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Status of Marine Debris Damage to Adult and Young Black-Tailed Gulls (*Larus crassirostris*) in Their Breeding Colonies in South Korea

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Abstract: Marine debris from fishing-related paraphernalia poses a threat to the survival of marine organisms, especially seabirds. Although the detrimental effects of marine debris on seabirds have been documented, studies on the extent of damage inflicted by marine debris on the seabird breeding population are scarce. Here, marine debris ingestion and entanglement damage to black-tailed gulls (*Larus crassirostris*) residing in South Korea were quantified. The five breeding colonies of black-tailed gulls were visited, and the frequency of ingestion and entanglement damage in adults and young were recorded. A total of 25 cases of marine debris damage were confirmed. As a result, damage by marine debris to gulls varied depending on breeding colonies. More adults suffered from entanglement damage than the young, and their most damaged parts were usually their legs. Fishing lines and hooks caused the most damage. We suggest that marine debris damage acquired in breeding colonies could affect breeding success.

Keywords: marine debris; ingestion; entanglement; black-tailed gull; breeding colonies; South Korea

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1. Introduction

Globally, marine debris is recognized as a major environmental threat to biodiversity [1,2]. Over 900 species of marine organisms are known to suffer from the ingestion or entanglement of marine debris [3]. Approximately 80% of species in seabirds, which represent the higher vertebrates in marine ecosystems and spend most of their lives in the sea, have already been reported to be damaged by marine debris [4].

Marine debris can harm seabirds through ingestion as well as entanglement. Ingestion of marine debris occurs when seabirds intentionally and directly consume marine debris by mistaking it for food. As an apex predator, seabirds may indirectly ingest marine debris by devouring prey that had been contaminated with marine debris while going through the food chain [5]. Seabirds that ingest marine debris may die due to intestinal obstruction, ulceration, and perforation [6–9]. Furthermore, the ingested plastics may cause nutrition loss, starvation [8,10], weight loss [11], and reduced fat accumulation [11] in an individual, leading to an impaired body condition and lower chances of survival [12,13]. Meanwhile, entanglement by marine debris commonly occurs when an animal forages and its body part is accidentally caught in fragments of fishing-related items such as monofilaments or plastic ropes, causing injury, movement disturbance, and drowning [14,15]. Entanglement poses a potentially serious threat to seabirds because it reduces both their flight capacity and foraging efficiency, resulting in long-term debilitation and starvation [6].

Marine debris can affect the survival and reproduction of breeding seabirds. Since seabirds spend most of their lives in the sea, including hunting, breeding, and resting, they are the most vulnerable marine organisms to marine debris exposure. Seabirds usually breed in groups on uninhabited islands far from the mainland; some seabirds use marine debris, including waste nets and fishing lines, as nesting materials [16,17]. Entanglement damage may occur to adults or young when marine debris is used as a nesting material [18]. As the marine debris introduced into the breeding colonies accumulates without being easily decomposed, it causes entanglement damage to the breeding seabirds, endangering their survival. Since seabirds have a long lifespan but low fertility, species survival and population maintenance are highly sensitive to both young and adult mortality [19].

Several documents [4,20–23] reported that most seabirds, particularly gulls, consume marine debris (e.g., Styrofoam, plastic, plastic fragments, etc.). Gulls mainly eat fish and marine invertebrates in the ocean or tidal flats as well as scavenge on fishery discards, e.g., [24]; however, some individuals eat leftover food discarded in trash cans or landfills [25–28]. As gulls are usually generalist feeders, they are more likely to mistake marine debris for prey or consume it while feeding [29–31].

The black-tailed gull (*Larus crassirostris*) is a common resident seabird that is regularly observed in Korea and Southeast Asia [32]. Unlike other gulls arriving in the Korean Peninsula (e.g., *L. canus*, *L. schistisagus*, *L. ridibundus*, and others), its distribution range is limited to the Yellow Sea (connecting to the East China Sea), South Sea, and East Sea. It is known that they mainly eat fish and marine invertebrates [33].

