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RESEARCH ARTICLE

Sources and reporting of oil spills and impacts on wildlife 1970–2018

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Abstract

The extraction, transport, and consumption of hydrocarbons occur daily worldwide and can lead to environmental pollution and significant incidents of wildlife mortality. This review of literature and publicly available databases from 1970 to 2018 summarises records on oil spill incidents, sources of spills, and reported effects on wildlife. During this time period, millions of tonnes of oil were released from over 1700 acute oil spills, with only 312 (18%) reporting wildlife effects. The most numerous reported spill source was shipping. From this review, there are obvious global gaps in reporting of oil spills and recording of effects on wildlife. We recommend there is a global need for increased consistency of reporting and availability of data of oil spills, and wildlife impacts. This information is critical to preparedness and response procedures for industry (shipping and oil) and governments.

Keywords Oil spill · Shipping · Reporting · Mortality · Impacts · Preparedness

Introduction

Petroleum can be a significant contributor to the pollution and deterioration of the world's marine and terrestrial environments (Atlas and Bartha 1973; Peterson et al. 2003; Murphy et al. 2016). A recognised source of oil pollution is acute oil spills. These spills result from oil well blowout (accidental or in the act of war; Jerneloev 2010; Allan et al. 2012); accidents involving marine vessels (oil tankers and marine vessels of all types and sizes; Wolfaardt et al. 2009; Sammarco et al. 2013; https://www.itopf.org/knowledge-resources/data-statistics/statistics); or increasingly reported spills from refineries, pipelines, and land transport (Frink and Clumpner 1995; Fingas 2012). Well blowouts are infrequent but often voluminous (Jerneloev 2010); marine vessel accidents occur more frequently and can equally result in large-scale oil contamination and effects on wildlife (Hansen and Tourk 1974). Pipeline spills, particularly those into waterways, can also cause large-scale contamination (Clarke et al. 1990; Cronk et al. 1990; Frink and Clumpner 1995; Fingas 2012). The frequency of oil spills in general has increased in the last decades, due to increased international transportation of cargo and consumption, therefore movement of fuel oil, not only in the marine environment but also on land (Goodman 2005).

The most noticeable and widely scrutinised effects of oil pollution, particularly during acute oil spills, are the effects on wildlife and the environment (Piatt et al. 1990; Furness and Camphuysen 1997; Henkel and Ziccardi 2018). Oil affects wildlife directly and indirectly causing harm through physical contact, ingestion, inhalation, and absorption. All oil types, light (i.e. petrel and diesel), intermediate, and heavy oils (i.e. crude and bunker), all interfere with water repellence of feathers and fur of wildlife. Oiled birds and mammals lose the ability to fly, dive, swim, or float, on contact with oil, and the ability to thermoregulate (their ability to control their own body temperature), leading to hypothermia, drowning, and death (Burger and Fry 1993; Heubeck et al. 2003; Helm et al. 2015). Similarly, when feathered and furred wildlife preen or groom, they ingest and inhale the oil on their bodies, which can cause internal contamination causing endocrine/hormone disruptions (Altamirano 1983; Eppley and Rubega 1990; Mearns et al. 1999). Ingestion, inhalation, and absorption are the main direct routes of impact for non-furred wildlife such as cetaceans (whales and dolphins), reptiles, amphibians, and fish. Without human intervention, many of the wildlife affected by oil will die (Helm et al. 2015).

