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Environmental Consequences of Oil Spills on Marine Habitats and the Mitigating Measures—The Niger Delta Perspective

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Abstract

The Niger Delta region has witnessed environmental impacts arising from oil production activities. Soil fertility in these areas and the entire marine habitat was investigated based on the re-occurring spill incidents in the area to establish the consequences of oil pollution on key performance indicators as well as the remedial actions for resuscitation. One of the bases of evaluation was on the fertility profile of the area impacted by oil spills as compared with the areas without oil spills influence. A suitable cost effective and environmentally friendly technique to handle the pollutions in the Niger Delta region can be found in systematic containment, recovery, clean up and restoration of the marine habitat to its initial capacity and status to be able to sustain life once again.

Keywords

Oil Spills, Environmental Consequences, Oil Pollution and Impact, Marine Habitats, Niger Delta

1. Introduction

The incidence of oil spillage constitutes serious marine habitats degradation in the Niger Delta. The area currently faces series of ecosystem depletion as most flora and fauna are exterminated. Oil spills from the activities in the oil industry in the region affect the environment in the operational areas, right of ways (ROW) and third party areas. These spills are consequent on equipment failures, leaks from corroded equipment and vandalisation (sabotage) etc. The spilled crude oil from the source, through a plausible transport mechanism and exposure pathway, gets to the receptors—soil, vegetation, surface and ground water, marine environment, animals and humans—and pollutes the environmental media thereby adversely affecting the ecosystem.

Oil spills in the marine environment can have wide spread impact and long-term consequences on wildlife, fisheries, coastal and marine habitats, human health and livelihood, as well as recreational resources of coastal communities and the ancestral heritage. Oil spill effects on fish, sea birds and other marine life are mostly due to the smothering and physical contamination or due to the toxicity of the chemical components of the oil upon its release into the environment.

The fisheries and mariculture sector are impacted by the physical oiling of equipment and contamination of seafood leading to tainting and the effects on commercial and subsistence fisheries lead to substantial losses. The repercussions of contaminated seafood on public perception are very serious and require restoration of market confidence and public health assurances to move the economy forward in this sector.

The impact of oil spills on coastal and marine environments can be both short and long term (Kujawinski et al., 2020). The degree of the damage caused by an oil spill event depends primarily upon the quantity of oil spilt, the chemistry and properties (type) of the oil and the sensitivity of the biological resources affected.

The impacts also include loss in the productive capacity of soil, with implications on living organisms and economically on the people in the polluted area, and consequently high poverty rate and unemployment.

2. Literature Review

A number of researches have been carried out on hydrocarbon polluted marine environment. The studies include Abii and Nwosu (2009) study on the effects of oil spillage on soil and Aghalino (2000) on the negative impact of oil activities on the marine wild life, soil, air, water and the ecosystem of communities.

The ecological effects include brownish vegetation and soil erosion, dead and extinction of marine wild life, diminishing resources of the natural ecosystem, fertile land turned barren and adverse effect on the life, health and economy of the people. In Amadi and Ue Bari (1992) study in the rainforest ecosystem in Nigeria, soil and microbiological properties were evaluated 17 years after oil spillage to assess the effects of oil and interrelationship between the hydrocarbon utilizing and nitrifying microorganisms in the marine ecosystem. The study showed that organic carbon, total nitrogen, carbon/nitrogen ratio, available phosphate and exchangeable potassium were high at moderate and high impacted zones. Also the distribution of aerobic petroleum hydrocarbon utilizing fungi and bacteria showed a lesser condition at the moderately impacted zone than at the highly impacted zones.

The effect of crude oil pollution on marine environment, soil fertility and the growth of plants and uptake of nutrients were investigated by Agbogidi, Eruotor and Akparabi (2007) by growing corn on a soil polluted by crude oil. The soil was analyzed for organic carbon, total and available nitrogen, extractable phosphate, and exchangeable potassium, calcium, iron and manganes after each cropping. It was observed that germination and yields were drastically reduced as the level of pollution increased. At 4.2 percent crude oil pollution level, the average reductions were 50 percent in germination and 92 percent in yield. The amount of organic carbon, total nitrogen, extractable phosphate, and exchangeable potassium, iron and manganese increased in the soil with level of crude oil addition, while extractable phosphate and exchangeable calcium were reduced. The poor growth was attributed to suffocation of plants caused by exclusion of air by oil and exhaustion of oxygen by increased microbial activity, interference with plant-soil-water relationships and toxicity from sulfides and excess manganese produced during the decomposition of the hydrocarbons.

