

# Streaked Shearwaters *Calonectris leucomelas* of the Korean Peninsula: distribution, status and potential threats

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About 90% of the global population of Streaked Shearwaters *Calonectris leucomelas* breed on islands in the seas around Japan. The species's status and distribution in Japan is fairly well documented, but for the Korean part of the breeding range, only limited information in Korean language sources exists. The species was first described in Korea in the 1880s and first studied on the breeding grounds by Japanese researchers in 1923. Our objectives were to compare and update information on the distribution of Streaked Shearwaters around the Korean Peninsula and discuss threats and conservation. An extensive literature review was undertaken and we made field visits to Chilbal Island, Ulleung Island, Gwan-eum Island and Juk Island to assess the presence and status of the species at these locations. In total, we collated data from 27 Korean islands of which 19 had confirmed Streaked Shearwater colonies, four possibly had colonies, one had no colony and the species had probably been extirpated from the other three. The biggest threat to the Korean colonies is from introduced predatory mammals such as rats *Rattus* sp. and domestic cats and dogs. Introduced predators are present on at least 10 of the 24 islands where Streaked Shearwaters currently breed, have bred or are evidently present. Introduced species severely reduce reproductive success on Sasu Island and have caused or contributed to extirpation on three other islands. Other threats include fisheries bycatch, oil spillage and military activity.

## INTRODUCTION

Seabirds generally have low fecundity, many only laying a single egg each breeding season, a long maturation period, most individuals being several years old before breeding, and a long chick-rearing period, lasting six months or longer in some cases (Schreiber & Burger 2001). Despite being found in all the world's oceans and seas, the ecology of many, including the Streaked Shearwater *Calonectris leucomelas*, a regular breeder off the Korean Peninsula, is poorly known.

Streaked Shearwaters are colonial burrow-breeders predominantly on islands and islets in the seas around Japan (Ochi *et al.* 2010, Yamamoto *et al.* 2010, Sugawa *et al.* 2014), with a smaller number of colonies on islands off the Korean Peninsula (Kuroda 1923, Park & Won 1993, Nam *et al.* 2014), on the Chinese island of Qingdao, north Yellow Sea (Cui 1994), on the Penghu (Pescadores) Islands, Taiwan, and on Karamzina Island, Far East Russia (Oka 2004). The distribution on Japanese islands, which hold about 90% of the global population, is fairly well documented (Oka 2004), but there is only limited information on the Korean breeding range—in Korean language sources (Kwon *et al.* 2007, Oh *et al.* 2008, Kang *et al.* 2012). Although Streaked Shearwaters are thought to be in decline throughout their breeding range, probably due to the introduction of alien mammals (Jones & Tershy 2008, Croxall *et al.* 2012, Nam *et al.* 2014, BirdLife International 2015), the population trend of the species around the Korean Peninsula is almost completely unknown. Although the Korean Peninsula hosts only a small part of the global population, the species is the second most abundant seabird in Korean waters (Park & Won 1993) and it is therefore important to improve knowledge of its range and conservation status in this heavily developed and much disturbed area. Our objectives were to compare historical data with more recent findings, update the information on the distribution of Streaked Shearwaters around the Korean Peninsula and discuss threats to the species's survival.

## METHODS

### Field observations

In 2014 we visited Chilbal Island (34.794°N 125.794°E) on 14–16 September and 14–15 November, Ulleung Island (37.505°N 130.866°E) on 13 September, Gwan-eum Island (37.549°N 130.923°E) on 13 September and Juk Island (37.525°N 130.936°E) on 14 September, as well as the seas around these islands, in order

to detect and assess the presence of Streaked Shearwaters. We also travelled to Sasu Island (33.923°N 126.632°E) as part of a separate research project in 2014 (20 June–3 July, 28 August and 30 October–1 November). During the visits to Ulleung and Juk islands we interviewed residents and gathered information about the presence and harvesting of Streaked Shearwaters and their eggs. On the small Gwan-eum and Juk islands, we actively searched on foot for burrows and other signs of Streaked Shearwaters from 07h00 to 17h00. On all visits we travelled by ferry and noted the abundance of Streaked Shearwaters at sea.

### Literature review

We made an exhaustive literature search for information on Streaked Shearwaters within the entire Korean Peninsula—the Democratic People's Republic of Korea (DPRK) and the Republic of Korea (ROK)—using online search engines (Google Scholar and Web of Science). Keywords such as 'Streaked Shearwater', '*Calonectris leucomelas*', 'Korea', 'Republic of Korea', 'Democratic People's Republic of Korea', 'rat', 'oil', 'bycatch', 'distribution' and 'threats' were used singly and in various combinations. We also searched the libraries of several Korean government departments, Kyung Hee University and those of several private individuals. We found technical reports, journal articles, symposia and conference proceedings, unpublished material and other literature sources in English, Korean and Japanese. We searched the references of all reviewed literature for additional information and sources. Unfortunately, we were unable to access some Korean technical reports and other material from before 1990. Owing to strict government control and the difficulty of independent travel in the DPRK, current data on the avifauna of the country are extremely limited.