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One of the first reported major oil spills (still classified as one of the biggest in the world even taking into consideration oil spills from acts of war) was a terrestrial spill in 1910, the Lakeview Gusher, Kern County, CA, USA (Rintoul and Hodgson 1990). Oil spills were increasingly reported in the early 1960s, particularly from oil tankers; however, it was not until the later years of the 1960s reports of oiled wildlife impact and responses were also reported from spills such as TV Torrey Canyon, UK, 1967, and the TV World Glory, South Africa, 1968 (Rogowska and Namieśnik 2010). In the 1970s, recording of acute oil spills became a more common occurrence from sources other than oil tankers. From a wildlife impact and reporting point of view, the Santa Barbara Paltform oil spill, USA in 1969 is cited as a major influence on the American environmental movement. Soon after this spill, the US National Environmental Policy Act (NEPA 1970), US Federal Water Pollution Control Act Amendments of 1972 (FWPCAA 1972, also known as Clean Water Act), US Endangered Species Act (ESA 1973), and US Marine Mammal Protection Act (MMPA 1972) were all passed (Henkel and Ziccardi 2018). Similarly, after the TV Exxon Valdez oil spill in 1989 (Piatt et al. 1990), with global media, reporting, and attention-highlighted impacts of oil on wildlife, the US Congress passed the US Oil Pollution Act of 1990 (OPA 1990). This act established a mandate that oil spill response planning must "provide for coordinated immediate and effective protection, rescue, rehabilitation and minimization of risk of injury to, fish and wildlife resources and habitat …", thus making oiled wildlife response in the USA mandatory (Henkel and Ziccardi 2018). However, this type of legislation, the level of reporting of oil spills, and oiled wildlife impacts are not shown to be an international requirement or trend.

This review searches current literature and publicly available databases covering almost five decades (1970–2018), summarising global data on oil spill incidents, sources (ships, tankers, wells, and other) and whether they reported affected wildlife. Wildlife, for this review, are classified as birds, mammals, reptiles, amphibians, and fish. This review analyses oil spill literature from 1970 onwards as little literature exists regarding oil spills, except large globally obvious oil tanker spills, before the 1970s. The focus of this review is records of reported acute oil spills (acute oil spills are defined here as being > 7 tonnes (minimum volume category from ITOPF records) and from one source). In this instance, acute does not refer to one off release although many of the spills are; it also refers to an ongoing release from one source such as from Deepwater Horizons (Allan et al. 2012), with recorded volumes. We acknowledge other sources of marine petroleum pollution including natural seeps of oil from the seafloor, also impacting the world's environment and wildlife, but these sources are not the focus of this review.

Material and methods

An online literature search was conducted with the aim of creating a list of publicly available reported acute oil spills from throughout the world, to document if oiled wildlife were reported and if wildlife were responded to (i.e. oiled carcasses collected, live oiled wildlife captured and rehabilitated). Acute oil spills are defined here as being > 7 tonnes (minium volume category from ITOPF records) and from one source. A source can be one release or ongoing from one source such as Deepwater Horizons (Allan et al. 2112). Primary sources of information included scientific journal articles through searches on Google Scholar or Web of Science database (search terms were in English and words included were oil spill, oiled wildlife, petroleum, spill, and marine pollution); Grey literature from US National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration (ORR), Historical Incidents database (https://data.noaa.gov/dataset/noaas-office-of-response-and-restoration-historical-oil-and-chemical-spill-incidents-database—primarily incidents that occurred in US mainland and territorial waters); International Tanker Owners Pollution Federation Limited (ITOPF) oil tanker spill statistics (https://www.itopf.org/knowledge-resources/data-statistics/statistics); The Centre of Documentation, Research, and Experimentation on Accidental Water Pollution (http://wwz.cedre.fr/en/); and papers from the proceedings of the International Oil Spill Conference (IOSC) (https://ioscproceedings.org/).

Spill events were characterised by year, location (country or area), the environment (marine (including coastal areas) or terrestrial (including inland river spills that are not recorded as reaching the marine environment)), source of spill (see categories below), oil type, estimated spill volume, and if wildlife was reported affected, specifically reported as not affected, or nothing reported about wildlife. If wildlife was reported affected, the total number of carcasses collected and, if available, approximate total numbers of wildlife captured oiled and rehabilitated was recorded. Additionally, wildlife was categorised by predominant species of wildlife reported: birds only; any combination of air-breathing wildlife (birds, mammal, reptile); and other (only non-air-breathing wildlife reported, i.e. fish). Number of carcasses collected or estimated from air-breathing wildlife only were categorised as:< 100; 100–1000; 1000–10,000; > 10,000; known deaths but no numbers; and unknown or if animals were known to be captured and rehabilitated: < 20; 20–100; 100–1000; and > 1000. We categorised spill sources into: oil tanker (including barge tankers), non-oil tanker shipping (referred to as general shipping), wells and platforms, pipelines (both marine and terrestrial), terrestrial refinery and tank spills, trucks/trains, and other (predominantly being aircraft). As 95% of the last two categories (trucks/trains and other) were only reported in North America and represent less than 3% of all spills reported