Wokocha, Emeodu and Ihenko (2011) examined the impact of crude oil spillage on the ecosystem, soil properties and food production in Ogba/Egbema/Ndoni Area in Rivers State, Nigeria. The results showed that the pH status of soil in heavily contaminated and moderately contaminated zones varied from acidic (pH 4.0) to neutral (pH 6.0). The chemical properties of soil indicated that percentage organic matter increased from 1.34 to 2.62, available phosphorus decreased from 15 ppm in control to between 7.34 and 5.42 in soil polluted with high level of crude oil. The result was in line with Amadi and Ue Bari (1992), and Ogboghodo, Osemwota, Iruaga and Chikor (2000).

Andrade, Cavelo, Vega and Marcet (2004) in an experiment on the effect of prestige oil on marine salt marsh ecosystem soils in the coast of Galicia (Northern Spain) revealed that oil pollution altered both physical and chemical soil properties, lowered porosity, and increased resistance to penetration and hydrophobicity. The crude oil spillage affected the physical, chemical and biological properties of soil and the entire marine ecosystem, resulting in low food production by reducing the nutrients availability in the soils through increased soil acidity and toxicity of crude oil fractions. The experiment on the effect of poultry manure on maize planted on crude oil polluted soils showed that percentage growth rate in plant height and yield decreased with increase in crude oil contamination (Ogboghodo et al., 2004).

Crude oil spillage also suppresses seed germination, regeneration and restoration and caused cellular and stomata abnormalities (Gill & Sandota, 1976). Ekundayo, Emede and Osayande (2001) confirmed that in crude oil polluted soils, possibility of grain yield is significantly reduced by 95 percent compared with the control. In a study of agricultural land in an oil producing area around Qua Iboe River in the Eastern Niger Delta of Nigeria, the fouled loamy soil samples polluted by crude oil were treated using chemical degreasers and detergents (Essien & John, 2010). The result of the treatments showed a significant effect on soil properties and crop growth parameters; however recovery level was significantly higher than the level of degradation, except in infiltration rate. Soil pH increased by 26% in fouled soil, attributed to bacterial biodegradation of crude oil under the anaerobic conditions present in the soil macro and micro-pores, and indicated the tendency of crude oil spills to buffer acidic soil to neutral. Hydraulic conductivity with 45% - 67% reduction from 82.24 cm/day in the control soil to 39.6 cm/day in polluted soil confirmed the blockage of polluted soils micropores by oil films. Crop growth, indicated by root elongation, diminished to 7.4 ± 0.64 cm in polluted soil ecosystem compared to13.47 ± 6.40 cm in the control soil ecosystem.

2.1. The Marine Habitats

A habitat is an ecological or environmental area inhabited by one or more living species. Marine habitats can be divided into coastal and open ocean habitats.

Coastal habitats are found in the area that extends from as far as the tide comes in on the shoreline out to the edge of the continental shelf. Most marine life is found in coastal habitats, even though the shelf area occupies only seven percent of the total ocean. Figure 1 describes the configuration and composition of the continental shelf showing the coastline, the continental slope, the continental rise and the ocean cavity.

Oil spills frequently kill marine mammals such as whales, dolphins, seals, and sea otters. Oil coats fur of otters and seals, leaving them vulnerable to hypothermia. Even when marine mammals escape the immediate effects, an oil spill can contaminate their food supply.

2.2. Beaches, Marshlands, and Fragile Aquatic Ecosystems

Oil spills coat everything they touch and become unwelcome with long-term effects on parts of every ecosystem they have contact with. When an oil slick from a large spill reaches a beach, oil coats and clings to every rock and grain of sand. If the oil washes into coastal marshes, mangrove forests, or other wetlands, fibrous plants and grasses absorb oil, which can damage plants and make the area unsuitable as wildlife habitat (Fukuyama et al., 2014).

