



Response to oiled wildlife in the management and evaluation of marine oil spills in South Korea: A review

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ABSTRACT

Oil spill incident is a serious source of pollution that causes direct and/or long-term damage to marine life, especially in East Asian countries, where maritime activities are high. However, the response to oiled wildlife was underestimated in the evaluation of oil spills and following management practices in many countries, including South Korea. The present study aimed to (1) summarize the impact of oil spills on wildlife and identification of potential risks, (2) collect data on the current status of oiled wildlife and relevant response techniques for rescuing oiled wildlife with corresponding national laws, regulations, and guidelines, (3) identify the challenges and/or weaknesses relating to the oiled wildlife responses (OWR), and finally (4) suggest the recommendations for future direction. Since the 1990s in Korea, there have been several large and small oil spills, including the worst case of the Hebei Spirit Oil Spill (HSOS) in 2007. The oil spill incidents have caused serious damages to marine organisms for the long period of time, e.g., > 10 years for the HSOS. The OWR is required at the national level for the protection of wildlife, but there were no relevant national laws, regulations, or guidelines, with no database to check the current status and implementation details at the time of the incident. Most of the oiled wildlife rescue activities were conducted by the non-governmental organizations (NGOs) in accordance with the guidelines of international organizations and targets were mostly limited to seabirds. Korea lacks expertise in the recovery and rehabilitation of wildlife in oil spills. Thus, an advanced response system was examined, and an attempt was made to prepare for future OWR construction. Overall, this first-time review for the assessment of OWR in Korea would provide a better understanding of current status, weaknesses, and future directions in national policy and management strategy for OWR.

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1. Introduction

There has been continual environmental pollution associated with human activities in coastal areas of South Korea during the past half-century. The increasing coastal development and activities following economic demands and prosperity in burgeoning Korea have resulted in varying environmental damage and ecosystem deterioration. The dramatic changes to ecosystem structure and function in coastal areas of Korea against man-made coastal and marine pollution have been repeatedly

documented elsewhere (Lee and Khim, 2017). The environmental issues of concern in Korea generally encompass loss of marine biodiversity and destruction of coastal and marine habitats linked to coastal eutrophication, environmental contamination, and marine litter, etc. (Khim et al., 2018). Among these, the oil spill derived marine pollution would be one significant concern due to its catastrophic, widespread, and relatively persistent ecological damage. Considering the high biodiversity of marine life (Costello et al., 2010) and various productive and healthy coastal habitats across the Asian countries, especially in Korea (Koh and Khim, 2014), the ecological and socioeconomic concerns should be much acknowledged.

Korean coastal waters show dynamic coastal and marine environments, which provide the variety of coastal habitats, including well-developed tidal flats and estuaries on the west and widely distributed rocky shores on the east coast. The oceanographic setting with geomorphological and sedimentological characteristics

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along the three sides of Korean coasts all collectively influence on highly variable environmental conditions (or processes) in the water body of Korean Peninsula (Choi, 2014; Hwang et al., 2014; Koh and Kim, 2014). Of note, varying tidal conditions, together with the Asian monsoon system, might have brought the diverse aquatic marine life across the coastal regions of Korea. One example of a broad spectrum of coastal commons would be well developed tidal flats in the Yellow Sea, supporting as mid-route feeding and resting places for migratory waterbirds in the East Asian-Australasian Flyway (Barter et al., 2002; Hua et al., 2015). In addition, numerous high-interest protected organisms, including sea turtles, seals, dolphins, and cetaceans, inhabit or migrate along the coastal area of the Yellow Sea (Won and Yoo, 2004; Jung et al., 2012; Lee et al., 2014; Song, 2014). The survival of protected wildlife in this region is under threat of numerous anthropogenic impacts, especially direct and/or indirect effects of oil spills.

Indeed, crude oil leakage causes direct and long-term damage to the aquatic ecosystem. The physical properties and chemical composition of crude oil make its presence in the marine environment very disruptive. Due to its high viscosity, leaked oil can cause damages to waterbirds by losing insulation, waterproofing, and buoyancy in the plumage (Burger and Fry, 1993). In the long-term, waterbirds would experience a significant population decline, breeding success reduction, and breeding phenology delay due to the ingestion of spilled oil (Wells et al., 1995). An oil spill at sea is also threatening to dolphins and whales, which causes damage to the sensitive tissues by inhaling the gasses of volatile fraction of the oil. In addition, it causes damages on ionic regulation and water balance by approaching sensitive mucous membranes, due to skin contact with oil and a gastrointestinal tract by ingestion of the oil (Geraci and St. Aubin, 2012). Over time, spilled oil spreads out, forming a thin film on the sea surface and tarballs, which would cause long-term adverse impacts on intertidal and coastal zones.

