Ocean and Coastal Management 202 (2021) 105509

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: http://www.elsevier.com/locate/ocecoaman

A perspective on oil spills: What we should have learned about global warming

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ARTICLE INFO

Keywords
Climate change
Contingency plans
Decarbonisation
Multilateralism
Social justice

ABSTRACT

Scientific knowledge of marine pollution and oil spill response (OSR) innovation has diffused over half a century. Local community resilience to spills and the equitable application of knowledge worldwide are constrained by several barriers. These range from access, governance, cost minimisation, through austerity and poverty in affected areas, to realpolitik (e.g. vested interests, nationalism, corruption, security breakdown and war). Ongoing incidents show inequalities in spill risk and OSR capability. Advances in knowledge have belatedly brought us to the conclusion that the logical way to reduce adverse impacts of oil in an era of global warming is to accelerate decarbonisation. This would rapidly and simultaneously reduce the frequency, magnitude and consequences of oil spills. Meanwhile, mitigating spills, managing OSR, and restoring local communities and ecosystems at spill sites are fundamental obligations for the oil industry. These obligations should be routinely enforced by all responsible governments, and backed by inter-governmental agencies and conventions. However, we must no longer assume that even the best practices in exploration, production, refining, transport and consumption of hydrocarbons can adequately reduce their leading role in the ongoing destruction of the global environment.

1. Introduction

1.1. Background

Aged fourteen and led by an ex-wildfowler parent, two of the authors had already visited the UK's teeming seabird colonies on Handa Island, Bass Rock, Farne Islands and Skomer Island. Seeing the 'Torrey Canyon' oil spill on TV on March 18, 1967 was a terminal shock to childhood. Marine oil pollution suddenly became the environmental hot topic internationally for the public. The background was one of increasing concern over persistent organochlorine pesticides, highlighted in USA by Rachel Carson (1962). Cold war tensions came to a head that year in the Cuban missile crisis. Although Pacific nuclear bomb tests continued into the 1990s, a treaty banning atmospheric testing led to peak fallout in 1963, until the Chernobyl accident (1986). There was socio-political upheaval in the civil rights and peace movements, with growth in multilateral pressure groups.

Public pressure on environmental problems achieves results. Leaded petrol was phased out from 1975 in USA, from 1983 in UK (after Royal Commission on Environmental Pollution), and completed in 1999. Some countries acted on ozone layer depletion in 1978, and (after work by British Antarctic Survey), the 1987 Montreal Protocol phased-out chlorofluorocarbons (CFCs) globally. By 1979 the international dimension of acid rain from SO_2 pollution made headlines leading to the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (the first global environmental accord). From 1990, SO_2 and NOx emissions reduced in USA with the first market cap-and-trade system. Acceptance of the economic case by industry and government was essential to finding alternatives to leaded petrol and CFCs. Growing public expectations of peace, social justice and environmental protection underpinned all these changes, and oil spills inevitably ceded their position as No. 1 environmental issue.

1.2. Anthropogenic climate change

Decades later, the perceptions of ordinary people have renewed

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https://doi.org/10.1016/j.ocecoaman.2020.105509
Received 9 October 2020; Received in revised form 24 December 2020; Accepted 28 December 2020
Available online 4 February 2021

intensity. Peak concern passed to greenhouse gas (GHG) emissions causing climate change. Compared to the outrage caused by dramatic oil tanker accidents, this change in perception started slowly but grows relentlessly. The global warming hypothesis is robustly tested and accepted (except by populists and vested interests) as much as major scientific hypotheses such as the Earth's age, plate tectonics and evolution. Unlike these subjects, runaway climate change is a man-made existential crisis. It is neither academic nicety nor liberal conspiracy.

Climate change is also the eponymous crisis of the Anthropocene: over-arching, synchronous, cascading processes affecting the harsh lived experience of hundreds of millions of people with ramifications for millennia. It is the key global stressor of the planet's ecosystems, driving coastal squeeze, desertification, flooding, food security, forest fires, freak weather, human migrations, invasive species and rapid extinctions. It increases the risk of wars and viral pandemics. These stressors are intensified by positive feedback loops that are not the product of mass hysteria from social media, or a vague perception of worsening weather in news reports.

The 2008 and 2009 Conference of Parties $(COP)_{14}$ and COP_{15} of the United Nations Framework Convention on Climate Change (UNFCCC) discussed a successor to the Kyoto Protocol that was postponed as the global financial crisis deepened. In 2015 the aim of COP_{21} to accelerate action and investment in a low-carbon future was enshrined in the Paris Agreement, from which President Trump would have withdrawn USA had he not lost the November 3, 2020 election. In 2019 COP_{25} was sabotaged by President Bolsonaro of Brazil and moved via Chile to Madrid, losing more precious time. Glasgow's COP_{26} is postponed until 2021 due to COVID-19.

By now we should have been well on our way to mitigating catastrophic climate change. Instead, we focused on bailing out the financial system that caused the economic crisis, and on restoring the very economy that massively discounts future impacts of climate change. A decade later we continue relying on the carbon industries, despite climate change and inequality being seen as the world's most pressing problems (Hulme, 2016). Foreign aid should encourage sustainable development, not fossil fuel projects such as $1.2 billion (B) from UK Export Finance for a Mozambique liquefied natural gas project. To avoid the calamity resulting from a mean temperature increase of 1.5 °C we have only a decade to cut CO_2 emissions by 45% from a 2010 baseline (UNFCCC, 2019).

It will take 'cold turkey' to stop a fossil fuel addiction that provides warm or air-conditioned homes, air travel, and ever-growing numbers of cars. In a poll of 26 000 people in 26 countries under lockdown in July/August 2020, the following percentages said they would use their car more afterwards: >60% in Brazil and S. Africa; >40% in Australia, India and USA; >30% in China and Italy; and >20% in Japan, Germany and UK (Watts, 2020).

Looking at three scenarios after COVID-19 ('good, bad and ugly'), the 'bad' scenario (business as usual) is identified as the most likely outcome (Hulme and Horner, 2020). With currently hollowed-out state sectors, there will be disastrous consequences if we return to the excessive consumption of business as usual, driven by poorly-regulated markets, out-of-control outsourcing, private equity, shell companies, offshore tax havens, money laundering and organised crime. Among the legal beneficiaries of the 'bad' scenario are opaque think-tanks, arms salesmen and the fomenters of fake news and climate change denial. What some powerful elites prefer, the rest of us as consumers apathetically seem to covet. The 'ugly' scenario (socio-environmental breakdown and war) would spread ever more widely. As to whether it will, our life and times are already framed by culture wars with each side seeing an enemy in plain view. In place of such populism, we must learn behaviours to manage the crises of politics, economics and environment.

Whereas a rapid shift to a low-carbon economy is extremely challenging, there is hope for a 'good' scenario if city and rural dwellers in developed and emerging regions are not divided and ruled by fossil fuel lobbyists, political donors and their protégés. We must 'build back greener' and not retreat into carbon-heavy lifestyles. An example is set by Vancouver, whose leadership in 2009 aspired to be the world's greenest city by 2020. It now leads North America in reducing carbon pollution, receiving requests for advice from 2000 cities worldwide. Standing alongside First Nations communities, Vancouver opposes bitumen export pipelines to the British Columbia coast from the Athabasca tar sands in land-locked Alberta (Mauro, 2018).

In hindsight, the 1967 'Torrey Canyon' and subsequent oil spills are landmarks clearly pointing to the climate crisis becoming the ultimate emergency. The OSRs we have conducted recognize the importance of prevention (mitigation), clean-up and restoration (adaptation). Our visceral reaction to TV footage of spill impacts on seabirds in 1967 was triggered visually. Consequences of climate change can be brought home to people using landscape visualisation (Sheppard, 2005). Although CO_2 is invisible, the mitigation and adaptation lessons must be applied globally, rapidly and visibly to avert climate catastrophe (Sheppard, 2012).

1.3. Research objectives

In a 2013 interview J.G. Speth articulated a serious practical dilemma: "I used to think that the top global environmental problems were biodiversity loss, ecosystem collapse, and climate change. I thought that thirty years of good science could address these problems. I was wrong. The top environmental problems are selfishness, greed and apathy, and to deal with these we need a cultural and spiritual transformation. And we scientists don't know how to do that" (quoted by Berry, 2018).

With the aim of addressing this dilemma, the following research questions were examined from the perspective of cumulative experience of oil spills:

1) What are the valuable lessons from the history of oil spills in terms of changes in public perception, responses to present and future threats and specifically to anthropogenic climate change?
2) What are the effects (on spills and climate change) of variations in public and private sector governance, ranging from moral, legal and multilateral actions to the opposite extreme of neo-colonialism and corruption among businesses and governments?
3) How can the attention of more people be stimulated to peaceful action on the urgency of global environmental protection, so that industry, governments and public cooperate on decarbonisation (i.e. GHG phase-out)?

2. Methods

With an emphasis on key oil spill incidents from 1967 to-date, the study approach was chronological but grouped into phases defined by growth in knowledge and the changing public reactions to spills. Concerns ranged from scientific to socio-economic, political and global development issues. Oil spill cases and responses were reviewed and interpreted. Climate change and oil spill perceptions were considered in cultural as well as scientific terms, illustrated by references to art, literature, music and video.

Questions for assessment of an oil spill contingency plan (OSCP) were used to invite comparison with the primary response to COVID-19. Sources included news media, technical reports, OSR handbooks and scientific articles. The lead author's knowledge since 1975 in the oil port of Milford Haven (UK) came from over 20 oil spills worldwide, spanning multiple years in four cases ('Exxon Valdez', 'Sea Empress', Gulf War, Niger Delta). Two of these assignments were as principal investigator and/or expert witness, and three as steering committee member/independent reviewer. If all spills were the same and all their OSR lessons were applied effectively and equitably, a 'career in spills' would have been unnecessary.

3. Results: oil spill impacts and response

3.1. The 'new normal' of spills

Oil has seeped into the ocean for hundreds of millions of years; thankfully, otherwise the microbial communities capable of breaking down hydrocarbons at sea would not have evolved. During WW2 fuel oil was spilled faster, in larger quantities and amid horrific loss of life. The only upside was that over-fishing was impossible in strategic waters during the conflict, and so marine fishery stocks recovered despite the oil. Oil spills affect seawater quality and ocean ecology on relatively limited temporal and spatial scales. Natural mitigating processes include: oil evaporation, spreading and dilution; water turbulence and mixing; flocculation, biodegradation, biopackaging and sedimentation of suspended oil droplets; rapid recovery or replacement as a result of plankton communities' patch dynamics; toxin depuration physiology of fish; and wildlife mobility or avoidance behaviours.

However, in sheltered areas of coastal seas, estuaries, deltas, and particularly in fine-grained sediments and wetlands, stranded oil is often persistent and toxic. Depending on the efficacy of response and clean-up, lingering oil can cause significant adverse impacts on receptors and natural resources, affecting biodiversity, ecological succession, and bioaccumulation (primarily in shellfish). The socio-economic activities affected include tourism amenities, desalination and cooling water intakes, wild fishery market closures, and oiling of seafood aquaculture facilities. In addition to any crew fatalities and injuries, human health is affected in some receiving environments. Impacts of some spills are well-documented, and we do not cover them here in detail. This section examines lessons from case studies of spilled oil fate, behaviour and effects, how they are assessed, and how they drive evolving clean-up options.