Black-tailed gulls usually breed in uninhabited islands in Northeast Asia, including South Korea, China, Japan, and Russia [34]. The gulls can be easily observed as they breed in groups on islands around the Korean Peninsula from April to July. In general, they have one to three eggs (mean clutch size = 1.9 $\pm$ 0.7 eggs), and the incubation period is about 24 to 26 days; plus, most eggs hatch in early to mid-May [35]. During the breeding season, parents take turns foraging, and they vomit food to feed their chicks [36]. So, they are exposed to a lot of marine debris while traveling between oceans and coasts during the breeding season [37].

It has been reported that the marine debris ingested by adults during the breeding season is also passed on to young in the breeding colony. During the breeding season, adults regurgitate their collected food to feed young; thus, the possibility of parental transfer of marine debris from adults to young is high [38–40]. However, although the fatal effects of marine debris on seabirds have been identified, quantitative studies explaining how the seabird breeding population is directly affected by marine debris during their breeding period are scarce.

This study aimed to assess the impact of marine debris on the breeding population of black-tailed gulls, the predominant seabird species around the Korean Peninsula. It investigated the extent of damage caused by marine debris on both adult and young gulls in various breeding colonies during their breeding period. A quantitative survey was conducted to record the frequency of marine debris ingestion or entanglement damage in both adult and young gulls. Note that the young gulls included in this study were hatched during the breeding season of 2021 but did not fledge. The survey also aimed to identify the type of marine debris that caused the most damage.

2. Materials and Methods

2.1. Study Sites

To identify the status of direct ingestion and entanglement damage inflicted by marine debris on the breeding islands of black-tailed gulls, five uninhabited islands in the Yellow Sea of Korea (i.e., west of the Korean Peninsula; Dongman Island: 37°32′ N, 126°16′ E; Nan Island: 36°39′ N, 125°49′ E; Gungsi Island: 36°39′ N, 125°51′ E; Napdaegi Island: 35°15′ N, 126°13′ E; and Bulmugi Island 34°45′ N, 126°13′ E; see Figure 1) (Table 1) [41].