In history, the Torrey Canyon incident in 1967, off the southwest coast of the United Kingdom, is one of the world's most serious oil spills with an estimated 25–36 million gallons of crude oil spilled and > 100,000 seabirds died due to the oil spill incidents (Bourne et al., 1967). The Exxon Valdez Oil Spill incident in 1989 occurred in Alaska and spilled nearly 11 million gallons of crude oil into the environment, and killed over 250 thousand seabirds and hundreds of marine mammals (Piatt and Ford, 1996). The worst part is that even 18 years later, the buried oil residues continued to cause harmful damages on marine species, such as sea otter and clams (Boehm et al., 2008). More recently, the Deepwater Horizon oil spill incident in 2010, which has a record of being the worst oil spill incident in the US, spilled around 4.9 million barrels of crude oil into the Gulf of Mexico and killed thousands of seabirds, mammals, and endangered species (Corn and Copeland, 2010).

Marine pollution is a common and significant environmental issue worldwide, particularly in coastal areas where human activities are concentrated. As mentioned above, oil spills are a particularly dire source of pollution with catastrophic and long-term adverse impacts on diverse marine ecosystems. Thus, accurate and prompt action to minimize, and ideally prevent, the effects of spilled oils on wildlife and the environment are of great importance. However, the oiled wildlife response (OWR) seems to be the most underestimated aspect in oil spill management and assessment (International Petroleum Industry Environmental Conservation Association (IPIECA), 2014). It requires an integrated and long-term mitigation practice through multiple levels of organisms and populations. Marine mammals, waterbirds, and benthic and pelagic communities are all susceptible to oil spills. In addition, the lack of significant direct correlations between

oil quantity and impact on wildlife has made it difficult to assess oiled wildlife outcomes accurately. Concern for protecting wildlife from oiling has been increasing at various levels from the public sector, industry, and to local or national government. Thus, systematic guidelines for an OWR and its management policy would be urgently needed following by timely implementation in Korea and elsewhere.

Here, we provide a review using the most up-to-date information and data on OWR in Korea and suggest recommendations for future management practices. The goals and contents are summarized below. First, the impact of spills on wildlife and identification of potential risks on the resources are summarized, with case examples when possible. Second, the current status for responses on oiled wildlife is discussed, supported by an analysis of data collected within Korea. Relevant response techniques for rescuing oiled wildlife and corresponding national laws and regulations are also summarized. Third, the challenges and/or weaknesses relating to these responses based on an analysis of previous cases and data are highlighted. Finally, future direction and activities are suggested.

2. Data collection and analyses

In South Korea, unfortunately, there were no documented research papers and reports from state agencies relating to the OWR. We collected all the available data on OWR and oil spill incidents in the coastal and open ocean of marine environments of Korea, including non-governmental organizations (NGO) activities (Moorea et al., 2007; Sea Alarm, 2009), national surveys from Hebei Spirit Oil Spill (Ministry of Land, Transport and Maritime Affairs (MLTM), 2013; Korea National Park Service (KNPS), 2015; Korea National Park Research Institute (KNPRI), 2019), national statistics (Ministry of Public Safety and Security (MPSS), 2014, 2016; Government Monitoring System (GMS), 2020), and research papers (Jung et al., 2013; Hong et al., 2014; Yim et al., 2017) (total of 11 documents). In addition, data on national laws, regulations, or guidelines related to wildlife protection were also collected, and parts related to OWR were examined.

3. Potential risks of the oil spill on wildlife and resources

South Korea is a country surrounded by sea on three sides. It has a well-developed trade industry, many ports, and relies entirely on imports for crude oil. There are many oil companies in Korea, and each has its own facilities on the coast. Since all Korean industrial facilities are mainly situated in the coastal region, serious oil pollution could occur in the given coastal area if an oil spill occurs. In addition, local seas are likely vulnerable to impacts by persistent and toxic substances in the event of an oil spill due to the coastal morphology and sedimentological features (e.g., dented coastal line and many islands (> 3000) and soft bottom sediment) as well as macro-tidal environments. Such oceanographic and geomorphological settings in the Korean coastal waters might have a slower ecological recovery than common coasts. Because physical exposures, deposition of oil components depending on sediment characteristics, restrictions upon control work, and clean-up activities can all affect the recovery rate. The variety of vessel operations and regional characteristics in this region put it at particularly great risk for negative impacts of oil spill accidents, followed by a huge ecological and socioeconomic cost for the complete ecosystem recovery.