When oil eventually stops floating on the water's surface and begins to sink into the marine environment, it can have similar damaging effects on fragile

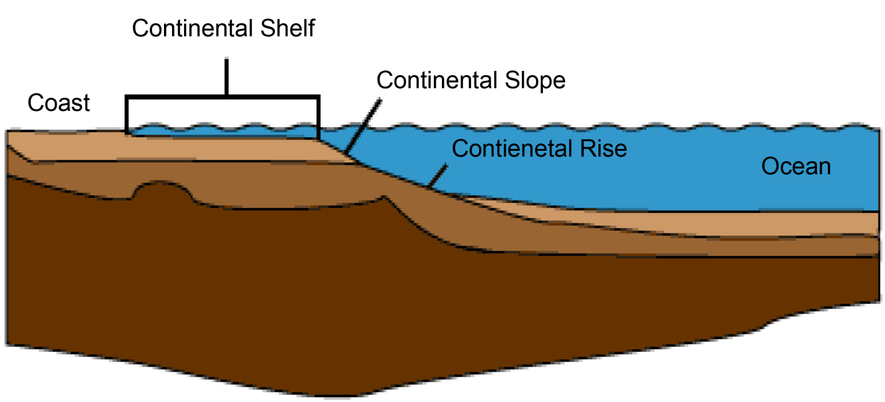

Figure 1. The continental shelf.

underwater ecosystems, killing or contaminating fish and smaller organisms that are essential links in the global food chain.

Despite massive clean-up efforts following the 1989 Exxon Valdez oil spill, for example, a study conducted by the National Oceanic and Atmospheric Administration (NOAA) found that 26,000 gallons of oil were still trapped in the sand along the Alaska shoreline. Confirming the recalcitrant nature of crude oil impact (Shigenaka, 2014).

2.3. Birds

Oil-covered birds are a universal symbol of environmental damage wreaked by oil spills. Some species of shore birds might escape by relocating if they sense danger in time, some may not. Some sea birds that swim and dive for their food are most likely to be covered in oil following a spill are likely vitims. Oil spills also damage nesting grounds, potentially causing serious long-term effects on entire species. The 2010 BP Deepwater Horizon offshore oil spill in the Gulf of Mexico, for example, occurred during prime mating and nesting season for many birds and marine species, and long-term environmental consequences of that spill won't be known for years. Oil spills can disrupt migratory patterns by contaminating areas where migrating birds normally stop (Gulf Oil Spill).

Even a small amount of oil can be deadly to birds. By coating feathers, oil not only makes flying impossible but also destroys birds' natural waterproofing and insulation, leaving them vulnerable to hypothermia or overheating. As birds frantically preen their feathers to restore their natural protections, they often swallow oil, which can severely damage their internal organs and lead to death. The best estimate of the Exxon Valdez oil spill is that it killed 250,000 seabirds (Carson et al., 1992; Haney et al., 2014). **Figures 2(a)-(c)** clearly shows the degree of impacts on birds after being oiled during oil spill incident.

The laughing gull was by far the most affected, with 32% of the entire northern Gulf of Mexico population killed because of the spill.

An oiled seabird was found dead on the beach following the Kuroshima oil spill near Dutch Harbor, Alaska, in November 1997 (NOAA).

2.4. Marine Mammals

Oil spills frequently kill marine mammals such as whales, dolphins, seals, and sea otters. Oil can clog blowholes of whales and dolphins, making it impossible for them to breathe properly and disrupting their ability to communicate. Oil coats fur of otters and seals, leaving them vulnerable to hypothermia.

Even when marine mammals escape the immediate effects, an oil spill can contaminate their food supply. Marine mammals that eat fish or other food exposed to an oil spill may be poisoned by oil and die or experience other problems.