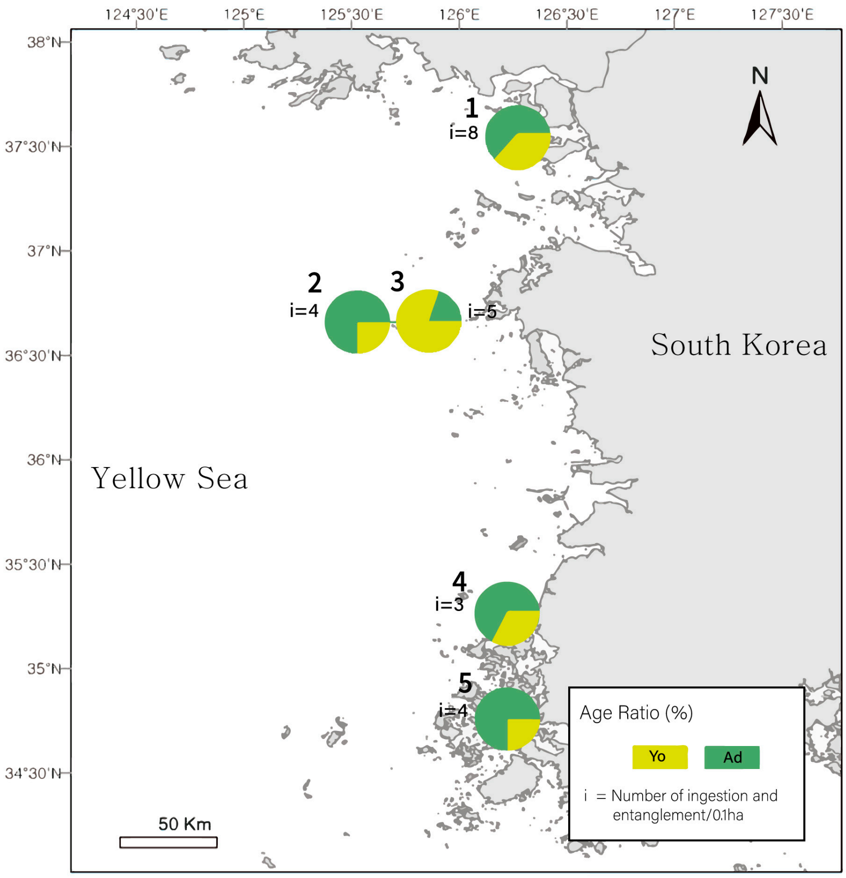

Figure 1. Location of black-tailed gull breeding colonies and the current status of marine debris damage (1: Dongman Island, 2: Nan Island, 3: Gungsi Island, 4: Napdaegi Island, 5: Bulmugi Island). The pie chart shows the percentage (%) of marine debris damage by age (Yo: young born in 2021 that did not fledge, Ad: adults). i represents the total population affected by ingestion and entanglement in a 0.1 ha survey area.

Table 1. Environmental characteristics of the breeding colonies of black-tailed gulls.

Breeding Colonies	Area (ha)	Altitude (m)	Distance from the Mainland (km)	Environmental Characteristics
Dongman Is.	8.23	93.9	3	Predominantly covered by woody plants at its center, with widespread sand/mud flats.
Nan Is.	4.76	80	27	Covered by sand grass, it dominates most of the island, and cliffs characterize its edges. The island is designated and managed as a natural monument, so there is limited access for people.
Gungsi Is.	15.82	85	24	Covered by Herbaceous plants such as sedges and rapeseed. The island is frequently visited by people, and black-tailed gulls have recently begun breeding.
Napdaegi Is.	0.76	20	8	Covered by woody plants and grass. Ample soil is exposed, providing breeding grounds for a small number of yellow-billed egrets (*Ardea brachyrhyncha*).
Bulmugi Is.	3.26	23	4.7	Covered by herbaceous plants and rocks

2.2. Field Works and Visual Inspection

During the breeding season of black-tailed gulls from April to July 2021, we conducted four visits once per month. The purpose was to assess the breeding density and estimate the size of the breeding population of black-tailed gulls on each breeding island. In May 2021, we randomly installed five circular quadrats with a radius of 3 m within the breeding area of black-tailed gulls. We then calculated the breeding density per unit area (hectares) by counting the number of nests within each quadrat [42]. In addition, the size of the breeding population was calculated by multiplying the breeding density per unit area by the possible area for breeding on the island. The possible area for breeding was calculated using satellite photo data [43].

To assess the status of marine debris intake and entanglement damage in black-tailed gulls whenever they visited each breeding colony, a quadrat (10 m × 10 m) was randomly installed in each breeding colony to set the survey area; then, the individuals present in the area were observed with the naked eye.

The carcasses of gulls in the breeding colonies were observed and dissected to determine whether they ingested marine debris or were entangled by marine debris. The amount of marine debris ingested and the frequency of entanglement damage were calculated based on the following criteria: the cases in which marine debris was attached inside the beak of living birds or carcasses and those wherein marine debris was swallowed were considered ingestion damage; however, the cases in which the body parts of living birds or carcasses were caught in marine debris were designated as entanglement damage.

2.3. Damage Identification

Upon identifying a living bird or a carcass damaged by marine debris based on these criteria, we recorded the following information: (i) the age and survival status of the individual (or carcass), (ii) the type of damage observed, (iii) the area of the body where the damage occurred, and (iv) the type of marine debris involved. Additionally, we documented the incidents by taking photographs using a digital camera (DSC-HX400V, SONY, Japan). For living gulls that were found entangled in marine debris, we employed safe retrieval methods such as bownet traps or insect nets. After safely capturing the birds, we removed the debris and released them back into their natural habitat.