Moreover, given the dynamic local marine environments, there are many creatures living on the Korean coast, including some of the world's most important protected species. South Korea has designated a total of 80 marine species as threatened or

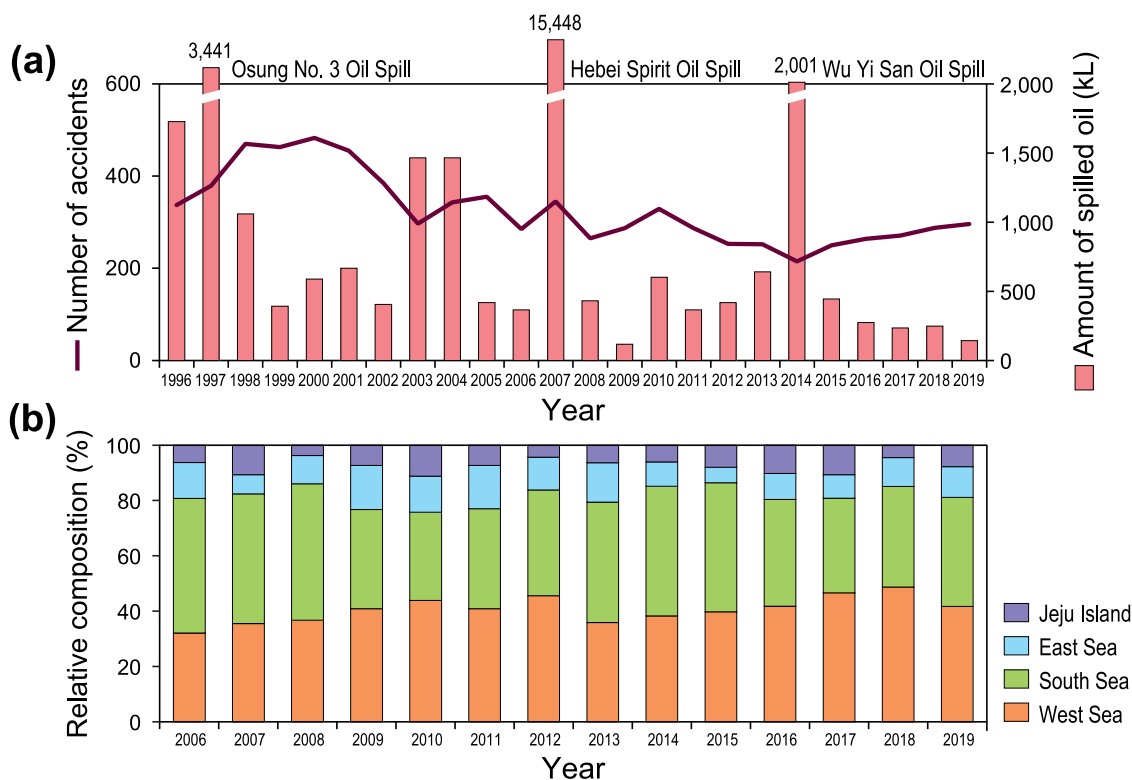


Fig. 1. (a) Number of oil spill incidents and the amount of spilled oil from 1996 to 2019 in South Korea ((data from (GMS, 2020)). (b) Oil spill incidents in coastal areas around South Korea since 2006 (data from (GMS, 2020)).

ecologically important species, which includes 16 marine mammals (e.g., whales and seals), 4 reptiles (e.g., turtles), and 14 seabirds. Some of these protected species occupy specific habitats, while others are distributed throughout the Korean waters. Accordingly, oil spills can have a tremendous negative impact on the ecology of those protected animals that live only in certain habitats, if any.

The number of oil spill incidents and the amount of crude oil spilled in the Korean maritime environment since the 1990s to the present are shown in Fig. 1a (GMS, 2020). The number of oil spill incidents and the amount of spilled oil had been decreasing in recent years, with the 2007 Hebei Spirit oil spill (HSOS) being a notable exception in history. In more recent years, however, the number of oil spill accidents increased, with the accidents being attributed largely to small vessels. Because small and mid-sized accidents involving fishing vessels and aged cargo vessels, which are poorly managed compared to large-scale oil tankers, occur frequently, there have been increasing efforts to educate fishermen and other stakeholders for marine pollution prevention. Approximately 41% of oil spill incidents in the region occur near the southern coast, where many vessels travel, while about 40% occur near the western coast; the remainder is split between the Jeju Island and eastern coastal regions (Fig. 1b) (GMS, 2020).

Several large oil spills have had a major economic impact on Korean fisheries, aquaculture, and tourism. For example, the Sea Prince Oil Spill in 1995 leaked 5035 tons of crude oil, causing damage to 3826 ha of fish farms, resulting in about 73.6 billion South Korean Won (~\$65 million) in damage (Shin et al., 2008). More recently, the Wu Yi San Oil Spill occurred in 2014, resulting in about 1000 kL of leaked crude oil (MPSS, 2014). Although substantial water quality and benthic ecology data have been collected, there has been little research on the effect of the Wu Yi San incident on waterbirds and marine mammals.

With the exception of HSOS related research, previous South Korean oil spill assessment and management have generally not supported quantitative studies on oiled wildlife (Yim et al., 2017), and also not provided for being equipped for OWR protocol. The undertaken bird recovery, rehabilitation, and release programs were led by civic and nonprofit organizations rather than governmental authorities. The South Korean Wildlife Protection Act does not include provisions for protecting and managing oiled wildlife, although those are already in place in most developed countries.