globally, these spills are discussed briefly; however, they are not presented in graphs. For this review, oil refers to crude oil and petroleum products, including gasoline and other fuels with oil type categorised into heavy (i.e. crude oil, bunker B and C, #6 fuel oil), intermediate (i.e. IFO 180, IFO 380, #4 Fuel oil), or light (i.e. petrol's, diesels, aviation gas, #1 and #2 fuel oils). Spills were only included in this review if the information was publicly available and an estimate of amount of oil spilled was included. Tonnes were used as a volume proxy to enable standardisation of data for all petroleum products, with 1 tonne being equivalent to 1165 L, 7.33 barrels, or 308 US gallons.

Results

Oil spills

A total of 1702 spills with reported oil spill volumes were accessible and analysed from publicly available sources. Eighty percent of all spills (n = 1362) were from the US mainland and territorial waters. Ninety six percent of all spills were from the Northern Hemisphere and 4% from the Southern Hemisphere. Forty seven percent of all reports were from general shipping, i.e. cargo, bulk carriers, cruise ships, and military and fishing vessels, 23% of all were reports from oil tankers and oil tanker barges, 12% pipelines, 9% terrestrial refineries and tanks, 6% wells/platforms, and 3% each from trucks/trains and other. General shipping–sourced oil spills show the highest and most continuous increase in the last five decades (Fig. 1). Oil tankers show a decline in incidents in the last two decades, while pipelines and wells show predominantly steady minor increases each period (Fig. 1). Terrestrial spills showed similar incidences to wells/platforms but have increased significantly in the last decade (Fig 1). Eighty-six percent of all reported spills were in marine environments. Terrestrial spills were minimal up until the 1980s, hovered around 10% per decade during the 1980s, 1990s, and 2000s, increasing in the last 8 years up to 14% mainly due to increased reporting from terrestrial facility and tank spills (Fig. 1).

There were almost 16 million tonnes (5.5 million recorded from tanker spills https://www.itopf.org/knowledge-resources/data-statistics/statistics) of oil recorded spilt in the last five decades from acute spills that reported spill volume. The average volume of oil spilled per source has decreased between the 1970s and 1990s for almost all spill sources (these results exclude Middle-Eastern war spill figures) and have stayed predominantly level since the 1990s (Fig. 2).

Of spills reported, 48% were crude and heavy fuel oil, 47% light fuel oils, and only 5% intermediate fuel oils. Considering oil types, of all spills reporting light oil spills, 72% were from general shipping, similarly, 60% of all intermediate oil spills reported were also from general shipping. For crude and heavy fuel oil spills, 35% of spills were from tankers, 23% from general shipping, 18% pipelines, and 10% each from wells/platforms or terrestrial refineries and tanks. The average size of spills for light and intermediate oil types, predominantly from general shipping spills, was 1300 tonnes per spill. For crude and heavy fuel oil, the average spill volume was significant larger at 320,000 tonnes; however, this included the enormous volumes from the Middle-Eastern war in the 1990s. Removing act of war spills, the average reduces to 16,000 tonnes per spill.

Reported wildlife impacts

Of 1702 reported spills analysed here, 312 spills reported impacts to wildlife (18%), 2% (n = 32) explicitly stated wildlife was not observed to be affected, leaving 80% of reported spills not mentioning wildlife (Table 1). Of the 312 spills reporting

