds, heavy seas and regionally typical winter weather (blizzards, freezing conditions and sea temperatures as low as 3 to 4 degrees Celsius). Much of the spilled oil was emulsified (water in oil chocolate mousse) as result of high winds, breaking seas and cold conditions. Following emulsion formation, the volume, viscosity and weight of the MFO was greatly increased.

14:4 Following initial grounding and subsequent cleaning of shorelines, secondary cleaning was frequently needed as oil was re-mobilized from un-cleaned areas and patches of buried oil in the sub tidal and inter tidal zones. Shoreline cleaning continued (on a weather permitting basis) for two years and was eventually terminated late summer/early autumn of 2006.

14:5 Impacts on birds: Around 2,200 oiled birds from 29 species (dead and alive) were collected/recorded. On the basis of research studies in sub-polar seas showing that collected oiled birds are only ever a proportion of the total mortality (0.3% to 56% of total), it may be hypothesized that the total bird kill arising from the Selendang Ayu spill was somewhere between about 4000 and 200,000 individuals. [Ref 24]

14:6 Research carried out through 2007/8 has shown that regional Harlequin Ducks were still exposed to, and carrying detectably elevated body burdens of, hydrocarbon markers. It was concluded that such birds were still being exposed to lingering hydrocarbons more than three years post spill. [Ref 25]

14:7 Individuals of a number of non-sea bird species were also reported to have been oiled. These included bald eagles, gulls and corvids and the assumption is that these birds were physically oiled while scavenging along oiled shorelines and consuming dead invertebrates, shellfish, fin fish, sea birds and others. The likelihood of dietary doses of hydrocarbon toxins to birds was considered high, but remained un-researched by any specific study. [Ref 26]

14:8 Impacts on marine mammals: Sea otters, sea lion and seals were observed swimming in, or surfacing through, oiled water (oil and sheen) in the Selendang Ayu spill impact area. The scientific literature confirms that heavy oil contamination of sea mammals can cause problems in thermo-regulation, locomotion, breathing and mortality. [Ref 27]

14:9 Six oiled sea otter carcasses were collected and necropsies on 2 individuals confirmed that their deaths were consistent with exposure to oil. There is no reporting of further studies of marine mammals within the spill area. [Ref 26]

14:10 Some oiled non-marine mammals (red fox) were also observed in near coastal environments. As with the non-sea birds mentioned above, the assumption is that these individuals were physically oiled while scavenging along oiled shorelines and consuming dead invertebrate, shellfish, fin fish, sea birds and others. Thus the likelihood of dietary doses of hydrocarbon toxins was considered high, but has remained un-studied by any specific scientific research. [Ref 26]

14:11 Impacts on invertebrates: Documentation of the damage to invertebrates is generally poor in all post spill environmental commentary. Full species range is rarely given and as such creatures are often present (and impacted) in their many thousands, accurate counts are rarely attempted. Marine worms, urchins, starfish, sea cucumbers are all highly susceptible to both smothering and toxic impacts from spilled oil. The Selendang Ayu spill was no exception.

14:12 However, Selendang Ayu response teams reported sub tidal and inter tidal oiling by negatively buoyant oil/emulsion/debris mats and balls on a cross section of oiled sub and inter tidal environments. **[Ref 26]**

14:13 Post spill reportage for the Selendang Ayu spill noted that: "Injury likely occurred to inter tidal and sub tidal biota. Additionally, injury to a variety of marine resources can be inferred from experience with similar sized spills in similar environments and from the scientific literature". **[Ref 26]**
Despite poor recording of invertebrate damage it is inevitable that invertebrates of many species would have been exposed in such scenarios.

14:14 Impacts on shellfish and crustaceans: Both shellfish and crustacean species were observed to be physically oiled. Follow on studies confirmed the presence of hydrocarbon compounds in some commercial crab stocks. Shellfish species were also noted to have detectable hydrocarbon compounds in their muscle tissue. As a result of both the actual tainting of marine foods and additional fears of hydrocarbon contamination, various fisheries suffered economic impacts.

14:15 The grounding and spill occurred in the Makushin and Skan Bay portion of the Eastern Aleutian District of Tanner Crab Management Area J. The Makushin and Skan Bay and Unalaska areas were the only allowable Area J near shore crab grounds during 2005, and were scheduled to open on January 15, 2005. However, crab and other fisheries in the Makushin/Skan Bay area were closed by the Alaska Department of Fish and Game (ADF&G) on December 27, 2004 due to spill concerns. Non-commercial harvesting of natural resources was also precluded in spill-affected areas during the spill clean-up process. **[Ref 26]**

14:16 In 2008, the presence of lingering oil was documented at 21 of 24 subjectively selected beach locations, despite an earlier announcement that coastlines were clean and cleaning had been suspended in 2006.