3. Results

Direct damage by marine debris to black-tailed gulls was observed in all examined breeding colonies. A total of 25 cases of marine debris damage were recorded, with 8 cases attributed to ingestion and 17 cases to entanglement. The highest number of cases (eight) was observed on Dongman Island, while the lowest number of cases (three) was recorded on Napdaegi Island (Figure 1, Table 2). Among the breeding colonies, Gungsi Island and Napdaegi Island experienced more ingestion damage compared to entanglement damage, whereas Dongman Island, Nan Island, and Bulmugi Island exhibited a higher incidence of entanglement damage (see Figure 2a). Notably, only entanglement damage was observed on Dongman Island and Bulmugi Island.

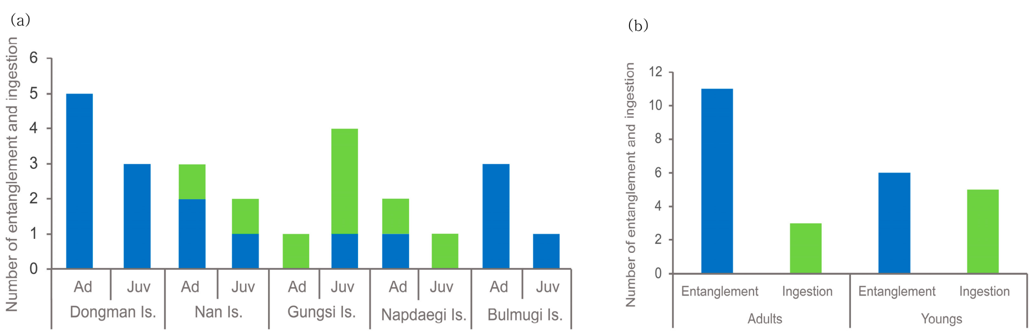

Figure 2. (**a**) Frequency of marine debris ingestion or entanglement damage in both adults and young gulls by breeding colony (green: ingestion, blue: entanglement); (**b**) frequency of ingestion and entanglement damage in both adults and young gulls in all breeding colonies. Note that no data from April were included in the analysis since no chicks hatched in this month.

The total damage caused by marine debris occurred in 14 adults and 11 young gulls (Figures 2b, 3 and 4). Among the adults, entanglement damage was more prevalent, according to 11 cases, while ingestion damage accounted for three cases. Conversely, among the young, the number of entanglement cases (six cases) was nearly equivalent to the number of ingestion cases (five cases). The incidence of marine debris damage was higher in adults than in young in the remaining four breeding colonies, except for Gungsi Island. Interestingly, in Gungsi Island, more damage was observed in young than in adults. All cases of ingestion and entanglement damage were confirmed in young birds, while only one case of ingestion damage was confirmed in adults. In contrast, in Napdaegi Island, all ingestion and entanglement damage were confirmed in adults; however, only one case of ingestion damage was confirmed in young (Table 2).