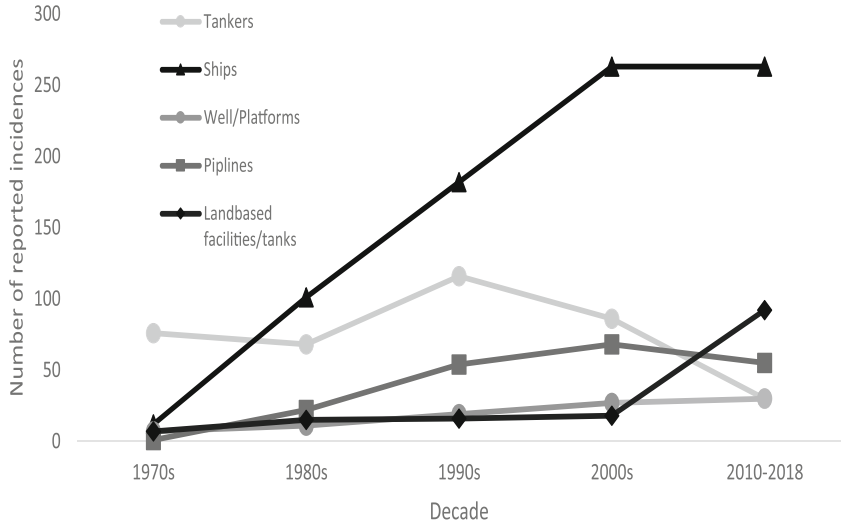

Fig. 1 Numbers of reported oil spills summed by decade, by spill source, across the almost five decades, 1970 to 2010–2018

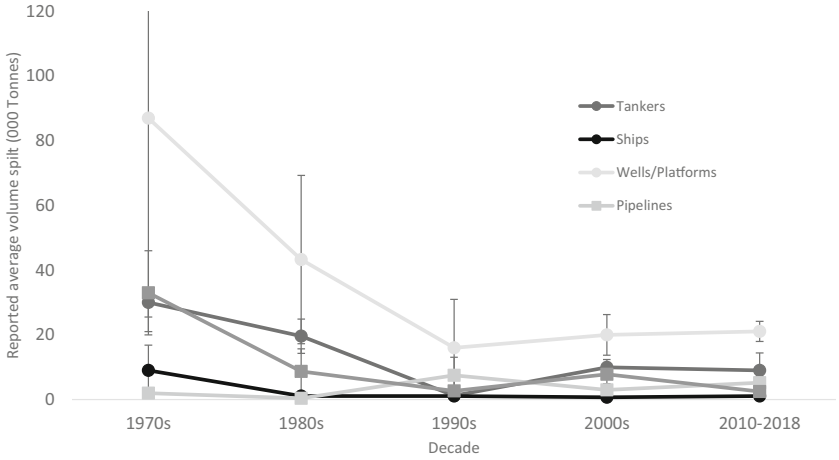

Fig. 2 Average volume of oil (± SE) spilled per spill source per decade, across the almost five decades, 1970 to 2010–2018 (not including Middle-Eastern war spills from wells, tankers or terrestrial tanks 1991)

wildlife impacts, 78% were from crude and heavy fuel oil spills, 15% light oil spills, and 7% intermediate oil spills.

The sources of the spills which reported wildlife affected were from tankers (38%), general shipping (24%), pipelines (19%), terrestrial spills (7%), and wells/platforms and trucks/trains/other 6% each, respectively. Given the numbers of spills reported from each of these sources (Fig. 1 and above data), the overall reporting of affected wildlife per spill source was 37% of all truck/train/other spills reported wildlife; 30% of all tanker spills; 29% of all pipeline spills; 19% of all well spills; 15% of all terrestrial spills; and only 9% of general shipping spills.

The predominant species reported affected were 45% birds only, 45% air-breathing wildlife which included birds and marine mammals and/or reptile species, and 10% non-air-breathing wildlife only, i.e. fish (Table 1). Of the 312 reported impacts on wildlife incidences, 207 reported mortalities specifically, although only 90 of the reports quantified the number of mortalities. There was no clear relationship between spill size and/or number of wildlife reported dead (Table 1, Fig. 3). One hundred and twenty-one of the 312 reported wildlife impacts reported rehabilitation of wildlife occurred ranging from < 20 individuals to > 1000 (Table 1). Similar to rates and quantity of mortality reported, there was no clear relationship between size of spill and number of wildlife rehabilitated reported (Fig. 4). These two figures indicate wildlife reporting and numbers of wildlife reported either dead or rehabilitated is not dependant on spill size.