15 Selendang Ayu response issues

15:1 Aspects of the response action demonstrate many of the major problems encountered by those responsible for oil spill response in polar and sub-polar waters. The spill site was remote from major infrastructure, and shorelines were accessible only by air or sea. Dutch Harbour, was the nearest settlement on Unalaska, it was 50 km away but had no airstrip or road network. Due to a lack of relevant infrastructure, the spill response was mounted from mainland Alaska, coordinated by the US Coast Guard base at Kodiak, 1,000 km away. **[Ref 21]**

15:2 Local islanders provided much of the manpower (250 people in total), but there was no significant local stock pile of spill response equipment or expertise. Eventually the response was supplied with equipment and supervision from the ship owner-appointed OSRO (oil spill response organisation). The response involved 23 vessels to transport personnel and equipment, and also to provide accommodation for workers. **[Ref 21]**

15:3 The poor weather conditions prevented any response at sea and initial shoreline operations were restricted to protective booming of salmon rivers, shoreline clean-up assessment technique surveys (SCAT), and bulk clean-up of mobile oil. The following spring, further SCAT surveys were conducted, which determined that 70 miles of shoreline required further clean-up. A net environmental benefit analysis (NEBA) approach was adopted, with active intervention designed to augment natural recovery. Manual and in situ techniques were used where possible due to the logistical challenges of bringing equipment in and removing waste, with surf washing and tilling used to clean oiled beach material. Initial clean-up was terminated in September 2005, some 10 months after the incident.

15:4 Final and precise details of the total weight/volume of recovered oily waste have not been provided. However, in June 2005 it was reported that "over 125,000 bags of oily waste" had been collected, and that these had a volume of approximately 1,400 cubic metres (approximately 3,000 tonnes). [Ref 29]

15:5 It has been estimated that the final, total amount of oily waste collected from the sea and the shore line was approximately 6 times the volume of the oil spilled from the Selendang Ayu. [Ref 30]. This would amount to about 6,850 tonnes.
15:6 Liquid waste was airlifted to Dutch Harbour, then shipped to Seattle, Washington for disposal. Solid waste was stored in small bags, which filled 6 containers. These were shipped to Dutch Harbour, and then on to Seattle; from Seattle the waste was transported overland to Arlington, Oregon for final disposal. [Ref 21]

15:7 It is evident from ITOPF and others that there was also a lack of baseline information about the Unalaska coastal environment. Due to a lack of basic data SCAT teams were poorly informed about the geomorphologic, habitat, ecosystem and wildlife habitat details of the Unalaska coastal environment. This meant that post spill surveying in respect of both assessing environmental impacts and appropriate (wildlife friendly) beach cleaning techniques had to "start from scratch" rather than having a pre-existing knowledge base to work from.

15:8 Similarly, despite the occurrence of a number of previous spills in the region, there was no reporting of pre (SELENDANG) spill hydrocarbon concentrations in regional environmental media. Thus there appears to have been little or no baseline data on the pre-spill levels of hydrocarbon compounds in Unalaska coastal environments against which to compare post spill impacts.

16 Selendang Ayu spill compensation claims and payouts

16:1 In August 2007 IMC Shipping (operators of the MV Selendang Ayu) reached a financial settlement with the State of Alaska in respect of damages relating to the spilled oil. It was agreed that the total payout would be 112million USD, which included:

Formalized response	Over US $ 100 ml
Criminal penalties (fines)	US $ 9 ml
Clean-up costs to the State of Alaska	US $2.5 ml
Payments towards oil spill wreck removal and lost taxes (fishing)	US $ 844,707
Beach monitoring	US $ 36,000

[Refs 31,32]

Oil spill response in polar and sub-polar environments

It is evident from the three case summaries above, that oil spills occurring in polar and sub-polar marine environments present a specific set of challenges to responders which are demonstrably reflected in the total costs of spill response actions.

17 Weather and sea conditions

17:1 It is widely agreed that the great Circle route (N/America to China/Russia and Japan) adjacent to the Aleutian chain presents some of the most taxing maritime conditions for shipping to be found in the northern hemisphere.

17:2 US Naval Forecasters state that: "From the point of view of the Navy sailor or aviator, the Aleutians' reputation for foul weather can hardly be exaggerated. Storms passing the Aleutians usually arrive from the west as deep occluded systems, sometimes as transformed versions of typhoons that have gone extra-tropical. Winds at sea and exposed regions on the islands often exceed hurricane force, sometimes further strengthened as a result of venturi effects through mountain passes or ocean gaps between islands. Visibilities are frequently severely restricted by fog, which can persist for days without improvement and for lesser periods on the islands and at sea through intense precipitation in cyclone activity. The tendency for extended consecutive days of bad conditions can be very frustrating for operations at sea, in the air, and at naval and air installations on the islands."[Ref 33]

17:3 Studies based on the Selendang Ayu spill report that the incident occurred during a "robust early December storm" and that "containment of spilled oil and cargo were hampered by the remote location of the accident and by challenging weather and sea conditions". [Ref 34]

17:4 The impact of cold/freezing water temperatures on the behavior and fate of refinery residual oil has been discussed (in section 2) above and demonstrates that HFO and MFO are strongly influenced by such conditions and that clean-up is made much more problematical in polar environments, especially during the winter months, when winter darkness also militates strongly AGAINST successful clean-up.

17:5 Following the Nakhodka spill there was considerable discussion about the impact of ambient sea and weather conditions and their effect on the management, containment and response to the spill. A number of research and policy papers were published which pointed out the importance of overcoming certain environmental parameters in order to improve spill response management.