Summary data are given in Table 1 for 24 larger tanker spills worldwide, showing key references in a range of locations, 50% European. Although smaller, the last three are included by the International Tanker Owners Pollution Federation (ITOPF). In 33% of these spills, all outside Europe, no opportunity for study arose or impacts were not assessed (N/A).

Table 2 shows the approximate costs of the oil spills in this study (footnote [b] in Table 1). In addition to the cause, size and oil type, the costs depend on weather conditions at the time, geographic location, access, security, geopolitics, governance, legal circumstances, and affluence in the affected region. The limit of insurance liability also drives/minimises costs. If, despite the 'polluter pays' principle, no spiller OSR is forthcoming, then government, United Nations (UN), European Commission (EC), ITOPF or non-governmental organisations (NGOs) may assist.

Over the two decades following 'Torrey Canyon' there were two further landmark spills: March 16, 1978 'Amoco Cadiz'; and March 24, 1989 'Exxon Valdez'. All three incidents catalysed international efforts to prevent spills, improve response and examine ecological impacts. Responders did not get it right every time, but by getting it wrong in new and imaginative ways they gradually made fewer mistakes. 'Torrey Canyon' was bombed by the RAF using high explosives and napalm. The first-generation dispersants sprayed and poured onto shorelines were industrial cleaning products (mostly aromatic hydrocarbons) that did more damage than Kuwait crude oil alone. After the 'Amoco Cadiz' spill (Iranian light and Arabian crudes), shoreline clean-up involved the French army removing an oiled saltmarsh. 'Exxon Valdez' (Alaska North Slope) crude oil was cleaned from rocky shores using hot seawater and pressure washing that was controversial: effective if the perception was that all oil had to be removed, but not necessarily using net environmental benefit analysis (NEBA).

In a spirit of cooperation, experts from industry, government, civil society and multilateral agencies lobbied, funded and conducted R&D. The Environmental Sensitivity Index (ESI) was developed to prepare for oil spills including in remote areas (Gundlach and Hayes, 1978).

Table 1
Major tanker spills worldwide in size order (ITOPF, 2020a).

#	Date	Incident and location	Oil (t) type	Shoreline oiled, bird corpses found[e], references
1	Jul. 1979	'Atlantic Empress', off Tobago, W. Indies[a]	287 000 crude	N/A
2	May 1991	'ABT Summer', S. Atlantic off Angola	260 000 crude	(N/A)
3	Aug. 1983	'Castillo de Bellver', off South Africa[a]	252 000 crude	1500 birds
4	Mar. 1978	'Amoco Cadiz', Brittany, France[b]	223 000 crude	400 km shoreline; 4572 birds; Gundlach et al. (1983); Sell et al. (1995); Little et al. (2003)
5	Apr. 1991	'Haven', Genoa Roads, Italy[a, b]	144 000 crude	Martinelli et al. (1995)
6	Nov. 1988	'Odyssey', N. Atlantic, off Nova Scotia, Canada	132 000 crude	(N/A)
7	Mar. 1967	'Torrey Canyon', Scilly Isles, Cornwall UK[a, c]	117 000 crude	500 km shoreline; 7815 birds; Smith (1968); Hawkins et al. (2017)
8	Dec. 1972	'Sea Star', Gulf of Oman, Indian Ocean[a]	115 000 crude	(N/A)
9	Jan. 2018	'Sanchi', off Shanghai, East China Sea[a]	136 000 condensate	Cargo burnt; 2000 HFO[c] and tarballs stranded
10	Feb. 1980	'Irenes Serenade', Navarino Bay, Greece[a]	100 000 crude	1000 HFO[c] spread 100 km
11	May 1976	'Urquiola', La Coruña, Galicia, Spain[a]	100 000 crude	60–215 km shoreline; few birds; Gundlach et al. (1993)
12	Feb. 1977	'Hawaiian Patriot', Honolulu, Hawaii, USA[a]	95 000 crude	(N/A)
13	Nov. 1979	'Independenta', Bosphorus, Turkey	94 000 crude	(N/A)
14	Jan. 1975	'Jakob Maersk', Oporto, Portugal[a]	88 000 crude	1–25 km shoreline; Gundlach et al. (1993)
15	Jan. 1993	'Braer', Shetland Islands, Scotland, UK[b]	84 700 crude	3–25 km shoreline; 1538 birds; ESGOSS (1993); Little et al. (2003)
16	Dec. 1992	'Aegean Sea', La Coruña, Galicia, Spain[a, b]	74 000 crude	20–96 km shoreline; few birds; Little et al. (2003)
17	Feb. 1996	'Sea Empress', Pembrokeshire, Wales, UK[b]	72 000 crude	200 km shoreline; 3495 birds; Law and Kelly (2004); SEEEC (1998)
18	Dec. 1989	'Khark 5', Atlantic off Morocco	70 000 crude	(N/A)
19	Dec. 1985	'Nova', Kharg Island, Iran, Gulf of Iran	70 000 crude	(N/A)
20	Apr. 1992	'Katina P', Indian Ocean, Maputo, Mozambique[b]	67 000 HFO[c]	3-1450 km shoreline; Little (2018)
21	Nov. 2002	'Prestige', Atlantic, off Galicia, Spain[c]	63 000 HFO[c]	240-3000 km shoreline; 9348-22 000 birds; Little et al. (2003); Albaigés et al. (2006)
[d]	Mar. 1989	'Exxon Valdez', Prince William Sound, AK, USA[b]	37 000 crude	2083 km shoreline; 41 000 birds; Wells et al. (1995), Wiens (2013)
[d]	Dec. 1999	'Erika', Bay of Biscay, off Brittany, France[b]	20 000 HFO[c]	400 km shoreline; 42 000-52 000 birds; Kerambrun and Laruelle (2001); Little et al. (2003)
[d]	Dec. 2007	'Hebei Spirit', W. coast of South Korea	11 000 crude	Shoreline 'several hundred' km; algae aquaculture

[a] Fire burned part of spill.
[b] Spills in this study.
[c] Heavy Fuel Oil.
[d] Lower rank for comparison.
[e] Approximately 5-25% of total killed.

Table 2
Approximate costs ranked for spills in this study, not limited to tankers (various media sources).

#	Spill incident, cause, date	Approximate costs, claims, awards ($US, uncorrected to present value)
1	'Deepwater Horizon' Gulf of Mexico blowout 2010	$65 billion (B) in total including clean-up and legal costs, $4.5B in criminal fines and $20.8B in 2016 settlement
2	First Gulf War spills due to sabotage of Kuwait oilfields 1991	$52.4B in approved claims, of which $4.3B (Kuwait, Iran, Jordan, Saudi Arabia) were environmental (excluding short-term cleanup), of which $0.52B were for Saudi Arabian coastal remediation, restoration and nature reserves
3	'Exxon Valdez' grounding 1989	$7B in total including Exxon paying >$2.5B clean-up, $1.8B restoration and damages, $1B in criminal fines and in 1991 civil settlement with US federal and state agencies
4	'Prestige' breakup, sinking 2002	$1.8B compensation awarded in 2018 court ruling against London P&I Club; clean-up costs $494 million (M) to Spain, $145M to Galicia, $68M to France; note International Oil Pollution Compensation Funds (IOPC) limited to $199M
5	'Aegean Sea' breakup, explosion, fire 1992	$287M claimed in court, and most was paid after 2001 settlement between Spanish government, IOPC and ship owner; $3.53M paid short-term to fishers
6	'Erika' breakup, sinking 1999	$200M in damages and $0.443M criminal fine of responsible party (Total oil company) in 2008 court ruling
7	'Sea Empress' grounding 1996	$95M - $153M estimated costs in total for clean-up response, of which $68M was paid from IOPC funds
8	Bodo [Ogoniland] Nigeria pipeline failures 2008; 10 years of oil theft/ leaks	$73M compensation awarded to Bodo community members by London court in 2015; [$1B wider Ogoniland fund suggested by United Nations Environment Programme (UNEP, 2011); $31M already spent by new remediation agency]
9	'Haven' explosion, fire, sinking 1991	$72M in total, including compensation from IOPC funds ($43M) and insurer ($28M)
10	'Braer' grounding, breakup 1993	$51M in total compensation claims awarded by IOPC funds; $6M for the clean-up; $0.7M initial funding from EC
11	Air raid on Lebanon Al-Jiyeh power station 2006	$15M received for response and support in kind from Organisation of Petroleum Exporting Countries (OPEC), UN and EC agencies (nothing from Israel), of $203M originally estimated claims by Lebanon government
12	'Katina P' Mozambique grounding, breakup, sinking, 1992	$4.5M received of originally estimated claims of $10.7M by Mozambique government, due to lack of contingency plans and not having signed International Maritime Organisation (IMO) OSR agreements

Entering into force in 1983, the IMO International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) was instrumental in preventing tank washing at sea and improving ports' waste reception facilities. Spill compensation schemes were refined (summarized in ITOPF, 2020b). Spill trajectory modelling, aerial surveillance and clean-up technologies improved the oil encounter rate at sea and the effectiveness of oil recovery equipment (pumps, booms, skimmers). Lower-toxicity chemical dispersants and aerial spraying capability came together. The reluctance to use dispersants after 'Torrey Canyon' was overcome for some spills where resource managers agreed that NEBA might result in less impact than oil alone. Training improved in

Table 3
Ten questions for assessing oil spill contingency plans (ITOPF, 1987).

#	Questions
1.	Has there been a realistic assessment of the nature and size of the possible threat, and of the resources most at risk, bearing in mind the probable movement of any oil spill?
2.	Have priorities for protection been agreed, taking into account the viability of the various protection and clean-up options?
3.	Has the strategy for protecting and cleaning the various areas been agreed and clearly explained?
4.	Has the necessary organisation been outlined and the responsibilities of all those involved been clearly stated – will all who have a task to perform be aware of what is expected of them?
5.	Are the levels of equipment, materials and manpower sufficient to deal with the anticipated size of the spill? If not, have back-up resources been identified and, where necessary, have mechanisms for obtaining their release and entry to the country been established?
6.	Have temporary storage sites and final disposal routes for collected oil and debris been identified?
7.	Are the alerting and initial evaluation procedures fully explained as well as arrangements for continual review of the progress and effectiveness of the clean-up operation?
8.	Have the arrangements for ensuring effective communication between shore, sea and air been described?
9.	Have all aspects of the plan been tested and nothing significant found lacking?
10.	Is the plan compatible with plans for adjacent and other activities?

deployment and monitoring the effectiveness and effects of counter-measures. As part of the OSCP, stockpiles of OSR equipment were created, and 'spill drills' simultaneously became world-class and routine. To improve OSR, clean-up cooperatives were established from 1985. Lessons learned were documented and fed back into the revised plans and clean-up manuals.

For positive outcomes to spills, a strategy and a well-rehearsed, tactical OSCP are both needed. These enable responders to apply the technical data and scientific knowledge that are codified in regulations, procedures, guidelines and advice. The uneven COVID-19 response worldwide has shown the critical importance of international coordination and rigorous testing of contingency plans. The UK central government and others failed to ask, let alone answer the right questions, as can be seen by substituting the COVID-19 equivalent in the following OSCP questions (Table 3; see section 4.1).