## RESULTS

### Historical collection and research

Streaked Shearwaters and other seabirds were familiar to many island-dwelling Koreans prior to the Korean War and the ROK's subsequent rapid industrialisation. Streaked Shearwaters were harvested for their eggs and meat on Nan Island, DPRK (Neff 1956), on Ulleung Island, ROK, and probably from other colonies near human habitation (Kim 2006). However, it was not until the late nineteenth century that they were formally collected and identified by foreign ornithologists.



**Figure 1.** The distribution of Streaked Shearwaters *Calonectris leucomelas* colonies around the Korean Peninsula.

Probably the earliest known specimen of Streaked Shearwater from Korea was taken by the American ornithologist Pierre Louis Jouy in 1884 when he visited Korea collecting specimens for the United States National Museum. Clark (1911) lists a specimen (USNM 114437) of a male Streaked Shearwater from Jouy's unpublished collection which was stated to have been obtained at 'Fusan' (Busan) on 18 May 1884. Austin (1948) mentions that this specimen was taken from Kyongsang Namdo, today's South Gyeongsang province—Busan was formerly the capital of this

province. No Streaked Shearwaters have ever been found breeding within Busan city limits; however, the bird could have been shot or taken as fisheries bycatch in coastal waters off the city. Fennell (1952) made interesting observations of Streaked Shearwaters in 1948 during ferry crossings of the Korean Straits between Busan and Hakata (Fukuoka, Kyushu, Japan), which support the notion that the species was formerly present in the Busan vicinity, at least during the breeding season. On 21 June he recorded "Three to four hundred were observed ... The largest concentration was observed

just outside Pusan Harbor between 7:30 a.m. and 8:30 a.m. Stragglers were observed at 10:30 .... All were flying low over the water, apparently in search of food and heading toward the center of the Straits.' On the return voyage, 4 July, he again observed a flock of about 500 on the Japanese side of the straits and also reported 'Stragglers were seen all the way across the Straits on this trip. However, during another crossing ... on October 12 I failed to see a single individual of this species.'

The Korean Peninsula was visited by two other contemporary specimen collectors: Jan Kalinowski, also in 1884, collected specimens for the Polish Count Branicki (Mlíkovský 2011), and in 1888 C. W. Campbell visited Korea on behalf of the British Museum (Austin 1948). Between them, they collected and identified 89 species new to the Korean bird list. Their departure coincided with the Japanese colonisation of Korea, which limited access to the country for foreign ornithologists. It was more than 20 years before another Streaked Shearwater specimen was collected by the Japanese scientist Seiichi Shimokoriyama while he was working and collecting for the Li Wong Museum, Seoul, Korea. During his collecting trips, Shimokoriyama travelled to the northernmost province of Korea, North Pyongan, and acquired a specimen, although it is unclear where exactly it was obtained; there are two islands in North Pyongan province where Streaked Shearwaters have bred—Rap Island (Scott 1989) and Samcha Island (KTO 2003).

Hong Koo Won and his son Pyong Oh Won were the pioneer Korean ornithologists and Hong Koo Won is credited with selecting the first Korean names for most Korean birds (Austin 1948). While working in South Pyongan province (now in the DPRK) as a teacher,

Hong Koo Won collected a specimen of a Streaked Shearwater on 4 June 1932 but, as in the case of Shimokoriyama's specimen, its exact origin is unknown (Austin 1948).

### Contemporary research

During the 1970s, 1980s and 1990s, Pyong Oh Won and his colleagues surveyed many of the ROK's islands and islets and recorded the presence and breeding status of Streaked Shearwaters and other seabirds (Won & Yoon 1971, Park & Won 1993, Yoon & Yoon 1996).

Since 2000, several independent groups have researched Streaked Shearwaters in various capacities. Staff of the Migratory Birds Center of the Korea National Park Service make regular trips each year to various islands which hold seabird colonies to monitor the birds, periodically conducting surveys in Shinan county (Korea National Park Service 2008, 2009). Birds Korea, an NGO based in Busan, has carried out various surveys including one recently in the Yellow Sea where they found Streaked Shearwaters near the DPRK and ROK border (Moores 2007). Finally, the Seabird Ecology Group at Kyung Hee University is engaged in long-term research at Korea's largest Streaked Shearwater colony on Sasu Island (Park & Won 1993, Lee *et al.* 2002, Nam *et al.* 2004, Nam *et al.* 2014).

### Distribution and status of Streaked Shearwater colonies

#### Democratic People's Republic of Korea

There are seven known breeding colonies in the DPRK (Table 1, Figure 1), although their current status is poorly known—the most recent report of Streaked Shearwaters in the DPRK is from Won (1963).