17:6 It was concluded and recommended that: "the much needed system to combat oil spills on the open sea should include countermeasures for dealing with oil spills in cold water"

17:7 and that such measures for dealing with cold water spills should include “the need to evaluate the effects of oil spills on the marine environment and to prepare a set of environmental sensitivity index (ESI) maps for shorelines bordering on cold water. Methods must also be developed to predict the spreading rate of spilled oil. The process of emulsification and sedimentation of spilled oil must also be studied” (in cold water environments). [Ref 35]

17:8 Reports state that “Rugged topography precluded remediation of certain segments of the oiled shoreline.” [Ref 34]

17:9 Weather and coastal terrain factors such as these strongly increase the risk of maritime accidents including oil spills. At the same time they militate against successful prevention of major marine accidents and similarly against oil spill response.

17:10 It is also apparent from various reports from “responders” to both the SELENDANG spill and the earlier KUROSHIMA spill (Unalaska Island:1997) that the lack of terrain baseline data was a significant factor adding to the difficulty and expense of the response. SCAT teams found that many areas were not familiar to responders and there was a lack, not only of topographical, and morphological data about particular sections of the coast, but also of those environmental, ecosystem and wildlife parameters which inform decisions about cleaning technologies to be used at specific sites.

17:11 By contrast, such parameters are generally well studied, documented and mapped on coastlines oiled in more developed areas. For example, the coastline of Pembrokeshire, heavily oiled during the Sea Empress oil spill (1996), has been an area of major maritime and naval activity for centuries, and was well charted and mapped. It has also been the subject of biological research since the Victorian era and is the base for a number of marine biological stations (Dale and Orielton FSC) and oil spill research units (OPRU). The Biscay coast of Western France, oiled by the Erika spill, is a similar example of well-studied coastlines.

18 Remoteness of spill sites

18:1 “Given travel distances to and from Unalaska/Dutch Harbor, and the remote location of the grounding, the response was particularly challenging and costly for state and federal government agencies. Formalized response resulted in known expenditures of over $100 million and detraction of many government personnel from their normal duties.”[Ref 36]. Such remoteness is particularly problematical when responding to oil spills and maritime accidents.

18:2 Distance from resources, means that at sea oil spill response equipment (booms, skimmers, grabs, spotter aircraft, protective clothing, face masks, gloves), dispersants and clean-up ships are all at distant sites and must be transported to the remote site. This is not only time consuming but also expensive, and if the remote site is also afflicted by heavy/extreme weather and sea states then expense and time issues will be exacerbated.

18:3 Additional issues arise in consideration of the required numbers of personnel involved in survey work, at sea and shoreline clean-up and “technical/ skilled” oil spill response. In the case of the SELENDANG spill specialist oil spill responders had to be shipped in to the spill area from outside. Once such personnel have been transported in to the remote area, they will of course require supplying with response equipment, fuel, food and accommodation. This will exert additional logistic strain on the response effort.

18:4 Similarly such remote sites are usually devoid of the technological infrastructure required for the treatment and/or storage of the large volumes of oily waste collected during shoreline and at sea clean-up. Such problems are very well illustrated by the SELENDANG spill clean-up.

18:5 Selendang Ayu liquid oily waste was airlifted to Dutch Harbor and stored on floating barges before shipment to Seattle, Washington (3,158 kms distant) for disposal. Solid waste was stored in small bags, which filled 600 containers. These were also shipped to Dutch Harbor, and then on to Seattle; from Seattle the waste was transported overland to Arlington, Oregon for final disposal. [Ref 36]

18:6 The incident location was remote from major infrastructure, and shorelines were accessible only by air or sea; the nearest settlement, Dutch Harbor, was 50 km away but had no airstrip or road network. A response was mounted from mainland Alaska, coordinated by the US Coast Guard base at Kodiak, 1,000 km away. Local islanders provided much of the manpower (250 people in total), with equipment and supervision from the ship owner-appointed OSRO (oil spill response organisation). The response involved 23 vessels to transport personnel and equipment, and also to provide accommodation for workers.
[Ref 36]

18:7 By contrast: the Nakhodka, Erika and Sea Empress spills and oiled shores have occurred on the coastlines of more “developed” areas where relevant resources (major ports and other facilities) where oil spill response equipment is stored, trained onshore and at sea response personnel are readily available and appropriate disposal and recycling facilities are also readily (and closely) available.

18:8 Even though the Nakhodka spill was indeed situated closer to resources than the Selendang Ayu spill the at-sea spill response effort involved major resource use. More than 80 vessels belonging to Japanese government agencies and departments were engaged in oil recovery from the sea surface. Several hundred fishing boats were mobilised to collect oil manually. Helicopters were deployed to spray a limited amount of dispersant.

18:9 Nakhodka shoreline clean-up was organised by local fishery associations, prefecture and municipal authorities. In the five most heavily oiled prefectures more than 500,000 man days were expended on shoreline clean-up. During the period of most intensive shoreline clean-up (end of Jan’/early Feb’) weather conditions were very severe with almost continual strong winds, sleet and snow. Despite this most of the shoreline oil had been removed by the end of February. By the end of May, all prefectures had declared that clean-up was completed, although there is some evidence to suggest that different areas had differing standards for identifying clean-up completion.

18:10 There is a wide consensus among oil spill responders, such as ITOPF et al., that decisions to stop at-sea and shoreline cleaning must be based, in part, on how much oil remains in the environment and it’s potential to impact on wildlife and the economy versus the escalating cost of highly expensive clean-up techniques deployed to recover a diminishing volume of oil from the environment. It is evident from aspects of the discussion above that remote polar and sub-polar marine and coastal environments are particularly susceptible to decisions based on the cost value of cleaning.