Discussion

Spill reporting—spill location

Generally, location of spills reported match human distribution, and production and use of petroleum. For example, 96% of all spills were reported in the Northern Hemisphere, which matches not only the human population distribution of the world (90% of the world's population lives in the Northern Hemisphere) but also where the majority of industry,

Table 1 Summary of the number of incidences of oil spills, the percentage that reported wildlife, the main species of wildlife affected, and mortality and/or rehabilitation numbers reported

Wildlife reported 1970–2018 Global total	Number of incidences 1702	Reported wildlife mortality						Reported wildlife rehabilitated				
		< 100 (%)	100–1000 (%)	1000–10,000 (%)	> 10,000 (%)	Known mortality but no number (%)	Unreported (%)	< 20 (%)	20–100 (%)	100–1000 (%)	> 1000 (%)	Unreported (%)
Not mentioned	1358											
Not affected	32											
Yes	312	6	6	15	6	42	25	8	12	15	8	57
- Birds only	138	7	7	12	5	35	34	9	10	13	6	62
- Birds, reptiles, and mammals	140	4	6	18	8	48	16	7	13	18	11	51
- Other (fish, molluscs, invertebrates)	34 (all unreported numbers)											

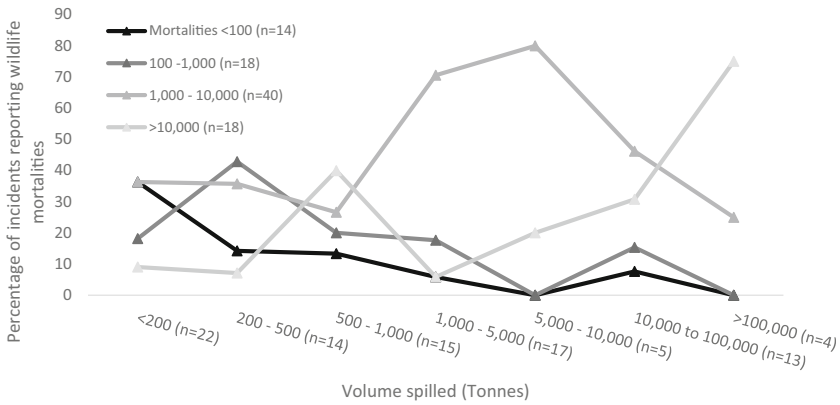

Fig. 3 Percentage of oil spills in each spill size range that reported numbers of wildlife mortalities. Numbers in brackets in legend and on volume spilled axis (*X*-axis) equal actual numbers of spills that were reported in that size bracket

consumption, production, and shipping of oil occurs. However, the most obvious result from this analysis regarding location of reported spills is that there are enormous geographical gaps in publicly available data on reported oil spills. One thousand three hundred sixty-two of the 1702 spills (80%) analysed were from US waters, mainly due to the existence of the NOAA database, where oil spills are consistently reported into that database and the database is publicly available. This finding leads to the first recommendation of this review, which is to encourage all governments and industries to require publicly available reporting of spill events. Given the number of spills listed in US territory, how many oil spills are not reported or information not available for analysis throughout the rest of the world such as examples from Nigeria (Aroh et al. 2010).

Spill reporting—spill source

Of all spills reported, 71% come from marine vessels, the majority of which are general shipping vessels, with the number of spills coming from general shipping consistently increasing annually (Fig. 1). General shipping alone, cargo, bulk carriers, cruise ships, and military and fishing vessels (does not include oil tankers or tanker barges), has been responsible for more than twice the number of spills than any other spill source. Tanker and tanker barge spills are the second most reported spill type (23%); however, their occurrence has decreased over the last five decades likely due to improvement in vessel design (double hull), safety requirements, and procedures (Fig. 1; http://www.itopf.com/information-services/data-and-statistics/statistics/). Given the reports from general shipping and tankers contribute 71% of the total number of spills reported, it is not surprising that 86% of all reported spills are in the marine environment; however, terrestrial spills are increasingly occurring and/or being reported (Fig. 1).