4. Current status for responses on oiled wildlife in South Korea

4.1. Cases of impacts of oil spill on wildlife

In South Korea, there are more than 300 cases of marine oil spill incidents annually, and thus further damage to marine ecosystems owing to the oil pollution could not be avoided (Jung et al., 2013). In 1996 and 2014, two representative oil spill outbreaks occurred along the Korean coastline (Table 1) (MPSS, 2016). About 7000 tons of crude oil was spilled from the two incidents, having a great impact on the marine ecosystem as well as on nearby fisheries and aquaculture. The effects on oiled wildlife were evidenced by photographic descriptions for some waterbirds and marine mammal casualties, and could not be evaluated quantitatively. HSOS, which occurred on December 7, 2007, was the largest oil spill incident in South Korea, and 12,547 kL of crude oil was discharged, according to the Korea Maritime Policy Agency (Hong et al., 2014; Yim et al., 2017). Within five days after the HSOS, a total of 35 km of shoreline encompassing Hakam port to Pado-ri was covered with oil, and major international bird community refuges were under immediate threat (Chan et al., 2004). Spilled oil flowing to Jeju coastal area in the southern sea could be seen at one month post the spill. Because the HSOS was unprecedented on the Korean coast, long-term

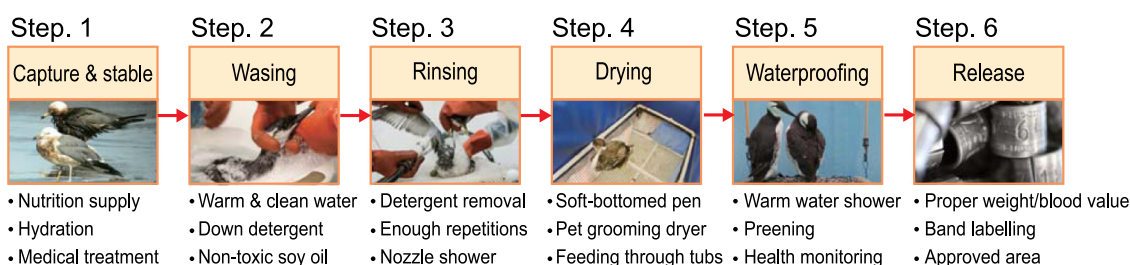


Fig. 2. Guidance for helping oiled birds in International Bird Rescue. Source: Modified from IBR (2007).

Table 1
Representatives of the oil spill that occurred in Korea.
Source: Data from MPSS (2016).

Oil spill	Cause of an accident	Amount of spilled oil (kL)	Oil type	Year
Hebei spirit	Collide	12,547	Crude	2007
Sea prince	Strand	5,034	Crude and others	1993
Yuil No.1	Collide and founder	2,392	Bunker C	1995
Osung No. 3	Founder	1,699	Bunker C	1997
Korea hope	Collide	1,500	Bunker C	1992
Honam sapphire	Collide	1,402	Crude Oil	1990
Kumdong No. 5	Collide	1,228	Bunker C	1995
Alexandria	Founder	916	Bunker C and others	1993
Wu Yi San	Collide	899	Bunker C and others	2014
Jungyang	Founder	623	Bunker C	1995

Table 2
Number of species in oiled waterbirds in Dec. 19–20, 2007.
Source: Data from Moores et al. (2007).

Species name	Number of oiled birds (n)
<i>Tadorna tadorna</i>	6
<i>Anas platyrhynchos</i>	1
<i>Bucephala clangula</i>	1
<i>Podiceps cristatus</i>	1
<i>Haematopus (ostralegus) osculans</i>	3
<i>Calidris alpine</i>	1
<i>Larus crassirostris</i>	289
<i>Larus canus</i>	12
<i>Larus vegae</i>	10
<i>Larus schistisagus</i>	3
<i>Larus heuglini</i>	1
<i>Larus ridibundus</i>	2
<i>Larus saundersi</i>	2
Total	333

Table 3
Monitoring data for the population of the Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) in the Korean coast after the HSOS since 2008.
Source: Data from KNPRI (2019).

Finless porpoise	Year									
	2008	2009	2010	2011	2014	2015	2016	2017	2018	2019
Individuals (n)	96	38	97	309	301	143	336	94	116	126
Frequency	18	9	20	69	69	46	48	49	22	22

ecological monitoring has since proceeded, and investigations into effects on birds and marine mammals have been conducted.

Marine birds, which tend to occupy high trophic levels in the food web, are monitored as an index of habitat environmental health because they are easily transportable. A total of 333 individuals of 13 waterbirds species were found to be dead at the time of 12 days after the HSOS (Table 2), with the majority of dead animals of black-tailed gull, *Larus crassirostris* (Moores et al., 2007). The number of waterbirds in a nearby area monitored by the KNPS, from 2007 to 2013, indicated timely increase after the HSOS, indicating the recovery of waterbird populations. In 2015,

KNPS discovered a hatching nest in the incident area, supporting the notion that the ecosystems are stabilizing to the normal stage (KNPS, 2015). The Indo-Pacific finless porpoise (*N. phocaenoides*) is one of the smallest marine mammals found in Korea. Its habitat encompasses shallow waters from mid-western Japan to Korea and Taiwan (Kim et al., 2000). After the HSOS, the KNPRI at KNPS reported baseline data on the occurrence, distribution, and abundance of these porpoises based on sighting surveys. The reports documented 7 dead bodies on December 18, 2007. Although sightings of individuals have since been increasing, there is insufficient historical data for an accurate comparative assessment for the oiled wildlife (Table 3) (KNPRI, 2019).