19 Emergency towing vessels (ETVs)

19:1 In the context of the relatively frequent spills in regional waters (Exxon Valdez, Kuroshimo, Nestucca, Selendang Ayu etc), there have been repeated calls for the establishment of an all year round emergency towing vessel (ETV) in the Alaska/ Aleutian Island chain sector of the sub-polar, north pacific great circle route. Such a vessel needs to be capable of dealing with extreme weather conditions, probably be "ice classed" and have a powerful towing capacity. It would also need to be maintained and serviced to the highest standards and be on duty on an all year round basis.

19:2 To date such a service has not been provided by any of the sovereign states bordering the relevant sea area or by those states whose vessels regularly use the route. Undoubtedly the costs of maintaining such a vessel, in such an environment, are a significant factor in the non-adoption of the proposal.

19:3 In the UK, an ETV fleet was instituted in1994 following recommendations made in the aftermath of the BRAER oil spill on the coast of the Shetland Islands. This ETV fleet operated from 1994 to 2011. Four vessels were placed on active deployment in the UKs most dangerous Marine High Risk Areas (MHRAs), where MHRA status coincides with relatively heavy marine traffic: (Western Approaches/ Lands End, Dover Straits, Hebrides/N.E. Atlantic and the Shetland Islands). The fifth vessel was kept in reserve and rotated for maintenance purposes. When on active deployment the ETVs were operational 24 hours a day, 365 days a year and at 30 minutes readiness to sail.

19:4 However, the policy was abandoned following the UK Government's 2010 Comprehensive Spending Review (CSR), when it was announced that the ETV service would be discontinued on the grounds that "state provision of ETVs does not represent a correct use of taxpayers money and that ship salvage should be a commercial matter between a ship's operator and the salvors". (The UK Government saved £32.5 million over the five year period of the CSR.)

19:5 During hearings of evidence following the Government statement, the House of Commons Transport Committee found that those involved in shipping, emergency response and spill prevention were sharply critical of the decision. The Director of Safety & Environment for the UK Chamber of Shipping, stated that "there have been numerous occasions in recent years—a large number—which could have gone very badly wrong and perhaps didn't go wrong because there were emergency towing vessels quickly on hand".

19:6 Others argued that the role for an ETV is not simply a service to industry, but a service to the general public, saying: "This is actually the taxpayers of the UK wanting reassurance that there is a method to stop vessels going ashore on their beaches and causing environmental havoc, rather than the response of industry to actually salvage the property of individual ship owners". The Western Isles Council and Shetland Islands Council argued that any savings made from canceling the contract would be wiped out by a single incident. The cost of cleaning up the Braer oil spill, for instance, was around £100m.

19:7 A representative of the Western Isles Local Authority offered the analogy of leaving your house uninsured: "Most of us feel that sooner or later there will be a major catastrophic incident. Whether it be salmon farming, coastal tourism, bird life and wildlife on the west coast, for all these factors we will pay a very heavy price for the removal of the ETVs".

19:8 The UK's government funded Coastguard Agency commissioned a risk assessment on ETV provision, which concluded that "The United Kingdom appears to have little option but to continue its involvement in the contracting of Emergency Towing Vessels [...] In cost benefit terms, averting one major shipping disaster and environmental incident of the scale of the Prestige would justify a contract price far in excess of that currently being paid until its expiry in 2011 and beyond". The Government's decision is therefore directly at odds with a risk assessment that it commissioned itself. [Ref 37]

19:9 On the basis of the advice/evidence of professional mariners, coastguard agencies, spill responders and local communities it would seem that there is a strong case for ETVs to be stationed (on a similar basis to the now defunct UK ETV fleet) in polar and sub-polar seas to assist the prevention of major marine pollution events. Given the reducing ice cover in Arctic sea areas, the subsequent "opening" of North West and North East Passages and the growing volume of shipping traffic now using these once "closed" seas, the policy of ETV provision plainly offers much additional protection. A policy of deploying ETVs to guard polar and sub-polar MHRA's and traffic choke points has much to offer the communities, environments and marine based industries of such regions.

20 Cultural and subsistence issues

20:1 Polar and sub-polar spill settlement claims frequently include claimants from recognised ethnic groupings with special rights in relation to natural resources and access to them. Thus both the Kuroshima and Selendang Ayu spills have generated claims for damages/expenses from recognised indigenous first people "tribal entities" in respect of their recognised and accepted particular and specific use of natural resources on a cultural/subsistence basis. [Refs 38, 39]

20:2 Such tribal/indigenous entities do not exist in more "developed areas" where such cultures no longer exist, or at least "local" people are not recognised as having any such cultural or subsistence rights and are hence NOT currently afforded such specific rights to claim against oil spill damages.

20:3 However, since such recognised tribal/indigenous entities do exist throughout the polar and sub-polar area and, in some sovereign states at least, have their peculiar rights recognised under law, it should be expected that claims from such entities will continue to be submitted in the event of spills. While successful claims from such entities, under the cultural/subsistence banner have, to date, been relatively small in the context of the total sums claimed and settled, it is possible that such claims may in time, and under certain circumstance, become a more significant segment of overall claim settlement, thus adding to the potential cost of future spills in polar and sub-polar areas.