Experiments conducted in the field, in the laboratory and at the meso-scale (e.g. tank tests and enclosed ecosystems), refined and confirmed many of the observations from oil spill case studies. Seminal work was conducted by scientists from the Field Studies Council (FSC) Oil Pollution Research Unit in Wales, who among others were also engaged in environmental monitoring of coastal refinery discharges and the proliferating oil and gas fields in the North Sea and elsewhere. Despite the inevitable blind alleys in oil spill R&D, learning from the mistakes and moving quickly on were hallmarks of the progress that was needed. The experimental, adaptive management approach facilitated controlled comparisons between clean-up options, leading to development of practical OSR guidelines that in turn informed contingency plans. The FSC and other natural history NGOs have wider historical, ecological and cultural importance, including tracking the evolution of perception and ethics in environmental learning (Berry and Crothers, 1987).

It seemed that the coincidental 11-year intervals between the three landmark spills were enough to make real progress. And yet it was too long because funding as well as public and professional vigilance dwindled before the next large spill. 'Amoco Cadiz' and 'Exxon Valdez' were cases that were heard or settled in US courts. Not content with the international compensation schemes that limit the spiller's liability (mainly relating to tankers), after 'Exxon Valdez' the USA quickly ratified the Oil Pollution Act 1990 (OPA 90). This created a comprehensive prevention, response, liability and compensation regime for oil pollution in US navigable waters (fresh and marine) and from all vessels and other facilities including offshore platforms. The Americans developed a

Fig. 1. Souvenir T-shirt in Valdez, for Cordova District Fishermen United (Troll, 1989).

formal process for Natural Resource Damage Assessment (NRDA), alongside compelling musical (Zappa, 1993) and artistic perceptions (Troll, 1989, Fig. 1).

Apart from NRDA, oil spill impact assessment was not standardised, and remained an evolving, patchy process. Many spills had no impact assessment and even those for 'Torrey Canyon', 'Amoco Cadiz' and 'Exxon Valdez' came from separate sources (Table 1). Tracking recovery from multiple inputs against fluctuating baselines can take decades (Hawkins et al., 2017). In addition to official assessments, essential knowledge was gained from experience, case studies and expert reviews during 'peacetime' between spills. In place of anecdotal data there was better understanding of the physics, chemistry and biology of oil spill behaviour and effects.

Some complained about the high cost and litigious nature of the 'Exxon Valdez' response, but the thorough science undoubtedly improved reliability of impact assessments. 'Exxon Valdez' technical innovations were deployed later in other spills (e.g. 'Deepwater Horizon' blowout in 2010, section 3.2.4). The multi-agency Shoreline Clean-up Assessment Technique (SCAT) included ground and aerial survey methods that, with early Geographic Information Systems (GIS), were pioneered in the 'Exxon Valdez' response. The Global Positioning System (GPS) and field computers later helped long-term impact surveys and NRDA. Fine sediment particle interaction with oil was shown to influence oil behaviour, and prolonged deep (>1m) oil penetration into coarse sediments was studied in unprecedented detail (Fig. 2).

Fig. 2. Sediment hydrocarbons sampling trench 18 months post-'Exxon Valdez', North Latouche Island, Prince William Sound, September 4, 1990 (E. Gundlach).

The advanced chemistry forensics, oil source fingerprinting, bioremediation trials, and wildlife and cultural resource programmes benefitted all sides in the 'Exxon Valdez' case. These innovations are still widely applied. Cultural resource studies used First Nations anthropology expertise from Alaska and British Columbia. The involvement of local communities continued after the spill (e.g. Alaskan Regional Citizens' Advisory Councils). In contrast, in some recent spills and geographies a science-led response seems impractical, cursory, and not always reliable or inclusive of local and indigenous communities (section 3.3).

3.2. *Growing recognition of oil's global impact*

3.2.1. *Changing circumstances*

At the end of Soviet communism (1991) and South African apartheid (1994), the years 1991–2002 saw growing democratic values, a sense of optimism, improving technology, and increasingly sustainable development. From 1991 to 2000 IPIECA produced 10 habitat-specific guidelines on oil pollution impacts, OSR and NEBA. Three key UN conventions on biodiversity, climate change and desertification followed the Rio Earth Summit (1992). In that year, tanker spill compensation liability limits were expanded to $280 million (M). In a temporarily 'unipolar' world where ascendant USA was committed to multilateralism, a UN agency with oil spill remediation and reconstruction responsibilities was created to assist recovery from the 1991 Gulf War (section 3.3.1).

The average numbers/decade of medium and large oil spills from tankers halved between the 1970s and 1990s. The reduction since the 1970s is now more than an order of magnitude, thanks to public pressure and better environmental management (e.g. effective regulation, standards, certification, audit, prevention, surveillance and reporting; Fig. 3).

Estimated oil inputs into World Oceans from shipping and other (including unknown) sources were 4 million t/year during the 1990s (Fig. 4).

The inverse, but not causal, relationship between rising emissions/concentrations of CO_2 and falling oil spill frequency is shown in Fig. 5. The juxtaposition and common inflection points in the early 1970s are striking. After the OPEC oil embargo in 1973, the reduction in spills' frequency (if not always their size) was sustained in spite of tanker trade increasing from c. 60 to 100 million t/year between the 1970s and 2000s. There is a huge difference between c. 4 million t/year of oil inputs to the oceans from all sources and c. 30 billion tons of CO_2/year emitted to the atmosphere. Oil spills are a low but highly visible hazard generating historically high levels of public outrage. In total contrast, anthropogenic climate change is an extreme hazard that until recently has produced little outrage, considering the acceleration in CO_2 inputs 50 years ago, when a 'red flag' should have been raised (Fig. 5).

Being unaware of climate change was the norm in 1970 but to deny it after the early 2000s is indefensible, given that the challenge of necessary adaptation far outweighs that presented by spills. Dismantling UN agreements is not the way forward. Instead, climate emergency planning is essential with UNFCCC taking the lead. Mitigating and adapting to the increased frequencies of extreme events also demands active transformation across society, industry and government.

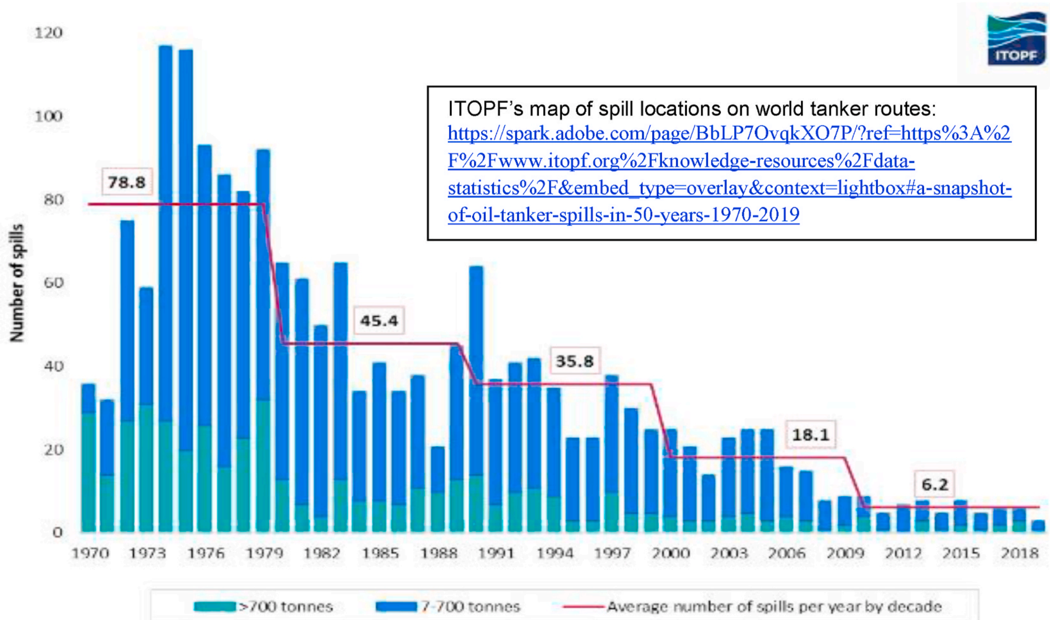

Fig. 3. Annual number of >7 t tanker spills 1970–2019, individual large tanker spills not visible in the number of spills (ITOPF, 2020a).

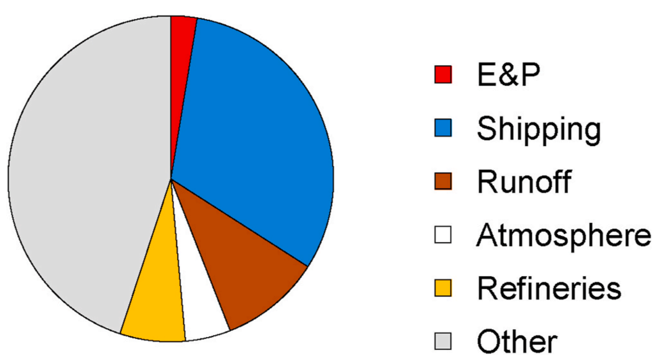

Fig. 4. Sources of oil inputs in 1990s to World Oceans (NRC, 2003); 'E&P' = oil exploration and production; 'Runoff' = river, sewage, municipal, and industrial (non-refineries); 'Other' = all non-marine transport and oil seeps.

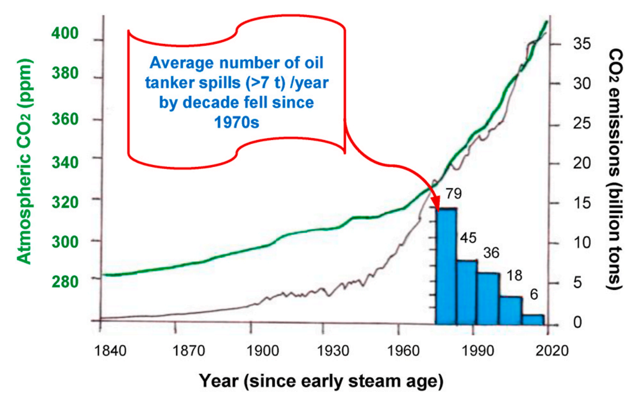

Fig. 5. Atmospheric CO_2 concentrations and emissions since 1840 (NOAA, 2020) compared to reductions in oil spill frequency since 1970 (generalised from Fig. 3); note that if comparable spill frequency data had been available prior to 1970 they would track the steep increases in use of oil during and after WW2 and the emissions of CO_2.

3.2.2. Winter(s) of discontent (Shakespeare, 1597)

Despite the general downward trend in number of tanker spills (Fig. 3), there was a spate of large spills from 1991 to 2002, mostly during northeast Atlantic winters (footnote [b] in Table 1). The adverse impacts of these spills did not change the whole direction and pace of oil spill response R&D as did the three landmark spills. This does not mean that the 1991–2002 spill record was acceptable; the large spills of the 1990s were a wake-up call to re-establish the positive trend. Innovative approaches to clean-up were developed on cliff coastlines using climbers, and R&D was commissioned into responses to spills of heavy oils.

The 'Haven' (Iranian heavy crude) and 'Aegean Sea' (Brent crude) spills burned and caused severe impacts and fishery closures. The latter vessel was a modern double-hulled tanker, as mandated by OPA 1990 for US trade, and yet she broke up and burned on the waterfront in the evacuated centre of La Coruña. Burning oil slicks floated >5 km across the bay setting fire to maritime cliff vegetation near Breixo. This failure of prevention shows that improvements in tanker design and also in countermeasures are not a panacea, due to variations in oil spill behaviour, weather and human factors.

