



Impacts of marine debris on wild animals in the coastal area of Korea

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ARTICLE INFO

Keywords:

Marine debris
Entanglement
Ingestion
Threatened species
Recreational fishing gear

ABSTRACT

Over the last decade, marine debris has become a major factor affecting the coastal ecosystem of Korea. This study compiled information regarding how marine debris impacts wildlife in Korea. Cases of marine debris impacting wildlife were collected from experts of various fields and from local participants through an open access website from February 2010 to March 2012. A total of 21 species were affected by marine debris: 18 species of birds, 2 species of mammals, and 1 species of crustacean. Five threatened or protected species were identified: black-faced spoonbill, finless porpoise, water deer, whooper swan, and greater painted snipe. Recreational fishing gears were the types of debris that most frequently impacted wildlife, especially birds. Black tailed gulls were the most vulnerable species to recreational fishing hooks and lines. Although it was preliminary, this study revealed that recreational fishing activities should be prioritized when managing marine debris in Korea.

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1. Introduction

Marine debris negatively affects marine ecosystems as well as navigational safety, beach aesthetic quality, and the economy (Balance et al., 2000; Donohue et al., 2001; Mouat et al., 2010). Marine biota such as seabirds, sea turtles, and marine mammals are especially vulnerable to floating, beached or sunken debris in the marine environment (Good et al., 2009; Jacobsen et al., 2010; Laist, 1987, 1997; Ryan, 1987). They can be injured or killed by getting entangled in marine debris and may frequently mistake it as food. This impact may become lethal (Derraik, 2002). Laist (1997) listed 267 species of marine animals that ingest debris or get entangled with debris in an extensive review he completed using available records and documents (e.g., Balazs, 1985; Day et al., 1985). Recent studies report that more species are increasingly being impacted by marine debris (Ceccarelli, 2009; Moore et al., 2009; Tourinho et al., 2010). Ingestion of indigestible materials may not directly lead to the death of an animal. Sub-lethal effects, such as a reduction in food ingestion and an obstruction in the gastrointestinal tract, however, are more likely to be long-term threats (Bjorndal et al., 1994; Ryan, 1987). Plastic ingestion and its bio-

chemical impacts have recently become an international concern regarding the management of marine debris (Boerger et al., 2010; Denuncio et al., 2011; Murray and Cowie, 2011; van Franeker et al., 2011). The management of marine debris in Korea started in the late 1990s with a sunken debris retrieval program. The first National Plan for Marine Litter Management (2009–2013) was established in 2009 under the Marine Environment Management Act and has invested approximately 20 million US dollars annually on average to remove sunken and floating marine debris (MLTM et al., 2009). Nationwide bimonthly monitoring focusing on beach debris started in 2008. Since 2001, nongovernmental organizations have organized coastal cleanup activities and marine debris surveys (Hong et al., 2011). No efforts were made, however, to monitor and understand the impacts of marine debris on the biota in the coastal area of Korea.

Information regarding the types and intensity of marine debris impacts on wildlife is essential to gather in order to restore marine ecosystem integrity and productivity (e.g., Donohue et al., 2001; Page et al., 2004). Considering the spatial and temporal distribution of marine debris and their impacts on wildlife, it is very difficult for expert researchers to cover the entire range of cases. Participation of local stakeholders on a national scale can provide substantial amounts of data over large spatial and/or temporal extents (Conrad and Hilchey, 2011; Devictor et al., 2010).

This study aimed to identify types and sources of marine debris that affect wildlife in the coastal area of Korea. It also provides

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Table 1
Institutes and organizations that provided records of wild animal impacts caused by marine debris in the coastal area of Korea.

Classification	Organization	Data collected by
Wild life rescue center	Busan Wild Animal Treatment Center	Veterinarians
	Chungnam Wild Animal Rescue Center	Veterinarians
	Jeju Wildlife Rescue Center	Veterinarians
NGO	Korea Wild Bird Protection Association	Birdwatchers
	Jeju Wildlife Research Center	Birdwatchers
	PGA Wetland Ecology Institute	Scientists
	Our Sea of East Asia Network	Scientists
	Gang-hwa Citizens Coalition	Birdwatchers
Research Institute	Korea Institute of Ocean Science and Technology	Scientists
	Migratory Birds Center of National Park Research Institute	Veterinarians/ Scientists

implications for management policies based on data and information collected through an internet-based reporting system, which relied on voluntary participation of local people and experts.