The average volume of oil spilled per source predominately decreased between the 1970s and 1990s (excluding Middle-Eastern acts of war spills) and have stayed predominantly level since the 1990s (Fig. 2). However, given general shipping and terrestrial spills are increasing in numbers, it still equates to an increasing amount of oil being spilled into the world's environment from acute oil spills. The predominant oil types reported spilled are crude/heavy and light fuels, which is not surprising as these are the most commonly consumed forms of oil (Bilgen 2014; Johansson et al. 2017). Sources of spills that were crude and heavy fuel oil spills were more evenly spread across source type, i.e. 35% from tankers, 23% from general shipping, 18% pipelines, and 10% each from wells/platforms or terrestrial refineries and tanks,

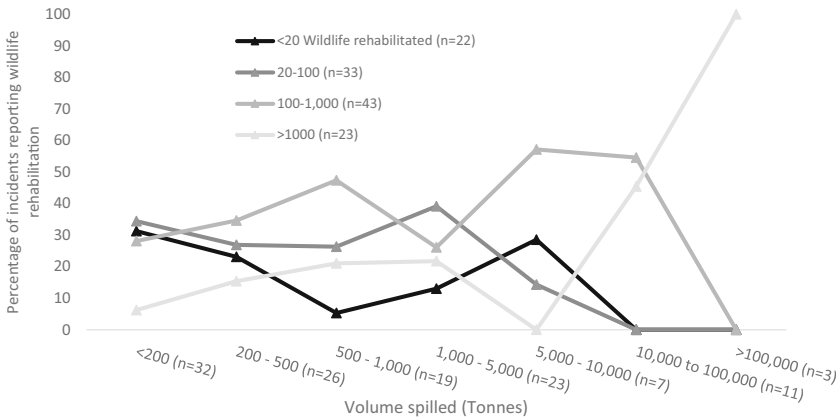

Fig. 4 Percentage of oil spills in each spill size range that reported rehabilitated wildlife numbers. Numbers in brackets in legend and on volume spilled axis (*X*-axis) equal actual numbers of spills that were reported in that size bracket

compared with light or intermediate oil spills where the majority of spills reported were from general shipping.

Reporting of wildlife effects

One of the most visible and scrutinised effects of an oil spill that gets public attention is its impact on wildlife. However, as this review shows, 80% of spills reported make no statement of wildlife seen, affected or not affected. Only 2% specifically state wildlife were not affected, while 18% report wildlife affects (Table 1). We suggest this is significant under reporting of interaction and affects. The importance of reporting wildlife impacts in a spill is not only so wildlife receive help if needed, but so there is baseline data on wildlife effects from oil spills. Reports of wildlife in and around spill sites can also be important first reports or baseline data for wildlife in the area. An example of this is the mortality records from the MV Rena oil spill (Hunter et al. 2019), which showed wildlife not commonly or had never been reported in that area, being found during the oil spill.

The second most noticeable result from this review regarding wildlife is that wildlife impacts are not proportional to the size of oil spill (Figs. 3 and 4). Significant numbers of wildlife are affected from just about any size spill. This has previously been reported with volume of oil spilled being clearly shown as an inadequate measure of environmental or wildlife damage (Whittington 2002). For example, the TV *Stylis* discharged a relatively small amount of oily bilge washings shortly before the tanker entered the Skagerrak, southern Norway, killing an estimated 200,000 to 300,000 seabirds (International Council for the Exploration of the Sea 2005). Similarly, an estimated 315,000 seabirds are killed annually from discharges of oil and oily bilge water from ships in southeastern Newfoundland with discharges often illegal (Wiese and Robertson 2004).

Greater understanding is needed that wildlife is not only impacted by crude and heavy fuel oil types but also by all oils (light, intermediate, and heavy). All oil types affect waterproofing and thermoregulation and can be absorbed, inhaled, and ingested (Burger and Fry 1993; Heubeck et al. 2003; Helm et al. 2015). However, due to crude and heavy fuel oil colour and persistence, it appears wildlife impacts are reported more often from crude and heavy fuel oil spills than lighter oils. Crude and heavy fuel types are more visible and have greater persistence in the environment allowing more time for wildlife to come in contact with it with these two factors likely biasing reporting, as is indicated in this analysis with 78% of the 312 spills reporting wildlife impacts, being from crude and heavy fuel oil spills. Overall, in considering impacts of oil spills on wildlife, it is more important to consider where an oil spill occurs in relation to densities of wildlife, than what oil type or how much oil was spilt (Piatt et al. 1990). This is one of the reasons for the importance of reporting wildlife, whether affected or not, in every spill, so records and analysis of effects can be investigated. Wildlife impacts have been reported from spills less than 1 tonne of oil. The world's largest live animal oiled wildlife response, the *Treasure* spill in 2000 South Africa, was approximately only 1400 tonnes. Yet, during this response 19,000 African penguins (*Spheniscus demersus*) were rehabilitated, as well as pre-emptive capture and relocation of 19,500 unoiled penguins to Cape Recife (800 km away) to prevent them from becoming oiled (Crawford et al. 2000; Wolfaardt et al. 2008a).