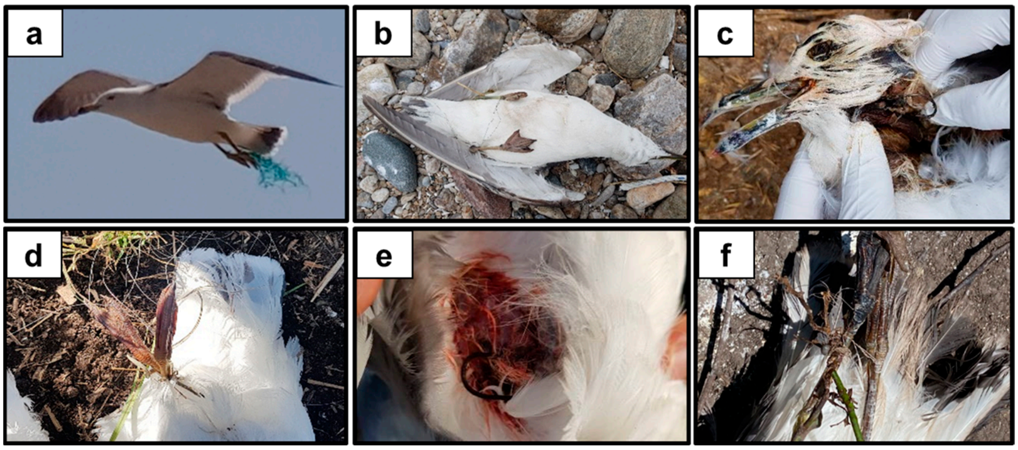

Figure 3. Adult black-tailed gulls that ingested or were entangled in marine debris during the breeding season in 2021. (**a**) An adult gull with pieces of net tangled in its legs (Dongman Island in April); (**b**) a dead adult with legs entangled in fishing line (Dongman Island in May); (**c**) a dead adult that swallowed a fishing hook (Nan Island in July); (**d**) a dead adult with legs entangled in fishing line (Bulmugi Island in May); (**e**) an adult gull with a fishing hook caught in its body (Bulmugi Island in June); and (**f**) a dead adult with legs entangled in a fishing line (Bulmugi Island in July).

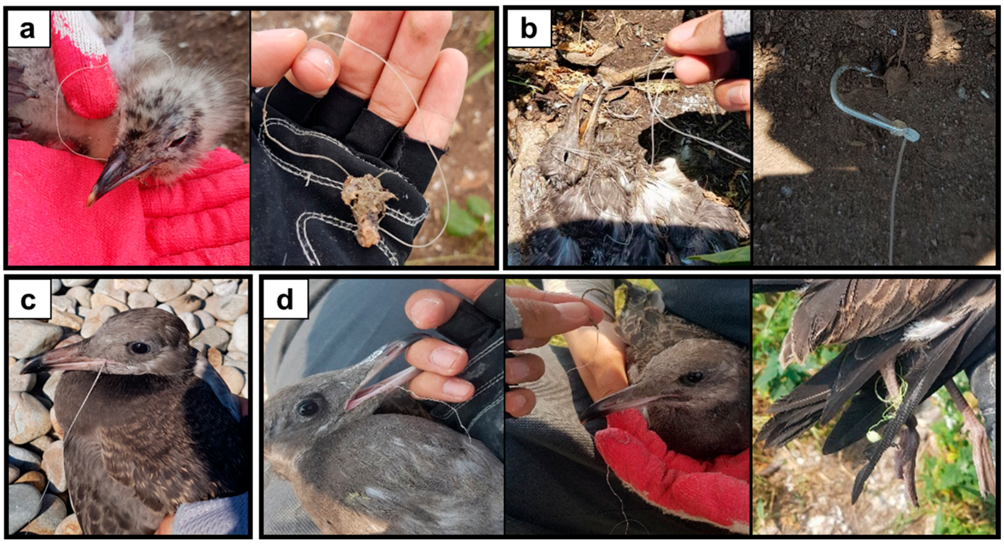

Figure 4. Young black-tailed gulls that ingested or were entangled in marine debris in their breeding colonies in 2021. (**a**) a young gull that ingested a fishing hook (Gungsi Island in June); (**b**) a dead young that ingested a fishing hook (Gungsi Island in July); (**c**) a young gull that ingested a fishing hook (Gungsi Island in July); and (**d**) a young gull that ingested a fishing hook with its legs entangled in fishing line (Nan Island in June).

Fishing hooks and fishing lines accounted for 92% (n = 23) of the marine debris that inflicted damage to black-tailed gulls, while fishing nets and ropes accounted for the remaining 8.0% (n = 2). The most damaged body parts of black-tailed gulls were their legs (60%; n = 15). Deaths caused by fishing hooks caught in the intestines of gulls that ingested marine debris accounted for 32% (n = 8) of the cases. The beaks and bodies accounted for 4% (n = 1) (Table 3).