4.2. Relevant response techniques for rescuing the oiled wildlife

Although there have been several large-scale oil spills impacting the damages along the coastal areas of South Korea, most of the action plan recovering the marine ecosystems has focused on social and economic aspects at the beginning of the spill. Our oil spill response system before the HSOS has not been well established without having the documented guidelines or protocols, which apparently resulted in the inadequate or slow action plan and/or measure after the spill, particularly during the golden-time. Despite such complex circumstances, with the volunteering supports from the public sector, oil spill affected areas could be cleaned quickly. Although the massive clean-up by over a million volunteers might have brought relatively quick recovery of oiled wildlife from the spilled oil, it could be better if there were an official OWR plan and sufficient training (Sea Alarm, 2009).

Although an official OWR has not been established in South Korea, there have been several NGO-led activities for rescuing some ecologically important marine wildlife after the HSOS. The rescues were performed according to the International Bird Rescue (IBR) Research Center guidelines, as follows (Fig. 2) (IBR, 2007); (1) put one individual in one container to minimize bird stress, (2) conduct basic medical examination, including wound assessments and blood tests, (3) rinse them with warm water at 32–42 °C at least 10 times, and let them dry at 32–35 °C for 3–4 h (continue this process until birds are stabilized), (4) provide

Table 4

The guidelines, laws/regulations, and weaknesses to oiled wildlife response in Korea, China, Japan, and Russia.

Source: Data from [NOWPAP MERRAC \(2018\)](#).

	Korea	China	Japan	Russia
Guidelines	NGO and researcher level - International Bird Rescue Research Center guidelines	NGO and researcher level - Technical Specifications for Rescue and Release of Rare and Endangered Wildlife	National level - Comprehensive Training for Response to Oil Spills	NGO and corporate level - Sakhalin Energy corporate standards for oiled wildlife response
Laws / Regulations	Not directly related legislation - Wildlife Protection and Management Law	Not directly related legislation - Marine Environmental Protection Law - Law on the Prevention and Control of Water Pollution - Regulations of PR China Concerning Environmental - Protection in Offshore Oil Exploration and Exploitation	Directly related legislation - Marine Pollution and Disaster Prevention Law	Not directly related legislation - Russian President Order on Arctic safety (No. Pr-1530) - On the procedure of arranging oil and oil product spill prevention and response measures in the Russian Federation
Weaknesses	Lack of formalized OWR Lack of expertise in OWR Lack of budget	Lack of formalized OWR Lack of expertise in OWR Lack of budget	Unbalanced rescue training systems in all municipalities Diminished interest in training OWR experts Underdevelopment of wild animal medicine	Lack of formalized OWR Lack of expertise in OWR Lack of budget

a place for feeding and swimming in freshwater, and (5) check each bird's condition before release, and chose a day with good weather ([IBR, 2007](#)).

According to the Korea Federation for Environmental Movements of Seosan-Taeon, 31 oil-exposed birds were treated and released from December 7 to 29, 2007. The Korea Animal Rescue & Management Association (KARMA) created a space to treat contaminated birds near oil spill area; however, no data on the numbers of birds they treat are publicly available. Reports about treating marine mammals have been insufficient due to local and habitat characteristics. The lack of research on waterbirds and marine mammals and the insufficient number of well-trained rescue teams have made it challenging to capture oil-exposed animals for treatment. Thus, future OWR requires proper planning and organization to restore the health of oil-polluted animals.

4.3. Relevant national laws, regulations, or guidelines

When the HSOS occurred in 2007, the MLTM of South Korea was the government agency responsible for oil spill responses, according to [Sea Alarm \(2009\)](#). The Korea Ocean Research & Development Institute (KORDI) supported by the MLTM conducted sensitive regional mapping. However, there were no specific details regarding formal guidelines and response objectives, strategies, or impact assessments at that time ([Table 4](#)). Consequently, there was not a proper national-level response to the HSOS disaster in 2007. In terms of stakeholder cooperation, South Korea is included in two conventions. South Korea is a member of PEMSEA (Partnerships in Environmental Management for the Seas of East Asia), which protects endangered mammals and seabirds. South Korea is also involved as a member country for the Northwest Pacific Action Plans (NOWPAPs). There are officially four regional activity centers, and oil spill response is closely associated with the Marine Emergency Preparedness and Response Regional Activity Center (MERRAC). However, there are no specific laws, policies, regulations, or guidelines for oiled wildlife in South Korea, despite its belonging to several organizations ([Table 4](#)). Although there are South Korean laws pertaining to wildlife protection and management, the purposes of act no. 15835 are limited to provide systematic protection and management of wildlife and their habitats, to prevent extinctions, and to promote biodiversity and ecosystem balance, and to secure a healthy natural environment. This legislation covers the protection of endangered wildlife, the designation of protected areas,

and the management of disease, but it does not include the component of oiled wildlife and/or OWR. Thus, the establishment of laws/policies, regulations, and guidelines relating to OWR would be urgently needed.