The 'Braer' and 'Sea Empress' both grounded in protected conservation areas, although each spill had rather less adverse impact than originally feared. The 'Braer' lost 85 000 t of Gullfaks oil as she broke up near the shore, but storm-force winds meant hardly any of the light crude oil stranded. Most oil evaporated or carried as aerosol overland. Remaining oil formed dilute oil-in-water suspensions in the water column. The 'Braer' cargo and bunkers were a total loss, with one-third eventually settling out with fine particles that had been suspended by the storm. The 'Sea Empress' losses of 72 000 t of Forties blend crude oil were mainly dispersed by February gales and effective use of chemical dispersants on the ebb tide before she was brought into the shelter of Milford Haven. Some bunker oil persists along with historic inputs sequestered in fine-grained sediments of the estuary. Nevertheless, it seems large oil tankers can suffer grounding or destruction on or near the shoreline without long-term ecological impact. It would have been a very different outcome if 'Braer' or 'Sea Empress' had foundered two months later, in the seabird breeding season.

In contrast, the persistence at sea of a relatively small spill of 20 000 t heavy fuel oil (HFO) lost in midwinter from 'Erika' led to probably the worst seabird kill in Europe, and heavy shoreline impacts. The 'Erika' and 'Prestige' HFO spills prompted improvements of spill response for

Fig. 6. 'Prestige' clean-up by thousands of volunteers, with some flights provided by Iberia Airlines (top: Nunca Máis, a Galician NGO; bottom: Stein, 2003).

this problematic oil type, better international cooperation in the European Union (EU), and HFO spill compensation under the 2001 Bunkers Convention. The formation of a viscous water-in-oil emulsion ('mousse') from HFO or crude oil under wave action creates a much higher volume of plumage-clogging, persistent pollutant that is also difficult to skim and pump. Galicians cried "Never Again" as they manually retrieved oil from 'Prestige' (Fig. 6).

One exception to these NE Atlantic incidents was the 'Katina P' spill of 66 700 t HFO in Mozambique, severely oiling 3 km of mangroves in Maputo Bay and less severely 1450 km in total (550 km in South Africa). The ship's 'innocent passage' was nothing to do with Mozambique, but Table 2 shows that the government did not receive much of their damage claim. This was harsh considering that 15 years of post-colonial civil war still had four months to run, with small arms fire heard during clean-up (Little, 2018).

Another problem with HFO is that there is low demand due to the welcome move away from its use in power generation, to protect air quality. Consequently it is surplus and cheap, leading to a perverse incentive for ocean-going ships to burn highly-polluting HFO with c. 1 billion t/year GHG emissions still not adequately controlled by IMO. In each of the above spills a substantial proportion of the HFO was burned or spilled along with the cargo. They all involved environmental and economic impacts including fishery closures. Each had novel features and was traumatic for local communities, and all became media events.

Despite, or maybe because of colourful and immediate media coverage of the 1990s incidents, public perceptions of these spills were increasingly subject to spill fatigue. In the long-run the 1990s incidents will not be regarded as R&D landmarks of the magnitude of 'Torrey Canyon', 'Amoco Cadiz' and 'Exxon Valdez'. These were landmarks not because of their size; after all, 'Exxon Valdez' lost 'only' 37 000 t. Rather, it was because they led to step changes in spill prevention, OSR capability, and lasting improvement in environmental understanding, all of which had been demanded by public opinion. Some of the innovations diffused very slowly. After 'Exxon Valdez' the UK scientific approach was improved, although not until 2007–9 were SCAT and advanced chemistry methods from Alaska fully codified in practical guidelines in UK scientific contingency plans (PREMIAM, 2009; 2018).

3.2.3. *Concern shifts from spills to climate change*

Although GHG impacts did not feature significantly in environmental impact assessment (EIA) until the new millennium, NGOs and the public were beginning to focus less on individual oil spills than on other concerns, including global warming. This focus was sharpened in 2005 by Hurricane Katrina and Vice-President Gore's 'An Inconvenient Truth' (Sheppard, 2012). By 2013, climate change and biodiversity were integrated into EIA more prominently in European Union guidance (EU, 2013).

Although public concern over spills remains a leading driver of opposition to coastal pipelines and tankers in places such as British Columbia, the oil that is not spilled is in fact the real problem. For example, spilled oil sedimenting out in an accretional environment is carbon that in effect is sequestered. The universal burning of fossil fuel is the main culprit in man-made global warming. Hydrocarbon combustion and agriculture are the main global stressors where the public (by exercising consumer choice) can play an urgent part in mitigating. A comparatively small contribution to global warming comes from oil spills, and this is mostly from the evaporation of volatile organic compounds (VOCs) from oil spilled at sea (and also welcomed by responders because it reduces shoreline impacts). Contributing to global warming from the upstream industry during leaks and upset conditions are potent GHGs such as methane, in particular from the industrial northern hemisphere. Downstream processing and retail sites have successfully improved VOCs capture and recovery.

Safety and high utilization (e.g. waste and emissions minimisation) are paramount for as long as we continue to use hydrocarbons. However, the pace of replacement of fossil fuels by renewables must now rapidly accelerate. Renewables technologies including hydroelectric projects are improving all the time, and some costs are coming down. There are concerns that lithium, palladium and rare earth elements (REE) used in batteries, fuel cells and other renewables processes lead to adverse impacts of mining (onshore, in the deep sea, and potentially off-planet). Conflicts might arise over access to REE resources due to their geopolitical scarcity. Nuclear power will remain a primary energy source beyond fossil fuels, partly because safe storage of radioactive wastes demands sustained expertise and vigilance.

3.2.4. *When life looks like easy street there's danger at your door (Hunter and Garcia, 1970)*

After about 2002, the oil industry must have seemed under control to the wider public, as headlines were not dominated by major oil spills. To secure their licence to operate, steady improvements had been made in the regulation and reduction of spills and drilling mud emissions from offshore oil and gas fields on continental shelves and in ever-deeper or colder waters. Whether the spills occur from tanker accidents, in E&P operations, from land-based sources, or down the drains of our industrial or housing estates, the cumulative knowledge gained can be effectively applied. It is possible to get through the emergency phase and manage OSR as a project like any other, preferably with transparent cooperation among industry, government, scientists, NGOs, media and public.

A lower visibility of pollution should not mean complacency. During 2002 there were other serious and ongoing distractions: the burst of the 'Dotcom Bubble'; Severe Acute Respiratory Syndrome (SARS) spreading human-to-human from Guangdong, China; and the aftermath of the 9/11 attacks in USA leading to the 'War on Terror' and the 2003 invasion of Iraq. Before it can be regarded a success, any response to oil spills (or chemical accidents, or viral pandemics) must protect lives and minimise health and safety impacts. At the same time, responders must trade-off economic/cultural resource impacts against adverse ecological impacts. As we see in COVID-19, getting these trade-offs right, documenting, validating and communicating them in a truthful, balanced way in the glare of the media, is the difficult part.

Step forward Tony Hayward CEO of BP, after the explosion and blowout of the 'Deepwater Horizon' drilling rig on April 20, 2010 in the Macondo prospect, Gulf of Mexico. With massive oil releases of 700 000 t from the seabed wellhead showing live on subsea video over four months, BP could not be shielded by their hierarchy of contractors. Outsourcing by BP had already been intensified by the previous CEO John Browne, but some deep water technological challenges were new. Serious doubts about blowout preventers were raised, prompting rapid and business-interrupting risk reassessments in the E&P industry around the world. Media and other stakeholders including President Obama sensed a BP cost minimisation back-story. Public perception darkened dramatically as Mr Hayward, while sympathising with the affected communities, declared: “We're sorry for the massive disruption it's caused their lives. There's no one who wants this over more than I do. I would like my life back”.

3.3. Problem spills during conflicts

3.3.1. Desertshore (Nico, 1970)

3.3.1.1. Gulf War spills. Away from TV cameras there were glimpses of other lives not being ‘back’, especially in war zones. These were spills that can make all the above seem ephemeral and colourful despite their impact. Even larger than the ‘Deepwater Horizon’ spill, the 1991 Gulf War spills (1 000 000 t) and fires in Kuwait were caused by sabotage by retreating Iraqi forces under Saddam Hussein. The spills were the first to be branded as eco-terrorism. The slicks contaminated 800 km of coastline including bays choked with oil in Saudi Arabia almost to Qatar. Much of the sediment infaunal community died when their burrows filled with oil, and algae bloomed in the absence of invertebrate grazing. Channels blocked by layers of algae and fine sediment led to feedback loops that changed the drainage hydrology and ecology of the tidal flats.

An inter-disciplinary impact assessment was made in 1991–1993, representing a high point in international cooperation in oil spill science. A special issue of Marine Pollution Bulletin (MPB, 1993) described the scientific response including the 100-day ‘Mt Mitchell’ marine survey in 1992. The survey produced scientific data, fostered environmental awareness and cooperation among 140 scientists from 15 nations, and was organised by: International Oceanographic Commission (IOC); UNEP; Regional Organisation for the Protection of the Marine Environment (ROPME); US National Oceanic and Atmospheric Administration (NOAA); and Marine Spill Response Corporation (MSRC). Because oiling conditions and impacts were likely to have changed in the decade since these international surveys just after the Gulf War, intensive shoreline monitoring and rapid ecological assessment surveys in Saudi Arabia were undertaken in 2002–3. The degree of change 1993–2003 was assessed by building on SCAT, modified for vegetated, burrowed, carbonate sediments. More than 3100 transects were surveyed, almost 26 200 total petroleum hydrocarbon (TPH) samples and 2660 fingerprinting samples were analysed.

Chemistry analyses were carried out in a state-of-the-art analytical chemistry laboratory established by Battelle close to the affected areas. The trained analysts produced top-notch data that was used later to calibrate SCAT field observations on oil character, to assess oil weathering, and to predict toxicity and ecological effects. The spills left TPH concentrations in visibly oiled sediment from 3200 mg/kg to 41 000 mg/kg. This oil persistence occurred despite the emergency response and initial clean-up. Using estimates of the volume of oiled sediment, this approximates to the total amount of oil lost by either the ‘Braer’ or ‘Sea Empress’. Less than ten years after these latter spills in high-energy areas, traces of remaining oil in sediment had been practically undetectable. In contrast, free-phase brown oil was visible after 20 years trapped in low-energy shorelines of the Arabian Gulf (Fig. 7).

3.3.1.2. UN Compensation Commission (UNCC). All oil spills caused by armed hostilities are hard to respond to, and unfortunately they are not covered by insurance and compensation funds. And so a new agency, the UNCC, was created after the first Gulf War. The necessary funds were raised from the sale of otherwise sanctioned Iraqi oil exports that were also used, amid some controversy, to fund emergency food and medical aid. From 1991, 2.6 million individual claims totalling $352B for wartime losses and compensation were processed by UNCC. Of these, after scrutiny by UNCC, about 70 claims were awarded for all losses ($52.4B). Of these, in 2005 the Follow-up Programme for Environmental Awards (F4) under Decision 258 awarded a total of $4.3B to Kuwait, Iran, Jordan and Saudi Arabia (Table 2).

Added to the initial response this was the most expensive spill between ‘Exxon Valdez’ in 1989 and BP's 2010 blowout. The $4.3B included $0.51B for contracts in Saudi Arabia covering coastal remediation and restoration projects, and concentrating on the worst-hit locations at the time (2003 data). In addition, $6.17M was awarded for the creation and management of several marine protected areas (MPAs) elsewhere in Saudi Arabia. In the decade since the design of a visitor and educational centre, it is not known if lack of progress in MPA designation is due to poor disclosure or graft.