21 Health impact studies

21:1 A health study carried out in the aftermath of the Sea Empress oil spill found that "Living in areas exposed to the crude oil spillage was significantly associated with higher anxiety and depression scores, worse mental health; and self-reported headache (odds ratio = 2.35, 95% CI 1.56, 3.55), sore eyes (odds ratio = 1.96, 95% CI 1.06, 3.62), and sore throat (odds ratio = 1.70, 95% CI 1.12, 2.60) after adjusting for age, sex, smoking status, anxiety, and the belief that oil had affected health. People living in exposed areas reported higher rates of physical and psychological symptoms than control areas. Symptoms significantly associated with exposure after adjustment for anxiety and health beliefs were those expected from the known toxicological effect of oil, suggesting a direct health effect on the exposed population." [Ref 40]

21:2 Following the Nakhodka spill, “two hundred eighty-two men and women involved in the clean-up activities between January 7 and January 20 were interviewed and examined by public health nurses to determine whether they suffered physical symptoms after exposure to the oil spill.”

21:3 “the principal symptoms included low back pain and leg pain, headache, and symptoms of eyes and throat. Among the subjects undergoing urine tests, only three people showed a higher level of hippuric acid, although they returned to normal in the second examination. Accordingly, the exposure to the oil and the subsequent clean-up efforts were suggested to inflict acute health problems on local residents.” **[Ref 41]**

21:4 After the Erika spill, a study on “ the health risk for people involved in cleaning activities and for tourists was evaluated with emphasis on the carcinogenic properties of this oil. The outcome indicates that the risks were limited to people who had been in bare-handed contact with the oil. Firstly they had an increased risk for developing skin irritation and dermatitis, however, these effects are in general reversible. Secondly they had an increased risk for developing skin tumours, but since the dermal contacts with the oil were of relative short duration, this risk is considered to be very limited. **[Ref 42]**

Photo: Erika spill: French military personnel attempting to prevent “oily runoff” from high pressure spraying. Credit Tim Deere-Jones

21:5 A 2010 review of health studies on the impacts of marine oil spills noted that “only a few studies have been compiled in the literature dealing with the repercussions of oil exposure on human health; most of them have focused on acute effects and psychological symptoms. The objective of this work was to gather all these studies and to analyze the possible consequences of this kind of complex exposure in the different aspects of human health. Studies found on this topic were related to the disasters of the Exxon Valdez, Braer, Sea Empress, Nakhodka, Erika, Prestige and Tasman Spirit oil tankers. The majority of them were cross-sectional; many did not include control groups. Acute effects were evaluated taking into account vegetative-nervous symptoms, skin and mucous irritations, and also psychological effects. Genotoxic damage and endocrine alterations were assessed only in individuals exposed to oil from Prestige.”

21:6 The results of the reviewed articles "clearly support the need for biomonitoring human populations exposed to spilled oils, especially those individuals involved in the clean-up, in order to evaluate not only the possible immediate consequences for their health but also the medium- and long-term effects, and the effectiveness of the protective devices used." **[Ref 43]**

21:7 A 2011 review study of oil spill health effects to humans reported that: "In the last two decades, potential health effects of eight major oil tanker spills have been evaluated through epidemiological studies on residents, clean-up workers, or both, and have been summarized in recent reviews. Most of these studies provided evidence for an association between exposure to the oil spill and the appearance of acute physical, psychological, genotoxic, and endocrine effects in exposed populations. However, most of the studies had a cross-sectional design and small sample sizes, collected only self-reported health information, or had other methodological flaws hampering proper interpretations. Long-term health effects have been addressed on very few occasions."

21:8 "A questionnaire survey conducted in more than 6,000 affiliates of 38 fishermen's cooperatives showed that participation in clean-up work was associated with an increased prevalence of lower- and upper-respiratory tract symptoms, reported more than 1 year after active exposure. This association was linked to various types of clean-up activities and the risk increased with the degree and duration of clean-up effort, and with a less frequent use of face masks. The latter indicated that inhalation was a relevant exposure route and suggested that relatively simple control measures may reduce health hazards."

21:9 "Fishermen were re-interviewed in a nested follow-up study 1.5 to 2 years after clean-up work, and it was found that respiratory symptoms were still more prevalent among fishermen highly exposed to oil, as compared with unexposed individuals. In addition, to explore mechanisms and to provide evidence using objective respiratory health endpoints, functional and biological tests were performed in strategic sub samples of exposed and unexposed individuals. While effects on conventional spirometric indices of lung function were not apparent, there was evidence of increased nonspecific bronchial responsiveness among the exposed, a finding that is compatible with the assumed airway irritation reflected by increased respiratory symptoms."

Photo: Clean-up volunteers at Prestige oil disaster

21:10 “In various studies on clean-up workers of the Prestige oil spill, potential genotoxic effects have been evaluated. A number of studies observed early effects on DNA during active exposure to the oil spill by using micronucleus tests, comet assay, and sister chromatid exchange. A higher risk of structural chromosomal alterations in circulating lymphocytes was found among fishermen 1.5 to 2 years after exposure. Although several of these biomarkers have been associated with an increased risk of developing cancer, the predictive values are largely unknown. A follow-up of both clean-up workers and unexposed individuals, including a repeated assessment of chromosomal damage 5 years after clean-up work, is currently underway.”