The Exxon Valdez oil spill killed 2800 sea otters, 300 harbor seals, and up to

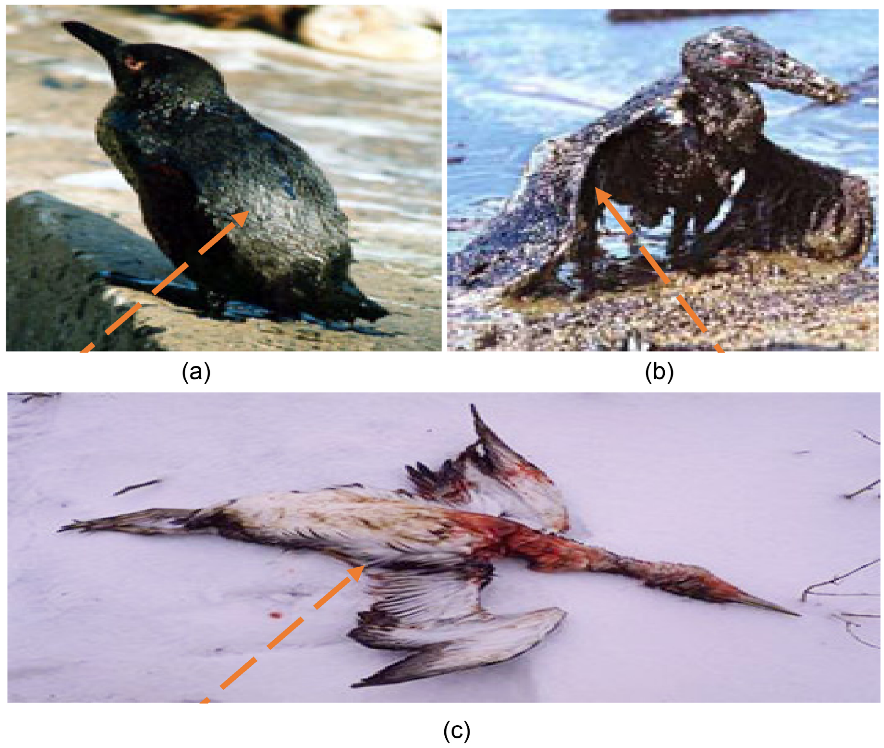

Figure 2. (a): Oil Spill Impacts on Birds. (b): Oil Spill Impacts on Birds. (c): Oil Spill Impacts on Birds.

22 killer whales (Harwell & Gentile, 2014). In the years after the Exxon Valdez spill, scientists noted higher death rates among sea otters and other species affected by the spill and stunted growth or other damage among additional species. Thirty-five years after the disaster, researchers have found that the Prince William Sound ecosystem seems to have finally recovered, and localized effects on sea otters appear to have been resolved (Fukuyama et al., 2014).

Long after the spill, impacts persist on marine mammals leading to more dead, threat of species extinction or stunted growth or other damage among other species as shown in **Figure 3(a)** and **Figure 3(b)**. Potential respiratory damage, hypothermia and other cellular injuries are eminent as a result of the oil spill impact.

3. Turtle

The survival rates of Turtles plummeted and the number of nests declined by 35% as a result of the BP oil spill which cause a surge of sea turtle strandings in the northern Gulf of Mexico with a majority in Alabama, Mississippi, and Louisiana (Gallaway et al., 2016).

3.1. Impact on Fish

Oil spills often take a deadly toll on fish, shellfish, and other marine life, particularly if many fish eggs or larvae are exposed to oil. Shrimp and oyster fisheries along the Louisiana coast were among early casualties of the BP Deepwater