**Table 1.** Summary of Streaked Shearwater *Calonectris leucomelas* colonies around the Korean Peninsula.

B: islands with confirmed Streaked Shearwater *Calonectris leucomelas* colonies; P: islands with potential Streaked Shearwater colonies; N: island confirmed without Streaked Shearwater colonies; E: islands where Streaked Shearwaters have possibly been extirpated

Ref	Island	Coordinates	Location (county/province)	Status	Estimate of breeding pairs	Introduced predators present	Reference(s)	Notes
<b>DPRK</b>								
1	Nan	42.235°N 130.536°E	Sonbong, North Hamgyeong	B	Unknown		KTO (2003), MAB National Committee (2005)	
2	Nan	40.651°N 129.553°E	Hwadae, North Hamgyeong	B	Unknown		Neff (1956)	
3	Samcha	39.416°N 124.723°E	Cheolsan, North Pyongan	B	Unknown		Lee & Lee (1996), KTO (2003)	
4	Rap	39.277°N 124.722°E	Seoncheon, North Pyongan	B	150		Won (1963), Scott (1989), MAB National Committee (2005)	
5	Al	39.003°N 128.065°E	Tongcheon, Gangwon	B	Unknown		Won (1963), Lee & Lee (1996)	
6	Deok	38.754°N 124.975°E	Oncheon, South Pyongan	B	75		Jeong <i>et al.</i> (2003)	
7	Seo	38.556°N 124.763°E	Nampo City, South Hwanghae	B	Unknown		Kuroda (1923)	
<b>ROK</b>								
8	Baengnyeong	37.950°N 124.680°E	Ongjin, Gyeonggi	P		Rats, cats, dogs	Moores (2007), Park & Kim (2009)	Inhabited
9	Daecheong	37.824°N 124.703°E	Ongjin, Gyeonggi	P		Rats, cats, dogs	Moores (2007), Park & Kim (2009)	Inhabited
10	Socheong	37.770°N 124.750°E	Ongjin, Gyeonggi	P		Rats, cats, dogs	Moores (2007), Park & Kim (2009)	Inhabited
11	Gwan-eum	37.549°N 130.923°E	Ulleung, North Gyeongsang	B	Unknown	Rats	K-BN pers. obs.	Connected to Ulleung Island via walking bridge
12	Juk	37.525°N 130.936°E	Ulleung, North Gyeongsang	B	>4	Unknown	Yoon & Yoon (1996), Kim & Nam (2001), K-BN pers. obs.	Inhabited
13	Ulleung	37.505°N 131.866°E	Ulleung, North Gyeongsang	E		Rats, cats, dogs	Won & Woo (1958), Kim (2006)	Inhabited
14	Dok	37.240°N 131.867°E	Ulleung, North Gyeongsang	B	>25	Rats, dogs	Woo & Koo (1981), Kim <i>et al.</i> (2007), Chung <i>et al.</i> (2010)	Inhabited
15	Daeryeong	36.971°N 125.748°E	Ongjin, Gyeonggi	B	Unknown	None	IMC (2007), MOF (2015)	
16	Soryeong	36.970°N 125.751°E	Ongjin, Gyeonggi	B	Unknown	None	IMC (2007), MOF (2015)	
17	Nan	36.660°N 125.824°E	Taeon, South Chungcheong	B	Unknown	Unknown	Park & Won (1993)	
18	Jik	35.894°N 126.074°E	Gunsan city, North Jeolla	B	200	None	CHA (1994)	Military live fire exercises since 1971
19	Chilbal	34.794°N 125.794°E	Shinan, South Jeolla	B	>100	None	Kuroda (1923), Hart <i>et al.</i> unpub. data	Inhabited 1905 to 1996
20	Jang	34.670°N 125.370°E	Shinan, South Jeolla	E		Rats, cats, dogs	J-G Park pers. comm.	Inhabited
21	Hong	34.534°N 128.733°E	Tongyoung, South Gyeongsang	N		None	K-BN pers. obs.	
22	Gugul	34.110°N 125.080°E	Gageo Island, Shinan, South Jeolla	B	2,623	Unknown	Lee (1986), Hahm <i>et al.</i> (1994)	
23	Gageo	34.050°N 125.070°E	Shinan, South Jeolla	E		Rats, cats, dogs, Siberian Weasels	Won & Yoon (1971), Park & Lee (2009)	Inhabited
24	Byeongpung	34.154°N 125.945°E	Jindo, South Jeolla	B	Unknown	Rats	Lee & Lee (1999)	
25	Yeoseo	33.970°N 126.920°E	Wando, South Jeolla	P		Unknown	Yoon (1982)	Inhabited
26	Sasu	33.923°N 126.632°E	Chuja, Jeju	B	20,805	Rats	Nam <i>et al.</i> (2014), Nam & Hart unpub. data	Inhabited pre-1945 Frequented by fishermen
27	Hwa	33.720°N 126.351°E	Chuja, Jeju	B	300	None	Kang <i>et al.</i> (2012)	

**1. Nan (or Sonbong Al) Island (42.235°N 130.536°E)**

This island in Sonbong county, North Hamgyong province, is also commonly referred to as Al Island, or Sonbong Al Island to separate it from Tongcheon Al Island (see below). Near the Russian border, it is located 15 km from Sonbong harbour and 8 km from the nearest coast at Uam-ri; designated Natural Monument 340 (Lee & Lee 1996, KTO 2003), it hosts diverse breeding seabirds such as Streaked Shearwaters, guillemot, puffins, cormorants, as well as tens of thousands of Black-tailed Gulls *Larus crassirostris* (MAB National Committee 2005).