21:11 “The clinical evolution of the observed effects, including respiratory symptoms and biomarkers, is uncertain. They may disappear, persist without apparent pathologic alterations, or evolve into a clinically apparent disorder that is at present unpredictable. Therefore, a continuous surveillance and follow-up of clean-up workers by health authorities is recommended.”

21:12 “Finally, because oil spills will occur again in many areas of the world, there is a need for a concerted, international action regarding human health effects. Although every spill has unique characteristics, common guidelines for preventive measures, the design of studies on the evaluation of long-term health effects, and surveillance of exposed clean-up workers and residents are necessary. Lessons from recent studies clearly indicate that potential health consequences in individuals exposed to oil spills can no longer be ignored.”**[Ref 44]**

21:13 In the context of the outcomes of both the studies described above, and the relatively frequent “stories” of health effects reported among oil spill communities by both clean-up and other response personnel, **[Ref 45]** it may become more likely that future spills will see health impact claims submitted in growing numbers as the “scientific respectability” of oil related health concerns becomes more publicly understood. Thus, such health effect claims may add to the potential cost of future spills in polar and sub-polar areas.

22 Community and societal impacts of oil spills in Arctic and sub-Arctic environments

22:1 The community and societal impact of oil spills is historically widely ignored by all of the participants in spill response and remediation. This is a specific outcome of what may be defined as a “respond quickly and leave fast” policy on the part of response agencies, oil companies and national governments. In the vast majority of marine oil spills, response action and any spill related research are closed within two or three years of the initiation of the response and funding for any further research is withdrawn.

22:2 Such a strategy contributes to the absence of data on the “non-economic” human effects of spills (health impacts, community impacts, and societal problems such as social disruption and psychological stress) and has generated a data gap about the longer term environmental impacts and an almost complete absence of any data on the social impacts of such events.

22:3 Only in the case of the 1989 Exxon Valdez spill (EVOS) has intermediate and long-term research been carried out on such aspects of spill impact. The Exxon Valdez Oil Spill Trustee Council (EVOSTC) has initiated much independent academic research over the 27 years post spill and thus generated an unusually detailed record of intermediate and long term environmental, ecological and social data.

The work of the EVOSTC has highlighted the real inadequacy of the standard short term work currently carried out by government agencies and oil company and shipping interests and amply highlights the incomplete representation of oil spill impacts usually presented to the general public and to oil spill impacted communities.

22:4 Anthropologists working on the EVOS have identified the impacted indigenous communities of the Prince William Sound region as unique communities intimately linked to their ambient natural environment and deriving their economic and cultural base from their local biophysical environment. Such communities are known as Renewable Resource Communities (RRCs) and defined as "a population of individuals who live within a bounded area and whose primary cultural, social and economic existences are based on the harvest and use of renewable natural resources".
One might add that, in many cases, there is also a "spiritual" dimension to the relationship between members of an RRC and their biophysical environment

22:5 This definition of the Prince William Sound indigenous populations is equally appropriate to the indigenous peoples of the wider Arctic and sub-polar coastal regions. Both are members of similar ethno-cultural groupings, share very similar life styles and both live in relatively extreme climatic and environmental conditions. Crucially they are almost all RRCs (to a greater or lesser degree) and closely bound to the ongoing productivity of local and regional natural resources.

22:6 "Long-TERM Community Impacts pf the Exxon Valdez oil spill: Patterns of social disruption and psychological stress 17 years after the disaster".
This 2007 paper, by J.Steven Picou and Cecelia G Martin of the Anthropology Department of University of South Alabama, provides a forty nine page review of anthropological investigation and reporting of the impact of the EVOS on the communities of the Prince William Sound area.

22:7 The Picou and Martin paper notes that a salient feature of RRCs in spill scenarios is that, rather than focussing on invisible long term chronic threats to human health, major concern is directed towards threats to those natural resources upon which the community depends for its well-being and sustenance and which underpin the relationship and the economic and cultural linkages of RRCs to their biophysical environment.

22:8 The fact that Arctic and sub-polar RRCs are usually geographically isolated and characterised by low occupational and economic diversity makes the impact of oil contamination on natural resources even more severe, as toxic contamination from oil spills of crude or Fuel oil disrupts the relationships between polar and sub-polar RRCs and their seasonal harvesting activities and alters their perception of their personal safety and security.

22:9 Picou and Martin note, "Traditional cultural values of Alaska Natives are intimately linked to the seasonal harvests of salmon, clams, seal and other marine wildlife. Such subsistence harvests provide a collective value set that links spiritual themes, conceptions of self and traditional knowledge and seasonal rituals and behaviours to the biophysical environment" and comment that

22:10 "Subsistence harvests were severely disrupted by the EVOS, severing the cultural infrastructure of Alaska Natives from the ecology, thereby producing negative impacts to cultural traditions and meaningful seasonal behaviour. Such impacts from the massive ecological contamination and destruction of ecological resources resulted in "collective trauma" for Alaska Natives, thereby generating a host of pathological behaviours".

22:11 Cultural linkages to the biophysical environment are specifically relevant for subsistence harvest of Arctic and sub-polar Natives but are also relevant for non-native residents of fishing communities. In the case of the EVOS, both Natives and non-natives included seasonal commercial fishermen, deckhands, net menders, cannery workers, electronic specialists and boat builders/repairers whose occupations were severely disrupted and/or eliminated for prolonged periods of time and in some cases were never restored.