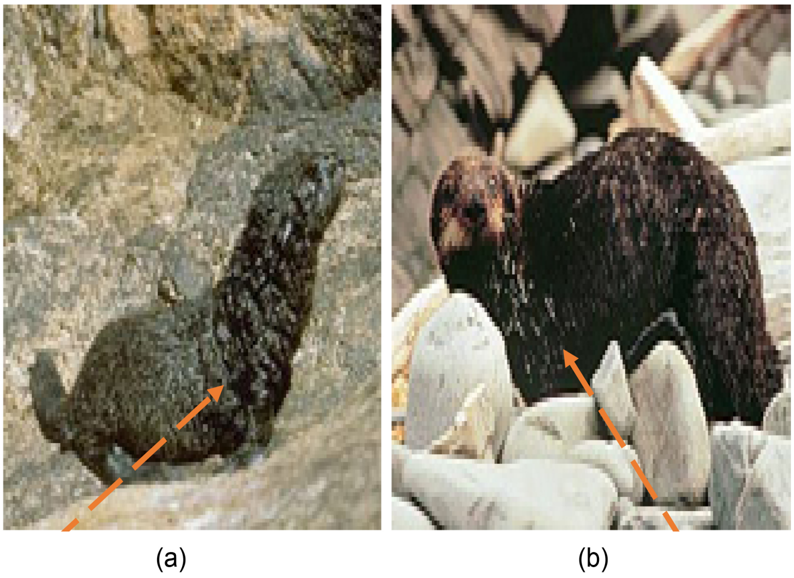

Figure 3. (a): Oil spill impacts on marine mammals. (b): Oil spill impacts on marine mammals.

Horizon oil spill. Similarly, the Exxon Valdez spill destroyed billions of salmon and herring eggs. Fisheries impacted by the Exxon Valdez took over three decades to recover (Quintana-Rizzo et al., 2015).

The shrimp and oyster fisheries are usually the first casualties of marine oil spills. In most cases, the fisheries hardly recover. Fish are affected through contacts with the gills, by ingestion, or by eating oiled prey. The oil contains polycyclic aromatic hydrocarbons (PAHs) which are the most toxic components of oil. Oil vapors can cause damage to an organism's central nervous system, liver, and lungs. Spilled oil can also have long-term reproductive problems in organisms that have been exposed to oil (Fukuyama et al., 2014). Fishes are very susceptible to oil spill impacts as shown in **Figure 4**. The severity most often result to death, deformation and extinction of species.

3.2. Cetaceans

A deadly toll on dolphin and whale populations contributed to the largest and longest marine mammal mortality event ever recorded in the area. Between 2010 and 2014, there were 1141 cetacean strandings recorded in the northern Gulf of Mexico, with 95% found dead. Bottlenose dolphins especially were killed both as a direct result of oil pollution and from long-term adverse health effects. Studies on the species conducted from 2010 to 2015 found that reproductive success rates for bottlenose dolphin females were less than a third of those in areas not impacted by the spill (Kellar et al., 2017).

3.3. Wildlife Habitat and Breeding Grounds

Spill have both acute, short-term impacts on wildlife and environmental health, and long-term effects that persist for a longer period (Schwing et al., 2015).

Figure 4. Oil spill impacts on fisheries.

Long-term damage to species and their habitats and nesting or breeding grounds is one of the most far-reaching environmental impacts caused by oil spills. Even species that spend most of their lives at sea, such as various species of sea turtles, must come ashore to nest. Sea turtles can be harmed by oil they encounter in the water or on the beach where they lay their eggs, their eggs can be damaged by oil and fail to develop properly, and newly hatched turtles may be oiled as they scurry toward the ocean across an oily beach.

Ultimately, the severity of environmental consequences caused by an oil spill depends on many factors, including: 1) the amount of oil spilled. The more the quantity of oil spilled into the environment, the more devastating the consequences on the ecosystem. 2) Type and weight of oil. The oil viscosity and the emulsification factor of the oil will determine the weight of oil. 3) The location of the spill. The spill location will also determine the severity of impact on the environment. 4) Species of wildlife in the area. Some species are quite adaptable to spills while some cannot survive and will die from the impact. 5) The timing of breeding cycles and seasonal migrations. There will be more severe impact on the organisms if the spill incident coincide with the breeding cycles as well as the migration period, and 6) even the weather at sea during and after the oil spill (Harms et al., 2019). A typical marine habitat is a beautiful environment; the opposite is the case when impacted with oil spill as shown in Figure 5.

There are many important factors relating to the impact of an oil spill on wildlife:

- the spread of the oil slick,
- the type of oil spilled, its movement and weathering characteristics,
- the location of the spill,
- the area of estuary, sea and foreshore impacted by oil,
- the sensitivity of the regional environment, eg proximity to bird breeding colony,
- the timing of the incident (during seasonal breeding, bird migration),
- the nature, toxicity and persistence of the oil; and

Figure 5. The marine habitats.