Table 2. Frequency of marine debris damage to adult and young black-tailed gulls during their breeding season in 2021 (Ad: adults, Yo: young born in 2021 that did not fledge).

Breeding Site	Area (ha)	Breeding Population (Number of Breeding Individuals)	Breeding Density (Nest/ha)	Age	Types of Impact	Apr.	May	Jun.	Jul.	Total
Dongman Is.	8.23	3579	3509	Ad	Ingestion					0
					Entanglement	2	1	2		5
				Yo	Ingestion					0
					Entanglement		1		2	3
Nan Is.	4.76	28473	10,468	Ad	Ingestion				1	1
					Entanglement		1	1		2
				Yo	Ingestion			1		1
					Entanglement			1		1
Gungsi Is.	15.82	12067	3508	Ad	Ingestion				1	1
					Entanglement					0
				Yo	Ingestion			1	2	3
					Entanglement				1	1
Napdaegi Is.	0.76	1586	3776	Ad	Ingestion		1			1
					Entanglement		1			1
				Yo	Ingestion				1	1
					Entanglement					0
Bulmugi Is.	3.26	3456	5858	Ad	Ingestion					0
					Entanglement		1	1	1	3
				Yo	Ingestion					0
					Entanglement				1	1
				Total		2	6	7	10	25

Table 3. Types of marine debris that inflicted damage on black-tailed gulls and their affected parts (Ad: adults, Yo: young born in 2021 that did not fledge).

Breeding Colonies	Age	Types of Impact	Types of Marine Litter			Damaged Part			
			Fishing Net	Fishing Hook/Line	Fishing Rope	Leg	Bill	Body	Digestive System
Dongman Is.	Ad	Ingestion							
		Entanglement		3		3			
	Yo	Ingestion							
		Entanglement		2	1	3			
Nan Is.	Ad	Ingestion		1					1
		Entanglement		2		2			
	Yo	Ingestion		1					1
		Entanglement		1		1			
Gungsi Is.	Ad	Ingestion		1					1
		Entanglement							
	Yo	Ingestion		3					3
		Entanglement		1			1		

Table 3. *Cont.*

Breeding Colonies	Age	Types of Impact	Types of Marine Litter			Damaged Part			
			Fishing Net	Fishing Hook/Line	Fishing Rope	Leg	Bill	Body	Digestive System
Napdaegi Is.	Ad	Ingestion		1					1
		Entanglement		1		1			
	Yo	Ingestion		1					1
		Entanglement							
Bulmugi Is.	Ad	Ingestion							
		Entanglement		3		2		1	
	Yo	Ingestion							
		Entanglement		1		1			
	Total		0	22	1	13	1	1	8

4. Discussion

In this study, the frequency of ingestion and entanglement damage caused by marine debris varied among each breeding colony of black-tailed gulls. Dongman Island and Bulmugi Island were identified as breeding colonies where entanglement was the predominant damage factor. Specifically, the higher occurrence of entanglement damage on Dongman Island compared with other islands can be attributed to the topographical characteristics of this particular breeding site. Black-tailed gulls typically nest on cliffs or slopes of uninhabited islands [44,45]. In general, marine debris introduced into the island by waves mainly accumulates in the lower part of the island in contact with the sea, and seabirds breeding at higher elevations might be less affected by naturally introduced marine debris, e.g., [46]. However, Dongman Island presents a unique scenario because of its high density of tall trees located in the central area, which might provide a nesting environment for black-tailed gulls on the gentle slope of the island. As a result, the gulls on Dongman Island are more susceptible to entanglement with marine debris because of their nesting habits and the distribution of debris within their habitat.

In breeding colonies other than Dongman Island, fishing lines or hooks are mostly introduced into the breeding colonies during feeding activities, causing harm to breeding individuals. In contrast, on Dongman Island, the nesting sites chosen by black-tailed gulls are already covered with marine debris, exposing them to greater risks associated with marine debris compared with the impact of fishing gear observed in other breeding colonies. Due to the selection of nesting sites according to these topographical characteristics, black-tailed gulls might have been exposed to a lot of marine debris that flowed into the island, making them vulnerable to entanglement.