Representatively, countries with advanced OWR are the United States, Canada, and Australia. In USA case, the US Federal Oil Pollution Act of 1990 (OPA-90), in consultation with the US Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration (NOAA), requires that a sensitive environmental plan would be developed into a National Contingency Plan that includes state fish and wildlife agencies ([Department of Fish and Wildlife , DFW](#)). In addition, the California Oil Spill Prevention and Response Act (OSPR), provides OPA-90-like regulations for fish and wildlife protection during a spill response. The OSPRA and subsequent laws provide for the establishment and financing of the Oiled Wildlife Care Network (OWCN) as an integral part of California's wildlife response capabilities. Facilities within the OWCN are to be maintained and ready to provide the best achievable treatment for rescuing waterbirds and marine mammals that are affected by oil spills. OSPRA administrators also set out legislation to provide biologists and other personnel with appropriate funds and support for assessing damage to natural resources as part of their response to a major oil spill.

In Canada, a publication produced by the government entitled "Protecting Wild Species at Risk of Canada" outlines a national policy for oiled birds and oiled species at risk ([Bourdages and Labelle, 2000](#)). In January of 2000, the Canadian Wildlife Service adopted a national policy on oiled birds and at-risk species that indicates the actions and roles to be taken by federal, provincial, and territorial jurisdictions for oiled wildlife. This policy includes all kinds of migratory birds and associated lands as well as freshwater, marine, and tidal habitats. This policy can promote combined actions from other organizations equipped to handle all wild species being affected by oil spills.

In Australia, the Department of Environment has implemented the Environmental Protection and Biodiversity Conservation Act of 1999 ([Department of Parks and Wildlife , DPW](#)), which specifies a legal framework for the protection and management of the federal maritime area. The DPW, which has the responsibility and legal authority to treat, protect, and destroy wildlife as specified in the Wildlife Conservation Act of 1950, is the responsible agency for oiled wildlife in Western Australia. Legislative requirements ensure humanitarian treatment, housing, and release or euthanasia of animals in protected areas under the Animal Welfare Act of 2002.

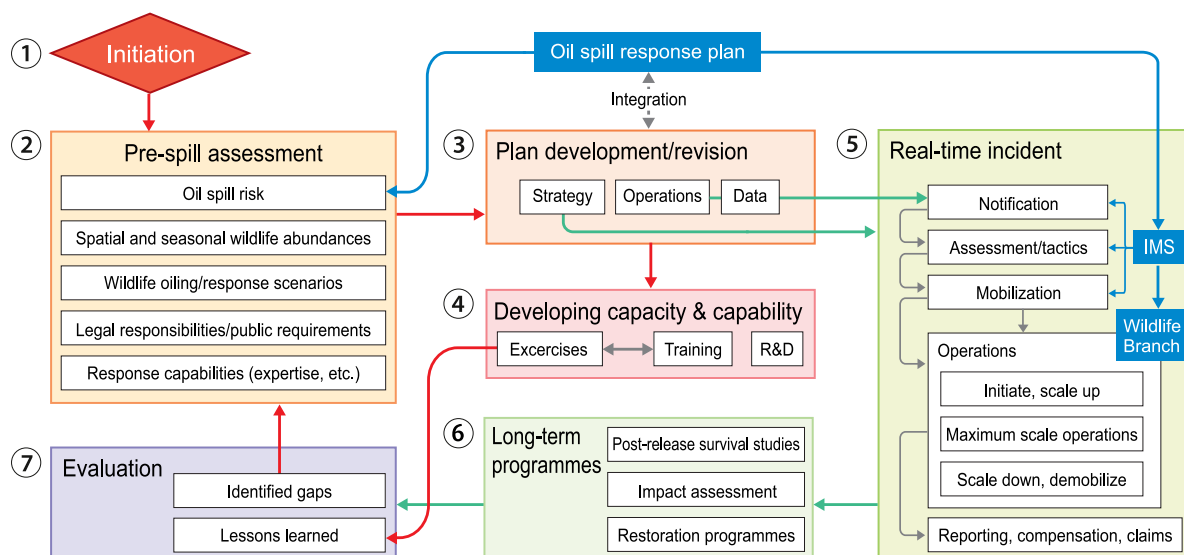


Fig. 3. Cycle for developing oiled wildlife response preparedness. Source: Modified from IPIECA (2014).