During 2007, teams of independent reviewers (IRs) for the F4 programme were organised by UNCC under contract to recipient states. Baseline IRs surveys took place in 2007–8 with the respective national focal point (NFP). In the hiatus after the 2002-3 surveys, the UNCC noticed in 2009 that there were two parallel NFPs in Saudi Arabia. One of these had already awarded a design contract for salt marsh remediation, initially costing more than the entire ’Haven’ or ’Braer’ response (Table 2), and which UNCC adjusted downwards.

After further scoping by the NFP, IRs and UNCC during 2009, tidal flats were added to marshes in the planned contracts. The coastal F4 contracts in Saudi Arabia were for clean-up and restoration of 1800 ha of heavily-oiled saltmarsh and intertidal flats, covering the worst areas of lingering oil. The projects to refresh the blocked channels, excavate new channels, transplant mangroves, till sediment flats, and monitor all operations were designed and supervised by a team of experienced environmental scientists (Pandion Technology-RPI, 2003). The team included some who took part in the shoreline surveys in both 1991–93 and 2002–3. Progress was at last being made, due to leadership

Fig. 7. Oiled algae blocking creek (left, plan view); algal mats inter-laminated with fine-grained carbonate sediment (right, section), Arabian Gulf tidal flats, Saudi Arabia, June 2010.

continuity and an approach using field experiments and adaptive management. The low-profile remediation included sign-off by quantity surveyors. Saudi Arabian restoration is still ongoing 30 years after the Gulf War.

The Saudi Arabia NFP was supported by advice from the regional offices of three of the 'big four' accountants (EY, KPMG, and PwC). One of these firms designed an accrual-based project accounting system because at the outset only cash-based accounting was in place. The first and smallest contract awarded was almost $10M for chemistry laboratory services. However, during the period of most intense remedial design and fieldwork, very few samples were analysed reliably, mostly overseas, despite the IRs' questions in their visits and six biannual reports (January 2010 to October 2012). In reply, there was no mention of the fit for purpose chemistry laboratory created in 2001 to compare sediment contaminants data to those from 1991 to 1993. Decadal sampling to compare sediment contamination could by now have been in its fourth collection phase, continuing the high standards set in 1992 (MPB, 1993) and by Pandion Technology-RPI (2003).

Including quantity surveyor and chemistry contracts, seven terrestrial and 13 marine remediation contracts covered most of the Saudi Arabia F4 programme. Information on bidders was scant. Few had demonstrable qualifications (e.g. website), which made it hard to check their remediation experience and identify possible collusion among firms. Improbably for competitive tendering, the winner and runner-up bids in each of the 20 contracts were separated by as little as 0.05% of the price. Across all contracts, there was low statistical probability ($p < 0.005$) that the significant separation of the two front-runners from the remaining bids occurred by chance. The IRs asked how this had occurred, but got no answer.

With all major contracts awarded and most payments disbursed to recipient nations, the UNCC wrote its final report on the F4 awards in 2012–2013 (UNCC, 2016). The Saudi Arabia IRs disagreed when in Decision 269 UNCC declared its mandate fulfilled by the systems and assurances for recipients to continue without independent review. At the disengagement of the UNCC, the unresolved issues included stakeholder engagement, oily waste management, provision of hydrocarbon data, creation of seed banks for desert re-vegetation, site protection and designation of MPAs. Apart from RPI's technical publications (e.g. Minter et al., 2014), there was little transparency since the departure of the Saudi Arabia IRs team and UNCC in 2012–2013.

3.3.2. *Multiple activities of UN agencies*

The UNCC had only one mission, albeit a huge one. As a consequence, UNCC was not available to assist in 2007 when requested by UN Development Programme (UNDP) following another deliberate Middle East oil spill in July 2006, this time in Lebanon. In retaliation to rocket attacks on Israel by Hezbollah, a fuel oil spill of 15 000 t (and fire c. 55 000 t) was caused by the Israeli Defence Force bombing El-Jiyeh power station in southern Lebanon (UN, 2007).

Spill assistance was by the EC, ITOPF, International Union for the Conservation of Nature (IUCN), and the following UN agencies: IMO Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC); Food and Agriculture Organisation (FAO); UNDP; UNEP; UN Educational, Scientific, and Cultural Organisation (UNESCO, focusing on Byblos World Heritage Site); World Bank; and World Health Organisation (WHO). UN estimated spill costs at $203M (1% of 2006 Lebanon GDP, and 28% of total war damage). Funding was by UNDP and OPEC, but only $15M of the estimate was paid by 2007 (Table 2).

Despite UNCC experience with planning environmental restoration after the Gulf War spills and various agencies' work in Lebanon, the UN system had difficulty coordinating these responses amid rising tensions in the region. This was not helped by the lack of success in gaining compensation from Israel, despite repeated UN Resolutions over 13 years to "direct Israel to respond with prompt and adequate compensation" (UN, 2019).

Briefly and without success, UNEP was considered from 2013 as a possible successor to UNCC to track progress in the ongoing Gulf War spills restoration (section 3.3.1). This did not happen, perhaps because UNEP was getting involved in assessment of the environmental effects of the Syrian civil war, including the use of chemical weapons by President Assad on his own people. As far as is known, there are no plans to revive UNCC despite the impacts of ramifying conflicts in the oil-rich region, for example the civil war in Libya or the aftermath of Daesh warfare across the fertile crescent of Iraq and Syria.

Oil spills are highly probable in Yemen due to ongoing civil war. A ballast tank was breached on the tanker 'Syra' after striking a mine in the Gulf of Aden on October 2, 2020. Another tanker 'Safer' was used as a floating storage and offloading (FSO) terminal until 2015, but now is held hostage with 155 000 t of Marib crude oil that threatens conservation sites in the Red Sea and Gulf of Aden (e.g. Farasan Islands, Socotra). The UN has been prevented from inspecting the FSO since 2019 (BBC, 2020a).

3.3.3. *Ogoniland conflict: foreign companies dey Africa carry all our money go (Fela, 1981)*

3.3.3.1. UNEP in ogoniland. By early 2007 after the Lebanon spill, UNEP was invited by the federal government to assist in a post-conflict response in Ogoniland in SE Nigeria. Ogoniland is part of what was called Biafra in the Nigerian civil war (1967–1970). The problems of gross oil pollution over decades had overwhelmed the capacity of industry and government to respond. However, in this case the local population density is high and most people are extremely poor. Despite the much smaller size of the individual Niger Delta spills compared to all the above examples, the environmental and social impacts are severe and tensions very high. So much so, that no oil production has been possible in Ogoniland for almost three decades. The deadlock came about because of civil and NGO protests that were met with a violent federal government response, leading to the trial and execution on November 10, 1995 (BBC, 2020b) of nine Ogoni leaders and writers including 'Ken' Saro-Wiwa (2013).

Neonatal mortalities are twice as high within 10 km of Niger Delta oil spills. Comparing pairs of siblings born to the same mother but conceived respectively before and after a documented nearby oil spill, there is a significant increase in neonatal mortality of 38.3 excess deaths/1000 live births ($n = 23\ 000$) according to Bruederle and Hodler (2018). Their paired sample design controlled for other factors than nearby oil spills, and found that oil spills occurring before conception are killing in their first month of life as many as 16 000 infants per year in the Niger Delta. Public health, housing, food and cooking fuel, sanitation, waterways, recreation, cultural life and livelihoods in Bodo are heavily dependent on local natural resources in the mangrove-dominated coastal zone. This contrasts with the sparse population and greater per capita wealth of Saudi Arabia, where the affected marshes are almost devoid of human activity.

Unlike all the major tanker spills described above, the poor in local communities affected in the Niger Delta are cast in a frankly colonial mentality as being part of the problem rather than for the most part as victims of criminally inadequate environmental practices. By stereotyping the local people as oil thieves, the western oil companies betray the majority of people of the Niger Delta while continuing to sell the oil. International oil companies have operated profitably in the Niger Delta since 1956 (Shell) and 1962 (ENI and Total). Potentially complicit parties include Nigerian National Petroleum Corporation (NNPC), Nigerian federal and local governments, judiciary, security forces, shareholders and pension funds (including those of the Church of England). To solve this, all that must be done is to uphold the rule of law (Figs. 8 and 9).

Environmental surveys have previously been completed (1980 Funiwa #5 20 000 t offshore well blowout; 1983 onshore production

Fig. 8. NGO bumper sticker, Centre for Environment, Human Rights and Development (CEHRD), Port Harcourt, 2013

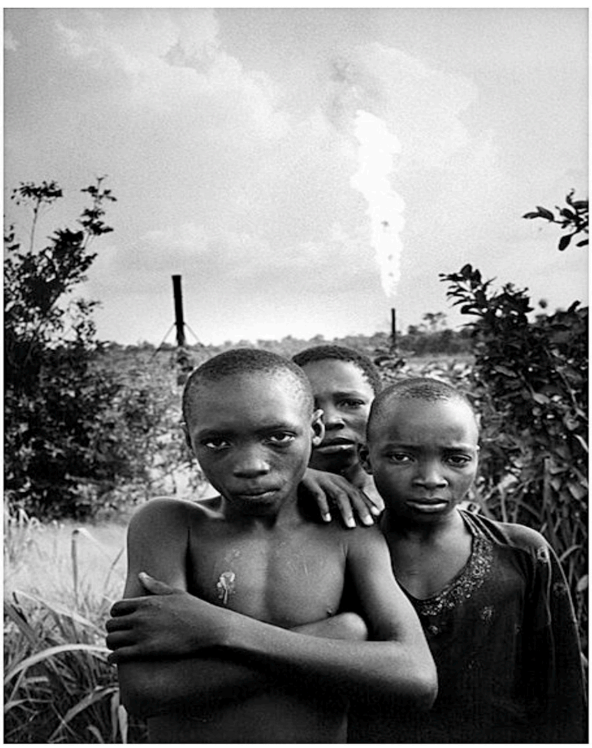

Fig. 9. Children in Akalu-Olu near oil industry flares, Ohoada West Local Government Area, Rivers State, Nigeria (Evans, 2002).

areas; 1995 delta-wide; and 1997 Niger Delta Environmental Survey). Each of these involved evermore strategic environmental and socio-economic scope. However, few were able to engage fully with the local affected people by seeking the free, prior, informed consent that inter-governmental agencies and NGOs agree are needed. A breakthrough looked promising in 2007 when the federal government invited UNEP to carry out a baseline survey of Ogoniland to assess the scale of remediation required.

The UNEP project was a detailed multi-discipline survey of air, water, sediment, soil, biota, and a preliminary study of human health, all of which showed that many local people are indeed 'living in oil' (UNEP, 2011). By overcoming logistical challenges and the legacy of mistrust, UNEP succeeded in providing a faltering start in planning the clean-up. A restoration fund of $1B was recommended, including a centre of excellence in remediation technology (Table 2). And so the federal government formed a new agency (Hydrocarbon Pollution Restoration Project; HYPREP). After some confusion between existing agencies charged with regulating oil pollution, if successful in Ogoniland, HYPREP could begin the huge task of clean-up across the entire Niger Delta. The Bayelsa State Oil and Environmental Commission are also now examining regional remediation precedents. But first the endemic oil theft must be stopped, or else any clean-up is futile. Meanwhile, according to the Extractive Industries Transparency Initiative, oil theft is costing Nigeria over $4B/year. This was almost 1% of GDP in 2019, after Nigeria displaced South Africa as the largest African economy. The failure to prevent criminal activity is an ongoing fatal flaw in all restoration plans because repeated inputs of fresh crude oil will inevitably stress or kill vegetation.