**2. Nan Island (40.651°N 129.553°E)**

Neff (1956) also documented Streaked Shearwaters in the DPRK. On the north-east coast, there is a small group of islands about 30 km offshore from the city of Kimchaek (formerly Songjin). On 5 May 1953, when Neff was collecting specimens for the Denver Museum of Nature and Science, a pair was pulled out of a burrow by a local resident. The female's body (DMNS 26776) was checked for the presence of an egg but none was found. However, Streaked Shearwaters do not usually lay until the first week of June and an egg cannot normally be felt until 1–2 weeks prior to laying; therefore, it is probable they were a breeding pair (Lee & Yoo 2002, Nam 2003). However, Neff was unfamiliar with the species and its nesting and breeding behaviour and although only this pair was found on the island, the presence of other occupied burrows was certainly possible. Fishermen formerly went there to collect the eggs of the many seabirds for food—some 3,000 seabird eggs were collected by local Koreans during Neff's survey. It should also be noted that the topography of Nan Island is strikingly similar to Chilbal Island (see below)—steep granite cliffs covered with grasses and shrubs with little to no tree cover—which accommodates a stable colony of Streaked Shearwaters.

**3. Samcha (or Chamcha) Island (39.416°N 124.723°E)**

This uninhabited island is designated Natural Monument 68 for breeding seabirds; Black-tailed Gulls are the predominant breeding species together with unknown numbers of Streaked Shearwaters, cormorants and auklets (Lee & Lee 1996, KTO 2003).

**4. Rap Island (39.277°N 124.722°E)**

Lying off the coast of Seoncheon county, North Pyongan province, about 65 km west of Pyongyang, Rap Island, designated Natural Monument 71, holds breeding colonies of Black-tailed Gulls, cormorants and Streaked Shearwaters (Won 1963, Scott 1989, Lee & Lee 1996, KTO 2003). The Streaked Shearwater colony was first described by Won (1963) and is estimated to hold about 300 birds (MAB National Committee 2005).

**5. Al (or Tongcheon Al) Island (39.003°N 128.065°E)**

This island named 'Al' (Korean for 'egg') lies just off the south-east coast of Tongcheon county, near the border with the ROK (Won 1963). The island is designated Natural Monument 211, and Streaked Shearwaters were found breeding together with Black-tailed Gulls, auklets and cormorants (Lee & Lee 1996, KTO 2003). There has been no estimate of Streaked Shearwater numbers so the current size of this population is unknown.

**6. Deok (or Tok) Island (38.754°N 124.975°E)**

Deok Island, South Pyongan province, is located 30 km north-east of Seo Island, just off the coast from Nampo city. A well-known seabird breeding site, it was designated Natural Monument 37 in 1980. During a visit to the island in 1995 to assess a colony of Endangered Black-faced Spoonbills *Platalea minor*, Jeong *et al.* (2003) discovered a small breeding colony of Streaked Shearwaters which they estimated to be 150 individuals, although an adequate survey specifically for Streaked Shearwaters was not carried out.

**7. Seo Island (Nishijima in Japanese) (38.556°N 124.763°E)**

This small islet, less than 900 m in circumference, lies 1.4 km off the coast of the much larger Cho Island. It served as a lighthouse station during the Japanese occupation and the lighthouse-keeper helped collect Streaked Shearwater eggs and adults in the early twentieth century, when it was noted that their numbers were few compared with the breeding population of Black-tailed Gulls, although the population was never quantified (Kuroda 1923).

**Republic of Korea**

There are 12 islands in the ROK with confirmed Streaked Shearwater breeding colonies, four with potential colonies, three possibly extirpated sites and one island where it was thought a breeding colony might be present, but it has now been confirmed that this is not the case (Table 1, Figure 1).

**8. Baengnyeong Island (37.950°N 124.680°E)****9. Daecheong Island (37.824°N 124.703°E)****10. Socheong Island (37.770°N 124.750°E)**

These three islands lying in the Yellow Sea, near the DPRK border, may hold Streaked Shearwater colonies. Although active Streaked Shearwater nests have never been confirmed, the species is often seen close to the islands and rafts occur in large numbers at sunset to the west of Socheong Island during the breeding season, with more than 6,400 individuals seen there in a single day (Moore 2007, Birds Korea 2010). Although Park & Kim (2009) searched Socheong Island and found no evidence of Streaked Shearwaters, many male and female Streaked Shearwater calls were heard from three different locations on the island in 2009 (Birds Korea 2010). A thorough search of all three islands is recommended; there appears to be a good chance of finding at least one Streaked Shearwater breeding colony, even though the islands are inhabited and rats and domestic cats and dogs have been introduced.