The situation is different in the case of China, Japan, and Russia, which are East Asian countries adjacent to Korea (NOWPAP MERRAC, 2018). Among the NOWPAP countries, Japan was the most well-established for OWR, and Korea, China, and Russia appeared to need more development of related systems (Table 4). In Japan, there is a legal system related to wildlife damage from oil spill incidents. In October 1995, Japan acceded to the 1990 International Convention on Oil Pollution, Preparedness, Response, and Cooperation (OPRC), an OPRC treaty addressing preparation and correspondence related to modifying oil pollution. Subsequently, Japan adopted its own National Contingency Plan on Oil Pollution, Preparedness, and Response policy based on the OPRC treaty rules. At present, China has not suffered from many serious oiled wildlife incidents, with the exception of oil spills that impacted mainly phytoplankton, zooplankton, and benthic organisms. Although a dedicated oiled wildlife response plan is not yet available in China, currently existing resources would be of assistance in the protection, rescue, and rehabilitation response actions for oil threatened and impacted marine mammals and birds (Table 4). In Russia, company-led OWR has been conducted rather than national-level OWR. This experience is the result of active implementation of projects in the north-eastern shelf of Sakhalin Island started in the 2000s under the Product Sharing Agreement (PSA) with western companies, namely ExxonMobil (Sakhalin I) and Shell (Sakhalin II). An official OWR plan was developed in 2009 to prevent and respond to oil and oil product contamination of wild animals in Russia. This plan outlines the necessary resources and procedures for coordination of actions between corporate units and external authorities.

5. Challenges and/or weakness on oiled wildlife response

In South Korea, there is a lack of laws/policies, regulations, and guidelines related to oiled wildlife. Environmental impact assessment of oil spill incidents in Korea is still under discussion, including investigation of residual oil distribution in marine environments, identification of ecotoxicological impacts, characterization of ecosystem changes, alterations in major ecological groups, assessment of the performance of microbial cleaning preparations, etc. (MLTM, 2013). Environmental restoration techniques are being addressed, but this issue does not include oiled wildlife content. Currently, there is no basic system dedicated to

OWR policy in South Korea; thus systematic management for an OWR is urgently needed. The biggest problem is the lack of a database to track data from accident areas. It is difficult to prepare OWRs when the status of wildlife in the area is not well known before the incident. In addition, there are not enough wildlife protection and rehabilitation specialists in South Korea. KARMA, a representative organization that participated in the HSOS clean-up in 2007, responded to oiled wildlife, but it is not truly a wildlife expert group, but rather a professional pet association (Sea Alarm, 2009). Birds Korea has expertise in wild birds and has expended efforts, such as drawing upon the expertise of other countries (Sea Alarm, 2009). However, its access to resources and experts are still limited. There is also a lack of manuals to guide safe recovery, rehabilitation, and release of wildlife in a future oil spill. Manuals are an important tool to support volunteers lacking expertise and thus are needed for the safe management of oil-exposed wildlife. Volunteers must learn how to conduct wildlife response work through a standard manual under the supervision of trained specialists.

6. Recommendations for future directions and activities

6.1. National level

Currently, there is no systematic response system for OWR in Korea. There is a need to elucidate how a step-by-step plan should be evaluated and how an OWR should be composed. IPIECA (2014) has provided an example in this aspect. There are two forms of preparation, such as (1) regular activities leading to comprehensive preparation and (2) activities to be developed immediately after events that threaten wildlife (Fig. 3) (IPIECA, 2014). A response plan should provide step-wise guidance in the event of an oil-spill incident. In addition, by evaluating these responses and results, the preparatory stage can be improved and advanced in the future. This process should be completed with the assumption that there are accurate environmental analyses with which to assess oil spill impacts and related environmental sensitivities. In Korea, current research is focusing on environmental assessment and restoration technology development concerning oil spills. Therefore, in the future, oiled wildlife guidelines may be developed based on environmental evaluation results.

At-risk resources must be assessed before and after the oil spill to reduce damage to wild animals. With respect to oil pollution

risk, there is a need to gather as much information as possible, including biological characteristics (e.g., migratory pathways, habitats, food sources, etc.) and the natural environments along the coasts and in surrounding seas where damage may occur. The data on the wildlife and environment conditions before an accident can be compared to those after the accident, and provide opportunities for other countries to prepare for oil-exposed animals, which cross borders. In Korea, specialists at universities and institutions have been gathered data on natural vegetation and intertidal organisms, including breeding places and habitat areas continuously. The collection of such data is difficult given how great living conditions vary throughout a year, and the fact that the sea areas being surveyed are very large. Accordingly, cooperation is needed on a national level to enable habitation data for wildlife to be updated spatiotemporally. It is also important to prepare both local and domestic wildlife response equipment and available professional manpower and to keep a record of their present statuses to enable manpower and equipment utilization and hasten OWRs.