2. Methods

A simple website (<http://www.osean.net>) was constructed to collect and share information on the cases of negative impacts on marine animals by marine debris in the coastal area of Korea. The website directed contributors to document the species affected and their conditions (e.g., injury types, dead or alive), the types of marine debris involved, the dates and places of detection, how the debris affected the animals, any treatment taken for the affected animals (e.g., released or disposed of dead animals), photographs of the animals and of the debris, etc. The website was open to anyone in the public who had information to report on their findings regarding the impacts of marine debris on wild animals. Participants could upload this information after an easy-to-use registration process. Experts from wildlife rescue centers, wild animal research groups, wetland protection groups, bird watching organizations, and marine pollution research institutes provided cases of animals affected by marine debris on a voluntary basis (Table 1). Their inputs were crucial in enhancing the quality of data collected for this study. Pictures of dissections or autoradiography provided by the experts were helpful in understanding the way in which animals were affected by the debris.

This study analyzed 45 cases from 55 reported cases that were collected through the website from February 2010 to March 2012. The affected species, the types of marine debris impacting the animal and their sources, the impact on the wildlife, and the relationship with foraging patterns or habitats of the species were analyzed. Ten cases were excluded from the analysis because wild animals were not involved or the impacts reported were not caused by marine debris. Some cases from inland areas, however, were included if they involved wild animals whose habitats also covered coastal areas. Cases that were caused by by-catches or active fishing gears were not included in the analysis.

3. Results

3.1. Spatial distribution of reported cases

A total of 45 cases of wild animals affected by marine debris spanning 10 years from September 2003 to March 2012 were collected for this study (Fig. 1). This does not include all of the cases of animals that were injured or killed by marine debris in the coastal areas of Korea during the time period. Many more cases were iden-

tified through personal communications with people who were involved in coastal conservation and wildlife management. They were not included in this analysis, however, due to the lack of robust records detailing the cases, such as associated photographs or documents.

Marine debris affected wild animals on all of the coasts of Korea, including the coasts of islands remote from the mainland. Busan, the largest Korean port city with a population of 3.6 million (MOPAS, 2011), had the highest number of reported cases ($n = 16$). Fourteen of these cases were observed in the estuary of Nakdong River, which enters the South Sea of Korea through the city. Jeju Island, the most famous tourist location in Korea, has a relatively well preserved ecosystem but had the second highest number of reported cases ($n = 9$); these cases were scattered around the island.

3.2. Species impacted by marine debris

A total of 21 animal species in 11 orders were affected by marine debris in 45 reported cases (Table 2). Birds were the most vulnerable animal to marine debris, accounting for 18 species in the reported cases. The remaining cases consisted of one terrestrial mammal, one marine mammal, and one crustacean. Five threatened species were among the impacted species: black-faced spoonbill *Platalea minor*, finless porpoise *Neophocaena phocaenoides*, water deer *Hydropotes inermis* (which are identified as an internationally threatened species on the IUCN red list), greater painted snipe *Rostratula benghalensis* and whooper swan *Cygnus cygnus* (which are protected by the Wildlife Protection Act of Korea). Black-faced spoonbills are also protected by Korean law.

3.2.1. Birds

Of the 18 bird species with reported cases that we analyzed, black-tailed gulls *Larus crassirostris* were the most frequent victims of marine debris impacts, as identified in 19 reported cases (42%). Incidents occurred nationwide. The black-tailed gulls were all affected by recreational fishing hooks and lines ($n = 19$, 100%). The birds most frequently ingested fishing hooks. Ingestion of and entanglement by hooks with monofilament lines attached was the next frequent impact (Fig. 2a and b). Only two reported cases involved entanglement of the animal by fishing lines. In one severe case, a black-tailed gull had a hook stuck in its oral cavity with attached fishing lines entwining the wings, head, and neck, preventing the animal from flying or foraging for food.

One young black-faced spoonbill *P. minor* had its legs entangled in plastic strings and was found nested in an artificial structure in the metropolitan city of Incheon (Figs. 1 and 2c). Its parents might have used plastic materials to build their nest. Another black-faced spoonbill had two hooks impaled in its neck, which was assumed to have caused starvation and weakness. It was released after the hooks were surgically removed.

Three whooper swans (*C. cygnus*) found in the Chungnam province had lead weights and other metallic debris in their stomachs (Fig. 2d). Their blood tests revealed serious lead poisoning. Lead levels in the blood of two whooper swans found dead in 2010 and 2012 were too high to measure (maximum concentration of the instrument used was 0.65 ppm). This indicates that ingestion of lead could be the direct cause of their deaths. A live whooper swan rescued in March 2012 had 0.65 ppm of lead in its blood, which is higher than the lead concentration of 0.5 ppm that is considered to be sub-lethal (US Fish and Wildlife Service, 1990). The poisoned swan was still under medical treatment after the lead weights were removed from it through endoscopy. All three reported cases showed several other metallic debris as well as lead weights in their X-rays (Fig. 2d), suggesting that heavy debris that

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