**11. Gwan-eum Island (37.549°N 130.923°E)****12. Juk Island (37.525°N 130.936°E)****13. Ulleung Island (37.505°N 130.866°E)**

Won (1963) recorded that Ulleung Island was once a Streaked Shearwater breeding site and in late summer the species was abundant at sea between this island and the Korean mainland (Gore & Won 1971). However, unfortunately when Ulleung Island was resettled from 1883 onwards, the species became a source of famine-relief food (Kim 2006). Birds and eggs continued to be used to supplement the food supply and the species was probably extirpated by the mid-twentieth century (Won & Woo 1958, Kim 2006), with the introduction of rats and domestic cats and dogs probably accelerating the extirpation. It appears that, at present, small relict Streaked Shearwater populations exist on Gwan-eum and Juk islands off Ulleung Island's north-east coast.

Gwan-eum Island, well known to the local community as a Streaked Shearwater breeding site, is close enough to Ulleung Island to be connected by a footbridge built in 2012 to accommodate walkers visiting the uninhabited island. Inevitably, the connection to Ulleung Island has led to the arrival of Black *Rattus rattus* and Brown Rats *R. norvegicus*, and in September 2014, during a reconnaissance of the island, we found the carcass of an adult Streaked Shearwater in a forested area—probably the result of rat predation—suggesting that any Streaked Shearwaters still attempting to breed on the island are under serious threat.

Juk Island, about 2 km south-east of Gwan-eum and 2.5 km east of Ulleung, is inhabited by a farming community who confirmed that at night the boisterous calls of Streaked Shearwaters were to be heard emanating from the forest in the south-east of the island, where Yoon & Yoon (1996) found at least four breeding pairs in their burrows. In April 2001, prior to the egg-laying season, about 100 unoccupied burrows were found, but obviously the population

could not be estimated (K-BN pers. obs.). The presence of rats has not been confirmed, but is likely given the island is inhabited and there are regular ferries.

There may be a small colony on one or both of these islands, as up to 900 Streaked Shearwaters were seen at sea in this area on 15 September 2014, the early stages of the chick-rearing season (K-BN pers. obs.).

#### 14. Dok Island (37.240°N 131.867°E)

Often referred to as the Liancourt Rocks, Dok Island is actually two small islets, both circular and about 350 m in diameter, named, in Korean, Seodo (West island) and Dongdo (East island), and 35 surrounding smaller rocks, lying about 90 km east-south-east of Ulleung Island. At present, the ROK occupies the islets and has built permanent structures on both; consequently, domestic dogs and Brown Rats are now present (Chung *et al.* 2010). Owing to strict government control, scientific access is difficult and data on Streaked Shearwaters have usually been limited to sightings at sea near the islets. However, Kim *et al.* (2007) discovered 50 breeding individuals in a small area of the island, while many more were heard calling from an inaccessible part of the island. Although the survey was not specifically for nocturnal, burrow-nesting seabirds, it demonstrated that there was still a breeding population on that island, possibly larger than the 50 individuals found. A thorough burrow search survey and night-time observations are recommended to achieve a more accurate estimate. The Vulnerable Japanese Murrelet *Synthliboramphus wumizusume* also breeds there and adds to the requirement for effective surveys of this group of islets (Kim *et al.* 2012).

#### 15. Daeryeong Island (36.971°N 125.748°E)

#### 16. Soryeong Island (36.970°N 125.751°E)

In 2006, during a general survey of the flora and fauna of coastal islands, Incheon municipal government researchers discovered breeding Streaked Shearwaters on these two small uninhabited islands, both about 5,000 m<sup>2</sup> in area, located about 80 km south-west of Incheon International Airport (Incheon Metropolitan City 2007, Ministry of Oceans and Fisheries 2015). Appropriate surveys for nocturnal burrow-nesting seabirds have not been carried out and are recommended as soon as possible.

#### 17. Nan Island (36.660°N 125.824°E)

Located off Taean county on the west coast of the ROK, the island was designated Natural Monument 334 in 1982 because it held a breeding colony of Black-tailed Gulls. During a visit in 1989, a small number of adult Streaked Shearwater were found on the island (J-Y Park pers. comm.). Park & Won (1993) later confirmed the presence of Streaked Shearwater when they were heard calling on the island at night, and there were further observations in the later 1990s (Oka 2004). The current status of this colony is unknown; gull egg collectors visit the island, which raises the possibility that shearwater eggs are also harvested and rats introduced (Park & Won 1993).

#### 18. Jik (or Pium) Island (35.894°N 126.074°E)

This uninhabited island has been used as a target for live fire exercises (LFEs) by ROK and US military forces since 1971. Although local fishermen have long known that seabirds, predominantly Black-tailed Gulls, bred on the island, it was first surveyed and confirmed as a seabird breeding colony only in 1994, when an estimated 200 pairs of Streaked Shearwaters along with many dead seabirds were found (Cultural Heritage Administration 1994). The Cultural Heritage Administration immediately suggested that the island should be designated a natural monument to protect the breeding seabird colony, but the request was denied for national security reasons. Vegetation and soil have been seriously disturbed and

habitat destroyed by the continual LFEs of the past four decades, and the current status of the seabird colony is unknown because of the lack of follow-up surveys. Austin (1948) noted that the Li Wong Museum, Seoul, had one adult bird and fifteen eggs collected 17 June 1916 off the coast of Kunsan, Cholla Pukto (currently, Gunsan, North Jeolla province), and these specimens seem to have been collected on Jik Island.