Unlike the other islands, a considerable amount of garbage flowing in from the sea becomes lodged on the shore of Dongman Island (Figure 5). Herbaceous and short woody plants grow densely on Bulmugi Island, unlike on the other islands. Marine debris, in the form of monofilaments, that seabirds bring along with their food is known to become easily entangled in tree branches, causing entanglement damage to adults or young in breeding colonies. When an adult black-tailed gull arrives at the breeding colony with a fishing line, the long fishing line that has not been swallowed is likely to become caught in a branch. Even if the adult dies from entanglement damage, the fishing line left on the branch will still inflict entanglement damage to the wings or legs of other gulls later. These environmental factors affect the occurrence of ingestion damage; interestingly, no ingestion damage was recorded on Dongman Island or Bulmugi Island. This finding reflects observation frequency bias because it is relatively easier to observe individuals suffering from entanglement damage than individuals suffering from ingestion damage. Entanglement damage can be readily recognized with the naked eye based on the appearance or movement of the affected individuals; however, ingestion damage can only be confirmed upon the examination of carcasses. Moreover, even though marine debris is exposed outside the beak, ingestion damage is difficult to observe visually.

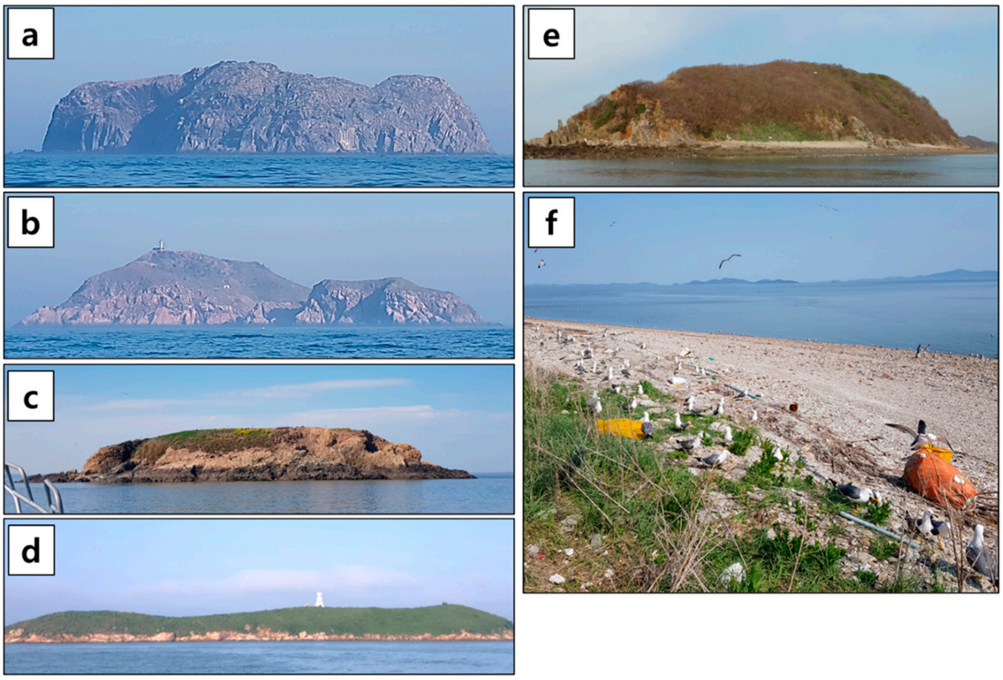

Figure 5. Photos of five breeding islands in black-tailed gulls ((**a**) Nan Island, (**b**) Gungsi Island, (**c**) Napdaegi Island, (**d**) Bulmugi Island, and (**e**) Dongman Island) and breeding near the marine debris washed up on the coast of Dongman Island (**f**).