When sources of oil spills are analysed and compared with reported wildlife impacts, the reporting of wildlife affected by source per spill was highest in terrestrial transport trucks/train spills. Thirty-seven percent of all truck/train spills reported wildlife effects, followed by 30% of all tanker spills, 29% of all pipeline spills, 19% of well spills, 15% of terrestrial spills, and only 9% of general shipping spills. From a reporting point of view, these results appear to be biased to wildlife reporting when spills are publicly visual, i.e. terrestrial spills (transport, pipelines, and tank/refinery spills), as the spill is likely very visual to the public given it is on land. Alternatively, but still as visible, tanker and well spills are usually extremely publicly obvious due to their size and rarity, hence having higher publicity, and are likely to have had coordinated oiled wildlife responses and therefore higher rates of wildlife reporting. It is the reporting of wildlife impacts from general shipping sources that appears disproportionately low. This could be due to several reasons. First, oil spills from ships do not necessarily occur near land or in public view. Second, oil spills from ships are proportionally more likely to be light or intermediate fuel types (60–72% of all reports of intermediate and light fuel spills were from general shipping), and with these fuels being lighter in colour and shorter in persistency, they are less likely to be thought of or seen to be affecting wildlife (although they are likely to, Helm et al. 2015). These observations would lead to the second recommendation of this review. We would highly recommend better observation and reporting of wildlife effects for general shipping to determine if this bias exists or not. For general shipping, as with all oil spill sources, reporting no effect on wildlife is as important as reporting effects so that true monitoring of wildlife impacts can be determined. However, this is particularly important when considering the number of oil spills from general shipping is not only the highest by number but is also increasing (Fig. 1).

Numbers of wildlife affected

Reporting numbers of wildlife affected during oil spills is rare (Table 1), with ranges rather than exact numbers usually stated. Exceptions are highly publicised events (such as *Exxon Valdez*, Piatt et al. 1990; https://darrp.noaa.gov/oil-spills/exxon-valdez, *Cosco Busan*, Cosco Busan Oil Spill Trustees

2012; Deepwater Horizon), or when coordinated oiled wildlife responses report records of wildlife causality and fatality as shown in the MV *Rena*, in NZ (Gartrell et al. 2019; Hunter et al. 2019) or Refugio pipeline spills, CA (https://www.darrp.noaa.gov/oil-spills/refugio-beach-oil-spill). The predominant species reported affected were 45% birds only; 45% air-breathing wildlife including birds and marine mammals and/or reptile species; and 10% non-air-breathing wildlife only, i.e. fish. This matches previous research showing that the majority of data regarding oil spill wildlife causalities was bird species (90%), with half including other air-breathing vertebrates. Only a few spills (*Exxon Valdez*, *Amoco Cadiz*, Deepwater Horizon, Cosco Busan, Prestige, Arthur Kill pipeline) quantified other wildlife species captured or carcass collected (for example marine mammals, turtles, and fish species; Piatt et al. 1990; Mearns et al. 1999; Camphuysen et al. 2010; Jerneloev 2010; Cosco Busan Oil Spill Trustees 2012; https://darrp.noaa.gov/oil-spills/exxon-valdez).

Conclusion: limitations and recommendations

This review demonstrates obvious gaps in availability of data and reporting of oil spills and associated impacts on wildlife globally. Notably, 80% of all reports in this analysis were from only one country, resulting in major unequal coverage of reporting across the world regions. From the availability of records of oil spills, there also appears to be significant lack of reporting and/or observation and reporting of wildlife effects. This may be due to lack of knowledge of impacts of all oil types on wildlife, or lack of observation, and/or reporting in general.