- the variety of species at the spill location.

Ultimately, the severity of environmental damages caused by a particular oil spill depends on many factors, but oil spills usually are always not a welcomed development for the environment. Figure 6 shows the Environmental Impact of 1989 Exxon Valdez Spill Incident on the Marine Ecosystem.

3.4. Recovery Rate of the Marine Habitats

The recovery rate of the marine habitats upon impacts as a result of oil spill incidents is a function of the fate of oil dynamics in the ecosystem. The Lagrangian Model PETROMAR-3D will be very useful in evaluating and simulating the interaction interface between the key parameters such as the characteristics of the type of oil, marine environment and the spill itself in managing the Complex Processes in Marine Oil Spills (Calzada et al., 2021).

In most cases, recovery typically takes place within a few seasonal cycles and for most habitats within one to three years. But mangroves takes longer time for recovery because of its high sensitivity to oil spills impacts as shown in Table 1.

3.5. Economic Impact

Economic impact of oil spills on the fisheries and the tourism industry as always been very devastating.

Salmon and herring fisheries lost income not just in 1989, but were hardest hit in 1993, as a result of oil spills, when the eggs that had been laid was destroyed by spill and could not reach adulthood. One estimate puts the cost at $300 million of economic harm to more than 32,000 people whose work depends on fisheries (Fukuyama et al., 2014).

It's hard to put a number on the value of the thousands of animals that have been killed by spills, but there were some estimates made for the per-unit replacement cost of seabirds, mammals, and eagles: that value was $2.8 billion for the Exxon Valdez spill.

Tourism spending decreased by 35% in southwest Alaska in the year following the spill and visitor spending resulted in a loss of $19 million to the Alaskan economy.

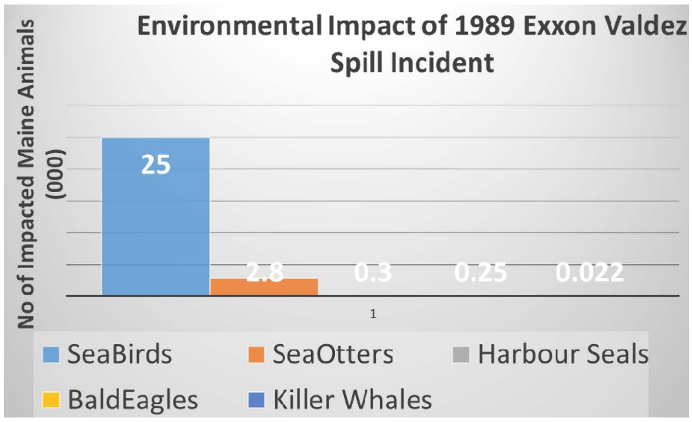

Figure 6. Environmental Impact of 1989 Exxon Valdez Spill Incident on the Marine Ecosystem. Source: "Status of Injured Resources & Services". *Exxon Valdez Oil Spill Trustee Council*, 2014.

Table 1. Indicative recovery periods after oiling for various marine habitats.

Habitat	Recovery Periods
Planktons	Weeks/Months
Sand Beaches	1 to 2 Years
Exposed Rocky Shores	! To 3 Years
Sheltered Rocky Shores	1 to 5 Years
Salt Marsh	3 to 5 Years
Mangroves	10 Years and above

Two years after the Exxon Valdez spill, the economic losses to recreational fishing were estimated to be $31 million.

Exxon spent over $3.8 billion to clean up the oil spill, which covered paying people directly to do jobs like wash off wildlife and spray oil-covered beaches, but also compensated 11,000 local residents for income loss. That amount also included fines (Carson et al., 1992).

After, most of the worst oil spill incident occurred, serious environmental protection campaign was initiated and driven. The result was drastic reduction in the number of spills and quantity of spills from 1970 to 2016 as shown in Figure 7.

4. Conclusion

A wide range of highly complex ecosystems exist within the marine environment and substantial fluctuations in abundance and diversity occur as a feature of their normal functioning. The marine environment is usually the receptacle to oil pollutions and other pollutants discharge.