Nevertheless, the observation frequency bias favoring entanglement over ingestion damage can further support data collected on Gungsi Island, where ingestion damage is greater than in the other breeding islands. It has been reported that boat fishing occurs more frequently in the surrounding waters of Gungsi Island and Nan Island than in the other breeding islands (unpublished data from the Ministry of Oceans and Fisheries in the Republic of Korea). During the breeding season, black-tailed gulls have been observed to follow fishing boats near the area to feed [37]. Yang et al. [37] also reported that the majority of marine debris in Nan Island was fishing-related. The high frequency of fishing activity occurring in the feeding sites adjacent to the breeding colonies of black-tailed gulls may affect the availability of food sources caught on fishing lines. Therefore, the difference in marine debris intake among the breeding colonies surveyed in this study is likely due to varying human activities, such as fishing, in the feeding sites of black-tailed gulls.

The degree of ingestion and entanglement damage varied depending on whether the birds could feed themselves in the feeding sites. Young black-tailed gulls, unable to find food on their own, directly take the food their parents have hunted into their bill. As a result, ingested marine debris can be passed on to young gulls through regurgitation and feeding [12,40,47]. Since juveniles cannot easily pellet indigestible food [48], unlike their parents, they may suffer more ingestion damage. In contrast, parents are more likely to become entangled in fishing lines or hooks while they forage. During hunting, parents often chase fishing boats to easily obtain fish (e.g., fish caught by fishing, fish discarded from fishing boats, fish trapped in fish farms, etc.) or obtain food from feeding sites such as tidal flats, ports, and fish farms [37]. When anglers throw baited fishing lines, parents try to take the bait fish and become caught in the hook (personal observations by M.-J.H); sometimes, their legs become entangled in the discarded fishing line while they walk and forage in the harbor or tidal flats. Therefore, to qualitatively evaluate the actual extent of ingestion and entanglement damage, a comprehensive study on the current status of marine debris damage on seabirds, taking into account the region and breeding colonies, should be conducted in the future.

The main types of marine debris that afflicted the black-tailed gulls observed in this study were fishing lines and hooks derived from recreational fishing activities. This finding aligns with the hypothesis that ingestion damage in black-tailed gulls is linked to recreational fishing conducted around the breeding colonies or within their feeding sites. In terms of entanglement damage, fishing lines from leisure fishing were the main type of marine debris in all surveyed islands. In Dongman Island, additional cases of entanglement by fishing nets were confirmed. The marine debris washed up along the coast of Dongman Island, including many waste nets and fishing ropes. Since nests are built on or around waste nets, there is a high possibility of entanglement damage on Dongman Island. To mitigate the discarding of fishing hooks and lines, it is suggested to install collection bins on fishing boats, enabling anglers to dispose of used fishing hooks and lines during leisure fishing activities. This initiative aims to collect marine debris generated from fishing activities. Furthermore, continuous education is advised for individuals, including boat captains and fishing enthusiasts, to increase awareness about the detrimental impact of discarded fishing hooks and lines on marine life.

5. Conclusions

This is a preliminary research study based on observations. It was conducted with the aim to present the status of damage caused by marine debris on black-tailed gulls in the Korean Peninsula during their breeding season. The results suggest that the frequency and type of damage caused by marine debris vary depending on the topographical characteristics of the breeding islands and the level of human fishing activities. Moreover, the main type of marine debris that causes ingestion and entanglement damage to black-tailed gulls during their breeding season is related to fishing, especially leisure fishing. Additionally, the presence of offshore wind farms in the vicinity of breeding colonies may introduce additional anthropogenic structures and activities into the marine environment. Therefore, additional studies should be conducted for a detailed and qualitative evaluation of the environmental factors and the effects of marine debris on black-tailed gulls, including the potential impacts of offshore wind farms. Furthermore, the direct and fatal impact of fishing activities on the marine ecosystem should be recognized so that regulatory measures can be established.

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