A status report on the clean-up published in June 2020 involved revisiting some original UNEP sites (FoE, 2020). The report concluded that a new start is needed across the entire delta. The emergency measures recommended by UNEP over a decade ago to protect human health have not been provided (e.g. replacing drinking water wells contaminated by benzene). No health impacts have been or are being monitored. Most contractors are not qualified; 11 of 16 companies contracted for oil clean-up are reportedly without expertise in remediation. Only 11% of the sites recommended by UNEP for clean-up and remediation are completed. HYPREP has been compromised by conflicts of interest and procurement irregularities, with $31m spent since 2018 not properly accounted for. HYPREP has now recruited new personnel with UNEP and Bodo project experience.

3.3.3.2. Bodo community. Bodo is a Niger Delta fishing village in Ogoniland. Pipeline maintenance failures led to two spills in late 2008 (totalling 580 t Bonny light crude oil). In this area, Shell Petroleum Development Company (SPDC) is the E&P operator on behalf of a joint venture with the NNPC, Total Exploration and Production Nigeria Limited and Nigerian Agip Oil Company Limited (part of ENI). Liability was admitted by SPDC for probably the largest mangrove kill in history, but partly due to endemic security problems it was unable to fix the pipeline, recover the oil, remediate the former mangrove sediment habitats, or restore their high biodiversity and subsistence values.

Despite SPDC experience in numerous smaller delta spills over decades and the back-up of Shell, Total and ENI international experts, a cumulative 1000 ha mangrove forest was killed in Bodo after the two pipeline spills in 2008. Shell, Total and ENI are shareholders in the industry-owned emergency response organisation (Oil Spill Response Limited; OSRL) whose website promises: "Wherever your oil spill risks lie in the supply chain, we are ready to respond with our expertise and resources anytime, anywhere". It is unclear whether OSRL was asked to deliver on this in 2008 by Shell or the SPDC joint venture. Implementation of the findings of the UNEP (2011) report is now described by subsidiary SPDC rather than Shell Nigeria, whose website link to 'UNEP implementation' appears defunct (Shell Nigeria, 2016). The parent company may be distancing itself from liability for its subsidiary's impacts in Ogoniland, but ultimate responsibility lies with Shell (Shell Nigeria, 2016).

Average TPH concentrations of 40 000 mg/kg were found in the former mangrove sediments seven years after the spills (Little et al., 2018). This is exacerbated by organised criminals who tap the export pipeline crossing Ogoniland to the Bonny Island terminal (Gundlach, 2018). The stolen oil is processed in improvised 'refineries' for sale locally and regionally. Fifty-three spills from over 200 illegal refineries occurred 2008–2019, totalling 1165 t of oil. Cooking up oil in leaky oil drums over open fires adds carcinogenic combustion products to the spills of crude oil (Fig. 8).

The Bodo Mediation Initiative (BMI) from 2013 and a successful court case prosecuted by the Bodo community in London in 2014 were both essential to breaking the deadlock with SPDC and getting clean-up underway to international standards, at least in part of the delta. In 2015 Shell settled the compensation claims against the company for $73M (Table 2). The cash was distributed to the individual victims of the Bodo community via newly opened bank accounts. The Bodo community separately agreed that their claim for clean-up would remain in place so that they could return to court in London in future if the BMI clean-up did not meet international standards. Shell tried to strike this out in June 2017, but the community's right was upheld in London in May 2018 (Leigh Day, 2018, Leigh Day, 2020).

Practical fieldwork could only begin in May 2015 after signing of a memorandum of understanding between SPDC and the Bodo community. Crucially, from May through August 2015 SCAT teams started to provide a strong participative framework for the essential scientific and technical aspects. Good agreement between SCAT descriptors and sediment TPH concentrations was established from the 2015 samples (n = 32; Little et al., 2018), and confirmed at-scale in 2017 samples (n = 624; Bonte et al., 2020). The reliance on chemistry sampling for monitoring against target levels is reduced by reaching field consensus on fine-tuning the clean-up methods for the vegetated and burrowed fine-grained sediments of Bodo.

The challenge is to use NEBA for in situ remediation, recognising that clean-up guidelines typically recommend 'leave-alone' in such habitats (after the oiled Île Grande marsh was destroyed during 'Amoco Cadiz' clean-up; section 3.1). Trial work is needed on how much nursery soil is transplanted with the seedlings to insulate them from lingering oil. Such adaptive management would track performance of the young trees as their root ball breaks out of nursery soil, compared to the effect of fresh oil spills on leaves or pneumatophores. Transplanted mangroves can grow successfully in cohesive oily sediments, in contrast with sediments that are flushed for long periods. Such intrusive treatment may produce cleaner sediments, but if they become liquefied then adverse impacts due to water-logging, loss of structure and erosion will delay recovery. In addition to mangrove seedling transplants, success depends on natural spread of healthy propagules. Phytoremediation improves longer-term sediment quality and biodiversity, even if in the short-term oil concentrations are high or temporarily increase (Bonte et al., 2020).

The project stopped for almost two years after violence erupted in October 2015 due to dissatisfaction with the procurement process (Bruyne, 2020). A phase of surficial oil removal between September 2017 and August 2018 was followed by sediment remediation from November 2019, now interrupted by COVID-19. The SCAT process has helped operator and community to embrace new ideas in clean-up. Only by building mutual trust will the inevitable concerns be addressed and tensions defused. The success of BMI and SPDC also depends on reducing the huge inequalities by supporting alternative employment opportunities to take people out of illegal refining.

3.3.4. Mauritius spill. On July 25, 2020 the bulk carrier 'Wakashio' grounded on a coral reef in SE Mauritius spilling >1000 t HFO and iron ore cargo. In addition to corals bleached by acidification from climate change, at risk are mangroves, seagrasses, coastal and pelagic birds, fishing communities and tourism. Under pandemic quarantine the vessel was 17% below required manning levels. Her Panamanian flag allowed contract extension such that two crew members had been onboard >1 year, risking crew fatigue. Panama's inspection blamed the incident on the change of course to look for internet signals, an allegation denied by the Japanese owner (PE, 2020). Regional investment in OSR and training has been patchy in East Africa and Indian Ocean, despite the efforts of foreign and UN aid programmes (e.g. Mauritius' coastal oil spill ESI atlas dates from 1989, before many states; Gundlach and Murday, 1989). Mauritius being a major tax haven, funds for OSR contingency planning and pollution control should be in place. In contrast, for the locals only partial sewage treatment is available. Tax avoidance is colonialism by other means, when accountability is as vulnerable as in authoritarian or hollowed-out state sectors (Little, 2018).

4. Discussion

4.1. Songs of innocence and experience (Blake, 1826)

In his poetry in 1789-1794, William Blake does not assume a uni-directional progression from ignorance to awareness, but the duality of human values and belief in the wisdom of young people. In order to overcome our climate crisis 'learning disability', we need to challenge authoritarian and paternalistic assumptions about learning. As when we were children, we can see now that many 'emperors' of business and government have no clothes (Andersen, 1837).

During COVID-19, economies and world trade struggle, mariners quarantine in their vessels, and layers of uncertainty halt investment. Record-breaking recession and unemployment are inevitable. In democracies, the pandemic response runs a gamut of kind and effective (New Zealand, South Korea) to dangerously incompetent (Brazil, UK, USA). Pandemic had already been identified as a primary threat, and incredibly in retrospect, the UK was rated highly for global pandemic preparedness. In October 2016, 'Exercise Cygnus' tested the UK response to an influenza pandemic, and the UK press reported overwhelmed health services, duplication of responsibilities, confusion, lack of preparedness and lack of clarity (PHE, 2017; redacted). Planning lessons got lost in the real emergency of 2020, replaced by confused messaging based on wishful thinking, cronyism in political elites, and expensive, wasteful and opaque procurements. According to the National Audit Office and legal challenges, lessons were neither documented nor revised in COVID-19 arrangements.

Multilateralism represented by agencies of the EU and UN is under assault by resurgent nationalism. Some leaders are emboldened to ignore UN agencies (e.g. WHO in COVID-19 response) and international law, to the extent of undermining multilateral arms-controls. Crisis managers, management consultants and public relations purport to 'manage complexity' amid raging political, economic, health and environmental crises. The first two of these preoccupied the Enlightenment economist and statistician Thomas Malthus, FRS. He thought geometric population growth would be limited only by arithmetic growth in food production (Malthus, 1798). This is controversial because rather than wealthy consumers (high-carbon footprint), he 'blamed' the demographic problem on the high birth rates of the poor (low-carbon footprint); unsurprising from Professor of Political Economy at the East India Company. Although he did not anticipate the agricultural revolution feeding more people, Malthus' pessimism may yet be vindicated by current stressors on humanity (e.g. cumulative environmental impacts of fossil fuels and modern agriculture).

The pandemic is re-shaping society's interest in science and understanding of the biodiversity/climate crises. The window of opportunity to meet these overlapping challenges places better leadership and governance front and centre of decarbonisation investments. The net-zero technologies are already here, with costs at-scale falling (e.g. hydrogen for fuel cells; lithium and REE batteries; electric multi-modal transport; wind, wave, tidal, solar and hydro-electricity; air- and ground-source heat pumps; carbon capture and storage for heavy industry). In his December 23, 2020 Reith Lecture, Mark Carney said "ask not what the climate is doing to your country, but what your country can do for the climate".

Without altering the ever-increasing GHG concentrations, the dramatic reduction of noise and toxic emissions during COVID-19 lockdowns gave a glimpse of nature's restorative capacity. Achievement of this vision as we mitigate and adapt to climate change was discussed by Sodha (2020), who argued that 'cathedral thinking' is needed to emulate the long-term projects that were not completed during the medieval builders' lifetimes. This perception would help us all to connect with our descendants properly, unlike the rich and powerful continuing to rely on inherited wealth. Young people will bear the brunt of the present crises. Solidarity with their values is our bridge to sustainability. In forging this emotional connection there is a vital role for arts and culture, and no place for culture wars. If we fail to connect, then a shocking metaphor for the 'ugly' scenario is visible in Goya's painting 'Saturno devorando a su hijo' (Goya, 1820).

4.2. The 'relationship' between oil spills and climate change

In the Russian Arctic on 29 May and July 12, 2020, two spills occurred at the giant Norilsk Nickel smelter. They were caused by melting permafrost, subsidence, and failure of a fuel storage tank and pipeline (respectively 21 000 t diesel and 45 t aviation fuels). North towards the Pyasina delta (Arctic Ocean) tundra and lake habitats are important for wildfowl. Environmental agencies requested $2B, referred to variously as compensation, fine, and clean-up estimate. Accusing the operator of negligence, President Putin declared a state of emergency, but a transparent impact assessment is unlikely. The spills were labelled by media "the Arctic's worst-ever environmental catastrophe", but the melting permafrost and release of methane and CO_2 from thawing and burning peat are part of a world catastrophe. Melting ice and permafrost was avoidable until recently, but the Norilsk spills are among the direct effects of anthropogenic climate change reaching 'tipping point'. Authorities are now checking other hazardous sites built on permafrost (BBC, 2020c).