22:12 The emotional impact of oil spills on local inhabitants from all cultural group types is major. Personal notes and observations (unpublished) from long term work on the Sea Empress spill (Pembrokeshire, Wales 1996) and as a resident of the Sea Empress spill impacted community, and similar work on the Erika spill (Brittany: 1999) recorded examples of adult men and women weeping in public in response to their observations of the destruction of wildlife, the massive pollution of their coastline and the economic hardships they were experiencing. These communities also expressed sentiments of anger, confusion, hurt, fear and betrayal. [Ref 46]

22:13 The Picou and Martin paper provided a summary of negative social, cultural and individual impacts from three major research projects. Two of these projects were cross sectional studies of fishing communities and Alaska Native villages published in 1990 & 1995, the third project was based on long term monitoring of community impacts from 1989 to 2004. Their results are set out in Table 1 (see Appendix 1) and show a striking, wide ranging and diverse set of negative impacts not previously recorded from oil spill impacted communities.

22:14 Picou & Martin noted that, in the case of the EVOS, "unlike other technological disasters, empirical research from 1989 to 2006 had documented a continuing legacy of severe economic, cultural, social and psychological impacts. These impacts have focussed on extremely vulnerable RRCs in isolated regions of south-central Alaska such as Prince William Sound. These resource-dependant fishing communities and Alaska Native villages are characterised by simple economies, which are highly dependent on commercial fishing and subsistence harvests. The EVOS directly threatened the long term survival of these communities".

22:15 Picou & Martin also observed a distinct chronological pattern of shifting community impacts. In the short to medium term the cause of stress, disruption and anger was the impact on commercial and subsistence activity (fishing, gathering). However, in the medium to long term, individuals and communities had experienced a shift in the source of disruption and stress from the spill impacts to the litigation.

22:16 Picou & Martin report that this observation is in accord with other studies of major technological disasters (non-oil spills) which have demonstrated that, following the primary disaster impacts, a series of chronic secondary disasters emerge over time "where an initial acute shock becomes a chronic condition".

22:17 In the EVOS case, being a litigant/claimant redefined social status in the community and predisposed individuals and communities to additional major stresses. The long term EVOS work confirmed that the litigation "resulted in constant anger and dismay for plaintiffs who, over time, lost trust in their government and legal system. The chronic collective trauma that has continued in the community was initiated by the economic harm originally engendered by the EVOS, but most important, perpetuated by fourteen years of mindless and frivolous legal appeals by the corporation responsible for the spill".

22:18 Over time, continued resource losses have been experienced by EVOS impacted communities and individuals. The herring fishery has been wiped out, local salmon fisheries are still much reduced and oil pollution remains endemic in sheltered, low energy environments and traces of oil toxicity are still detectable in some species of regional wildlife.

22:19 Picou & Martin hypothesise that, when the claims are finally settled, final distribution of compensation will not automatically restore these communities to pre-spill conditions. They noted that the outcome of the distribution of damage awards to EVOS impacted communities would not result in a vibrant and productive herring fishery because it has already collapsed. “Furthermore, the distribution of damage payments will be subject to taxes, payments of debts incurred over the years and many other types of chronic resource loss” and that the social impacts of the distribution of large damage claims to small and vulnerable RCCs highly dependent on their links to the biophysical environment and individuals “characterised by chronic collective trauma may actually threaten the survival of fishing communities and Native Villages more than the original disaster”.

22:20 Given that this is the only study of the social impacts of oil spills on RCCs, the Picou & Martin social impact paper’s outcomes strongly imply that RCC communities elsewhere in the Arctic and sub-arctic will be subject to similar impacts following oil spills in their regional and local marine environments. [Ref 46]

23 Other studies

23:1 A number of other studies have investigated the difficulties of responding to at sea-spills of HFO, MFO and other “heavy” oils and the relative costs of marine oil spills. The conclusions broadly concur with the findings reported above, however, within the time scale of this report, it has not been possible to find any studies specifically and exclusively investigating such parameters (other than Exxon Valdez) in polar or sub-polar environments. The lack of such specific work strongly indicates the need for detailed and in-depth research to be conducted. [Refs 47, 48, 49, 50, 51, 52, 53]

24 Relative clean-up costs: variations between the case study spills

24:1 Any discussion of the cost of oil spills is fraught with difficulties derived from the extreme financial complexity of post settlement and litigation processes.

24:2 In many cases, a large number of claims are settled out of court, without recourse to litigation. Such settlements are largely driven by the inability of many claimants to wait for claims settlements to be achieved by extremely prolonged court action.

24:3 Thus, in the case of the Nakhodka spill (1997) most settlements through the Japanese and International Funds awarding system were not completed until 2002.
In the case of the Erika spill (1999), most settlements through the French legal system were not completed for a decade (2009), in some case longer (2012).

24:4 In such prolonged legal cases, smaller claiming entities lack the financial backing to wait for such settlements and generally settle earlier by mutual agreement with the responsible parties in order to maintain business viability, cash flow etc. Such settlements are poorly recorded in the available literature and are often subject to confidentiality clauses that restrict claimants right to publicly report the settlement.