Even with a somewhat geographically restricted data set, some positive trends emerge. First the number of oil tanker spills is decreasing (Fig. 1; https://www.itopf.org/knowledge-resources/data-statistics/statistics). Second, in general, the amount of oil spilled has decreased from most spill sources (Fig. 2). However, there are also continuing negative trends, such as oil spills reported from general shipping has increased significantly across the timeframe of this study. When all shipping spills are considered, shipping is responsible for significantly greater numbers of spills than all other sources combined (Fig. 1). Concurrently, there are also increases of spills reported from terrestrial facilities and holding tanks (Fig. 1). Remembering that a spill of any size or oil type can significantly affect wildlife (Figs. 3 and 4, Whittington 2002), and with the numbers of oil spills reported increasing, there still remains significant concern for wildlife impacts from acute oil spills.

Oil spill response and oiled wildlife response require planning and preparedness, and as the IPIECA Tiered Preparedness and Response model indicates (http://www.oilspillresponseproject.org/wp-content/uploads/2016/02/GPG-Tiered-Preparedness-and-Response.pdf), there is a need for a three-tiered approach, integrating industry, local, national, and global preparedness. There are states (CA, USA), countries (New Zealand), and individual oil and oil response companies that are showing a level of professional preparedness through funding, planning, personnel, and equipment for oiled wildlife response. However, these are few and far between relative to the number of oil spills reported globally. Given the increasing numbers of spills reported by general shipping particularly, there appears to be a lack of regulation, legalisation, or industry responsibility taken by general shipping over preparedness for oiled wildlife response. In many countries, oil industries are regulated requiring response plans including oiled wildlife response before drilling or operations are undertaken. These regulations do not appear to exist or are limited for shipping in most areas.

Based on this review, general recommendations for requirements for industries (shipping and oil), governments, and other stakeholders concerning spill reporting and particularly reporting wildlife impacts from a spill include the following:

- Increase consistency of reporting and availability of data of oil spills globally, which may need changes in legalisation or regulation such as what happened in the USA after the Santa Barbara Platform and Exxon Valdez oil spills (Henkel and Ziccardi 2018);
- Increased understanding of the effects oil spills, of any size and type of oil, can have on wildlife among industry (shipping and oil), government agencies, and any other organisations that govern spill response and assessment within their country or region.

With this increased understanding:

- Increased requirements and efforts for preparedness and documentation of wildlife and wildlife effects during oil spills through the strengthening of laws, regulations, policies, or other official directives;
- Ensure governments and industries alike develop plans and protocols for wildlife response across all tiers of response to ensure wildlife are more frequently considered in oil spill preparedness responses, spill-related data collection, and assessment of spill effects.

There is ever increasing pressure for triple bottom line accountability (financial, social, environmental) globally for all industries. Oil spills are recognised as significant sources of environmental degradation and wildlife mortality, highlighting prevention and preparedness as keys to minimising these impacts. Impacts on wildlife during an oil spill are variable

and are impacted by factors including the nature of the spill (oil type, size, duration of release etc.), the location relative to wildlife densities and species, and the preparedness of the industry or region to respond (Henkel and Ziccardi 2018). Increasing evidence shows wildlife response and rehabilitation during oil spills is beneficial to individual animals and entire species (Wolfaardt and Nel 2003; Altwegg et al. 2008; Wolfaardt et al. 2008b; Sievwright et al. 2019a, b). Post-release research of rehabilitated wildlife after an oil spill shows survival and reproduction rates equal to control non-oiled animals and have an overall positive effect on impacted species (i.e. Heubeck et al. 2003; Wolfaardt and Nel 2003; Altwegg et al. 2008; Wolfaardt et al. 2008a; Sievwright et al. 2019a, b). Added to this is the already established ethical, animal welfare, and legal requirements to care for wildlife, and the intrinsic value of animals in most countries. The first steps to ensuring oiled wildlife effects are understood and can be responded to are the accurate and consistent reporting of acute oil spills and wildlife effects. Governments and industries (shipping and oil) need to ensure reporting, response plans, and procedures for oil spill response globally including wildlife response.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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