Norilsk is also the site of a major study of conifer tree rings linking reduced growth rates since the 1960s to degraded air quality from point-source pollution (Kirdyanov et al., 2020). The thinning of tree rings is also due to Arctic air mass circulation and long-range transport of particulates reducing incident sunlight, photosynthesis and growth rates. As temperatures rise the optimism that boreal forests would sequester more carbon is diminished. Instead, both tundra and taiga join tropical rainforests in their vulnerability to global warming, with cascading impacts in drainage basins and downstream coastal zones from Tropics to Arctic.

Hardly ever an exact science, at least OSR is conducted in good faith. Thanks to effective knowledge creation and diffusion, oil spills can be managed provided access, equipment and expertise are made available and tested by contingency planning. Unfortunately, the continuity of such efforts depends on the price of oil. Success is possible in spite of the inequitable distributions around the world of spill risk, OSR capability, and community resilience. It is impossible to predict where and when spills will occur, and those during armed conflicts prevent immediate response. The impacts of deep sea tanker losses and many unreported spills in remote and war-torn countries go undocumented. In hindsight, oil spills were not an environmental hot topic, only a door to our slowly-awakening perception. Although locally to regionally damaging, the ecological effects of spills rarely deserve the 'disaster' or 'catastrophe' label. The bigger problem is climate change and long-term socio-environmental catastrophe, to which the young are especially vulnerable (Fig. 10).

We can no longer ignore the global scale of fossil fuel impacts. The processes and responses we describe are rooted in carbon: oil exploration, production, transport, refining, and consumption cause pollution throughout the life cycle of fuels and petrochemicals. The oil 'spilled' by everyone into the air by combustion is the gravest problem, driving global warming and melting sea ice, ice caps and permafrost. Slumping tundra peat causes further damage and spills, releasing more GHGs to drive runaway climate change. These feedback loops are irreversible, as are the impacts on wetlands, shorelines, cities and livelihoods that are lost to sea level rise, wildfires, and refugee camps full of migrating people. While temporarily in the background of COVID-19, the global climate emergency intensifies. The pandemic has itself been facilitated by a feedback loop of the biodiversity/climate crisis: ▶habitat loss imposing ecological stress on wild animals ▶capture and sale of live animals infected by viruses ▶viral infection spreading to humans ▶rapid viral spread via high-carbon international air travel ▶'refueling' the climate crisis.

In the global north we have wasted precious time ('easy street') that might have speeded our transition to low-carbon. Considering the massive costs to everyone of burning oil, the current low price could be used to leave hydrocarbon assets stranded in the ground. Skilled oilfield engineers could be re-employed to shut in the wells and retrain in renewables (Bloomberg, 2020). Coal was largely closed down in the 1980s with little thought for the UK communities left behind. Despite some evidence of societal learning, there are actually deep learning disabilities manifested in denial and procrastination. To overcome such disinformation we need good information literacy and critical thinking. Just doing good OSR anywhere in the world is no longer enough. Oil spills in this sense have even been a distraction. We can and should restore damaged wetlands, shorelines, communities and ecosystems because they support local people and wildlife, provide coastal protection, and sequester carbon. Beyond this, we cannot avoid the conclusion that industry, governments and people must now rapidly decarbonise.

5. Conclusions and recommendations

1) Globally, oil spills represent a relatively low hazard but attract high levels of public outrage. Climate change is almost the exact opposite: an extreme hazard that until recently has produced too little outrage.
2) There are stark contrasts between responses to spills from oil tankers and blowouts in the global north to those in the Middle East and Africa. These contrasts reflect inequalities in affected communities, and often follow corruption, security breakdown or war.
3) Spill contingency planning and OSR are necessary but not sufficient everywhere. OSR should continue using NEBA to mitigate and manage spills, adaptive management to restore habitats, and adherence to health, safety and waste minimisation standards for as long as hydrocarbons are in use.

Fig. 10. Greta Thunberg-inspired climate strike near Goya museum and statue, Plaza del Pilar, Zaragoza, Spain, September 27, 2019.

4) Access to social justice can mitigate vulnerability to spills and also to climate change. We should ensure more equitable deployment of OSR resources before/after spills, and also adapt OSR planning arrangements to create, fund and build community resilience to the hazards of climate change.
5) Landmark oil spills might have forewarned us of the ultimate crisis of global warming. Decarbonisation will require improved infrastructure, energy conservation and best practice in the renewables sector. Leaders must ensure foreign aid is only for sustainable development, and not conditionally linked to weapons or fossil fuel businesses.
6) GHG emissions drive runaway climate change. Governments should use market-based incentives, investments and education to accelerate transition to renewables in all sectors and livelihoods (health, food, housing, sanitation, fuel, transport, recreation, cultural life).
7) Despite multilateral values, societal learning is disabled by climate change denial. Aspects still lacking in the real world include critical thinking, carbon consciousness, sustainable consumer attitudes ('think global, act local'), and leaders committed to universal health, education and social justice.
8) The best way to reduce the number and severity of oil spills and the need to manage their impacts is to accelerate decarbonising the global economy. By ceasing to use oil as fuel and only using it as essential chemical feedstock, the world could approach sustainability.

CRediT authorship contribution statement

David I. Little: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Roles/Writing – original draft; Writing – review & editing. **Stephen R.J. Sheppard:** Investigation, Validation, Visualization, Writing - review & editing. **David Hulme:** Investigation, Validation, Visualization, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This article is dedicated to Victor Lindesay (1953-2019) and Peter Kenyon (1952–2020). We are grateful to five anonymous reviewers and for comments from families, friends and colleagues: S. Bilko, G. Cook, J. Gray, M. Hogan, P. Kenyon, J. Little, A. Marples, J. Moffat, K. Plough, J. Podmore, G. Rigby, T. Stewart, and S. Tepper. Image acknowledgements: CEHRD, S. Evans, E. Gundlach, ITOPF, Nunca Máis, and R. Troll. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Previous OSRs, contingency planning, audits and field/laboratory experiments funded by: AEA Technology, Agip KCO, American Petroleum Institute, Athens airport, BP, Clean Sound, Countryside Council for Wales, Department of Environment, EC (DG XI), English Nature, Environment Agency, Esso Petroleum/Exxon, Government of Mozambique, Institute of Petroleum, International Association of Ports and Harbours, IPIECA, KPMG, Maritime and Coastguard Agency, MOL Rt., MSRC, Natural Environment Research Council, Oil & Gas UK, Petrobras, Presidency of Meteorology and Environment of the Kingdom of Saudi Arabia, Qatar Petroleum, Samarec, Sarpom, Shell, Ultramar, Umweltbundesamt, UNEP, Wessex Water, and West of England Shipowners Insurance Services Ltd.

References[1]

Albaigés, J., Morales-Nin, B., Vilas, F., 2006. The 'Prestige' oil spill: a scientific response. Mar. Pollut. Bull. 53, 205–207.

Andersen, H.C., 1837. The Emperor's New Clothes, C.A Reitzel. https://en.wikipedia.org/wiki/The_Emperor%27s_New_Clothes.

BBC, 2020a. Yemen: Decaying Oil Tanker in Red Sea Threatens Disaster. https://www.bbc.co.uk/news/world-middle-east-53417464.

BBC, 2020b. Ken Saro-Wiwa: 25 Years Later Ogoni Pipo Still Dey Wait for Justice. https://www.bbc.com/pidgin/tori-54894885.

BBC, 2020c. Russian Arctic Oil Spill Pollutes Big Lake Near Norilsk. https://www.bbc.co.uk/news/world-europe-52977740.

Berry, R.J., 2018. Environmental Attitudes through Time. Cambridge University Press, p. 268.

Berry, R.J., Crothers, J.H., 1987. Nature, natural history and ecology. Biol. J. Linn. Soc. 32 (1), 152. https://onlinelibrary.wiley.com/toc/10958312/32/1.

Blake, W., 1826. Songs of Innocence and of Experience, Showing the Two Contrary States of the Human Soul, London. Rosenwald edition. US Library of Congress, Washington DC, p. 54. http://hdl.loc.gov/loc.rbc/rosenwald.1801.2.

Bloomberg, M.F., 2020. Let's Hire Laid-Off Oil and Gas Workers to Fight Climate Change. Bloomberg Opinion. August 2020. https://www.bloomberg.com/opinion/articles/2020-08-03/let-s-hire-laid-off-oil-and-gas-workers-to-fight-climate-change?utm_source=url_link.

Bonte, M., Gundlach, E.R., Iroakasi, O., Visigah, K., Giadom, F., Shekwolo, P., Nwabueze, V., Cowing, M., Zabbey, N., 2020. Comparison of chemical sediment analyses and field oiling observations from the Shoreline Cleanup Assessment Technique (SCAT) in heavily oiled areas of former mangrove in Bodo, eastern Niger Delta. Q. J. Eng. Geol. Hydrogeol. 53, 219–230. https://doi.org/10.1144/qjegh2019-018.

Bruederle, A., Hodler, R., 2018. Effects of oil spills on infant mortality in Nigeria. P. Natl. Acad. Sci. USA. 116, 12. https://www.pnas.org/content/pnas/116/12/5467.full.pdf.

Bruyne, M. de, 2020. The painstaking clean-up of Nigeria: who will help Ogoniland out of the oil? De. groene Amsterdammer 49. https://www.groene.nl/artikel/wie-helpt-ogoniland-uit-de-olie?utm_source=De+Groene+Amsterdammer&utm_campaign=55d1eedb9b-Wekelijks-2020-12-02&utm_medium=email&utm_term=0_853cea572a-55d1eedb9b-70899949.

Carson, R., 1962. Silent Spring. Houghton Mifflin, Boston MA, p. 323.

ESGOSS, 1993. In: Ritchie, W., O'Sullivan, M. (Eds.), The Environmental Impact of the Wreck of the 'Braer', Ecological Steering Group for the Oil Spill in Shetland. The Scottish Office Environmental Department, Edinburgh.

EU, 2013. Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment. European Union. https://doi.org/10.2779/11735. https://ec.europa.eu/environment/eia/pdf/EIA%20Guidance.pdf.

Evans, S., 2002. Dirty Oil Business. http://www.sophiaevans.com/dirty-oil-busness-images/.

Fela, Anikulapo-Kuti, 1981. International Thief-Thief, 'Black President'. Arista Records Ltd.. Edition Boucharlet. https://www.youtube.com/watch?v=HT7uSeYHkaY&feature=share

FoE, 2020. No Clean-Up, No Justice, Friends of the Earth Europe, Amnesty International. FoE Netherlands/Milieudefensie, FoE Nigeria/Environmental Rights Action. http://www.foeeurope.org/sites/default/files/extractive_industries/2020/no_clean-up_no_justice_final.pdf.

Goya y Lucientes, F. de, 1820. Saturn Devouring His Son. Prado Museum, Madrid, Spain. https://www.museodelprado.es/en/the-collection/art-work/saturn/18110a75-b0e7-430c-bc73-2a4d55893bd6.

Gundlach, E.R., 2018. Oil-related mangrove loss East of Bonny river, Nigeria. In: Makowski, C., Finkl, C.W. (Eds.), Threats to Mangrove Forests, Coastal Research Library, vol. 25. Springer Nature, pp. 267–321. https://doi.org/10.1007/978-3-319-73016-5_13.

Gundlach, E.R., Hayes, M., 1978. Classification of coastal environments in terms of potential vulnerability to oil spill damage. Mar. Technol. Soc. J. 12 (4), 18–27.