The marine environment has a strong capacity for natural recovery from severe perturbations caused by natural phenomena as well as oil spills, however, depending on the volume of release may be overwhelmed thereby impacting on

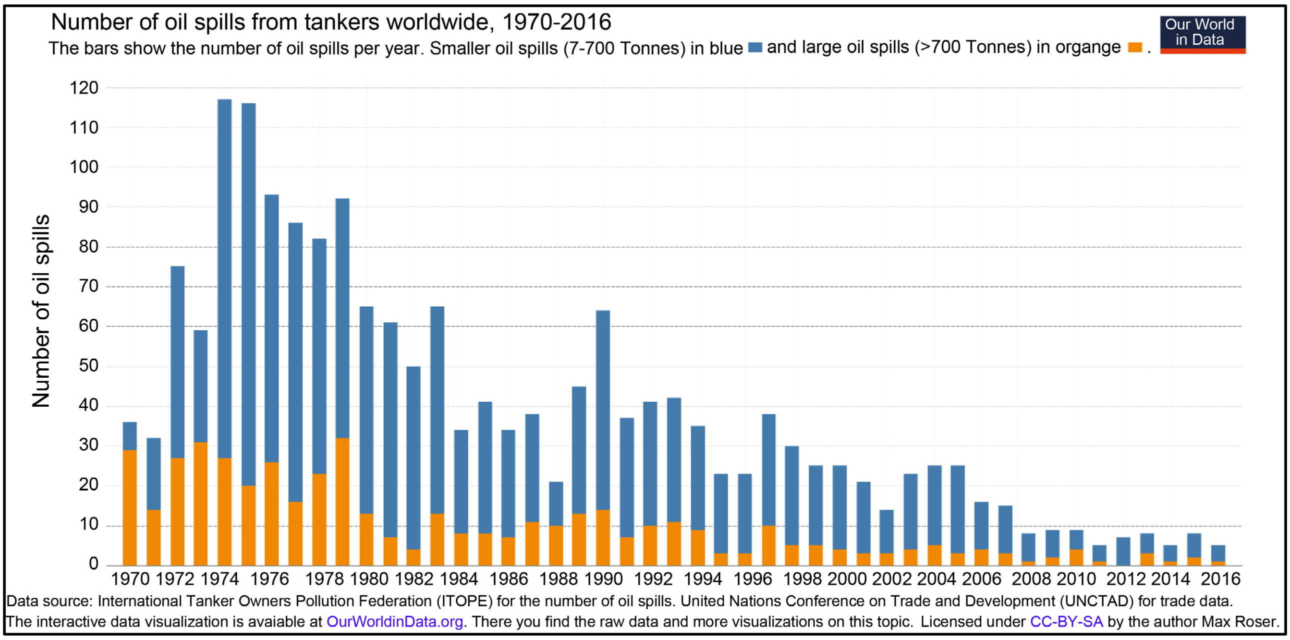

Figure 7. Numbers of marine oil spills from tankers worldwide from 1970-2016. https://ourworldindata.org/oil-spills/.

the recovery rates.

The key mechanisms for environmental damage from oil spills are smothering and toxicity but the severity of the damage depends very much on the type of oil spill, and how volume released, time of season of release and timely response helping the oil dissipate relative to the location of resources sensitive to oil pollution.

The most vulnerable organisms are those found on sea surface or shorelines. Saltmarshes and mangroves are the most sensitive shoreline habitats in the marine ecosystem.

Seabirds are particularly at risk, some species, and penguins in particular, respond well to cleaning, however, others may not survive for long when released back into the wild ecosystem after cleaning or may have difficulty breeding successfully.

Although short term impacts can be severe, lasting damage is usual even following the largest incidents, where observed long term damage has been restricted to geographically discrete areas where conditions have permitted accumulations of oil to persist and therefore continuous monitoring and evaluation become necessary.

Effective planning and execution of response operations both mitigate damage and provide the first step to recovery by the removal of oil and adequate cleanup operations followed by well-designed reinstatement measures which enhance natural recovery processes.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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