Currently, there is no official manual on oiled wildlife in Korea, which could delay OWR activities. Therefore, it is necessary to develop guidelines for a basic manual based on other reference cases. Preparedness for Oil-polluted Shoreline clean-up and Oiled Wildlife interventions (POSOW) (POSOW, 2013) provides guidelines that can be applied uniformly to oil accidents in any area. POSOW provides methods for catching wild animals exposed to oil, constructing a rescue center near accident areas, and rehabilitating wild animals. If a formal and unified manual, like POSOW, is established, it could not only alleviate the shortage of professional staff by educating volunteers, but also reduce the wildlife damage caused by amateur volunteers.

Before assigning authority for operational and decision-making rights in OWR, policymakers should be aware of the requirements of the landing legislation (IPIECA, 2014). The OWR system should include conservation and species protection (licenses for contact and handling and protection of priority species), animal welfare, food safety, worker safety, environmental protection, and public access laws/regulations. If the system is successfully established, particular agencies, ministries, or departments will have legal authority in various aspects of wildlife responses. The institutional roles and responsibilities of various authorities should be respected and recognized in planning. The greater the stakeholder involvement in the planning process, the better the plan will be reflected in acceptable and appropriate command systems and approaches.

6.2. Regional level

International cooperation is needed to prepare for unexpected oil spills, particularly spills that might occur in international waters. The Baltic marine environmental protection commission (Helsinki Commission, HELCOM) was established about four decades ago to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental cooperation. HELCOM has provided an example of the framework for cooperation on oiled wildlife response, including the integrated wildlife response planning and the ministerial level commitments among the Contracting Parties (HELCOM, 2010). The Contracting Parties are to develop a wildlife response plan integrated into the oil pollution contingency plan either on a national/local level and to apply commonly agreed guidelines. In addition, an Expert Working Group on OWR has worked to strengthen the cooperation between the Contracting Parties through the forum for the exchange of information on progress and best practices, creation of joint standards, and training courses (HELCOM, 2013). The Baltic Sea countries are currently developing their national

wildlife response plan. HELCOM is providing the operational procedures for joint OWR operation and recommend best practices and standards to be uniformly applied in the whole Baltic Sea.

Each NGO and governmental institution need to continue to share information on response activities on oiled wildlife. Furthermore, supports from qualified experts such as veterinarians and sharing mobile oiled wildlife response units among the members are needed, and sending trained volunteers could be another good option for cooperation at the regional level. For this, training programs for veterinarians and volunteers should be operated, and joint guidance on oiled wildlife response could also be developed. In conjunction with this, it is important to conduct the joint practical exercise, which may include the participation of observers from other countries and to cooperate for visa and custom issues in advance. In addition, the regional sensitivity mapping and transboundary modeling of oil spill accidents are required to initiate scientific researches through the exchange of database which is related to wildlife. Information related to OWRs in nearby countries should also be shared through workshops and meetings among experts. Through such information sharing, it is expected that an OWR will be achieved if local and national networks form in relation to the accident and if actions are made compulsory by legal elements.

7. Conclusions

This study introduces the content of OWRs in Korea with a brief introduction for neighboring and some developed countries and suggests future improvements. Since the 1990s, several large and small oil spills have occurred in Korea, and continued oil spills in recent years caused the necessity of various action plans and implementation. However, in response to these accidents, socio-economic contents, such as damage scale and economic loss, have been more highlighted with a solid and systematic investigation. Of note, ecological studies on water quality and benthic community responses have been assessed, but less specific structural activities and environmental health studies have been conducted in relation to oiled wildlife. There are still not consistent laws/policies, regulations, and guidelines for national OWR; Korea shows a low level of responsiveness compared to responses in other countries with a cohesive system, and inter-governmental cooperation at the national level has not been fully recognized or emphasized in the East Asia region until now. Currently, oil spill studies in Korea primarily focused on the evaluation of environmental impacts as a result of incidents and the establishment of restoration techniques. However, there seems to be a lack of experts on examining and/or addressing the status of wildlife and OWR. Thus, it is necessary to prepare for the continuous planning and construction of OWRs and the evaluation of such responses in the future. The process requires political cooperation, legal preparation, accurate analysis of the accident, collection of data on wildlife, and a standardized manual cross the cases and countries. It is also necessary to share information through workshops and meetings to enable cooperation between neighboring countries to enable sharing of prior experience with countries where there have been no specific plans yet in place. Overall, it is necessary to strengthen the capacity building at the national level and continuously discuss regional cooperation on the oiled wildlife at the regional level.

CRedit authorship contribution statement

Seongjin Hong: Conceptualization, Investigation, Formal analysis, Statistical analyses, Visualization, Writing - original draft.
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Visualization, Writing - original draft. **Taewoo Kim:** Investigation, Formal analysis. **Jongseong Ryu:** Writing - review & editing, Project administration. **Seong-Gil Kang:** Writing - review & editing, Project administration. **Jong Seong Khim:** Conceptualization, Writing - review & editing, Project administration, Funding acquisition, Supervision.

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.

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