#### 19. Chilbal Island (34.794°N 125.794°E)

This island, Natural Monument 332, lies about 50 km west of Mokpo City in the south-west of the country and is a 120 m high granite rock with very steep slopes and cliff edges; it is about 13.5 ha in area and predominantly grassy, being covered with the sedge *Carex boottiana* (Choi *et al.* 2010). There are no permanent residents but it is visited from time to time for lighthouse maintenance.

The only published survey of Streaked Shearwaters on Chilbal Island was by Kang *et al.* (2008), who made a brief survey and estimated that there were only 10 breeding pairs present. However, they made only day-time burrow searches using only five 2 × 2 m quadrats and one 5 × 5 m quadrat and, given the limited number of sample burrows and the difficulty in assessing Streaked Shearwater occupancy by hand due to burrow depth, this is probably not an accurate assessment. In 2014, KAH *et al.* made simple night-time observations and audio recordings and concluded that there were at least 100 pairs present.

#### 20. Jang Island (34.670°N 125.370°E)

The island is important because it holds Jangdo High Moor, a pristine mountainous wetland, designated Ramsar site 1458. According to residents of the island, which lies about 100 km off the mainland close to the larger Heuksan island, there had been a population of Streaked Shearwaters there in the past. During a brief daytime visit to confirm this anecdotal report, old nests were found but no individuals were currently breeding at that site (J.-G. Park pers. comm.). Although a simple daytime survey cannot be regarded as conclusive, human occupancy has inevitably led to the presence of domestic cats and dogs as well as rats, which may have extirpated the colony.

#### 21. Hong Island (34.534°N 128.733°E)

This island, designated Natural Monument 335, near the city of Busan, hosts a large colony of Black-tailed Gulls. It has been suggested that the island could be a breeding site for Streaked Shearwaters based on observations of the species at sea nearby—about 150 in 1992 and 1,000 in 2003 were seen flying in the vicinity (Park & Won 1993, Oka 2004, Kwon *et al.* 2007). However, burrow searches and night-time surveys have failed to find evidence of their presence (Oka 2004, K-BN pers. obs.) and it appears that the birds observed were foragers from other colonies (one large Japanese colony is only 150 km away). Perhaps limited nest space and the rocky terrain has prevented Streaked Shearwaters from establishing a colony.

#### 22. Gugul Island (34.110°N 125.080°E)

This uninhabited island, Natural Monument 341, lies about 3 km north-north-east of Gageo Island (see below). A peak count of 2,623 Streaked Shearwaters was reported from a simple daytime survey (Cultural Heritage Administration 2001). Although the population size is unconfirmed, Streaked Shearwaters undoubtedly breed there as confirmed by the presence of eggs and nesting adults, and other researchers have seen more than 1,000 birds rafting on the water near the island at dusk (Won & Lee 1986, C-YC pers. obs.). Gugul Island is very important for seabirds, holding the world's largest breeding population of Swinhoe's Storm Petrels *Hydrobates monorhis* and probably also holding Korea's second largest Streaked Shearwater colony (Won & Lee 1986).

### 23. Gageo (also known as Soheuksan) Island (34.050°N 125.070°E)

Won & Yoon (1971) noted that local villagers knew of a seabird colony around the northern tip of Gageo Island, which was suspected of holding breeding Streaked Shearwaters (Oka 2004). Located 3 km from Gugul Island (see above), the larger Gageo Island was thought to be a potential breeding site for shearwaters. However, during a broad avifaunal survey, Park & Lee (2009) found no evidence of the presence of Streaked Shearwater. The island is inhabited and the consequent introduction of rats, domestic cats and dogs, and Siberian Weasels *Mustela sibirica*, may have caused the extirpation of Streaked Shearwaters.

### 24. Byeongpung Island (34.154°N 125.945°E)

This island was previously thought to be a potential breeding site for Streaked Shearwaters (Oka 2004). During the early 2000s a number of surveys of the flora and fauna of uninhabited islands throughout the ROK were made and, according to the Cultural Heritage Administration (2001) island survey, Streaked Shearwaters were confirmed to breed on Byeongpung Island although numbers are uncertain.

### 25. Yeoseo Island (33.970°N 126.920°E)

Oka (2004) reported the potential for breeding on this inhabited island lying in the Jeju Strait. We have been unable to confirm or update the situation because we have failed to find any additional pertinent reports.

### 26. Sasu Island (33.923°N 126.632°E)

The largest and best documented colony in the ROK and Natural Monument 333, Sasu is a small, tree-covered island approximately 22 ha in size, off the south coast, between the mainland and Jeju Island (Lee & Yoo 2002).

Non-native Brown Rats *Rattus norvegicus* are present and are known to reduce Streaked Shearwater breeding success (Nam *et al.* 2014). It is not known when the rats were introduced but they probably arrived by ship as humans occupied the island until the end of the Second World War and it is still frequented by fishermen.