24:5 In addition, a number of larger claims remain unsettled and are still the subject of ongoing action, through various legal systems.

24:6 Further complications arise when considering the historical deflation/inflation parameters that have taken place since the settlements were reached. Such considerations become additionally complex in the context of the fluctuating relative exchange rates of the currencies in which settlements were originally awarded. Thus Nakhodka claims were settled in Japanese Yen, Erika claims in Euro's and Selendang Ayu claims in US dollars.

24:7 The only reliable data on settlement of claims is that which has been pursued through, and eventually reported by relevant national and/or international compensation funding award processes. Using such incomplete data, but with specific reference to reported total payouts (see case study details above), costs may be calculated as follows.

Spill & year	Cost per tonnes oil spilled (USD)	Cost per tonne oily waste recovered (USD)	Cost per km oiled coast (USD)
Nakhodka 1997	14,023	4,880	244,000
Erika 1999	7,642	661	339,666
Selendang Ayu 2004	93,333	16,350	811,594

Conclusions and recommendations

1

Polar and sub-polar marine environments are characterised by their potentially very extreme weather and sea conditions, their extreme remoteness from technological and man-power resources and a limited data base of ecological, coastal morphology and hydrocarbon baseline information. As such, polar and sub-polar marine environments present some of the most extreme challenges for response to any marine oil spill.

This report concludes that, because of the very specific nature and behavior and fate of MFO and HFO (refinery residuals) in polar and sub-polar conditions, spills of MFO and HFO present the most extreme difficulties for oil spill responders.

2

The apparent cost of the three parameters reviewed (per tonne of oil spilled, per tonne of oily waste recovered from sea surface and shoreline, per km of oiled coast cleaned) strongly supports the contention that marine spills of crude oils, refined products and refinery residuals (MFO and HFO) in polar and sub-polar environments, winter conditions or "remote" locations are more costly (in terms of response and impact costs) than spills of similar oil types occurring elsewhere. All oil spills in polar and sub-polar waters are potentially more costly in terms of response.

This report further concludes that, because of the very specific nature and behavior and fate of MFO and HFO in polar and sub-polar conditions, response to spills of MFO and HFO is more difficult and more costly in such environments than spills of other oil types.

3

With specific focus on refinery residual oils such as MFO and HFO, this report notes that data about the financial costs of polar and sub-polar spills of such oils is limited and poorly compiled.

On the basis of the available information, this report concludes that there is an evolving body of evidence to confirm that such costs (MFO and HFO spills) are in excess of those generated by spills of fuel oils and most other liquid hydrocarbons in more temperate and less remote sea areas.

4

In the context of the above findings, this report recommends that immediate and ongoing consideration should be given to fuel oil spill mitigation/prevention strategies including:

a the deployment of regional ETVs, and
b a more intense and localised stockpiling of spill response equipment.
c The rapid identification of strategically placed SAFE HAVENS/Port of Refuge

5

This report advises the instigation of long term, detailed field research to investigate and report a wide range of polar and sub-polar fuel oil (MFO & HFO) spills of all sizes and across a broad range of polar and sub-polar sovereign state marine jurisdictions.

NB: Studies should focus specifically on the difficulties of responding to such spills, the detailed environmental impacts, the acquisition of detailed environmental/habitat and shoreline substrate baseline data, the acquisition of historical hydrocarbon pollution data and the identification of relevant polar specific mitigation strategies.

6

Finally, this report's principal advice is that a precautionary approach dictates the cessation of transport of refinery residual MFO and HFO, by sea, through polar and sub-polar seas (i.e. an immediate cessation/moratorium of such transport).

N.B. The precautionary principle to risk management states that if an action or policy has a suspected risk of causing harm to the public, or to the environment, in the absence of scientific consensus (that the action or policy is not harmful), the burden of proof that it is not harmful falls on those taking an action that may or may not be a risk.

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Appendix 1

Social structural impacts	Cultural impacts	Individual impacts
Increased population size	Social conflict between drift and set netter fishers	Declines in children's school grades
Competition for labor between local business and government with the cleanup industry	Strained community relations	Increased levels of collective stress
Housing shortages	Decline in community cohesiveness	Increased drug and alcohol abuse
Increased demands for childcare services	Disruption of subsistence lifestyle	Increased mental distress
Decrease in tax revenues	Damage to/theft of archaeological resources	Children often left unsupervised
Decrease/increase in crime	Sense of place and evaluation of as safe threatened/ damaged	Disruptions to daily life
Delayed infrastructure projects	Uncertainty about short & long term effects of EVOS on ecosystems and human communities	Disruptions to family life
Concerns over public perception of price, quality and demands of fish	Loss of trust for parties responsible for protecting the community from future threats	Feelings of helplessness, betrayal, anger characteristic of community members
Using reserves and investments to pay for cleanup	Social conflict between those who worked the cleanup and those who did not	Increased prevalence of mental disorders (depression, anxiety and PTSD)
Closure of drift net fishery	Public distrust of oil transportation and oil companies	Children experienced problems such as fear of being left alone, problems with relationships with parents and other children
Loss of staff due strain of excessive cleanup work	Long-term loss of social & economic resources	Self imposed isolation and avoidance of spills related discourse
Economic losses for commercial fishers and support businesses	Community mental health organizations overstressed	Long-term income loss spirals for commercial fishers
		Litigation stress as a chronic pattern

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