Gundlach, E.R., Murday, M., 1989. Coastal Sensitivity Atlas of Mauritius for Oil Spill Response. Ministry of Housing, Lands and Environment Mauritius. cooperation with IMO and UNEP, Port Louis, Mauritius.

Gundlach, E.R., Boehm, P.D., Marchand, M., Atlas, R.M., Ward, D.M., Wolfe, D.A., 1983. The fate of the 'Amoco Cadiz' oil. Science 221, 122–129. https://doi.org/10.1126/science.221.4606.122.

Gundlach, E.R., Neff, J.M., Little, D.I., 1993. Evaluation of Marine Post-spill Sites for Long-Term Recovery Studies. Marine Spill Response Corporation, Washington DC. https://www.researchgate.net/publication/303666736_Evaluation_of_Marine_Post-spill_Sites_for_Long-term_Recovery_Studies.

Hawkins, S.J., Evans, A.J., Moore, J., Whittington, M., Pack, K., Firth, L.B., Adams, L.C., Moore, P.J., Masterson-Algar, P., Mieszkowska, N., Southward, E.C., 2017. From the 'Torrey Canyon' to today: a 50 year retrospective of recovery from the oil spill and interaction with climate-driven fluctuations on Cornish rocky shores. Int. Oil Spill Conf. Proc. https://doi.org/10.7901/2169-3358-2017.1.74.

Hulme, D., 2016. Should Rich Nations Help the Poor? Polity Press, Cambridge UK, p. 148.

Hulme, D., Horner, R., 2020. After the immediate coronavirus crisis: three scenarios for global development. Glob. Policy J. Durham University and Wiley-Blackwell,

[1] Accessed 21 December 2020.

Hoboken NJ. April 2020. https://www.globalpolicyjournal.com/articles/development-inequality-and-poverty/after-immediate-coronavirus-crisis-3-scenarios-global.
Hunter, R., Garcia, J., 1970. Uncle John's Band, 'Workingman's Dead', Grateful Dead. Universal Music Publishers Group, Warner Chappell Music Inc. https://www.youtube.com/watch?v=j6FsJeJvZk8.
ITOPF, 1987. The International Tanker Owners Pollution Federation Ltd, 1987. Response to Marine Oil Spills. Witherby & Co. Ltd., London, p. 115.
ITOPF, 2020a. Oil Tanker Spill Statistics. https://www.itopf.org/knowledge-resources/data-statistics/statistics/.
ITOPF, 2020b. Handbook. https://www.itopf.org/knowledge-resources/documents-guides/document/itopf-handbook/.
Kerambrun, L., Laruelle, F., 2001. 'Erika' oil spill: some innovations in the French shoreline response and beach cleanup methods. Proc. 24th Arctic and Marine Oilspill Program (AMOP) Technical Seminar. Environment Canada, Ottawa, pp. 671–678.
Kirdyanov, A.V., Krusic, P.J., Shishov, V.V., Vaganov, E.A., Fertikov, A.I., Myglan, V.S., Barinov, V., Browse, J., Esper, J., Ilyin, V.A., Knorre, A.A., Korets, M.A., Kukarskikh, V.V., Mashukov, D.A., Onuchin, A.A., Piermattei, A., Pimenov, A.V., Prokushkin, A.S., Ryzhkova, V.A., Shishikin, A.S., Smith, K.T., Taynik, A.V., Wild, M., Zorita, E., Büntgen, U., 2020. Ecological and conceptual consequences of Arctic pollution. Ecol. Lett. https://doi.org/10.1111/ele.13611.
Law, R.J., Kelly, C., 2004. The impact of the 'Sea Empress' oil spill. Aquat. Living Resour. 17, 389–394. https://doi.org/10.1051/alr:2004029.
Leigh Day, 2018. Press Release. https://www.leighday.co.uk/News/News-2018/May-2018/Shell-fails-in-High-Court-bid-to-halt-Nigerian-Com.
Leigh Day, 2020. https://www.leighday.co.uk/Blog/October-2020/Black-History-Month-the-responsibility-of-the-glob?utm_campaign=coschedule&utm_source=twitter&utm_medium=leighdayintl.
Little, D.I., 2018. Mangrove restoration and mitigation after oil spills and development projects in East Africa and the Middle East. In: Makowski, C., Finkl, C.W. (Eds.), Threats to Mangrove Forests, Coastal Research Library, vol. 25. Springer Nature, pp. 637–696. https://doi.org/10.1007/978-3-319-73016-5_30.
Little, D.I., Deakin, T., Fichaut, B., Meech, R.J., 2003. Some observations on heavy fuel oil spills: trends, impacts and comparisons with crude oil spills. Proc. 26th Arctic and Marine Oilspill Program (AMOP) Technical Seminar. Environment Canada, Ottawa, pp. 971–998.
Little, D.I., Holtzmann, K., Gundlach, E.R., Galperin, Y., 2018. Sediment hydrocarbons in former mangrove areas, southern Ogoniland, eastern Niger Delta, Nigeria. In: Makowski, C., Finkl, C.W. (Eds.), Threats to Mangrove Forests, Coastal Research Library, vol. 25. Springer Nature, pp. 323–342. https://doi.org/10.1007/978-3-319-73016-5_14.
Malthus, T.R., 1798. An Essay on the Principle of Population. J. Johnson, London.
Martinelli, M., Luise, A., Tromellini, E., Sauer, T.C., Neff, J.M., Douglas, G.S., 1995. The M/C Haven oil spill: environmental assessment of exposure pathways and resource injury. Int. Oil Spill Conf. Proc. https://doi.org/10.7901/2169-3358-1995-1-679.
Mauro, I.J., 2018. Beyond Climate. https://vimeo.com/286529400/cd27dc0811.
Minter, T.G., Hale, J.A., Cormack, C.D., Cotsapas, L., Michel, J., 2014. Tidal flat and sand beach remediation: choosing remediation techniques to speed ecological recovery of habitats still impacted 20 years after the Gulf War oil spill. Int. Oil Spill Conf. Proc. https://ioscproceedings.org/doi/full/10.7901/2169-3358-2014.1.1719.
MPB, 1993. Special issue on the Gulf war spills. Mar. Pollut. Bull. 27, 3–380. https://www.sciencedirect.com/journal/marine-pollution-bulletin/vol/27/suppl/C.
Nico, 1970. All that Is My Own, 'Desertshore', Reprise. Warner Brothers Records Inc. https://www.facebook.com/1814324762203309/videos/nico-all-that-is-my-own/436734263718313/.
NOAA, 2020. National Oceanographic and Atmospheric Administration. https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.
NRC, 2003. Oil in the Sea III: Inputs, Fates, and Effects. National Research Council. The National Academies Press, Washington, DC. https://doi.org/10.17226/10388.
Pandion Technology-RPI, 2003. Oiled Shoreline Survey in Support of the Marine and Coastal Damage Assessment. Research Planning Institute (RPI), Columbia SC.
PE, 2020. Shipping news: 'sea sores'. Private Eye 1533, 23. October - 5 November 2020.
PHE, 2017. Exercise Cygnus Report: Tier One Command Post Exercise Pandemic Influenza, vols. 18–20. Public Health England. October 2016. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/927770/exercise-cygnus-report.pdf.
PREMIAM, 2018. Pollution Response in Emergencies: Marine Impact Assessment and Monitoring, second ed. https://www.cefas.co.uk/premiam/guidelines/.
Saro-Wiwa, K., 2013. Silence would be treason: last writings of Ken Saro-Wiwa. Conseil pour le Developpement de la Recherche Economique et Sociale en Afrique.
SEEEC, 1998. The Environmental Impact of the 'Sea Empress' Oil Spill. Final Report of the Sea Empress Environmental Evaluation Committee. HMSO, London. https://www.researchgate.net/publication/303855428_The_Environmental_Impact_of_the_Sea_Empress_Oil_Spill_Final_Report_of_the_Sea_Empress_Environmental_Evaluation_Committee_SEEEC_1998_London_The_Stationery_Office_ISBN_0_11_702156_3.
Sell, D., Conway, L., Clark, T., Picken, G.B., Baker, J.M., Dunnet, G.M., McIntyre, A.D., Clark, R.B., 1995. Scientific criteria to optimize oil spill clean-up. Int. Oil Spill Conf. Proc. https://doi.org/10.7901/2169-3358-1995-1-595.
Shakespeare, W., 1597. The Tragedy of King Richard III. Stationers' Company, London.
Shell Nigeria, 2016. UNEP Report implementation. https://www.shell.com.ng/media/2016-media-releases/unep-report-implementation.html Access failed. (Accessed 6 December 2020).
Sheppard, S.R.J., 2005. Landscape visualisation and climate change: the potential for influencing perceptions and behaviour. Environ. Sci. Policy 8, 637–654. https://doi.org/10.1016/j.envsci.2005.08.002.
Sheppard, S.R.J., 2012. Visualizing Climate Change: Guide to Visual Communication of Climate Change and Developing Local Solutions. Routledge, London and New York, p. 511.
Smith, J.E. (Ed.), 1968. 'Torrey Canyon': Pollution and Sea Life. Marine Biological Association of the UK. Cambridge University Press, p. 196.
Sodha, S., 2020. We've Got to Start Thinking Beyond our Own Lifespans if We're Going to Avoid Extinction. The Observer, 16 August 2020. https://www.theguardian.com/commentisfree/2020/aug/16/weve-got-to-start-thinking-beyond-our-own-lifespans-if-were-going-to-avoid-extinction.
Stein, N., 2003. Report Book. Galicia 'Prestige', Barcelona, p. 145.
Troll, R., 1989. 'Tanker from Hell' T-Shirt.
UN, 2007. Oil Slick on Lebanese Shores Report to the Secretary-General United Nations. https://www.researchgate.net/publication/290296782_Oil_slick_on_Lebanese_shores_Report_of_the_Secretary-General_A62343.
UN, 2019. Press Release. https://www.un.org/press/en/2019/gaef3526.doc.htm.
UNCC, 2016. Post-conflict Environmental Restoration: the UNCC Follow-Up Programme for Environmental Awards. https://uncc.ch/sites/default/files/attachments/Publication_Final%20-%201523671_E_Web.pdf.
UNEP, 2011. Environmental Assessment of Ogoniland. UNEP, Nairobi. https://www.unenvironment.org/explore-topics/disasters-conflicts/where-we-work/nigeria/environmental-assessment-ogoniland-report.
UNFCCC, 2019. United Nations Climate Change Annual Report 2018. https://unfccc.int/sites/default/files/resource/UN-Climate-Change-Annual-Report-2018.pdf.
Watts, J., 2020. People Plan to Drive More Post-covid, Climate Poll shows. The Guardian, YouGov and Cambridge Globalisation Project. https://www.theguardian.com/environment/2020/nov/10/people-drive-fly-climate-crisis-global-poll-green-recovery-covid-pandemic?CMP=share_btn_link.
Wells, P.G., Butler, J.N., Hughes, J.S. (Eds.), 1995. Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters, vol. 1219. American Society for Testing and Materials STP, Philadelphia PA, p. 955.
Wiens, J.A. (Ed.), 2013. Oil in the Environment: Lessons and Legacies of the Exxon Valdez Oil Spill. Cambridge University Press, p. 458.
Zappa, F., 1993. Outrage at Valdez, 'The Yellow Shark', Ensemble Modern, Barking Pumpkin Records. https://www.youtube.com/watch?v=Ewpkx95GB_s.