Estimates of numbers of Streaked Shearwaters have varied. Park & Won (1993) estimated that there were 16,094 pairs in 1992, while Lee & Yoo (2002) estimated a population of about 7,500 pairs in 2000, and Kang *et al.* (2008) suggested a further decrease to less than 5,000 pairs—indicating a significant and worrying decline in the main ROK Streaked Shearwater colony during that period. However, these three estimates were made at different stages of the species's breeding cycle and therefore reflect different nest attendance patterns. To ensure maximum nest attendance, K-BN & KAH surveyed Sasu Island from late June to early July 2014 during the incubation period, and estimated 20,805 breeding pairs.

### 27. Hwa Island (33.720°N 126.351°E)

This uninhabited island lies close to Sasu Island (see above), about 30 km north of Jeju Island, and appears to be free of invasive mammals (Kang *et al.* 2012). However, many sport fishermen visit the island, raising the possibility of infestation in the future. Between 2009 and 2010, Kang *et al.* (2012) spent four days searching for signs of breeding Streaked Shearwaters and other birds. They found adults and chicks in burrows and estimated there were 300 pairs on the island.

## DISCUSSION

Streaked Shearwater colonies are found around the entire coastline of Korea, but there is a marked concentration of them in the south-west of the ROK, where we estimate more than 60% of the Streaked

Shearwaters on the Korean coastline breed. This might be explained by the higher level of ocean productivity in that area relative to the rest of Korea (Son *et al.* 2005, Yamamoto *et al.* 2010). Sasu Island is well established as the largest breeding colony in Korea (Park & Won 1993, Lee & Yoo 2002, Kang *et al.* 2008). Because few high-quality surveys have been made elsewhere, the relative size/importance of other colonies is hard to assess. However, based on observations of the species at sea near Socheong, Daecheong and Baengnyeong Islands, Gugul Island and the west coast islands of the ROK appear to hold the next largest colonies (Moores 2007, C-YC & K-BN pers. obs.). Although there is no definite data on the size of other colonies, it appears that most outside the south-west area are probably small, holding fewer than 1,000 pairs.

## Potential threats to Streaked Shearwaters

### Invasive species

Introduction of predators, mainly rats and domestic cats, has led to the decline and even extinction of seabirds on many remote islands worldwide (Jones & Tershy 2008, Nogales *et al.* 2013). Small, burrow-nesting, nocturnal seabirds are the most heavily affected by these predators (Donlan *et al.* 2003, Jones & Tershy 2008). Introduced mammals are present on at least 10 of 24 islands where Streaked Shearwaters currently breed, have bred or are evidently present (Table 1). Considering their close relationship with humans, it is likely that any island with an established human presence also has introduced rats and/or domestic cats. These introduced animals are undoubtedly having negative effects on Streaked Shearwater populations and are probably why shearwaters are rare on Gwan-eum, Byeongpung and Dok Islands. Streaked Shearwaters also appear to have been extirpated from Jang, Ulleung, and perhaps Gageo Islands as a result of introduced species and overexploitation. Near Ulleung Island, the species has survived as two relict populations on Gwan-eum and Juk Islands; however, with the recent construction of a footbridge connecting Gwan-eum to Ulleung Island and the subsequent invasion by rats, and with a permanent human presence on Juk Island, Streaked Shearwaters in this region are at high risk of extirpation.

On Sasu Island, Brown Rats were introduced more than 60 years ago and are known to have had serious effects on the survival and reproductive success of Streaked Shearwaters, destroying more than 90% of eggs and chicks in some years (Lee & Yoo 2002, Nam *et al.* 2004, 2014). While one would assume this high rate of predation is causing a decline in the total population, the sustained Streaked Shearwater population on Sasu Island suggests another factor is involved, such as a high rate of immigration from other colonies. Until a series of standardised surveys are completed on Sasu Island, the long-term effects of this high rate of predation will not be clearly understood.

### Fisheries bycatch

Streaked Shearwaters are vulnerable to drowning as a result of fisheries bycatch, having been accidentally caught in large numbers in gill-nets in the waters around Japan (Nakamura 1974), Hong Kong (Everett & Pitman 1993) and Taiwan (Blackshaw 1978). Streaked Shearwaters also regularly follow fishing vessels, attracted by discarded bait and fish parts (Warham 1990, Birds Korea 2009) and recreational fishing gear (KAH pers. obs.), which may leave them vulnerable to mortality in the long-line fishery. Recreational fishermen frequent the waters around Sasu Island and Streaked Shearwaters appear to be attracted by their baited lines; some birds that swallow baited hooks manage to break the line and escape, sometimes with metres of line trailing from their mouths (KAH pers. obs.). These birds inevitably get entangled in trees and perish (KAH pers. obs.).

Streaked Shearwaters have also been photographed around the vessels of the commercial tuna pole-and-line fishery near Japan (J.

Holmes pers. comm.). The probable outcome of their attraction to baited long-line hooks is that, in common with other similar-sized shearwater species e.g. Flesh-footed Shearwaters *Puffinus carneipes* in the Pacific Ocean (Baker & Wise 2005) and Cory's Shearwaters *Calonectris diomedea* in the Mediterranean (Belda & Sanchez 2001), they may be drowned in significant numbers. No information currently exists regarding the bycatch of Streaked Shearwaters in long-line fisheries, and to determine the number and significance of such events further research is necessary.

#### Military activity

Over the past 40 years, the Streaked Shearwater breeding population on Jik Island has been greatly threatened by the ROK and USA military forces LFEs. When the colony was first identified, hundreds of shearwaters were still breeding there despite 20 years of aerial bombardment (Cultural Heritage Administration 1994). Today, in the face of socio-economic and safety debates, the island continues to be used as a LFE ground target because of complex political, diplomatic, and national security issues.

#### Oil spillage

On the Korean peninsula during the breeding season, the majority of Streaked Shearwaters are concentrated near the south-west corner. This is a relatively productive region, but also one which sees frequent maritime activity (Kim *et al.* 2010). Large oil spills are devastating to entire ecosystems and attract significant media attention, e.g. the VLCC Sea Prince accident off the south coast of Korea (Yim *et al.* 2002) or the MT Hebei Spirit oil spill which dumped more than 12.5 million litres into the coastal waters of south-west Korea (Kim *et al.* 2010); both of these incidents were within the foraging range of the Korean population of Streaked Shearwaters. However, chronic or micro-spills occur far more frequently (Carter 2003) and are arguably more damaging to seabirds over time (Hampton *et al.* 2003a), whilst attracting little or no public or political attention. The term 'chronic oil pollution' is used to describe a persistent release of oil at a low concentration that results from the inefficient extraction, transportation and/or consumption of oil. In waters around the USA chronic oil pollution makes up about a third of the total released annually. There are many sources of chronic oil pollution in the marine environment, e.g. deliberate discharge by marine vessels of bilge water contaminated with oil and other chemicals, the slow leaking of oil from wrecks, leaks or spills during loading and unloading of tank ships, and run-off from land-based activities (Hampton *et al.* 2003b). The chronic release of oil by ships is a continuing threat to seabirds living near shipping lanes, and heavy mortality of birds due to this has been documented in Japan (Kazama 1971). In the aftermath of the 2014 sinking of the ferry MV Sewol within 100 km of the two largest Streaked Shearwater colonies in Korea, the possibility of a chronic leak of oil from its wreck is of particular concern.

Unfortunately, there is little information on oil-related Streaked Shearwater fatalities in Korea, but every year Ancient Murrelets *Synthliboramphus antiquus* killed by oil contact are washed up on the Korean shoreline (Sea Alarm Foundation 2010) and many other oiled seabirds have been seen off both west and east coasts during winter (Birds Korea 2010). The actual mortality from a particular oil spill is probably at least 4–5 times higher than the beached bird count suggests (Burger 1993). Carcasses sink, are eaten by scavengers, buried by sediment on beaches or drift further out to sea, thereby never being included in damage assessments. So it is likely that the majority of Streaked Shearwaters which perish due to encounters with chronic oil releases in Korea are never seen. Considering the massive impact of oil pollution on all seabirds, especially diving seabirds which spend significant periods on the sea surface, it is likely that around Korea Streaked Shearwaters are affected by oil; an in-depth study is required to assess the seriousness of this impact.

## CONCLUSIONS

Oka (2004) provided a detailed account of the global distribution of Streaked Shearwaters, including those around the Korean Peninsula. However, in the years since its publication, through an increased interest in seabird research on the Korean Peninsula, several new Streaked Shearwater colonies have been documented. Colonies on the islands of Hwa, Soryeong, Daeryeong, Jang (although possibly now extirpated), Nan (DPRK), Samcha, Al, Deok and Gwan-eum were unknown in 2004 but have since been confirmed. Colonies are also thought to exist on Socheong, Baengnyeong and Daecheong (Moores 2007, Birds Korea 2010) while the absence of Streaked Shearwaters on Hong and Gageo Islands has been confirmed (Kwon *et al.* 2007, Park & Lee 2009, K.-B. Nam pers. obs.). Oka (2004) listed Byeongpung Island as a potential breeding site and breeding there has since been confirmed.

The number of new colonies discovered in the past decade not only reflects an increased interest of Korean ornithologists in their local seabird populations but also indicates just how little we know about Streaked Shearwater distribution around the Korean Peninsula. These birds can be found in every marine location surrounding the peninsula and, because of their foraging behaviours and role as a food source for marine animals, are important in the regulation of marine environments (Wootton 1992, Polis & Hurd 1996). They play a significant role in maintaining the biodiversity of Korea's marine ecosystems.

Park & Won (1993) attested to Korea's serious need for a seabird population assessment and long-term monitoring and protection programmes. While some Streaked Shearwater colonies are protected by government as 'natural monuments', there is a lack of long-term, extensive monitoring, which makes it impossible to assess changes to Streaked Shearwater populations (Moores 2012). However, by looking at global trends and also factoring in the introduction of alien predators to some colonies, it is a safe assumption that numbers have declined over the past 100 years and will continue to do so.

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